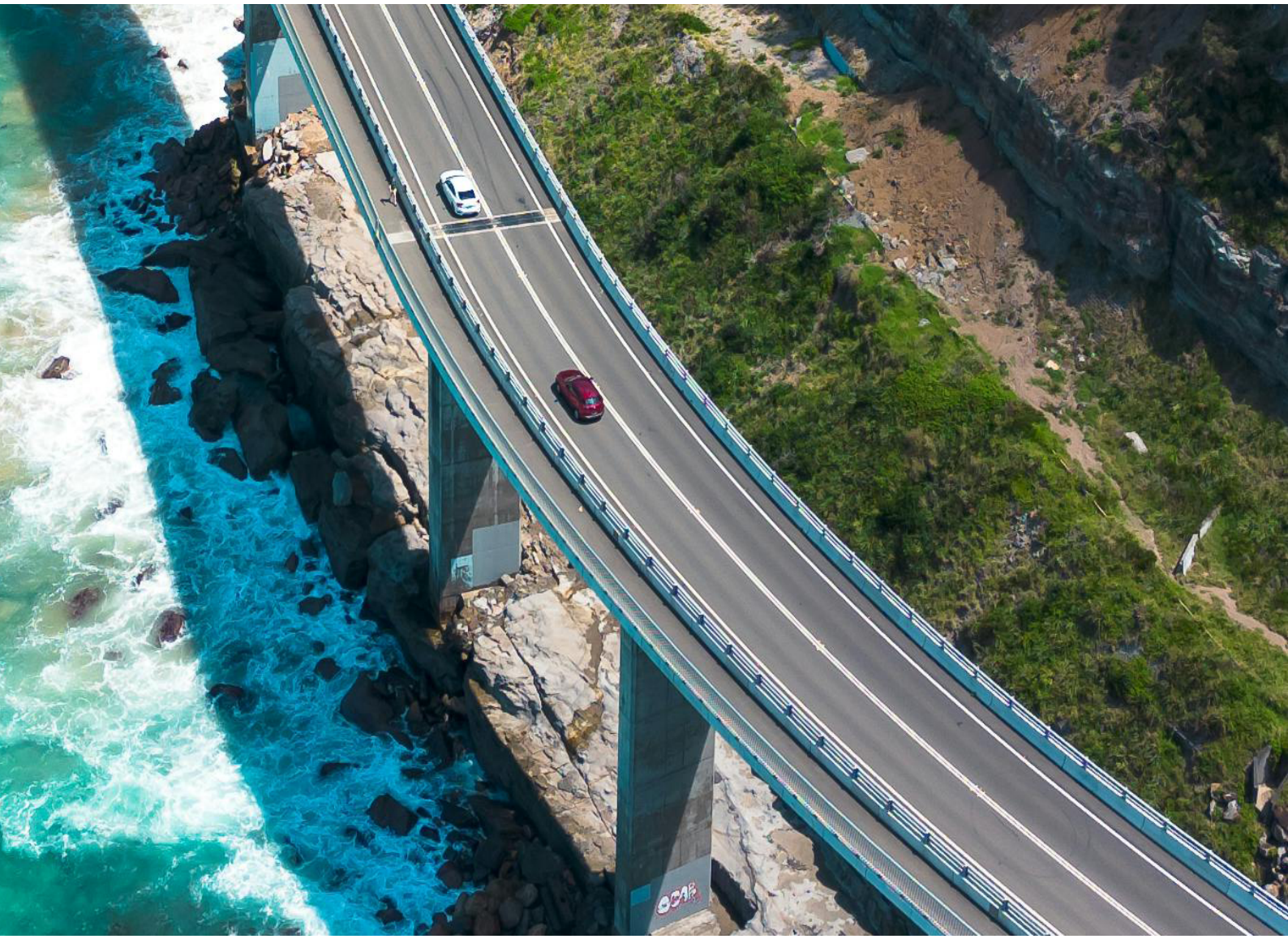
GUIDE

CEMENT CONCRETE & AGGREGATES AUSTRALIA

Guide to Off-form Concrete Finishes



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Cement Concrete & Aggregates Australia

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CEMENT CONCRETE & AGGREGATES AUSTRALIA

Cement Concrete & Aggregates Australia is a not-for-profit organisation established in 1928 and committed to serving the Australian construction community.

CCAA is acknowledged nationally and internationally as Australia's foremost cement and concrete information body – taking a leading role in education and training, research and development, technical information and advisory services, and being a significant contributor to the preparation of Codes and Standards affecting building and building materials.

CCAA's principal aims are to protect and extend the uses of cement, concrete and cement-based products by advancing knowledge, skill and professionalism in Australian concrete construction and by promoting continual awareness of products, their energy-efficient properties and their uses, and of the contribution the industry makes towards a better environment.

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01 Introduction

Concrete is the most commonly used construction material for loadbearing and non-loadbearing elements. Its ability to be shaped and reflect the surface against which it is placed enables it to provide an extensive range of decorative and architectural off-form finishes which can eliminate the need for additional, and often costly, applied finishes using other materials.

With the variety of constituent materials that can be used in concrete's manufacture and the extensive range of options for moulding and treating the surface, a wide range of finishes can be produced. By utilising concrete's aesthetic potential as well as its well-known structural properties, a cost-effective building solution can be achieved.

This publication provides guidance on how to achieve good quality off-form concrete finishes. It discusses the factors influencing the quality of off-form finishes starting from planning and design to construction and maintenance. Recognising that many architectural finishes involve subsequent treatment of the off-form finish, some guidance is also included for typical treatments such as abrasive blasting. Information is also given on the important factors to be considered when specifying these types of finishes, so that specifications can be realistic and acknowledge what can be achieved on site.

02 Planning and design

2.1 COMMUNICATION

High-quality off-form or architectural finishes require special attention. They demand a formwork of high quality, extreme care in the choice and production of the concrete mix and a high level of workmanship and care by all contractors involved. As the difference between success and failure depends on the contribution of so many people, effective communication between them is essential.

Achieving quality off-form finishes does not depend solely on how the concrete is placed. The stages influencing the result include:

- **Design** Designers must be aware of detailing issues that will impact on the placement of the concrete; items such as minimum wall thicknesses to avoid scoring the form surface during compaction, and spacing of reinforcing bars to facilitate concrete placement and avoid honeycombing.
- **Concrete Supply** Suppliers need to be aware of any special mix requirements such as colour control, low bleed rates, more-stringent tolerances on slump and colour pigments.
- **Formwork** Formworkers must supply the appropriate materials and be aware of the limitations on reuses in terms of maintaining the specified quality of finish. Formwork must also be designed to adequately support the loads from placing and compaction of concrete without excessive deflection, be constructed with the finished appearance in mind and be clean. Form release agents must be selected to allow easy stripping, avoid damage to the concrete surface and allow the required colour and texture to be achieved.
- **Placing** Concretors must place, compact and finish the concrete in such a way that uniform finishes will be achieved.
- **Curing** Concrete must be cured properly and uniformly if colour control is critical.
- **Assessment** Finishes should be assessed at an appropriate time (as colour may vary with age) with acceptable criteria established at the commencement of the project and clearly understood by all contractors responsible for the work.

The importance of communication between all parties involved in a project can not be over-emphasised, particularly if special off-form finishes have been specified. Unless everyone has an appreciation of what is required, is committed to achieving it and understands how their role can influence the quality of the finish, the result may fall short of expectations.

Test panels (or construction of non-critical parts of the actual structure) can be used to assess whether or not the specified materials and processes can produce the required off-form finish under actual site conditions. An assessment of the finish and review of procedures will identify whether some areas need to be improved. The placing of several trial sections that incorporate all the typical features of the structure is an ideal way to gradually refine the construction process and gain confidence that finishes can be readily reproduced for all elements anywhere within the structure. Acceptance of an agreed test panel then sets the standard and forms the basis for approval of subsequent work. Note that AS 3610[1] requires test panels to be provided for certain finishes.

2.2 TYPES OF ELEMENTS

The relative importance of the various factors influencing the achievement of an off-form finish will vary according to the type of element involved (eg column, wall, beam).

Greater care is required with vertical elements such as columns and walls as the lateral pressure from the fluid concrete may result in greater formwork deflections. If concrete is placed in stages to reduce pressures, attention to placement methods is necessary if 'joint' lines are to be avoided. If colour control has been specified and more than one batch of concrete is used in a column or wall, the consistency of the concrete will be critical.

Building facades will require appropriate detailing of joints between concrete placements and attention to colour control if this has been specified, as it is difficult to achieve consistent colour over large areas (this will be particularly critical if the area can be viewed as a whole).

Shallow elements such as beams are more easily compacted and do not suffer the same problems as walls or columns in terms of expelling entrapped air (reducing the occurrence of blowholes) and cleaning of formwork prior to concrete placement.

2.3 INSITU v PRECAST

While the more-appropriate approach will vary from project to project, precast has some advantages over insitu work in terms of the range and quality of off-form finishes that can be achieved. The main advantage of precast is that concrete elements are manufactured under factory-controlled conditions; therefore the finish and quality are generally of a higher standard than concrete elements constructed on site. Other advantages are that vertical elements such as columns and wall panels are cast as horizontal elements (providing ease of manufacture and elimination of tie-rod holes) and that work can be inspected prior to delivery to site.

Figures 1 and 2 illustrate some of these advantages. The first shows a wall panel being cast on steel casting beds which – because form-face deflections are negligible – produce flat, straight surfaces. The second shows pigments being used to colour only the surface layer of concrete (a veneer) – a very economical way to provide a coloured finish.

The main disadvantages of precast are limitations on the size of the elements that can be manufactured, transported to site and erected by crane, and the inevitability of joints between panels or column/beam junctions. While early consideration can resolve most of these issues, many projects require concrete to be placed in situ.

Comprehensive information on the finishes available on precast concrete are provided in the NPCAA's *Precast Concrete Handbook*[2].

2.4 RANGE OF SURFACE FINISHES

2.4.1 General Off-form concrete finishes can either be smooth or textured. Smooth finishes are typically achieved by using a smooth form-face material such as steel or plywood with a phenolic film on the surface. Textured finishes are created by either attaching materials to the formwork such as rope **Figure 3**, timber boards **Figure 4**, formliners **Figure 5** or other materials, or by using profiled form-face materials such as corrugated sheeting **Figures 6 and 7**. Subsequent treatments such as tooling, bush hammering and abrasive blasting can also produce textured finishes.

2.4.2 Smooth/plain finishes are typically specified by nominating a Class 1 to Class 5 finish in accordance with AS 3610.

Classes 1, 2 and 3 are for typical architectural applications where the concrete surface is visible. Class 1 finishes should generally be specified only for selected small elements contained in a single pour, and not for entire building facades, since they are costly to achieve and difficult over large areas. Only the best quality and new form-face materials are suitable, and the formwork required is of carpentry standard. Class 1 is often specified for residential and public applications where close scrutiny of the finish is possible or the finish is to reflect the importance of the building or structure. **Figure 8** shows typical Class 1 finishes both in quality and colour control.

Class 2 finishes are appropriate for exposed concrete in areas where people have the opportunity to view

FIGURE 1
Casting of a wall panel in a precast factory

FIGURE 2
Placing a green pigmented concrete surface layer for a large wall panel. (Note layer extends around window reveals)

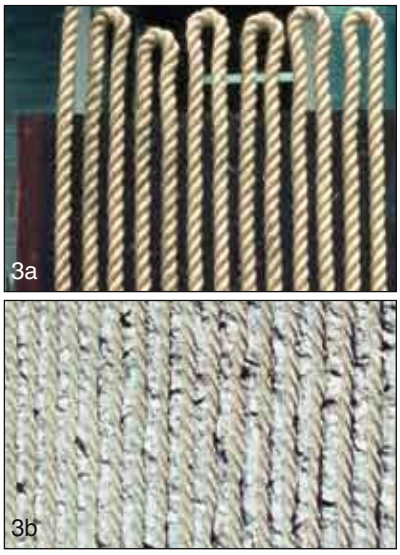


FIGURE 3
Rope finish
[a] Rope attached to formwork
[b] The resulting finish

the finish in detail. Typically, Class 2 would be the minimum finish for residential applications and other building and structural elements that can be seen from close up. Good-quality form-face materials are required but (unlike that for a Class 1 finish) some reuse of each face is possible, providing greater economy. Often Class 2 is specified as the 'default' for any architectural finish where the concrete is left exposed, but in reality Class 3 would be suitable for most applications such as carparks, fire stairs and building facades above, say, level 2 or 3 where the finish can never be viewed from close proximity **Figure 9**.

Class 3 finishes would suffice for most exposed concrete applications such as carparks where the structure is viewed as a whole, and people are less alert to the actual finish.

For each class of finish, AS 3610 nominates a number of parameters **Table 1** which must be complied with. The combination of these is deemed to provide an appropriate quality of finish for the particular class. For the more subjective areas of blowholes and colour control, photographs of typical blowholes for Class 1, 2 and 3 finishes, and a colour chart are provided. These allow a direct comparison with the actual

FIGURE 4
Board-marked finish
[a] Forms in place
[b] The resulting finish

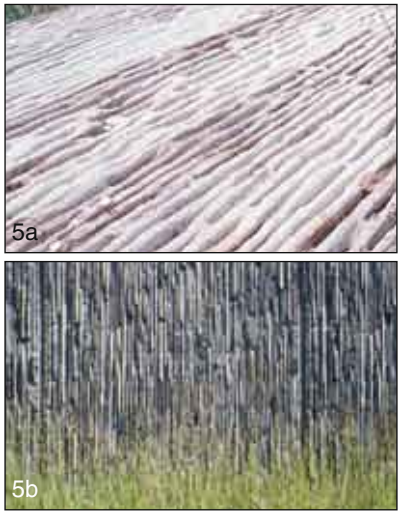


FIGURE 5
Silicone rubber formliner used for texture
[a] Formliner in place
[b] The resulting finish

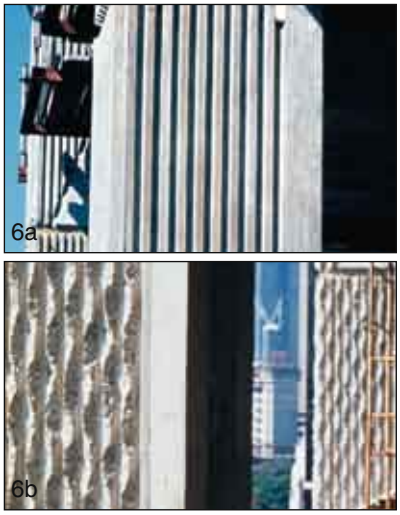


FIGURE 6
Profiled surface
[a] After form removal
[b] After subsequent treatment (hammered nib)

FIGURE 7
Custom orb steel sheeting used as form-face material, Kings Beach, Queensland

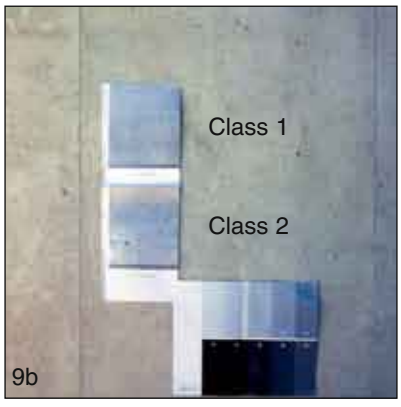
FIGURE 8
Class 1 finish to terrace colonnade, Parliament House, Canberra.
[a] General view
[b] Close up
[c] Comparison of blowholes in column to photograph in AS 3610

TABLE 1 Acceptable minimum quality of surface *(from AS 3610)*

QUALITY OF SURFACE FINISH	Class 1		Class 2		Class 3		Class 4		Class 5	
1 Blowholes	Refer photographs in AS 3610 for examples						N/A		N/A	
2 Form face deflection	Lesser of 2 mm or span/360		Lesser of 3 mm or span/270		Greater of 3 mm or span/270		Greater of 3 mm or span/270		N/A	
	Tolerance for straight elements with smooth surface, in millimetres									
	% of readings									
	95	100	90	100	80	100	70	100	70	100
3 Face step										
within the element	1	2	2	3	3	5	5	8		
at in situ construction joint	2	3	2	3	3	5	5	8	*	*
4 Surface undulations**										
l = 300 (a – b) ≤	1	2	2	4	3	4	5	7	*	*
l = 1500 (a – b) ≤	2	4	3	6	5	7	8	10		
5 Flatness										
1.25 m grid	4	5	6	7	7	10	*	*	*	*
at 5 m over 10 m	5	7	7	10	10	15	*	*	*	*
(not applicable to precast concrete)										
6 Out of plumb										
height < 3 m	3	5	4	6	5	7	*	*	*	*
3 < height < 8 m	6	8	8	10	10	12	*	*	*	*
(not applicable to precast concrete)										

Notes N/A *indicates not applicable*
** Limited by AS 3600*
*** a and b are respectively the maximum and minimum distances from the straightedge*

9a



9b

FIGURE 9
Class 2 finish to Telstra Tower, Canberra
[a] General view
[b] Comparison of blowholes to photograph in AS 3610

finish to assess compliance. The example shown in **Figure 10** indicates that the finish is a Class 2 with respect to the occurrence of blowholes. Note that the off-form finish must be assessed prior to any subsequent treatment. As shown in **Figure 11** the sand blasting of this Class 2 surface has revealed a number of blowholes that would otherwise have remained concealed below the surface of the concrete.

Classes 4 and 5 are for typical structural applications where the concrete surface is either not visible, or the surface finish quality is not critical (eg footings, concrete frames covered by other finishes). While some requirements for Class 4 finishes are included in AS 3610, they are generally governed by the requirements of AS 3600[3], ie structural design rather than appearance of the surface. Lower-grade form-face materials with a greater number of reuses are permitted, giving the most economical formwork system.

2.4.3 Textured finishes can provide intricate patterns that are clearly discernable at close range, but become less obvious as the viewing distance increases to, say, 20 m, where the appearance may be nothing more than a general striation of the surface. For this reason, while they may be used for medium- to high-rise buildings, the additional cost of providing such finishes above the fourth or fifth storey (where they cannot typically be viewed from close range) should be borne in mind.

Some specific finishes include:

■ Rope finishes These surfaces provide excellent weathering properties as the extremely rough texture distributes water flow and minimises the visual impact of streaking from the accumulation of contaminants such as dust. The type of rope, diameter and spacing are critical to the appearance of the finish, and these should be selected from previous experience and/or confirmed via test panels. Ideally, there should be no flat areas such as those seen in **Figure 12**. Either the rope diameter should be increased or the spacing reduced to avoid these areas.

■ Board-marked finishes Board-marked finishes generally produce a fine, shallow texture and, similar to rope finishes, can be seen clearly at close range but clarity diminishes as the viewing distance increases.

The timber for board-marked finishes can be either quarter-sawn or back sawn depending on the visual appearance desired **Figure 13**. Quarter-sawn boards tend to simply reflect the grain direction, whereas back-sawn board can add interest to the texture. Boards can be either fine-sawn **Figure 13** or rough-sawn **Figure 14** and also vary in thickness to create a three-dimensional finish **Figure 15**.

Boards are available in a variety of widths and thicknesses, with wider boards generally tending to cup and warp more. They should be a minimum of 1600-mm-long to minimise end joints, which, where required, should be staggered and not less than 900 mm apart **Figure 16**.

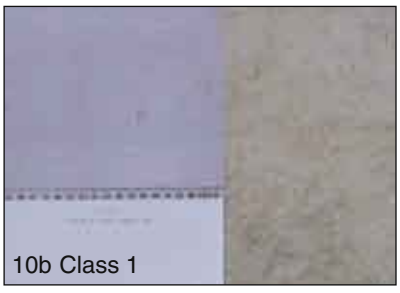


FIGURE 10
[a] Determining class of finish with respect to blowholes by comparison with photographs in AS 3610
[b] Close-up of surface in Figure 10a indicating Class 2 finish achieved

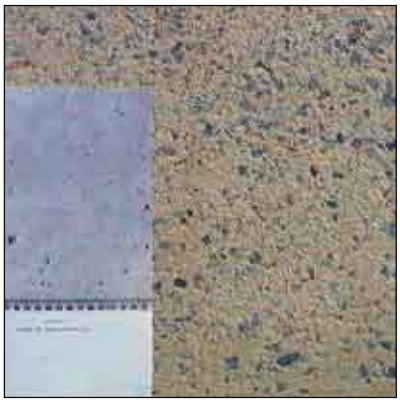


FIGURE 11
Increased blowholes in sand-blasted Class 2 off-form finish

Reuse of boards varies considerably depending on the preparation, care and timing of stripping and re-handling. Anywhere from one to thirty reuses may be obtained.

Note that board-marked finishes tend to hold dirt on the surface and may harbour fungal growth in tropical climates and thus be inappropriate in some locations. The application of a sealer may overcome some of these issues.

■ Formliners Formliners are materials placed against the form face to provide a negative mould against which the concrete is cast. Almost any texture or pattern can be reproduced, from rope and board marked finishes to various stone/rock patterns. The common materials used include styrene foam, rigid plastics and fibreglass, profiled steel sheet, and elastomeric materials such as polyurethane and silicone rubbers.

The use of formliners may be a more economical way than the use of ropes or boards (described above) to achieve a heavily textured finish over large areas, especially if a number of reuses are possible to offset the initial cost. Formliners can generally be reused many times, considerably reducing the cost per square metre.

FIGURE 12
Rope finishes should not contain flat areas between rope locations

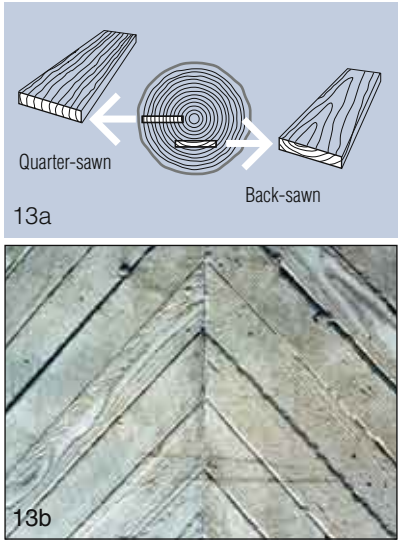


FIGURE 13
Types of timber boards
[a] Sawn boards
[b] The resulting finishes

FIGURE 14
Off-form finish from rough-sawn boards

FIGURE 15
Board-marked finish

FIGURE 16
Joint between timber boards (board-marked finish) located away from column. Staggering of end joints would assist with continuity and direction of the element.

FIGURE 17
Insulated concrete forms with texture moulded into polystyrene form

For patterns such as that shown in **Figure 5** and for which off-the-shelf formliners may not be available, elastomeric formliners made from silicone rubber or polyurethane in a liquid form can be used to make a formliner/mould from almost any background. These elastomeric materials generally have a high initial cost but this is offset by the high number of reuses, perhaps 80 to 100 being possible. The flexibility of elastomeric materials also allows undercutting (negative draft) to enhance the textured finish.

Rigid plastics and fibreglass formliners are also commonly used for complex shapes and profiles that would be difficult or impossible to achieve by other means. They give a very smooth, mirror finish to the concrete (unless textured); because of this they should be used for surfaces that can be viewed only from a distance (see Section 3.2.1). About 10 reuses may be possible, with patterns generally not as intricate and undercutting not possible. The joints between adjoining panels are difficult to disguise and, as with other materials, they are best accentuated.

Polystyrene is a 'once-off' material having limited applications because of its difficult stripping characteristics despite the use of release agents. Many insulated concrete formwork systems (ICFs) are now available with textures moulded into the face of the polystyrene to produce a finish on both sides of the wall **Figure 17**.

Formliners can be created in a number of ways using a variety of other materials, some of which can be relatively inexpensive and produce individual patterns. Crumpled paper or aluminium foil was used to create the finishes shown in **Figure 18**, plastic sheeting over packers for the finish in **Figure 19**, and pieces of formply fixed in either a random or set pattern **Figure 20**. Experimentation and the construction of test panels with these materials is essential to confirm the anticipated texture and appearance, and to ensure satisfactory results for the particular member and surfaces involved.

Some formliners can consist of different materials that become a permanent feature of the finish such as various brick and stone facings **Figures 21**, **22**.

Formliners generally provide surfaces with good weathering characteristics by breaking up water flow across the surface and thus controlling streaking.

Formliners may not be suitable for all classes of finish (eg Class 1), while communication between designer, contractor and formliner supplier is essential, as is the production of a realistic test panel. Important considerations include the fixing method, appropriate release agents, stripping techniques, maintenance and repair techniques. A formwork system compatible with the liner must be used, as must a quality of concrete capable of transferring the texture to the concrete surface. Placement and compaction procedures to eliminate segregation and blowholes within the texture are also critical.

Joints between formliner sections/panels may also need to be discussed with the supplier as the pattern and/or edge fixing details may not allow a continuous pattern/texture to be formed. If joints can not be concealed **Figure 23** detailing of the joints should be considered. The size and detailing of these should suit the texture provided to the surface and the scale of the element. Further information on formliners can be found in CCAA's *Briefing: Form Liners*[4].

FIGURE 18
[a] Crumpled paper used to create recesses in concrete panels
[b] Off-form finish using crumpled aluminium foil in an apartment building

FIGURE 19
Off-form finish using plastic sheeting over packers, Inner City Bypass, Brisbane

■ Moulds Textured finishes can also be produced from moulds. Similar to formliners, moulds are mainly used in precast factories for the repeated provision of a pattern **Figure 24**; if a pattern/texture is required on both faces, the top surface can be stamped **Figure 25**. The pattern can also be designed to create a recurring, yet seemingly continuous pattern over a number of elements **Figure 26**. Apart from the formlining materials discussed above, if they do not have to be moved (ie in a precast factory), materials such as concrete could also be considered for moulds offering a large number of reuses. **Figures 27**, **28** are examples of where the formwork itself can be used as a mould to shape the off-form concrete surface.

■ Form coatings Various coatings can also be applied to the form face in order to provide a decorative finish to the off-form concrete surface. **Figure 29** shows the result of coating the form face with a material containing powdered copper which becomes embedded into the concrete surface. As the copper oxidises over time, the finish takes on the green copper-oxide colour. Powdered copper (and other materials) can also be trowelled into the concrete surface to produce various metallic effects **Figure 30**. Detailed discussion of these finishes is beyond the scope of this Guide.

Set retarders can also be used to provide texture and colour; they are applied to the form face to retard the set of the concrete surface. Once the formwork is stripped, the cement paste on the surface is removed to reveal the aggregates, changing the colour and texture of the surface. Photo-engraved finishes are typical of this method where an image is revealed by altering the depth of exposure of the coloured aggregate using varying amounts of set retarder **Figure 31**. Details of this process can be found elsewhere[5].

■ Water washing This process is used to expose the aggregates by removing the cement paste prior to the hardening of the concrete surface. While it is usually used for precast concrete elements, it may be used for insitu work in conjunction with set retarders applied to the formwork surface prior to concrete placement.

■ Tooled finishes Tooled finishes (which provide texture and colour by exposing the coarse aggregate) are sometimes used on off-form concrete surfaces and some basic description is included in this Guide. Note that these finishes are generally labour intensive and the use of formliners to provide texture and create light and shade (but not expose the aggregates or their colour) may be more economical.

Tooled finishes involve mechanically tooling or hammering the off-form finish to produce a rough texture. Common methods include bush hammering, point tooling, abrasive blasting and hammered-nib.

Bush hammered finishes **Figure 32** range from removal of the surface cement paste (exposing the aggregates) to extensive removal of the matrix and possible fracturing of the stone. The depth of hammering must be specified (typically 1 to 8 mm) and the appearance verified by a test panel. Note that as the removal of the surface will tend to highlight any imperfections, a good quality off-form finish is required. Also, to avoid chipping the edges/corners, untreated borders some 25 to 40 mm in width should be provided.

FIGURE 20
[a] Off-form finish using pieces of formply (off-cuts), Roma Street Parkland, Brisbane
[b] Layers of formply used to reproduce artwork in off-form finishes
[c] Timber battens used to create horizontal pattern

FIGURE 21
Permanent formlining materials – brick inlay system
[a] Form face lined with brick batts
[b] Removing plastic frames to reveal brick finish

Point tooling **Figure 33** provides a very coarse texture about 15 mm in depth. The coarse texture is suitable for larger elements, and will generally remove or conceal any surface imperfections. A large aggregate should be used.

Abrasive blasting **Figure 34** can also be used to remove the surface paste or matrix around the stone to expose the coarse aggregate. The depth of removal should be specified, but in no case should more than one third of the aggregate particle become exposed to ensure adequate bond into the concrete. Acid etching is an alternative method of exposing the aggregate **Figure 35**; its use is generally limited to precast elements.

Hammered-nib finishes **Figure 6** involve producing a smooth off-form striated finish and then hammering the nib to produce a rugged broken appearance that highlights the coarse aggregate. As the colour of the off-form finish predominates, unlike other tooled finishes, the off-form concrete finish must itself be of a high quality.

FIGURE 22
[a] Form face lined with random pieces of marble
[b] Close-up of the polished marble concrete finish in 22a

FIGURE 23
Joint between formliner panels
With permission from Buck Scott of Scott System, Inc., Denver, CO, USA. Design created by Carolyn Braaksma (also of Denver, CO)

FIGURE 24
Wall panels cast in special moulds, National Museum of Australia, Canberra

FIGURE 25
Stamped precast panel enabling texture on both sides

FIGURE 26
Retaining wall panels cast in moulds, Liverpool to Parramatta bus transitway, NSW

FIGURE 27
Polyethylene formwork system moulded to produce rock-faced off-form finish

TABLE 2 Recommended aggregate size for tooled finishes

Viewing distance (m)	Aggregate size (mm)
6	6 – 10
12	10 – 20
20	20 – 35
27	25 – 32

The coarse texture of tooled surfaces generally provides colour via the exposed coarse aggregate and a surface that is less likely to be affected by staining from atmospheric contamination and weathering.

Similar to rope and board-marked finishes, the effect of exposing the aggregates depends on the viewing distance. **Table 2** provides an indication of the appropriate aggregate size for various viewing distances.

If a combination of both insitu and precast is being used, and various tooled finishes that expose the

FIGURE 28
Aluminium formwork system providing brick textures

FIGURE 29
Green copper oxide finish from coating form surface

FIGURE 30
Copper dust trowelled into surface (sealed to prevent oxidisation)

FIGURE 31
Set-retarder applied to form surface (photo-engraved concrete) *With permission from The Concrete Society, UK*

FIGURE 32
Exposing the aggregates by bush hammering

FIGURE 33
Course texture achieved by point tooling

aggregate have been specified, the appearance may vary due to the orientation of the coarse aggregate particles **Figure 36**. A greater area of aggregate will be seen in elements cast flat (typical of precast), than in those cast vertically unless a cubic aggregate is used in the concrete mix for both.

Further information on these types of finishes is provided by Jones[6].

A smooth texture can be achieved by honing and polishing of the surface **Figure 37**.

2.5 FORMWORK

2.5.1 Materials In Section 2.4, formwork was considered in the context of the surface finish it produced; this section covers its function purely as a temporary structure that holds the fluid concrete (moulded into the desired shape) in the correct position until it is able to support its own weight and the loads imposed upon it.

As fresh concrete is a plastic and malleable material which will accurately reflect the shape, texture and finish of the surface against which it is cast, the formwork is critical to the final appearance of the hardened surface. Any imperfection or inaccuracy in the formwork surface will be reflected in the off-form concrete finish. Form-face materials must therefore be chosen both to achieve the required surface finish and, in conjunction with all the elements that support the form face, maintain tolerances and stability under all the loads imposed during erection and concreting, and until the concrete has gained adequate strength. Failure to meet the required tolerance, stability and strength requirements may lead to formwork failures such as bowing, warping and misalignment, all of which will be reflected in the off-form concrete finish.

As part of the formwork system, a number of materials can be used for the form face against which the concrete is cast. In addition to its texture, the absorbency and watertightness of the form face also affect the appearance of the concrete cast against it.

The requirements for formwork include:

- Strength All formwork components should be designed to carry the loads imposed on the formwork.
- Stiffness Formwork should not bow, bulge, sag or otherwise distort/deflect to an extent that the specified shape, tolerances or appearance of the off-form surface can not be achieved. While the metal support system shown in **Figure 38** may provide a rigid frame to restrain movement, the deflection (within tolerance) of the more-flexible timber form-face material during concrete placement resulted in the off-form surface shown in **Figure 39**. Both the shape and tolerance requirements have been satisfied, but the visual quality of the surface has not met the expectation of a 'flat' surface. The deflection of the timber formwork system used for the walls in **Figure 40** has resulted in the overall shape not being maintained.

A lack of stiffness leading to deflection and movement during concrete placing and compaction may also contribute to a range of defects such as colour variation or a mottled appearance sometimes referred to as aggregate transparency. These are discussed in Appendix A.

FIGURE 34
Abrasive blasting, exposing the aggregates

■ Tolerance The tolerances on formwork should generally be tighter than those desired in the finished concrete structure or element, and should ensure shape, size and cover to reinforcement.

The tolerance required may affect the selection of the material from which the formwork is to be built, or govern its design. For example, steel formwork will enable tighter tolerances to be maintained.

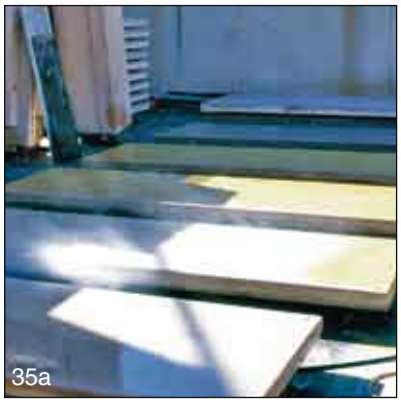
■ Absorbency Variable absorbency of the form face will result in colour variation, possibly even dark staining of the surface. This is caused by changes in the water-cement ratio of the concrete at the surface. While this typically affects only the surface layer, a sufficient depth may be affected such that subsequent surface treatments such as tooling of the concrete may not remove the staining. The colour variations are usually most noticeable when adjacent form-face panels have different absorbency. Note that the absorbency of 'new' formwork changes after a number of uses. This should be taken into consideration when replacing old or damaged formwork sheets with new ones. Also, the uniformity of the release agent coating can affect the absorbency of the form face.

■ Watertightness Loss of moisture and/or cement grout through lack of watertightness can lead not only to ragged edges and colour variations from hydration staining, but also to other problems, notably honeycombing.

■ Robustness Formwork should be robust enough to withstand repeated stripping, storing and erection to enable reuse.

TABLE 3 Common formwork materials

Material	Typical uses
Timber	Form-face supports such as studs, bearers, joists and whalers.
Steel	Formwork framing and in precast factories particularly for repetitive work. (While strong and robust, requires some standardisation and multiple reuses to warrant the cost.)
Coated plywood	Slabs, columns and beams. (Readily worked and capable of multiple reuses.)
Cardboard	Column forms, edge forms. Normally for one-off use only.
Glass reinforced cement (GRC) or plastic	Permanent formwork (where it provides a decorative finish) or as the mould for intricate shapes (particularly precast elements).
Concrete	As permanent formwork for standard elements or components produced in precast concrete factories.
Rubber, silicone, thermoplastic and polystyrene	Formliners providing intricate effects and decorative finishes. (Most materials are capable of multiple reuses.)



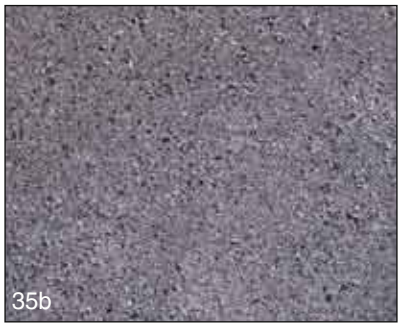


FIGURE 35
Acid etching of precast elements
[a] Process
[b] Exposed fine aggregate
[c] Exposed coarse aggregate

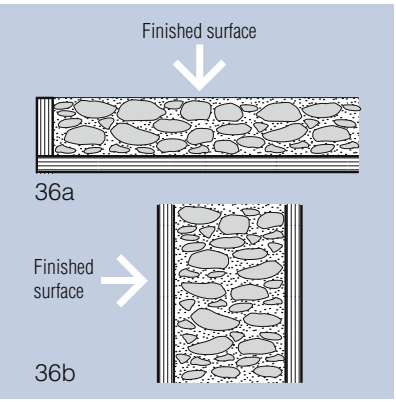


FIGURE 36
Orientation of aggregates may affect appearance
[a] Elements cast flat – aggregate particles tend to lie horizontally
[b] Elements cast vertically – aggregate particles will also tend to lie horizontally

■ Ease of stripping Formwork should be easy to remove to avoid damage to the concrete surface and/or to the formwork itself.

Of the above properties, those with most impact on off-form finishes are stiffness, absorbency and watertightness.

Many materials may be used for formwork. For small projects that involve a great deal of cutting and fitting, and therefore increased wastage, lower grade materials may be an option if the surface finish is not critical. For large projects, made-up elements such as table and wall forms could provide economies. The quality of the finish required and the overall cost of the formwork are likely to be the principal determinants. **Table 3** provides a brief overview of the characteristics of the most common formwork materials.

The use of permanent formwork (ie formwork which is left in place) could minimise subsequent finishing operations. While precast concrete and GRC are commonly used for permanent formwork, materials such as fibre cement sheet, polystyrene **Figure 41**, and reinforced plaster **Figure 42** are also used in various concrete walling systems.

FIGURE 37
Smooth texture achieved by honing

FIGURE 38
Metal formwork supports to timber form face

FIGURE 39
Deflection of timber form-face material shown in Figure 38 reflected in off-form concrete finish

FIGURE 40
Loss of shape resulting from defection of timber formwork

FIGURE 41
Polystyrene formwork (ICF or insulated concrete formwork) system to retain concrete infill

FIGURE 42
Reinforced plaster wall panels to retain concrete infill

Recent developments have seen new materials used in formwork systems and the incorporation of various surface textures ranging from rock faced to brick and block patterns **Figures 43, 44**.

For some elements in a structure it will often not be necessary to provide the same quality of finish on all faces. Critical faces should be identified and perhaps be specified as a higher class of finish – say Class 2, with other less critical parts of the structure that can not be viewed at close range having a Class 3 finish. In this way formwork materials can be reused for lower quality (less critical) faces.

2.5.2 Design

All formwork design should comply with the provisions of AS 3610. The formwork drawings should show the pattern of the form face, if any, and typical joints between formwork panels. Careful detailing of such joints is critical to the success of off-form finishes. For example, all control and construction joints on vertical surfaces should either be boldly expressed or disguised.

2.5.3 Release Agents

While generally regarded as a minor item, the selection of an appropriate release agent and application method may be critical to the success of the project, affecting both the quality and colour of the surface finish.

As concrete will bond to most form surfaces, release agents are primarily used to allow the formwork to be cleanly released from the concrete surface. Equally important is their role in protecting and extending the life of the formwork, enabling a good quality off-form finish to be maintained with each reuse of the formwork. Release agents can also affect the colour of the surface and the adhesion of subsequent finishes or coatings.

There are two main categories of release agent: barrier and reactive. Barrier compounds form a physical barrier between the concrete and formwork, while reactive compounds not only form a barrier, but also contain ingredients that react with the calcium hydroxide in the concrete to form a chemically inert metallic soap that helps minimise adhesion of the form, keeps the form clean, and thus extends its life.

Barrier products commonly used include water-based or solvent-based petroleum products; paraffin-based materials; or soap type release agents, which vary in ease of application. They tend to build up on the form surface, which will therefore require regular cleaning.

Reactive release agents generally contain a small percentage of fatty acids. They can be either vegetable oils, or more commonly, petroleum-based materials. They allow easy release of forms and assist with minimising blowholes. As they will react with metals such as brass, bronze, aluminium and steel, the use of appropriate application (spraying) equipment is essential.

With the variety of products on the market, each contributing differently to the off-form finish, care in the selection of a release agent is required. Manufacturers' recommendations should be sought for

FIGURE 43
Stone textures created by use of formliners

FIGURE 44
Three-dimensionally profiled polystyrene formwork used to cast curved wall *(as appeared in 'Residential Concrete' November 2005)*

FIGURE 45
Colour variation due to release agents

specific projects. If colour control has been specified, once a release agent has been chosen, it should not be changed during the course of the work without due consideration to the effects on colour and finish. **Figure 45** shows the colour variation possible from a variety of different release agents, and **Figure 46** the effect of changing a release agent midway through a project.

Test panels built prior to construction provide the best method for assessing the suitability of a release agent for the given application.

2.6 TOLERANCES OF OFF-FORM SURFACES

The tolerance of an off-form concrete surface is the allowable variation from the specified flatness, shape or location. Tolerances are provided to ensure that the finished concrete surface is acceptable for the application and/or the intended function while acknowledging that some degree of variation is inherent in all building work.

Tolerances on visual aspects of concrete are specified in AS 3610. Tolerances on structural aspects (eg the position of a member) are covered by AS 3600 and are not discussed in this document. Detailed information on all tolerances can be found in Data Sheet: *Tolerances for Concrete Surfaces*[7].

Tolerances for Classes 1–5 are specified in AS 3610 for various aspects of the surface finish **Table 1**. If required by the application, other tolerance values can be specified and indicated by the suffix 'X' after the class of finish, eg Class 2X. The limits of any varied tolerances should be included in the project documentation, but should not be less stringent than the tolerances given in AS 3600 for structural adequacy.

Referring to the Class 2 off-form finish shown in **Figure 39**, while the appearance may not meet expectations, the form-face deflection is within the limits given in AS 3610. It is therefore important to understand the relevance or limitation of specifications for particular applications, and how they can influence the appearance of the off-form concrete surface. Note that the form-face deflection limits in **Table 1** are quite stringent for Class 1 and 2 finishes and the specification of a more-stringent tolerance may not be practical. The solution for vertical elements may be to specify limits on the height of concrete that can be placed in any one lift in order to reduce the pressure on the formwork and hence deflection of the form face.

While some tolerance requirements for Class 4 finishes are included in AS 3610, the tolerances for Class 4 and 5 finishes are generally governed by the requirements of AS 3600, ie structural design rather than appearance of the surface. An appreciation of the tolerances provided is required in the context of the fit of the various building components.

Specified tolerances should realistically reflect the requirements for the appearance and function of the concrete element. The practice of specifying more-stringent tolerances than required to cover unforseen circumstances should be avoided. Recommended tolerances for various elements are discussed in *Tolerances for Concrete Surfaces.*

FIGURE 46
Colour variation resulting from the use of two different release agents

FIGURE 47
Staining from aggregates containing iron oxide

2.7 CONCRETE

Generally, concrete is manufactured and supplied in accordance with AS 1379[8] which classifies concrete in two broad groups; normal and special class. If the concrete must satisfy additional requirements; these should be discussed and specified in consultation with the supplier.

While specifying a normal class concrete and method of placement may suffice for some off-form finishes, consistent high-quality surface finishes are more demanding. A special class concrete must generally be specified if:

- any of the concrete properties (strength, slump, aggregate size, method of placement, air entrainment and testing) vary from the range of values allowed for normal class concrete by AS 1379;
- special performance parameters or materials are required, including:
  - colour control
  - the type/colour of cement (GP, GB or off-white) and supplementary cementitious materials, their source and relative proportions, to minimise colour variations throughout the work;
  - the sand, and its source, again to minimise colour variations;
  - the coarse aggregates and especially the amount of flat, flaky or elongated particles to be permitted (a minimum practical limit is advisable because of the adverse effect such particles have on the textural quality of off-form finishes); and
  - a minimum cement content. The mix design for concrete for high-quality finishes will, typically, have a higher cement content and a lower water-cement ratio than may be necessary for the strength requirements of the work. The concrete is sometimes less workable than 'normal' structural concrete and, hence, may not be suitable for pumping. It may also require more-intense vibration to compact it.

The importance of consultation becomes apparent where colour control is required especially since colour control may be affected by other factors such as the method of placement and weather conditions at the time. For large projects on which colour control is specified, the requirement for consistency of supply is particularly important. All the factors affecting this must be considered, eg the impact of different admixtures used in summer and winter. The stockpiling of aggregates may be necessary as part of maintaining consistency over time.

On many jobs, a suitable mix design will be agreed only after the construction of adequate test panels, which then serve as reference panels as the work proceeds. Alternatively, reference can be made to previous projects which are similar in finish and colour to that proposed.

An occasional presence of pyrite in some aggregates may cause spot staining **Figure 47** which can be treated/removed. Similar stains may also occur due to reinforcement tie wires and wire bar chairs close to the surface.

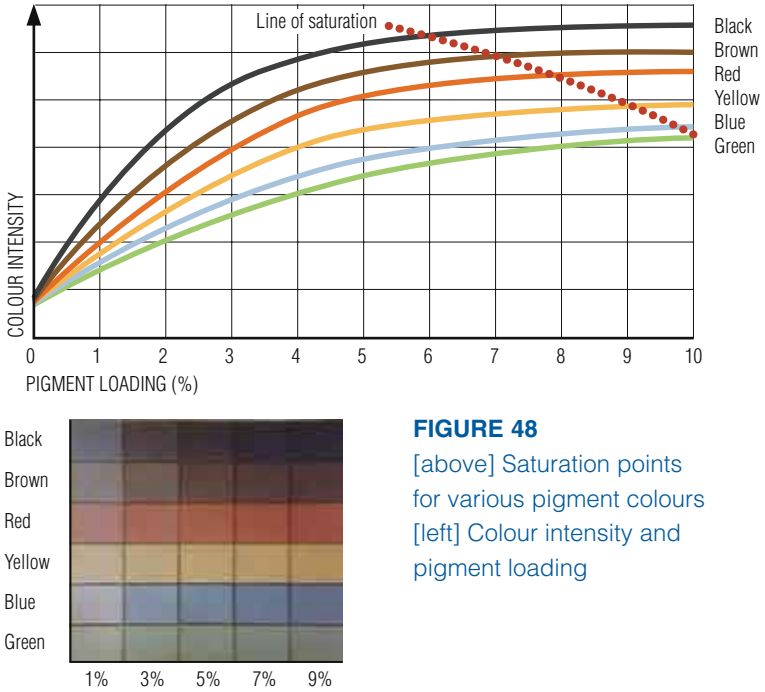


FIGURE 48
[above] Saturation points for various pigment colours
[left] Colour intensity and pigment loading

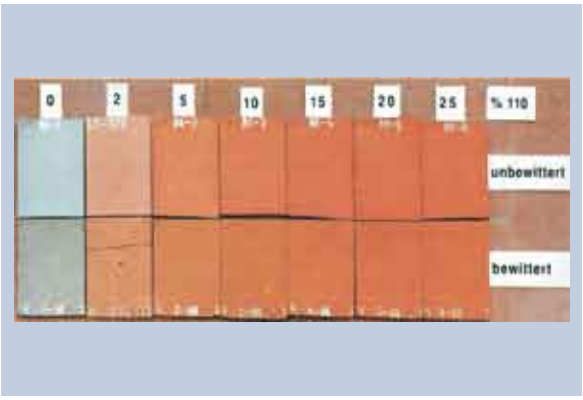


FIGURE 49
Effect of pigment concentration on weathering
– top row, unweathered
– bottom row, weathered for 4 years
With permission from Betonwerk + Fertgeil-Technik

2.8 COLOURED CONCRETE

2.8.1 General There are a number of ways to provide coloured off-form concrete finishes: using off-white or white cement; adding a colour pigment to the concrete; applying a coating to the form face that becomes an integral part of the surface finish, or applying a surface stain or coating after the concrete has cured. If the suface is tooled to expose the aggregates, then the use of coloured aggregates is also an option.

2.8.2 White and off-white concrete Concrete can be produced by using off-white or white cement instead of the normal 'grey' cement.

The grey colour of cement is primarily due to its iron content. By lowering the iron content, off-white and white cements can be produced. Off-white cement is manufactured in Australia to meet the requirements of Type GP, GB or HE cements in AS 3972[9]. White cement is imported into Australia and availability should be checked prior to specifying its use.

It is not economically viable for all concrete batching plants to stock different cements, however, at least one plant in a larger group of plants will generally stock off-white cement.

Note that there are many different shades of off-white and white, and if these colours are critical to the off-form finish, then a sample panel should be constructed to ensure the colour is acceptable.

2.8.3 Coloured concrete The use of pigments is the most common method of colouring the full thickness of concrete, providing a coloured surface on all faces of a concrete element and eliminating the need for subsequent surface coatings/paints. **Figures 5, 6, 8, 19, 20a, 20b and 26** are examples of finishes achieved using colour pigments. 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.

Most colours (reds, yellows, browns and blacks) are oxides of iron. Most are now manufactured, hence the name synthetic iron oxides. These mineral or inorganic oxide pigments are permanent and not affected by the sun's ultraviolet (UV) rays. This is because oxides are materials in their most basic form and hence there is no mechanism for them to further degrade or change. They are insoluble (prevents leaching out), chemically inert (do not interfere with the cement reaction), alkali resistant (suitable for concrete which has high alkalinity), light fast (eliminates fading), harmless to the environment, and once bound into the concrete matrix they provide a permanent colouring solution. Note that some colours such as blues and greens are considerably more expensive than the natural yellows, browns and blacks due to the manufacturing process to produce these special metal-oxide pigments. The use of white or off-white cement and light coloured aggregates could enhance the brightness of these colours.

The following should be considered when using pigments:

- Pigment concentration. The normal way to specify the pigment concentration is to relate the quantity of pigment to that of cement, by specifying that it be a percentage by mass of the cement content of the concrete.

The amount of pigment required may vary depending on the colour and its tinting ability. **Figure 48** gives the saturation points for various colours, beyond which no increase in the colour intensity will occur and shows how various pigment concentrations affect the colour intensity. A pigment concentration (or loading) of 5% typically provides good colour intensity; lower concentrations may not give the colour intended; and adding more than the saturation point is an expensive way of simply adding more fine material into a mix. Because the colour is affected by the pigment concentration and tinting strength of the pigment, it is generally preferable to specify colour by selecting a particular colour from a manufacturer's range. The pigment manufacturer is then responsible for determining the required pigment concentration for the specific concrete mix. Note, with adequate pigment concentration weathering could have little effect on the colour **Figure 49.**

For large areas, the concrete strength must be kept the same. Increasing strength usually means increasing the cementitious content which results in more pigment per cubic metre and possible colour variations. Note that many factors can affect the final colour, some of which are covered in Section 3.8.3 *Colour Control*.

- Cement colour. Grey cement will always take the brilliance out of any colour, which is why the colours in concrete made with white, and even off-white cements will appear brighter. However, much depends on the desired effect and pigment colour. A range of pleasing colours can be obtained using grey cement; there will be no difference with black pigments, little difference with dark reds and browns, but a significant difference with the lighter yellows and blues. With the lighter coloured pigments the use of off-white cement should

be considered in preference to the more expensive imported white cements. Note that variations in the colour of each type of cement can also influence the final colour of the pigmented concrete.

- Concrete strength. Colour pigments added at the typical concentration of 5% will not affect the strength of the concrete. However the introduction of excessive amounts of fine material (pigment) beyond the saturation concentration will increase the water demand and hence water-cement ratio and may affect the strength.

- Efflorescence. The formation of efflorescence (a white coating on the surface) can appear to lighten the colour and give the impression that any colour pigments used have faded. It will have less impact on lighter surface colours.

- Aggregate colour. Aggregates are usually covered by a thin layer of coloured cement paste (cement, sand and pigment). However, if the aggregates are not completely covered or become exposed through wearing, weathering or even subsequent tooling of the surface, then the final colour will be affected by the colour of the aggregates; the sand initially and then the coarser aggregates. **Figure 50** shows the change in colour once the aggregates are exposed. The lighter the colour, the more influence the aggregate colour will have. Thus the selection of appropriate aggregates and aggregate colours may be an important consideration.

For surfaces with subsequent treatments that highlight the aggregate colours, the pigment concentration can be as low as 0.5 to 1% by mass of cement, to complement the aggregate colour rather than as a source of colour.

2.8.4 Coatings Off-form finishes, particularly those with colour pigments, provide a decorative low-maintenance finish displaying the characteristics of the concrete material. Each project is as uniquely individual as the concrete used to create the finish.

Coatings on the other hand provide a uniform colour over the entire surface and are generally used where no colour variations are acceptable. They conceal the substrate and, depending on the type of coating, may provide a moisture and/or a chemical barrier to the concrete. This may extend the design life of the concrete element.

Coatings range from various paint finishes (**Figures 24 and 51**) to coloured cementitious materials that provide similar results to coloured off-form finishes but with improved colour consistency.

2.8.5 Chemical Stains The use of chemical stains is a method by which individual or limited areas of an off-form concrete finish can be coloured. Stains penetrate into the concrete surface and rather than the uniform appearance achieved with coatings, distinctly individual effects are produced depending on the extent of absorption of the stain into the concrete. **Figures 52, 53** are examples of the effects possible using chemical stains.

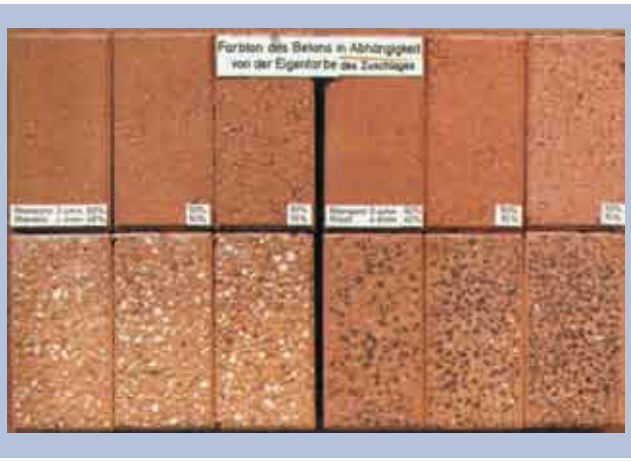


FIGURE 50
Effect of aggregate exposure (different types and percentages)
With permission from Betonwerk + Fertgeil-Technik

FIGURE 51
Formliners used to produce stone pattern to building facade, paint finish used to provide uniform colour and waterproofing

2.9 JOINTS

The location and method by which joints (expansion, control or construction) are incorporated into the concrete structure/element can have a significant influence on the final appearance.

The joints between adjoining panels, shapes and plywood sheets are difficult to disguise and as with other materials, they are best accentuated by making a feature of them. Typically, a rebate/recess that creates a shadow line within the surface is used **Figure 54**. Rebates range in size and shape depending on how prominent a feature is desired, and whether it is part of a surface pattern that may be used to break up large areas and provide a sense of scale to the surface.

The precise position of joints should be specified if the surface finish is critical. The structure will often determine appropriate locations for joints **Figure 55**. For column and beam construction, the junction between individual elements is a logical place to locate joints **Figures 8, 56**. Visually, beams are expected to span from column to column, and columns from floor to floor.

2.10 SEALERS

Sealers can be used to prevent staining, facilitate cleaning of the surface, reduce the occurrence of efflorescence and contribute to the finish/colour through tinting.

Sealers work by sealing the pores in the surface layer of concrete that otherwise allow the movement of substances either into or out of the concrete. Thus materials that could potentially stain the concrete are either prevented from penetrating the surface, or find it more difficult to become entrapped within the pores/texture of the concrete. This also facilitates cleaning of the concrete surface. Reducing or preventing the movement of water either into or from the concrete surface also assists in controlling efflorescence (the deposition of lime/salts) and growth of moss on the surface of the concrete.

When considering the large variety of sealers on the market, some issues to consider relating to off-form concrete finishes are:

- Function. The type of sealer may be governed by whether it is required to fulfill a particular function (eg an anti-graffiti coating), to minimise staining and make stain removal and cleaning easier, to prevent build up of grime on the surface, or as a waterproofing membrane.
- Film-forming or penetrating sealers. Sealers that form a film on the surface of the concrete impart a gloss appearance to the surface, the level of which depends on the characteristics of the sealer. Penetrating sealers are absorbed into the concrete, providing a matt finish to the surface and more-natural appearance to the concrete.
- Types of sealer. The main types of sealers are:
  - Wax-based. Natural bees wax and petroleum-based waxes provide a soft finish that will require regular re-application in areas subject to wear and/or staining. If the build up of wax is too thick, dirt may become embedded in the wax, necessitating its removal and re-application.

FIGURE 52
Moulded formwork used to cast 'rock' wall which has been coloured using chemical stains

FIGURE 53
Formliners used to produce concrete pier with block pattern, stains used to achieve colour on 'blocks'

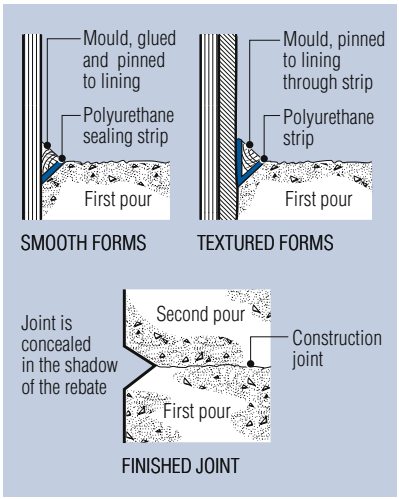


FIGURE 54
Construction joint on vertical surface

— **Acrylic.** Either water- or solvent-based, these sealers provide relatively good protection against staining at a low cost. They can be tinted, are easy to apply and can be re-applied over the old sealer.

— **Urethane.** Urethane sealers are hard wearing, resistant to a range of substances, may be re-applied, and generally form a gloss film on the concrete surface.

— **Silicone.** Solvent is used to transport the silicone into the concrete surface layer where it provides a natural matt finish without affecting the colour. Note that silicon will affect the adhesion of any subsequent surface coatings.

— **Epoxy.** Epoxy-based sealers are hard wearing, durable, can be tinted, offer excellent protection against staining and give a high gloss finish.

■ Colour. While sealers generally give a clear finish, tinting in a range of colours (both opaque and translucent) may be possible to complement other finishes. The presence of sealers will generally change the light reflectivity of the surface and therefore alter the appearance of the off-form finish without actually affecting the colour of the concrete. **Figures 57, 58**.

■ External or internal surfaces. For exterior applications, sealers should be water and UV resistant, ie non-yellowing. While all sealers are suitable for internal use, typically acrylic and silicone sealers are used for external applications. Manufacturers' recommendation regarding the appropriate product and application should be followed.

■ Water or solvent based. For interior use, low-odour, non-toxic water-based sealers are generally recommended. Solvent-based sealers typically need to be applied while the concrete is dry to prevent the sealer from turning a white colour. Water-based sealers can usually be applied while the concrete is still moist. Note that the durability and hardness of both are similar with current formulations.

■ Subsequent finishes/coating. As it is difficult to bond to some sealers, ie silicon and epoxy products, their use may limit future options.

■ Compatibility. Sealers should be compatible with other materials that may come in contact with them, eg joint sealants and sealants around window openings.

■ Test panel. If a sealer has been specified, it should be applied to the test panel in order to assess the overall appearance of the completed finish.

■ Patching. If patching of the off-form finish is required, the sealer should not highlight the patched area through, say, differing rates of absorption.

■ Precast. With precast, the sealer can be applied in the factory while the panel is in a horizontal position. The ability to pond the material on the surface may reduce the cost of achieving the manufacturer's recommended rate of application, and/or result in a greater penetration of the sealer into the concrete.

FIGURE 55
An appropriate location for the construction joint would be in line with the bottom of the upper opening

FIGURE 56
Joints between beams and columns positioned at junction of elements

FIGURE 57
Clear anti-graffiti coating on columns

■ Maintenance or ease of reapplication. Penetrating sealers end up below the concrete surface and are protected by the concrete itself. Film-forming sealers may be subject to wear (depending on the location) and require re-application. The extent of preparation required prior to recoating depends on the type of sealer, ie epoxy-based sealers will require the surface to be roughened to allow mechanical bonding of new to old sealer. Depending on the surface texture of the off-form concrete this may be difficult or even impossible to achieve.

2.11 DETAILING OF ELEMENTS FOR WEATHERING

Some of the common detailing issues that affect the long-term appearance of off-form concrete finishes are discussed briefly below. These should be considered at the design stage to ensure the longevity of the desired appearance.

■ Tops of walls. The tops of walls are often constructed flat/horizontal. This results in a build up of detritus which, with rain, is washed over the edge and down the vertical face of the wall **Figure 59**. The tops

FIGURE 58
Sealing of surface can affect the reflectivity and perception of colour (same columns shown in Figure 57, different sun angle)

FIGURE 59
Build up of detritus on flat surface (top of wall) washed over vertical finish resulting in festoon staining

FIGURE 60
Top of walls profiled to reduce build up of detritus

FIGURE 61
Discharge from balconies causing staining

FIGURE 62
Vertical surfaces have reduced accumulation of detritus

FIGURE 63
Short sloping sections result in increased accumulation of detritus

of walls should slope inwards, with runoff and detritus collected and discharged to the stormwater system. An alternative solution may be the profiling of the top of the wall to reduce the build up of detritus **Figure 60**. In areas of high rainfall where detritus is flushed from the surface, or where the surface is not porous, this issue is not as important. However, for most situations, rainfall combined with porous surfaces results in a build up of detritus on the surface of the concrete. Balconies should also be drained rather than rainwater being discharged over the edge **Figure 61**.

- Sloping surfaces. Similar to horizontal surfaces, sloping surfaces collect more detritus than vertical surfaces **Figure 62**. To reduce the build up of detritus in porous concrete, sloping surfaces should be sealed to reduce the surface porosity and allow improved self cleansing. The reduced moisture ingress will also decrease the likelihood of moss growth. Even short lengths of sloped surfaces result in increased buildup of detritus **Figure 63**.

- Cappings. Walls are often provided with a capping or flashing, the joints in which act as discharge points which tend to concentrate runoff and thereby the collection of dirt in the concrete surface below the joint, typically causing streaks. Again, the capping should fall towards the roof where runoff can be drained away, or joint locations carefully detailed **Figure 64**.

- Porosity and texture of surface. The more textured and porous the concrete surface, the greater the opportunity for detritus to collect on the surface and cause staining.

- Different shaped elements. Joining two differently shaped elements, eg circular and rectangular, may result in concentration of runoff at the junction and streaking of the surface below **Figures 65, 66**. Consideration should be given to such junction detailing to avoid poor weathering performance.

- Cover to reinforcement. Often neglected in quality control schemes, the correct cover is critical if durability is to be achieved and the off-form finish is to remain low maintenance during its design life and not be affected by rust stains or spalling concrete from the corrosion of embedded reinforcement **Figure 67**.

- Surface features. Features such as rebates, false joints and other architectural patterns, apart from providing scale to large wall areas, can assist with breaking up or channelling water flow over the surface and hence contribute to controlling the weathering of a facade.

- Texture. Highly textured surfaces break up the flow of water over the surface and produce a more uniform weathered appearance. Surfaces with dense exposed aggregates tend to be better in maintaining the original colour/appearance.

FIGURE 64
Joints in capping concentrate runoff and collection of detritus in wall. Known as festoon staining

FIGURE 65
Junction of rectangular and circular elements

FIGURE 66
Transition from linear to circular elements

03 Construction

The practices used in all stages of concrete construction affect both the appearance and structural performance of the concrete. When the concrete is not exposed in the completed building its structural performance will typically be the overriding consideration. It is self evident that when an off-form finish has been specified, its appearance will be equally important.

This chapter covers only those aspects of concrete construction that relate specifically to concrete with an off-form finish. Comprehensive coverage of matters relevant to concrete construction in general can be found in Guide to Concrete Construction[10].

3.1 TEST PANELS

As the construction of test panels should employ the same materials and procedures as the actual work **Figure 68**, it is logical that where possible, they should form part of the structure or building. This reduces costs and allows a better assessment to be made of the contractor's ability to produce the specified finish. With proper consideration of the factors necessary to produce the finish, the initial test panel or concrete placement should achieve the required result. Note that it is not possible to assess the colour consistency from a single test panel, so only the physical characteristics and initial colour of the surface can be assessed and used as a control for the remainder of the project.

If some aspects of the finish need to be improved, the contractor then has the opportunity to refine or adjust the materials or procedures in order to achieve the required outcome. The ability to use more than one concrete placement as a test panel is often beneficial if minor adjustments need to be made. Colour consistency can also be assessed with subsequent placements in non-critical sections of the project.

As the surface finish must be assessed prior to any further surface treatments, the approved test panel must remain as an off-form finish until the project is completed. If treatments such as abrasive blasting of the surface have been specified, then either an approved second test panel with this finish, or a small portion of the off-form test panel can be used to assess the quality of the subsequent treatment.

The assessment of colour by comparison to the test panel must also be carried out with care. The colour of

FIGURE 67
Insufficient cover to reinforcement

FIGURE 68
Test Panels should reflect all aspects of the proposed construction.

FIGURE 69
Worn formwork surface and grout lines at corners

the off-form finish will change with time, the continuing hydration of the cement and moisture content. The colour of the off-form finish immediately after stripping of the formwork, cannot therefore be compared to a test panel that was placed some time earlier. Time for the final colour to develop must be allowed.

Note that AS 3610 mandates use of test panels for the following:

- Class 1 and 2 untreated surfaces
- Colour control
- Surface treatments (eg abrasive blasting).

3.2 FORMWORK

3.2.1 General The type of formwork, its condition, construction, care and maintenance will all impact on the quality of the off-form finish.

AS 3610 specifies the acceptable minimum quality of the surface for various classes of surface finish, ie Class 1 to 5 (see **Table 1**). The requirements for face steps and surface undulations may be difficult to comply with if formwork is worn **Figure 69**, delaminating **Figure 70** or warped **Figures 71, 72**. Such deficiencies may also increase blowholes and cause colour variations. An inspection of the formwork prior to fixing

FIGURE 70
Result of delaminating timber formwork surface

FIGURE 71
Formwork panel for Class 1 finish with colour control – uneven support may cause warping

FIGURE 72
Inadequate storage/care of formwork materials

FIGURE 73
Effect of stacked formwork on off-form finish

FIGURE 74
Formwork joint detracts from appearance

of reinforcement (as required by AS 3610) can quickly identify any form-face sheets that need replacement in order to achieve the quality of finish specified.

Formwork must be adequately supported to avoid excessive deflections during placement of concrete. If tall vertical elements are placed in a single lift, the lateral pressure on the formwork will necessitate additional tie rods or braces to avoid the types of deflections in the finish shown in **Figure 40**.

Because the absorbency of the formwork can affect the water content in the concrete and therefore the colour, it is important that all formwork has uniform properties. The discolouration seen in **Figure 73** was caused by pieces of formwork stacked on the wall formwork prior to erection. The darker coloured areas are where the wall formwork was protected from rain and remained drier, allowing more water to be absorbed from the concrete after placement.

The type of formwork and how long it is left in place will also have an influence on the finish and colour. Impermeable formwork such as steel will result in more water being retained in the concrete and thus generally give a darker colour. Also, the more difficult it is for air within the concrete to escape through the formwork, the greater the risk of increased blowholes – both size and number. The selection of an appropriate form release agent is therefore an important consideration (see Section 3.2.4).

Formwork suppliers generally produce various grades of material, classified as suitable for particular classes of finish. While most cater for Class 2 to 5, the suitability of material for Class 1 finishes should be checked with the supplier.

Smooth faced materials such as plastic-coated plywood and fibreglass should not be used on surfaces that will be viewed close-up, ie from closer than three metres. This is because it is difficult to ensure that such surfaces are blemish-free and very difficult, if not impossible, to repair. However, they can be used for surfaces visible only from greater distances. A light sanding of the face with fine sandpaper will help improve colour control as will 'pickling' the formwork surface before use. Pickling helps to avoid the variable absorbency of new boards or sheets and involves the application of a cement grout or slurry to the surface, which is then allowed to dry before being brushed off.

For Class 1 finishes, form-face materials would generally be used only once, while the standard of workmanship for formwork erection should be as for carpentry work. When formwork becomes unsuitable for a particular class of finish it can be used for lower classes of finishes and eventually cut for infill pieces.

3.2.2 Joints in Formwork The location of joints between formwork sheets may have a considerable impact on the appearance of the off-form concrete finish. The joint shown in **Figure 74** some 300 mm above a construction joint in the column detracts from the appearance of the element, and could be unacceptable if the appearance of the surface was critical. Formwork should have been continuous from the construction joint to the soffit of the beam.

Formwork should be constructed with tight joints and no gaps at corners or edges to prevent grout loss during placement – which may stain the finished work

FIGURE 75
Grout/water loss may cause hydration staining, honeycombing and stain finished surfaces below

FIGURE 76
Grout lines from gaps between timber boards

below **Figure 75**, or form grout lines along the joints/edges **Figure 69**. Timber or plastic fillets are often used in corners to seal any gaps between the form faces. They produce a chamfered edge to the corner and reduce the risk of such defects as honeycombing and grouts lines. A 'closed cell' foam tape can be used between formwork and existing concrete surfaces to seal the gap and prevent grout/water leakage which may cause hydration staining, grout loss or honeycombing.

This is especially important with board-marked finishes, as grout lines can affect the appearance of the off-form finish. Depending on the gap between boards, grout loss and honeycombing along the joints may occur **Figures 76, 77**. Ensuring that the joints remain tight will produce the finish shown in **Figure 78**. To achieve tight joints, the boards need to be maintained in good condition and not allowed to dry and shrink, opening up gaps between them. **Figures 79, 80** show typical ways of protecting/maintaining boards on site, while **Figure 81** shows the boards being prevented from drying prior to placement of the concrete. New boards need to be primed before use to ensure similar absorbency to the old boards. The colour variation seen in **Figure 82** is probably the result of variable absorbency of boards.

3.2.3 Other Considerations Apart from selecting the appropriate formwork material and/or system, some other items to consider regarding formwork and its impact on the off-form concrete surface include:

- Tie-rod holes. If the surface appearance is critical, the tie-rod hole locations/setout must be uniform to create an even pattern/appearance **Figure 83**. **Figure 83b** shows an example of where the tie-rod spacing has not been consistent.
- Quality and condition of formwork. As the off-form concrete surface reflects the quality and condition of the formwork against which it is cast, the formwork must enable the specified finish to be achieved. Class 1 finishes usually require the use of new form-face materials. While re-used form-face sheets may provide Class 3 or even Class 2 finishes, if edges are damaged and face veneers are delaminating, it may not be possible to comply with the face step or deviation requirements in AS 3610. Checking the formed surface prior to concrete placement will identify any inappropriate form-face materials or gaps between sheets. Sheets should be replaced and gaps filled as part of the quality assurance system to ensure the quality of the finished off-form concrete surface **Figure 84**.
- Sloping surfaces. As there is an increased risk of entrapped air within the concrete adhering to sloping surfaces, the risk of blowholes in such surfaces is also increased. Typically, greater compaction than that required for vertical surfaces is required to produce a finish with a similar number of blowholes. This in turn may require the formwork to be stiffer, with additional supporting members **Figure 85**.
- Stripping of formwork. Care must be exercised when removing formwork to avoid damage to the off-form concrete surface. The use of appropriate form-release agents and detailing will facilitate this. Battens used to create rebates at joints or liner features must also be removed or may cause staining of the finish

FIGURE 77
Honeycombing from grout loss through joints

FIGURE 78
Tight joints between timber boards should prevent grout lines

Figure 86a. Similarly, formwork materials should not be stacked against completed work **Figure 86b**.

■ Curing of concrete. The less-permeable form materials such as steel and polypropylene will not allow the loss of any moisture from within the concrete. This may be required to achieve particular durability requirements until such time that the formwork is removed and alternative curing procedures are implemented. For normal curing requirements, retention of timber formwork provides satisfactory curing.

■ Blowholes. Less-permeable formwork allows less entrapped air to permeate out of the concrete, possibly resulting in an increased number of blowholes. For any particular form-face material an appropriate release agent must be selected and attention paid to proper compaction of the concrete to ensure entrapped air is adequately expelled.

■ Markings/stains. Any markings or stains on the form surface such as crayon from steel fixing (marking bar spacing), chalk from string lines and rust from reinforcement may also be reflected in the off-form surface.

■ Ply orientation. Plywood form-face materials should be orientated so that the grain in the surface ply is at right angles to the supports.

FIGURE 79
Protection of formwork for board-marked finish

FIGURE 80
Formwork for board-marked finish watered to prevent drying

FIGURE 81
Erected formwork kept moist to prevent shrinkage

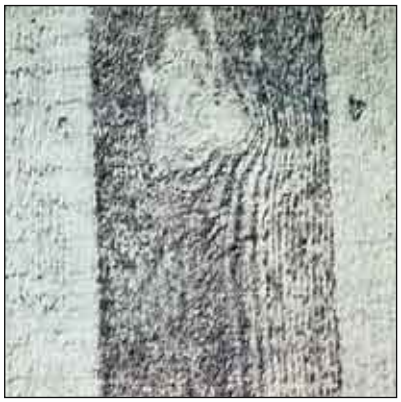


FIGURE 82
Variable absorbency of boards causing colour variations

FIGURE 83
[a] Examples of uniform tie-rod hole patterns
[b] Non-uniform tie-rod spacing

3.2.4 Release Agents While the most common application method for release agents is spraying; painting, wiping and dipping are alternatives. Only a thin coat is required, and this will minimise the possibility of staining and blowholes. Thick coatings of some release agents may have a retarding effect on the surface layer of concrete, and thus affect the final finish.

It is essential that release agents are applied uniformly and evenly over the form surface at the minimum rate consistent with full coverage to ensure that the entire form surface has the same characteristics. Surplus release agent should be removed prior to concreting. This will assist in producing an even colour as variations in the porosity of the form-face material will affect the water content of the concrete at the surface, and this in turn may result in colour variations **Figure 87**. Depending on the weather conditions, type of release agent used, and delay between coating and placement of concrete, re-application may be necessary to restore a uniform coating. Thicker materials such as waxes which usually have

FIGURE 84
Checking the formed surface prior to concrete placement will identify any inappropriate form-face materials

FIGURE 85
Sloping formwork generally needs to be stiffer

FIGURE 86
[a] Timber left in rebate causing surface staining
[b] Stacking of formwork materials against completed work may cause staining

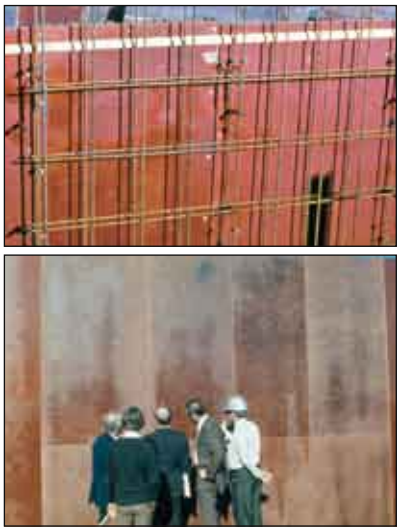


FIGURE 87
Uneven coating of release agent may cause colour variations

to be wiped on, may affect the texture of the surface if a uniform thin coat is not applied. Note that the reinforcement should not be coated as this will affect its bond to the concrete.

Release agents are also used to 'season' the forms prior to concrete placement (both timber and metal), and protect them from corrosion and deterioration during storage and transit.

3.2.5 Cleaning of Forms/Removal of Water

Prior to placing concrete, forms must be cleaned of all debris and ponding water. With deep beams and columns it may be impossible to remove debris from the bottom of the element once the formwork has been completed, so cleaning openings must be left, or the procedure for completing formwork allow for cleaning while areas are accessible. Removal and repair of areas such as that shown in **Figure 88** are time consuming, costly and may affect the appearance and durability of the structure.

Another often overlooked item is water ponding in the base of columns, beams or walls prior to concrete placement. This must be removed as it will affect the water-cement ratio of the concrete, and, under the pressure of the concrete above in vertical elements, will be forced out of the mix and to the top as the concrete settles. **Figure 89** shows examples of how the off-form finish has been affected by excess water or bleed water tracking up the side of the formwork following placement and settlement of concrete.

3.3 REINFORCEMENT

Reinforcement is not generally associated with achieving off-form concrete finishes, but some detailing issues can impact on the ability to adequately place and compact concrete which will in turn have an impact on the concrete finish.

There must be sufficient space both between layers of reinforcement and between the reinforcement and formwork to adequately compact the concrete **Figure 90**. If the vibrator can not reach into all areas of the concrete, inadequate compaction may result in honeycombing. If the vibrator makes contact with the formwork, it will score the formwork and cause lines which will be reflected in the off-form finish **Figure 91**. In thin walls or parapets compaction should be undertaken from the non-critical face, and concretors made aware of any such special requirements.

If reinforcement will remain exposed for any length of time, then to avoid corrosion and staining of the finish **Figure 92**, the reinforcement should either be galvanised or coated for protection **Figure 93**, or covered as shown in **Figure 94**.

Also, the bar chairs supporting the reinforcement should be appropriate for the off-form finish. Subsequent treatments that remove the surface layer of concrete, eg sand-blasting, tooling, may expose the ends of the bar chairs and detract from the appearance of the surface **Figure 95**.

FIGURE 88
Debris not removed prior to placing concrete

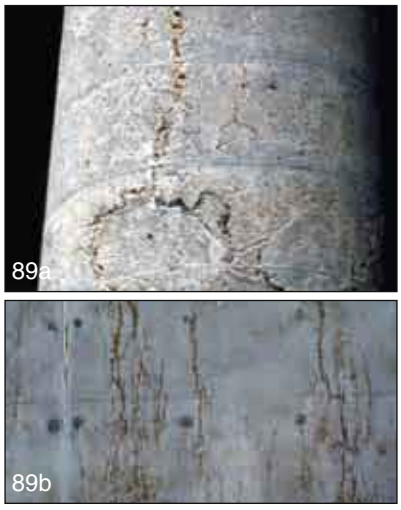


FIGURE 89
Water tracking up face of formwork – scouring
[a] Columns
[b] Walls

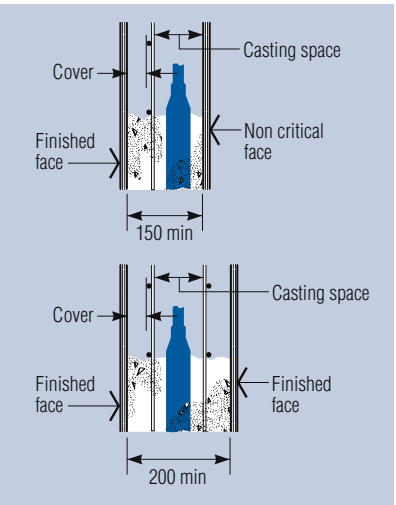


FIGURE 90
Provide sufficient clearance to formwork to allow compaction

3.4 CONCRETE SUPPLY

Generally, concrete is manufactured and supplied in accordance with AS 1379 as either normal class or special class concrete.

Some construction issues that should be considered if colour control is required are:

- Ingredients and the concrete mix design should be kept consistent throughout the project. Because colour is sensitive to water content, the total water content should be kept the same for each batch of concrete. Excess water should not be added on site. Also, if pigments are used for colouring concrete, the specified quantity of pigment must be added to the concrete batch and mixed thoroughly. If pigments are added on site, the quantities for each batch must be the same.
- Concrete should be thoroughly mixed when it arrives on site. Inadequate mixing may lead to colour variations. As each type of transit mixer may vary in the time taken to adequately mix the concrete, AS 1379 requires concrete suppliers to establish the time required for thorough mixing and ensure that this is provided prior to discharging the load.
- Concrete strength should be maintained. Changing the strength by adding more cementitious material or reducing the water content will affect the colour **Figures 96, 97**.
- Minimum total water content. When concrete is compacted, any water that can not be held within the spaces between the aggregate and cement particles will bleed to the surface. If excessive bleeding occurs along the form face, scouring or streaks may result as shown in **Figure 89**. If bleed water in vertical elements is trapped in the setting concrete at the top, hydration staining may result **Figure 98**. Where colour control has been specified, the use of low-bleed mixes is particularly important.

3.5 PLACING

Techniques for placing concrete can have a significant effect on the appearance of the off-form concrete surface. The main issues are formwork pressure, joints and colour.

The concrete should be placed at a continuous rate and consistently for each section of the work. In walls, the placing rate should be such that the lateral pressure assumed in the formwork design is not exceeded. If concrete for vertical elements is placed full height, the increased lateral pressures exerted by the fluid concrete may cause deflections in both individual formwork components (deflection of form face in **Figure 39**) and the overall formwork system (deflection over placement height in **Figure 40**) which exceed allowable limits. Even if deflections do not exceed these limits, they can still detract from the off-form finish by creating shadows over the surface under particular lighting conditions. While all formwork will deflect under pressure, if achieving a relatively 'flat' finish is critical to the project, then tighter tolerances on formwork deflection may be required.

Also, the settlement in each layer should be substantially complete before the next layer is placed, taking care to avoid the formation of cold joints.

FIGURE 91
Vibrator marks against formwork

FIGURE 92
Staining of concrete finish due to corrosion of reinforcement

FIGURE 93
Galvanised coating preventing staining of concrete finish

This minimises bleeding into the layer above and consequent changes to the water-cement ratio, and hence colour.

Placement should occur in uniform horizontal layers, care being taken that the concrete is not moved horizontally or made to flow by the use of vibration. Placing in layers may result in a number of different batches of concrete being incorporated into the same element. For the example shown in **Figure 96**, placement in layers would have lessened the visual impact of the colour variation between the batches of concrete, albeit creating bands within the wall.

Placing in layers can also have other implications. During placement of the first layer, at least some of the form face will become coated/splashed with cement paste from the concrete **Figure 99**. This may dry and form a thin coating on the surface. If it is not removed by the abrasion of the subsequent concrete being placed, it will influence the water absorbency of the form surface and hence the colour of the off-form surface, resulting in lighter coloured areas within the finish **Figure 100**.

When placing by pumping, the lines are usually first coated with a cement slurry to reduce the friction and

FIGURE 94
Protection of off-form finish, particularly from staining near ground level
[a] Note covering of reinforcement at top to prevent staining of completed work
[b] Corners also protected to prevent physical damage

FIGURE 95
Bar chairs exposed during subsequent surface treatment

FIGURE 96
Colour variations may appear better in horizontal layers

FIGURE 97
Variation in colour with different concrete strength

FIGURE 98
Colour variation from concrete placed in layers and hydration staining

drying of the concrete mix as it is pumped through the line. Sometimes a small quantity of diesel (oil) may be used. It is important not to allow this material to be placed onto/into the forms as it may coat the formwork, or mix with the concrete and alter the off-form finish and/or colour.

3.6 COMPACTION

Proper compaction is especially important for high-quality off-form finishes as it ensures that the formwork is completely filled (eg no pockets of honeycombing), that blowholes are minimised and that sand streaks are not formed.

Compacting concrete using immersion vibrators firstly sets the aggregate particles in motion, reducing the internal friction and causing the concrete to slump and fill the form. With further vibration, the entrapped air is expelled from the concrete. Vibration must be continued until air bubbles no longer appear on the surface, otherwise areas of honeycombed concrete **Figure 101** and particularly blowholes **Figure 102** in the off-form finish may result.

Thorough compaction of the top section of vertical elements such as columns and walls is particularly important. Fewer blowholes usually occur in the lower half of vertical elements because the weight of the fluid concrete above provides additional compaction to the lower part of the element. Without the weight of concrete to assist compaction of the top section, a greater number of blowholes may occur **Figure 102**. To minimise the formation of blowholes in the top section, the top half metre of walls and columns should be rodded and/or revibrated prior to the concrete stiffening.

Special care should be taken to avoid touching the form face with immersion vibrators during compaction as any damage to the form face will be reflected in the off-form finish **Figure 91**. Sand streaks may also be formed in the surface of the concrete due to the incorrect withdrawal of the vibrator.

3.7 CURING

With off-form concrete surfaces where colour control has been specified, some special precautions are required to ensure the finish is not stained or discoloured during the curing process.

If the formwork is kept in place to cure the concrete it is best to leave it in close contact with the concrete, thereby preventing air movements which may cause the surface to dry out. Even slight gaps between the form face and concrete can result in non-uniform curing conditions and hence colour variations.

The darker coloured areas on the concrete upstands in **Figure 103** were caused by the formwork not being in uniform contact with the concrete surface; a combination of the pressure of the fluid concrete during placement and subsequent shrinkage of the concrete during drying. The darker areas are where the formwork remained in contact with the concrete surface and the lighter areas are those where a gap developed, allowing the surface to dry more rapidly.

With off-form finishes, however, it is often best to ease the formface from the concrete at an early age to prevent scabbing. When this is done, it is essential to ensure that all faces are loosened, uneven curing may otherwise result in colour variations.

FIGURE 99
Cement paste on form surface

FIGURE 100
Light coloured areas resulting from cement paste splashed on formwork

FIGURE 101
Honeycombing caused by inadequate compaction

Thus formwork must remain in close contact with the concrete and be stripped after the same period of time for each element. When planning large projects, concrete placement should be scheduled so that this is possible. Placement should, for example, be scheduled so that stripping is not required when labour is unavailable, say on a weekend.

Once formwork is removed, any subsequent curing methods should allow consistent moisture conditions to be maintained to avoid discolouration.

The following should be considered:

- Water curing can cause streaks and non-uniform discolouration whilst run-off onto completed work can cause similar problems. Iron salts or similar impurities in the water may have disastrous effects.
- Curing with wet hessian can also cause problems **Figure 104**. Firstly, the hessian itself must be thoroughly washed before use to ensure it does not stain the surface. Secondly, it is necessary to ensure it is kept uniformly wet and in contact with the concrete surface to avoid discolouration.

FIGURE 102
[a] Blade column with large blowholes which have been patched
[b] Inadequate compaction causes blowholes

FIGURE 103
Non-uniform contact of formwork

FIGURE 104
Inadequate curing and non-uniform contact will result in colour variations

FIGURE 105
Curing membrane must be held tightly against concrete surface

FIGURE 106
Stain being applied by brush

- Curing with plastic sheets **Figure 105** is a satisfactory method, provided the sheets are prevented from making uneven contact with the concrete. Uneven contact can result in dark patches at the point of contact, where the surface is prevented from drying, and thus retains more moisture.
- Liquid membrane-forming curing compounds may also be used. They are readily applied, bond to the concrete surface and are a convenient way to extend the curing period after formwork removal, particularly in windy conditions. Note that the adhesion of subsequent finishes may be affected. As with other materials, trials are advisable to ensure that no permanent staining will result from applying the selected curing compound.

As curing can contribute significantly to the appearance of off-form concrete finishes, it must be consistent, especially if colour control has been specified.

3.8 COLOURED CONCRETE

3.8.1 Pigments Pigments can either be added at the batching plant or on site. Adding at the batching plant is preferable for accuracy of dosage and safety reasons. Prior arrangements need to be made with the concrete supplier for the supply of a coloured concrete.

3.8.2 Chemical Stains Colouring concrete by the use of chemical stains appears simple, but in fact requires careful planning and a high level of skill in its application. This is why many commercial suppliers of decorative products usually supply only to approved applicators.

Because chemically staining concrete is often considered as an afterthought, or as a solution for existing concrete, the required preparation to achieve a good-quality result is usually missing. Also, chemical stains will not deliver a uniform colour. As the reactions between the stain and concrete constituents (which create the colour) depend on the stain penetrating into the concrete surface, a mottled finish rather than a uniform coloured surface is produced due to the variability of the hardened concrete. The end result is a unique coloured finish.

As chemical stains react with the excess calcium within the hardened concrete, they should not be applied within 28 days of placing the concrete, to allow the concrete to achieve its design strength. Concretes incorporating blended cements or lower strength concretes have lower calcium levels, resulting in less intense colours. Release agents, debonding and curing compounds can all affect the rate at which the stain will penetrate into the concrete surface.

While small areas can be carefully painted with a brush **Figure 106**, skill is required to avoid brush marks in the finish. Such decorative panels suit precast or tilt-up methods of construction where stains can be applied while the panel is horizontal. Finishes such as those shown in **Figures 52, 53** suit brush

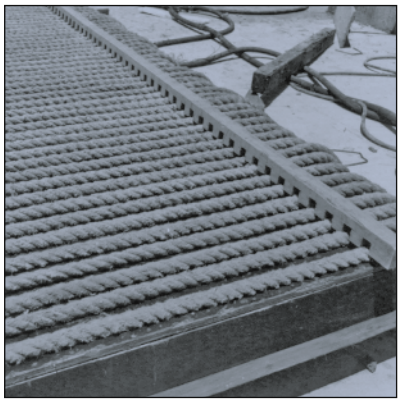


FIGURE 107
Timber batten over rope to seal bottom of formwork

FIGURE 108
'Firring' of radiata pine boards where pieces of timber adhere to the concrete

FIGURE 109
Nail heads reflected in off-form finish

applications as marks and colour variations tend to be concealed by the texture and/or pattern.

Staining of large areas is suited more to flatwork than vertical finishes, due to the liquid stain not 'running' or leaving streaks on flat surfaces (particularly between different colours), and it being possible to apply the stain by spray gun to avoid brush or roller marks.

3.8.3 Colour Control When colour control has been specified, all of the points covered earlier in this chapter assume greater importance. In particular, a consistent approach to all aspects of construction is desirable if colour variations are to be minimised.

On all projects the following warrant particular attention:

- Absorbency of forms (see Section 2.5.1)
- Water tightness of forms (see Section 2.5.1)
- Consistency of curing (see Section 3.7)
- Consistency of concrete supply (see Section 3.4)

With large projects on which work is carried out over a long period of time, attention should be given to matters such as the effect of the different admixtures used under various climatic conditions. If the aggregates are to be exposed, consideration should be given to stockpiling a sufficient quantity for the whole project.

3.9 TEXTURED FINISHES

3.9.1 Rope Finishes The ropes should be attached to the formwork in such a way that it can be stripped, and the ropes pulled out later, usually after about 48 hours depending on the concrete strength, but possibly as long as six weeks. Early removal may pull out coarse aggregate particles, while late removal will increase the effort required. One length of rope is normally used to form two adjacent runs **Figure 3**, with the loop at the top used to assist in the removal (by allowing the attachment of a winch or similar device if necessary).

The release agent may be applied to both formwork and rope, alternatively it can be applied to the formwork only, and the rope wetted prior to concreting. The latter may assist in controlling swelling of the rope, but both have been used successfully.

A profiled timber batten is used at the top and bottom of the formwork **Figure 107** to either form the construction joint at the top, or seal the bottom of the formwork into the previously cast rebate or joint. Foam packing can be used to ensure a watertight joint between the rope and timber batten. The rope, commonly 25–40 mm diameter, should be fixed to the formwork with pins at about 250-mm centres.

Depending on the rope type (hemp is common), up to eight or ten reuses of the rope should be possible.

As the rope is attached to the formwork, the formwork itself can be specified as for, say, a Class 3 finish in accordance with AS 3610 to control the general alignment. Note that as the removal of the rope provides an extremely coarse textured surface, items such as steps between form face sheets and blow-holes are not critical to the appearance of the finish.

3.9.2 Board-marked Finishes Oregon is generally used for board-marked finishes as it provides good texture. Note that the texture can be enhanced by light abrasive blasting or use of a stiff nylon brush. Wire brushes should not be used as they may cause discolouration. Softer timbers such as radiata pine and western red cedar may cause 'firring' where the adhesion to the concrete is greater than the strength of the timber at the time of stripping **Figure 108**. Applying a sealer to the timber may improve the situation. Hardwoods are generally not used because they are difficult to work and may cause staining.

To avoid variable absorbency, new boards should be sealed with several applications of a form oil and then 'pickled' by the application of a cement grout or slurry to the surface, which is then allowed to dry before being brushed off.

Special attention to the care of timber boards is required to ensure a good quality off-form finish. The expansion and shrinkage of timber with changes in its moisture content may result in grout lines between the boards **Figure 76**. If this feature is to be avoided, timber must be kept at a constant moisture content to prevent gaps between boards opening up prior to the placement of concrete **Figures 79–81**.

Boards are generally fixed to plywood to reduce deflections. As nailing from the front can cause splitting of the timber and affect the finish **Figure 109**, back screwing is often specified as the method of fixing **Figure 110**. For tongue and groove boards, concealed nailing from the front may be possible. Alternatively, in a performance approach, the decision can be left to the contractor. Joints between boards must be watertight to prevent water/grout loss and possible hydration staining or even honeycombing.

3.10 SEALING

As sealers may interfere with the concrete curing process, they should generally be applied once the concrete has reached its design strength and the surface has been allowed to gradually dry out. This is particularly important for solvent-based sealers that are designed to penetrate into the concrete. If water-based sealers that are not affected by the moisture in the concrete are being used, applying the sealer earlier will assist in minimizing the risk of efflorescence.

Surfaces should be clean and free of all dirt, grime, salt, moss and oils. Form release oils should either not affect the adhesion or penetration of sealers, or be cleaned from the surface prior to the application of the sealer. Similarly, with the construction of tilt-up concrete wall panels where debonding agents are used to prevent adhesion of panels during casting, once erected, sufficient time should be allowed for the debonding agent to degrade prior to sealing the surface. Alternatively, the debonding agent must be removed with proprietary paint-stripping products.

Precast elements, particularly for high-rise projects, can be sealed (or painted/coated) economically in the factory where access is easier. Suitable form-release agents and sealers are required in this situation. Sealers applied in the factory also enable the edges to be coated and spray equipment to be used, whereas most site applications are by roller or brush.

Sealers should be applied at the rate recommended by the manufacturer. For some penetrating sealers, the ability to apply them to wall panels lying horizontally in a precast factory could be an advantage.

Some sealers may not readily penetrate a steel trowelled or honed surface, or may need to be thinned in accordance with the manufacturer's recommendations. Thus precast elements may require different sealers to insitu concrete elements.

3.11 PROTECTION OF FINISHES

High-quality off-form finishes are difficult and costly to repair/reinstate. Finished work should therefore be protected from both accidental damage and staining until the completion of the project.

While accidental damage can be caused in various ways, normal care should be sufficient to reduce the risk of such accidents. One that is not always guarded against, however, is the accidental splashing of finished work with fresh concrete or mortar from continuing construction activities (particularly on sloping surfaces), or staining by grout leakage from subsequent lifts **Figures 75, 111**.

Protection of finished work should commence immediately after completion, ie as soon as the formwork has been stripped. One means of doing this is to wrap the element in polythene film. Note that the polythene film must not be in contact with the fresh concrete surface during the curing period as colour variation may result. Surfaces which have been cured will not be harmed by subsequent wrapping in polythene.

Work should also be protected from rust washed onto it from projecting (and unprotected) reinforcement **Figure 92**, from formwork and screens on upper lifts **Figure 112**, and from props or other steel products

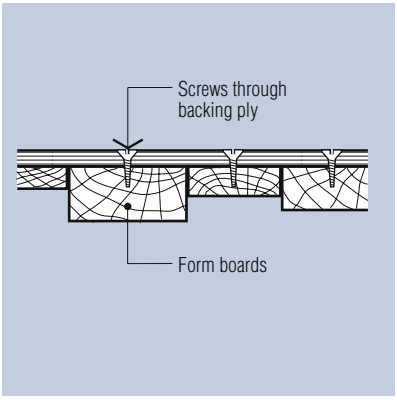


FIGURE 110
Fixing boards by back screwing

FIGURE 111
[a] Protection of off-form finishes using available materials
[b] From construction work above

used in subsequent lifts. Reinforcement may be protected by painting with a cement slurry or cold galvanising compound, wrapping in plastic (not recommended in areas of high humidity) or by use of galvanised **Figure 93** or stainless reinforcement.

Figure 94 shows examples of where off-form finishes have been carefully wrapped in polythene film for protection and to prevent staining at ground level by mud or soil 'splashed' onto it during rain or by passing vehicles. If sharp clean edges are required additional protection with suitable timbers should be considered to reduce the risk of physical damage. Good site management will also contribute to the protection of finished work.

If the member is required to be protected only from staining, an alternative solution may be to provide a surface sealer to prevent materials from penetrating the surface and allow easy cleaning at the completion of work.

Protection from subsequent operations such as installation of railings and other fixtures and fittings may also be required. **Figure 113** shows the effect of inadequate removal of cement slurry after installation of the railing – after a number of years of weathering. Cement slurry not thoroughly cleaned from the surface may affect the colour both in the short and long term.

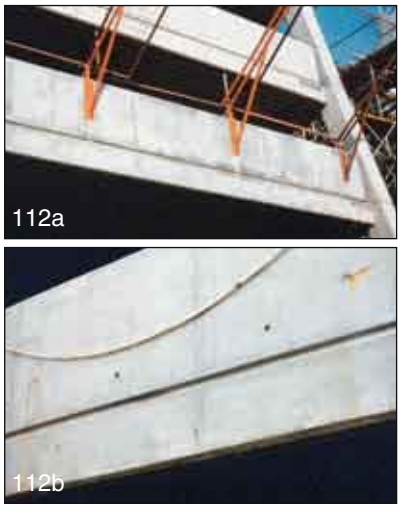


FIGURE 112
Rust stains from temporary brackets
[a] Brackets in place
[b] Resulting stains

FIGURE 113
Cement slurry not cleaned from surface may affect colour

04 Assessment of finishes

Off-form concrete finishes can be assessed objectively only if the project documentation makes it clear what is expected. This is usually achieved by nominating specific items (type of finish, colour, etc) directly, and the general matters (tolerances, etc) by reference to other documents (eg Standards).

The construction and approval of test panels is also usually specified – and is highly recommended. Reference to another project is also an option, although the effects of age (particularly on colour) should be recognised.

Once a mutual understanding of what is expected has been established, the assessment of what has been provided is relatively straightforward. On a typical project, the following aspects of surface quality would be looked at and any need for rectification of physical defects established. (**Table A1**, Appendix A, lists physical defects and their causes.)

- Blowholes. Typically checked for compliance with AS 3610.
- Honeycombing and grout loss. Typically checked for compliance with AS 3610.
- Scouring. Can vary from a surface blemish to deeper channels that require repair.
- Misalignment. Typically checked for compliance with AS 3610 and AS 3600.
- Streaks in surface. Affect appearance and may require repair.
- Scaling, spalling or chipping, and form scabbing. Can vary from a surface defect causing aesthetic problems to deeper spalling that requires repair.
- Crazing. Crazing describes the very fine cracks which appear on the surface of concrete after it has been exposed to the atmosphere for some time. While more of a problem for trowelled surfaces, it may also occur on formed surfaces with smooth faces cast against low-permeability form-face materials. Crazing rarely requires repair as it does not normally lead to any serious problems.
- Cracks caused by formwork movement. If there is movement of the formwork (whether deliberate or unintentional) after the concrete has started to stiffen but before it has gained enough strength to support its own weight, cracks may form. Such cracks have no set pattern. The need for repair will depend on their location and extent.
- Tie-rod pattern. If specified, this can be checked against the project documentation. Missing holes could be drilled (up to 5 mm) to reinstate the pattern.
- Surface pattern details. The location and detail can be checked against the specification. Note that if a particular concrete feature is included in the project documentation, AS 3610 requires that the details be specified.

If colour control has been specified, tonal values are typically checked for compliance with AS 3610. Note that if a test panel has been cast and the colour approved, depending on the range of tones that occurs during the project, the test panel could in fact end up being either the lightest or darkest tone produced. The colour of the test panel does not automatically become the central tone in a four- to six-tone range.

If the concrete is coloured (pigmented, etc) acceptability can be realistically checked only by comparison with approved test panels. Colour variations and their possible causes are listed in **Table A2** of Appendix A.

05 Patching/repair of off-form concrete finishes

Patching (eg filling tie-rod holes) and repairs (to correct defects) are carried out to improve the surface appearance or to reinstate the required minimum concrete quality and cover to the reinforcement, or both. This Section covers only remedial work undertaken for appearance reasons. Note AS 3610 gives the option to exclude repairs to Class 1 finishes.

The following precautions and procedures should assist in securing the best possible results. Careful considerations should be given to the effect of repairs or remedial work on the surface appearance of the concrete.

- Repairs should be carried out by skilled and experienced tradesmen.
- Repair techniques should be established early in the construction programme, preferably using test panels, and an acceptable standard established. If repairs are required, they can be completed as work proceeds while access is readily available.
- Repairs should be undertaken at the earliest possible opportunity, preferably as soon as the form has been stripped, in order to ensure that the repair and the concrete are given the same curing and/or other treatments. Note that it is essential that the surface to be repaired is cleaned of any form oils or other contaminants that may affect the bond of the repair material.
- Surfaces that are to be tooled, and that exhibit significant defects such as blowholes or honeycombing, must be patched prior to tooling. Reliance should not be placed on tooling to mask such defects. Sufficient time should be allowed for the patches to gain strength before tooling is commenced.
- Care should be taken to establish a colour match between the concrete surface and the repair. The mortar for minor repairs should contain the same materials (sand and cement) used in the original concrete. If 'grey' cement has been used, substituting up to about 40% of the cement with off-white cement should assist in matching the colour of the repair mortar to that of the original concrete. Repairs with the original mix will inevitably result in a darker colour; as does the tendency to use more cement to ensure bonding to the substrate **Figure 102**.

If colour control has been specified, then trial patches should be approved prior to any more extensive areas being repaired. For larger repairs requiring a concrete mix, the same coarse aggregate should also be used.

- Extensive repairs may require the area to be formed up. Forms used in this situation should have the same patterns and absorbancy characteristics as the original formwork.
- Bonding agents are often used to ensure adhesion to the substrate, particularly to high-strength concrete. Bonding is typically achieved by the mixing water drawing cement particles into the surface of the substrate, where cement hydration creates a chemical bond into the surface. High-strength substrates are generally relatively impermeable and this hinders the movement of water, cement particles and hence bonding.

Bonding agents should be suitable for the application. For high strength concrete substrates, SBR's (styrene butadiene rubbers), acrylic polymers or EVA (ethylene vinyl acetate) emulsions may be used.

Bonding agents should be mixed with cement or cement/sand mixtures to form a slurry. They should be applied immediately prior to the repair mortar/concrete, so that the adhesive slurry is still wet when the repair material is applied. Manufacturers' instructions should always be followed.

- Where proprietary repair materials are used for colour controlled finishes, trial repairs should be carried out to assess the colour match.

Blemishes that may require patching or repair include:

- Blowholes. These may be filled using a colour-controlled repair mortar and a spatula. The surface should be lightly moistened prior to repair and an earth-damp mixture forced into the hole. Care should be taken not to smear the surface of the surrounding concrete with the repair mortar.
- Honeycombing. The repair technique will vary with the depth and the area involved. In shallow areas, all loose or partly adhering material should be removed and the periphery of the area trimmed to a depth of 4–6 mm. The existing concrete should then be primed with a bonding agent and a suitable mortar packed into the hole and consolidated. The surface should then be finished to match the surrounding concrete, being careful not to overwork it.

- Tie-rod holes. The treatment of tie-rod holes is especially important to the overall appearance of off-form concrete, as they are typically present over the entire surface.

  Holes may be made good or filled with either plastic or concrete plugs fixed in position with epoxy mortar. Alternatively, they may be filled with a dry-packed mortar rammed into position. In either case the plug or filler should be recessed some 6–10 mm below the surface of the concrete finish.

  Where possible, precast concrete plugs should be made with the same concrete as used in the element, to avoid colour contrasts.

  If a dry-packed mortar is used, this should consist of a 1:3 cement:sand mixture employing the cement and sand used in the original concrete, except that as before, some 30–40% of the cement should be replaced with an off-white cement to lighten the colour of the mortar. This compensates for the generally darker colour of small patches which in this case may be accentuated by the shadow effect of the recessed surface or plug.

  To reduce shrinkage, and the possibility of a more fluid material staining the surface of the finished work, the mortar should be an earth-damp mix which is compacted by ramming.

- Minor grout runs, form scabbing and some hydration stains. These can usually be repaired by rubbing the surface with a carborundum stone or using an angle grinder with an appropriate grinding pad. Such treatments should, however, be limited to small areas and care taken not to damage the surrounding surface.

  Acid etching, bleaching or similar treatments should be considered only as a last resort as the results may well exacerbate the problem instead of curing it.

- Cracks. When repairs to a crack are being considered, the following factors should be taken into account:

  — The cause of the crack. This is essential to provide a long-term solution. For example the repair of cracks caused by corroding reinforcement, without remedying the cause of the cracking, will inevitably provide only a short-term solution.

  — Whether the crack is dormant (unlikely to extend or open further) or live (subject to further movement). Dormant cracks have traditionally been filled with a cement grout or mortar and live cracks sealed with a flexible material which can accommodate the movement in the crack.

  — The width and depth of the crack. The width and depth of dormant cracks will influence the materials and methods chosen for its repair.

  — Repairs may highlight the crack, rather than conceal it, especially if widening of the crack surface is required to create a reservoir for the repair materials.

  Comprehensive information on the repair of cracks can be found elsewhere[11].

- Crazing. Crazing and other very fine cracks are difficult to repair effectively and in many cases the best option may be to do nothing. Autogenous healing of very fine cracks may occur with time.

  If the problem is an aesthetic one, rubbing down the surface with a carborundum stone followed by sealing with a water-repellent material, such as sodium silicate, may provide a solution. This should prevent dirt collecting in the very fine cracks and accentuating them.

- Staining. While staining from items such as the reinforcement may be overcome by using particular chemical cleaning products and methods, the bleaching action of the sun over time can also even out the colour and remove stains. When there is staining due to aggregate containing iron oxide, the offending aggregate should be removed and the surface made good prior to treatment of the stain.

06 Cleaning of off-form concrete finishes

Over time, dirt may become trapped within porous concrete surfaces causing the types of surface appearances shown in **Figure 62**. This is because the light rainfall that is typically experienced is insufficient to cleanse the surface. While this 'weathering' process can create an aged patina and does not affect the durability of the concrete, the variability of the discolouration can be aesthetically displeasing.

Three common cleaning methods are available to remove the dirt and restore the surface.

- Water washing. Using a water jet from a normal hose or high-pressure water blasting to loosen and flush dirt from the surface is probably the most common method. As very high water pressures are available from modern equipment care should be taken not to damage the concrete surface. The procedure can be supplemented by scrubbing the surface with a stiff-bristled brush or broom.
- Detergent water cleaning. As above, except that a strong detergent solution is used, and the surface is thoroughly rinsed afterwards.
- Steam cleaning. This is probably one of the most effective methods of cleaning a variety of stains and dirt from a concrete surface. High-pressure steam cleaning is used in conjunction with detergents or non-solvent emulsifying agents suitable for use in high-pressure steam cleaners. The surface is again thoroughly rinsed afterwards.

Apart from dirt, concrete surfaces can be subjected to a variety of stains. Most off-form finishes tend to be vertical elements on which staining is less likely than on horizontal areas such as walkways. Procedures for removing some common stains from off-form finishes are given below.

- Efflorescence (salt deposits). Initially white deposits on the concrete surface can be removed with a stiff-bristled broom, possibly with the assistance of some clean water. Insoluble salts will require cleaning with diluted acid (typically hydrochloric acid) at the ratio of 1 acid to 20 parts of water. Surfaces should be saturated with water prior to application to prevent acid from soaking into the surface, and thoroughly rinsed off afterwards to remove all traces of acid. Note that this may change the colour as well as etch the surface of the concrete so a trial area should be treated initially to assess the effect on the finish.
- Fungal growth. Vigorous scrubbing with chlorine bleach followed by thorough rinsing (repeated as necessary) is commonly used. High-pressure water cleaning can also be used to remove the fungal growth, with chlorine bleach then applied over the surface and rinsed off thoroughly.

FIGURE 114
Mortar staining

- Mortar stains. Staining due to, say, mortar splashes from bricklaying operations may be treated with a dilute acid solution as for efflorescence – noting the risk of etching and/or changing the colour of the concrete. **Figure 114** is an example of where the concrete surface has been etched from the cleaning of the brickwork above using an acid solution. Depending on the depth of etching, the aggregates may also become exposed and change the colour/appearance of the off-form finish. In terms of the colour, the acid dissolves the lighter coloured calcium at the surface of the concrete and thus tends to change it. If an acid wash is used on finishes with light and dark patches, a more uniform colour should result.
- Clay soil. The stained surface should be scrubbed vigorously with warm soapy water and then rinsed with clean water. Stubborn stains may require scrubbing with chlorine bleach, in which case the surface should be wet prior to applying the bleach and rinsed off afterwards.

07 Specification of finishes

7.1 GENERAL

There are three broad approaches to the specification of surface finishes, viz:

- by performance;
- by prescription (method); and
- by a combination of performance and prescription.

Performance specifications may be based on the provisions of AS 3610 and Supplement 1 to that Standard. A class of finish suitable for the application and having the appropriate visual characteristics is specified. Other details such as colour, test panels and tie rod pattern, for which guidance is given in the Standard, may also need to be specified.

Completed work is assessed against the parameters contained within AS 3610 and the photographs and colour chart in the supplement. Note that in addition to specifying the finish in accordance with AS 3610, building tolerances which may affect the fit of components will also need to be specified. While these can be specified as in accordance with AS 3600, more-stringent tolerances may need to be specified for specific items to achieve the desired appearance, ie a combination of the off-form finish and good fit of components.

Prescriptive specifications describe the method or technique which is to be used to achieve the required finish. Such specifications need to be complete and unambiguous if satisfactory results are to be obtained. Good communication between all parties responsible for achieving the finish is also important, as they must have a clear understanding of what is required by the specification. Prescriptive specifications must be used for off-form finishes that involve anything other than the standard plain finishes included in AS 3610, such as textured, tooled or abraded finishes.

A combination of prescription and performance in the one specification is the least satisfactory although it can be made to work if there is some objective standard, such as a test panel, against which to measure performance. For example, a rope finish may be specified by the type and size of rope, method of fixing to the formwork, spacing, treatment at joints, etc. The formwork to which it is fixed could be specified as Class 3 with colour control, along with other characteristics from AS 3610 such as tie rod pattern and test panels.

7.2 CHECKLIST

Some of the items that may need to be borne in mind in preparing the specification include:

DESIGN

- Concrete elements should be wide enough to allow placement and compaction of concrete without damage to the form face.
- Formwork design should allow for concrete pressures without excessive deflection of form face.
- Joint details and locations.
- Sufficient cover to allow for subsequent treatments such as tooled finishes if required.

FORMWORK

- The class of off-form finish (Class 1, 2 or 3 in accordance with AS 3610 – specify Class 1C, 2C or 3C if colour control is required). Specify Class 1X, 2X, 3X if tolerances other than those contained in AS 3610 for the particular class of finish are required, along with any new limits.
- Items from Table 3.4.1 in AS 3610, including:
  - Test panels – mandatory for Class 1 and 2 finishes and for Class 3 if colour control or subsequent treatments have been specified. Test panels should be representative of the actual structure or element, materials to be used and construction procedures to be adopted including reinforcement, openings, stripping of formwork and curing. They should be of an appropriate scale (specify size) to permit adequate assessment. If non-critical parts of the actual structure can be used as test panels, the location(s) should be nominated. If the structure will permit more than one test panel to be cast, the area available should be nominated so that the contractor has the opportunity of resolving any minor issues that may become evident from the first test panel prior to moving on to more-critical areas of the structure.
  - Tie-rod pattern – required for Class 1 and 2 finishes, optional for Class 3. Specify tie rods to be at uniform centres in both directions, or specific distances from surface features such as joint rebates or patterns.

- **Liner details and accuracy for Class 1, 2 or 3 finishes.** Specify items such as rebate details for patterns or at control or construction joints (shape, depth, width), locations and the accuracy with which they are to be located, eg within plus or minus 10 mm of the designed position. Also, direction of joints between formwork sheets.
- **Surface pattern details.** If the surface is to receive a pattern/textured finish, the extent of the treatment and details such as edge strips.
- **Form-face span and direction of span** – plywood form-face materials have layers of veneer bonded together in different directions. Class 1 and 2 finishes have the option of specifying which direction the outer layer of veneer spans, ie vertically or horizontally. Typically it should span between supports as this provides greater strength and less deflection.
- **Distance between face steps** – optional for Class 1, 2 or 3 finishes. This limits the possible use of small or randomly sized pieces of formwork.
- **Plumb of elements where the height ≥ 8 m** – Tolerances should be specified since AS 3610 applies only to heights up to 8 m.
- **Repairs** – 'not to be repaired' may be specified for Class 1 finishes if applicable.

- Treatment at edges and corners, eg fillets.
- Cambers to control long-term deflections of the concrete.
- Inspection of formwork prior to placement of concrete. AS 3610 requires that formwork for insitu concrete be inspected prior to placement to ensure among other items that it 'has the potential to achieve the required surface finish'. Many off-form finish defects could be avoided by ensuring that a simple check of the form face is carried out prior to placement.
- Requirements for stripping.
- Marking of formwork (generally not permitted).

COLOUR

- Cement type – off-white or white (default will be normal grey).
- Pigment – manufacturer and colour (from colour chart). If a special colour has been developed for the project, specify manufacturer and sufficient details to identify colour. Approval to be based on test panel.
- Fine aggregate – for subsequent treatments such as light abrasive blasting that will expose the sand (and its colour), the type and source.
- Coarse aggregate – for subsequent treatments such as heavy abrasive blasting, bush hammering or tooling that will expose the stone (and its colour), the type and source.
- Stains – colour, method of application, timing, preparation. (Note experienced applicators should be employed.)

TOLERANCES

- The limits given in AS 3610 have been shown to provide satisfactory finishes. More stringent tolerances can be specified if required.
- The limits for the structure or overall concrete element given in AS 3600 are generally adequate. These may need to be more stringent to ensure fit of components or position of critical elements.

SUBSEQUENT SURFACE FINISHES

This applies only if subsequent treatment of the off-form finish is required. In this case the specification would normally become a combination of performance and prescriptive, eg a Class 2C off-form finish (performance) having the following treatment (prescribe the exact surface finish required and the method by which it is to be achieved). Approval is generally by reference to an accepted test panel.

- Tooled. Type of tool (eg chisel type), depth to which surface is to be removed and when the treatment is to be applied, eg after curing for a minimum of 28 days, once the design strength has been achieved.
- Rope. Type of rope, diameter, spacing, fixing method, distance from edges (to ensure sharp corners if required), detail at construction joints, treatment of tie rod holes, release agent, stripping of formwork and stage at which rope is to be removed.
- Board marked. Type of timber (oregon preferred) and cut of boards (quarter sawn, back sawn or a combination), fine sawn or rough sawn, width, thickness (a combination of thicknesses can be used), tongue and groove profile if required, length (if no joints allowed between construction joints), seasoning prior to first use, maintenance and protection while on site, use as form face or lining (may determine minimum thickness of boards), treatment of replaced boards.

- Abrasive blasted. Sand or shot blasting (if not critical simply specify abrasive blasting), depth of exposure of fine or coarse aggregate (maximum one third of coarse aggregate to be exposed), timing of procedure.
- Acid etched. Typically, acid etching is carried out under factory conditions. In, say, a precast yard, all that is required is a performance approach where only the process and depth of etching/exposure of aggregates need be specified.

CLEANING OF FORMWORK

- All debris and water to be removed from forms prior to concrete placement.

RELEASE AGENTS

- Specify a particular product, that it be applied by experienced personnel and that the application be in accordance with the manufacturer's recommendations.
- Alternatively, if the choice of product is left up to the contractor, that the release agent be appropriate for the type of formwork and finish required, does not affect the colour or adhesion of subsequent surface treatments (if colour control or further treatment specified), that no change to the product is made during construction without approval and that it be applied by experienced personnel in accordance with the manufacturer's recommendations.

REINFORCEMENT

- Ensure sufficient cover to formwork
- Ensure spacers or chairs used to provide required cover do not affect appearance of finish after subsequent surface treatments. This may require reinforcement to be secured from the non-critical face of the element, eliminating the need for chairs where surface treatments are to be applied.
- Use appropriate chairs for durability requirements. Plastic tipped wire bar chairs may not be suitable for coastal environments, while plastic bar chairs may not be suitable for marine applications as concrete does not bond to plastic.
- Avoid areas of congested reinforcement to facilitate placement and compaction of concrete.
- Avoid staining of formwork prior to placement from corrosion of reinforcement.
- Avoid staining of completed concrete from exposed reinforcement.

CONCRETE SUPPLY

Many decisions here will reflect the importance of the concrete to the off-form finish required. If colour control and finish are not critical, then a performance approach by specifying a normal grade of concrete of the required strength and placement method is all that is required, eg N32 concrete to be pumped. However, most will require the specification of a special class of concrete, along with the requirements that make it a special mix:

- Concrete strength grade, eg S32
- Manufactured and supplied in accordance with AS 1379
- Colour control
- Cement colour – off-white or white
- Pigments – manufacturer and colour (from colour chart)
- Placement method – pump or chute
- May need to specify aggregate types and quantities for treated surfaces
- May need to specify bleed characteristics, eg low bleed
- Each batch to be consistent, particularly slump if colour control has been specified
- Ensure concrete truck adequately cleaned prior to batching, particularly for pigmented concrete where previous load of 'grey' concrete may affect the colour
- Discharge time after batching should be consistent
- No additional water to be added on site
- Test slump on site to determine consistency of concrete, particularly if colour control has been specified.

CONCRETE PLACEMENT

- Exclude pump priming material from placement in completed work. For coloured work, the priming material (cement slurry) should also be coloured, or sufficient concrete discarded initially to ensure the specified colour is incorporated into the work.
- The concrete should be placed at a continuous rate and consistently for each section of the work. A minimum placing rate of 2 m/h is recommended.
- The placing rate should be such that the lateral pressure assumed in the formwork design is not exceeded.
- The settlement in each layer should be substantially complete before the next layer is placed, taking care to avoid cold joints.

- If placement is in layers, it should occur in uniform horizontal layers (300–400 mm thick).
- Damage to the form face from concrete placement should be avoided.
- The concrete should not be moved horizontally or made to flow by the use of vibration (to reduce risk of segregation).
- Concrete should not be dropped from a height exceeding 2 m (to reduce risk of segregation).
- Requirements for hot- and cold-weather placement.

CONCRETE COMPACTION

- Compact concrete thoroughly to remove entrapped air.
- If placed in layers, compaction by immersion vibrators should extend into previous layer.
- Additional compaction should be provided to top 500 mm of vertical elements (and all sloping surfaces) prior to concrete stiffening to minimise formation of blowholes.
- Damage to form face from contact with immersion vibrators should be avoided.

FORMWORK STRIPPING

- If colour control has been specified, formwork stripping time must be consistent for all elements.
- Time of stripping – earlier is preferred to minimise risk of damage to off-form surface and uneven curing due to gaps between formwork and concrete.
- Concrete placement to be scheduled to allow formwork stripping after the same period of time for all elements if colour control has been specified.
- May require minimum concrete strength prior to stripping to avoid damage to finish from stripping operation.

CURING

- Curing method – forms left in place, plastic sheeting, liquid membrane forming curing compound.
- Application – method and time. If plastic sheeting used for curing and protection, method to avoid contact with concrete surface to reduce risk of hydration staining.
- Curing time (minimum 3 or 7 days depending on exposure classification).

Also, if colour control has been specified:

- Curing procedure consistent for all elements.

PROTECTION OF FINISHES

- Protection of off-form finish from cementitious slurry/spoil, eg drilling for fixtures and bolt holes, grinding surfaces, placing concrete above.
- Protection of concrete following removal of formwork.
- Protection until subsequent construction work is complete.

SEALING

- Sealer to be used.
- Extent of sealed area.
- If colour control has been specified, sealer not to be changed during project.
- Applied by experienced personnel in accordance with the manufacturer's recommendations.

ASSESSMENT

- Time of assessment.
- Measurement criteria.
- Comparison to test panels.
- Allowable variations.

FIXINGS

- Type of fixings and/or bolts/anchors (eg stainless steel) to avoid future staining from corrosion.

REPAIRS

- Procedures for minor and major repairs.
- Criteria for acceptance/rejection, eg colour match, finish.
- Trial repairs to test panel for approval.
- Repairs to be completed as soon as possible to provide same curing conditions as remainder of work.
- Repairs to off-form finish to be carried out prior to any subsequent surface treatment.
- Repairs to be carried out by suitably qualified and experienced personnel.
- Whether or not repairs are allowed for Class 1 finishes.

CLEANING

- Water washing (ensure water pressure is not such as to damage off-form finish).
- Use of detergents or chemicals. Evaluate effect on off-form finish (texture and colour) by application to test panel prior to general use.
- Procedures for removal of particular stains. Either specify products and procedures or request contractor to submit these for approval prior to any work being undertaken. Procedures can be evaluated on test panel.
- Efflorescence. Specify how this is to be dealt with, eg removed on occurrence by scrubbing and rinsing with fresh water only, or perhaps left to the end of the defects liability period.
- Use of acid-based cleaners/products that may etch the surface should be avoided. Acids such as oxalic acid should not affect the finish but trials on the test panel should always be used to confirm the suitability and dilution ratio of products and their effect on the colour.
- Hydrochloric acid (also known as muriatic acid) should be used as a last resort. A less dangerous acid that will perform equally well under most circumstances is phosphoric acid, which is typically found in a variety of concrete and grout cleaners.
- All surfaces to be thoroughly rinsed after any cleaning operation.

References

1 AS 3610 *Formwork for Concrete* Standards Australia.

2 *Precast Concrete Handbook* National Precast Concrete Association Australia, 2002.

3 AS 3600 *Concrete Structures* Standards Australia

4 Briefing 06 *Form Liners* Cement & Concrete Association of Australia, 2002.

5 *Extracting an Archive in Concrete* Mix 17 March 2005 Cement Concrete & Aggregates Australia, 2005.

6 Jones IJ *Off-form, architectural concrete, Why success: Why failure?* University of New South Wales, School of Building, July 1985

7 *Tolerances for Concrete Surfaces* Cement Concrete & Aggregates Australia, 2005

8 AS 1379 *Specification and supply of concrete* Standards Australia

9 AS 3972 *Portland and blended cements* Standards Australia.

10 *Guide to Concrete Construction* C&CAA T41/SAA HB64 Cement & Concrete Association of Australia and Standards Australia, 2002.

11 *Causes, Evaluation and Repair of Cracks in Concrete Structures* ACI 224.1R-93 Report by ACI Committee 224. ACI Manual of Concrete Practice Volume 5, 2005.

Further information

The following Data Sheets are available from the CCAA web site www.concrete.net.au.

- *Cleaning Concrete*
- *Removing Stains from Concrete*
- *Removal of Mortar*
- *Sealers for Exposed Concrete Flatwork*

Appendix A
Colour variation and physical defects

TABLE A1 Physical defects and their causes

DEFECT	DESCRIPTION	MOST PROBABLE CAUSES
Blowholes **Figure 102**	Individual cavities usually less than 12 mm diameter. Smaller cavities approximately hemispherical; larger cavities often expose coarse aggregate.	**Formwork** Form face impermeable, with poor wetting characteristics Face inclined, face too flexible **Release agent** Neat oil without surfactant **Concrete mix** Too lean Too coarse sand Workability too low **Placing methods** Inadequate compaction Rate of placing too slow
Honeycombing **Figure 101**	Coarse stony surface with air voids, lacking in fines.	**Formwork** Leaking joints **Concrete mix** Insufficient fines Workability too low **Placing methods** Segregation Inadequate compaction **Design** Highly congested reinforcement Section too narrow
Mortar loss or grout loss **Figure 77**	Sand textured areas, devoid of cement. Usually associated with dark colour on adjoining surface.	**Formwork** Leaking at joints, tie holes, and the like **Concrete mix** Excessively wet Insufficient fines Too lean **Placing methods** Excessive vibration of wet mix
Scouring **Figure 89**	Irregular eroded areas and channels having exposed stone particles.	**Concrete mix** Excessively wet **Placing methods** Water in forms Excessive vibration of wet mix Low temperature

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TABLE A1 Physical defects and their causes *continued*

DEFECT	DESCRIPTION	MOST PROBABLE CAUSES
Misalignment **Figure 40**	Step, wave, bulge or other deviation from intended shape.	**Formwork** Damaged, deformed under load Joints not securely butted **Placing methods** Too rapid or careless
Streaks in surface **Figure 91**	Narrow areas of varying length where the texture of the surface varies.	**Formwork** Damaged form face **Compaction** Contact between vibrator and formwork **Design** Section not wide enough to allow use of immersion vibrator.
Plastic cracking	Short cracks, often varying in width over their length. On vertical faces, cracks are more often horizontal than vertical.	**Formwork** Poor thermal insulation Form profiles or reinforcement which restrain settlement of the concrete **Concrete mix** High water-cement ratio Low fines content Excessive bleeding **Ambient conditions** Conditions leading to high evaporation of moisture from concrete
Scaling, spalling or chipping, and form scabbling	Scaling is the local flaking or peeling away of a thin layer of mortar from the concrete. Spalling or chipping is the local removal of a thicker layer or edge of mortar. Form scabbling is the adhesion of portions of the form surface, including sealant or barrier paint, to the concrete.	**Formwork** Inadequate stripping taper Inadequate stiffness Movement of form lining due to change of hydrostatic pressure of concrete with depth Keying of concrete into wood grain, saw kerfing, and interstices in form surfaces Local weakness of form face **Ambient conditions** Frost action may cause spalling **Stripping** Stripping too early may cause scaling Stripping too late may cause scabbling
Crazing	A random pattern of fine shallow cracks dividing the surface into a network of areas from about 5 to 75 mm across	**Formwork** Form face of low absorbency, smooth or polished **Concrete mix** A high water-cement ratio combined with a cement-rich mix can be a contributory cause **Curing** Inadequate
Tie rod pattern **Figure 83**	The location of formwork tie rods	**Design** Locations not specified **Formwork** Located wrongly
Joints and rebates (liner) details **Figures 55, 56**	Construction, control and expansion joints, rebates, etc	**Design** Locations not specified **Formwork** Located wrongly Incorrect detail used

TABLE A2 Colour variations and their causes

DEFECT	DESCRIPTION	MOST PROBABLE CAUSES
Inherent colour variation **Figures 96, 97**	Variation in colour of the surface.	**Materials** Change of cement brand, type or quantity Change in source of fine and coarse aggregates Variation in admixtures **Concrete mix** Variations in mixing procedure
Aggregate transparency	Mottled appearance having dark areas on the surface similar to the size and shape of the coarse aggregate.	**Formwork** Too flexible, causing a 'pumping' action during compaction **Concrete mix** Low fines content Gap grading of sand **Placing methods** Excessive vibration
Negative aggregate transparency	Mottled appearance having light areas on the surface similar to the size and shape of the coarse aggregate.	**Materials** Aggregate dry or highly porous **Curing** Inadequate (rapid drying)
Hydration discolouration (due to moisture movement within or from plastic concrete) **Figures 98, 103**	Variation in the shade of the surface. Hydration staining and discolouration tend to be more severe at the top of a lift and at construction joints due to localised variations in the water-cement ratio, incomplete compaction, and differential loss of moisture. Rebates at joints tend to disguise the discolouration by creating shadows on the surface.	**Formwork** Variable absorbency Leaking through joints **Concrete mix** High water-cement ratio High bleed **Release agent** Uneven or inadequate application **Curing** Uneven
Segregation discolouration or sand runs (separation of fine particles due to bleeding at the surface of the form) **Figure 89**	Variation in colour, shade or texture, giving a flecked appearance.	**Formwork** Low absorption Water in bottom of forms **Concrete mix** Lean, high water-cement ratio Unsuitably graded aggregate **Placing methods** Excessive vibration Low temperature
Dye discolouration or contamination **Figures 86, 92, 112**	Discolouration foreign to the constituents of the mix.	**Formwork** Stains, dyes, dirt on form face, timber stains, rust from reinforcement or metal from components **Release agent** Impure or improperly applied **Materials** Dirty Contaminated by pyrites, sulfates, clay, organic matter or other impurities **Curing** Impure curing compounds Impure curing water Dirty covers

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TABLE A2 Colour variations and their causes *continued*

DEFECT	DESCRIPTION	MOST PROBABLE CAUSES
Oil discolouration **Figures 45, 46**	Cream* or brown discolouration. Sometimes showing sand or coarse aggregate.	**Release agent** Excessive amount Low viscosity Impure Applied too late or unevenly
Lime bloom, or efflorescence **Figure 113**	White powder or bloom on surface	**Design** Permitting uneven washing by rain **Release agent** Type **Curing** Lack of or uneven conditions
Retardation dusting	Matrix lacking in durability. Dusty surface which may weather to expose aggregate and which will erode freely under light abrasion at early ages, particularly in the period immediately following stripping of formwork.	**Formwork** Timber or plywood linings, the faces of which have had prolonged exposure to sunlight Retarder in or on the form faces Loss of contact between the form face and hardened concrete (rapid drying) **Release agent** Unsuitable Excessive use of chemical release agent Water soluble emulsion cream* Unstable cream Oil with excessive surfactant **Curing** Inadequate (very rapid drying)
Banding	Coarse texture corresponding to the width of the slipform, the bands often being of different colour.	**Slipforming** Stop-start method of slipforming Hardened concrete behind slipform cannot be finished at the same age as the rest and has different hydration conditions. A more nearly continuous slipform motion causes less prominent banding

** Cream refers to an emulsion of an oily constituent in water*