AALBORG WHITE®

Concrete Surfaces
– beautiful solutions with AALBORG WHITE®

AALBORG WHITE® is white cement
– a product of nature's own raw materials,
refined with unparalleled technology,
for use in the creation of beauty and functionalism.

Contents

In describing concrete surfaces, this issue covers much ground – from pore-free surfaces on dividing wall elements to coloured and exposed facades. The demands in connection with surfaces in different colours and profiles thus depend to a large extent on the application.

"Concrete Surfaces" shows a number of surfacing possibilities offered by white and coloured concrete. It examines methods of finishing fresh and hardened concrete. Examples are given of selecting concrete recipes and production methods, including formwork technique, methods of compacting, and surface finishes. It also deals with blemishes and discoloration, pore formation and, finally, the environmental effects to which the completed concrete construction is exposed.

"Concrete Surfaces" is aimed primarily at architects, the concrete element industry, and contractors.

Concrete surfaces – the natural solution

Historical development shows that since the end of the 19th century, the use of concrete has progressed because it is mainly an inexpensive and flexible material able to solve constructional problems arising in heavy building work. This new material made it possible to undertake constructions such as large foundations, substantial fortifications, towers, etc. in a more economical way.

Concrete was originally seen primarily as a load-carrying material. Requirements concerning strength, durability and not least appearance were quite modest. If appearance or durability became important, the concrete was clad in natural stone, plastered, or treated in some other way. With the introduction of reinforced concrete (not least prestressed concrete), the understanding of the significance of the "w/c ratio", and with the use of air-entrained concrete, progress reached a point where consulting engineers and architects dared use concrete as a material in its own right where both appearance and strength were concerned.

It was the industrialisation of the concrete production process that

created interest in the material. New methods of construction meant that it became impossible to conceal concrete behind plaster or other materials.

Only after concrete producers and contractors had solved various problems did cast-in-situ concrete, which stood untreated after formwork removal, make its breakthrough – a form of architecture that relies heavily on the utilisation of the monolithic structure of cast-in-situ concrete buildings. Such buildings are now erected using certain numbers of prefabricated elements, including facade elements. It has thus become possible to put up buildings consisting of elegant forms with varying surface structures and colours.

If grey cement is used, the "natural" colour of the concrete normally becomes slightly cool grey. However, on closer inspection it can be seen that there are varying shades, in that there are local deviations in the general grey tone.

When looking at the causes of colour variation, it can be seen that the colour of concrete depends on the type of cement used and, to a not insignificant extent, on the colour of the filler used (filler is particles of less than 0.25 mm).

Alternating between cement types or cement dosage carries with it the risk of colour variations. A substantial step in achieving uniform colour tone is to replace part of the grey cement with AALBORG WHITE®. As regards filler, natural sand can also vary. Filler material contributes to the colour of the concrete so that even small filler variations can result in quite large colour differences. For example, the use of filler from white marble, feldspar, etc. gives far greater colour uniformity and makes it easier to control the colour of the concrete.

Surface texture

Since concrete is a flexible, formable material it can be given almost any surface texture desired. The surface texture can be created in the fresh phase by profiling or similar methods, or in the hardening phase by machining or exposure of the coarse aggregate. An examination of architecture today shows clearly that many of the most elegant examples are buildings where the surface texture of concrete has played a large part in the design.

Untreated surfaces

Characteristic of untreated concrete surfaces is that the outer cement paste is not removed and helps in creating an impression of the formwork surface.

The simplest way of profiling such a surface is through the use of unplaned planks. It is wise to be careful when selecting shuttering boards to make sure that they have all been subjected to the same storage conditions, and most important of all, to make sure that they are all neutralised as far as sugar content is concerned. Boards should only be reused a limited number of times in order to ensure that the unplaned surface texture is preserved.

A special phenomenon when casting untreated surfaces is the formation of pores. These arise because air clings to the surface during vibration. The number and size of pores is closely connected to the composition of the concrete. In particular, water content, formwork surfaces, formwork oil and vibration method have an influence. The best result is obtained by using easily worked concrete, e.g. using air entraining agents and various plasticisers so that the water content is held at a suitable low level. Additionally, it is important to use good formwork oil or wax.

Experience shows that an absorbent and not too tightly sealed formwork gives the least number of pores resulting from air. Narrow unplaned boards make ideal formwork material when a minimum number of surface pores is desirable.

A special effect can also be achieved by using sand-blasted or flame-cleaned wooden shuttering. These processes bring out the grain of the wood in the form of soft curves in the surface of the concrete. If the wish is for surfaces with the distinctively coarse texture of wooden formwork on all facades, it is advantageous to manufacture the formwork using artificial rubber moulded over a wooden matrix.
A coarser surface texture can also be obtained by laying matrixes of different materials in the formwork, such as rubber, PVC, polystyrol, etc.

Surface textures

Treated surfaces

Removal of the outer cement paste on concrete surfaces gives better control of the many aesthetic problems connected with untreated surfaces. It also provides the possibility of varying the colour and texture of concrete surfaces.

Exposure by retardation. Washing unset concrete exposes the coarse aggregate in the surface. This process is performed on elements being cast with the visible side upwards. If retarder is applied to the formwork side, the most usual method, the facade part is cast towards the formwork. Concrete surface setting is thus retarded until the formwork is removed. Washing to expose the concrete is then possible. In both cases, the process combines brushing and water flushing.

Exposure is normally only used in connection with concrete elements. In principle, an exposed concrete surface resembles a sand-blasted one, but the exposure goes deeper and the aggregate retains its natural brilliance. The composition of concrete which is to be exposed more or less follows the same lines as that of concrete for sand-blasting.

The typical aggregate content of concrete is 70%, often with quite large steps in particle size. Depending on the grain shape (cubic/flat) there will be a difference in aggregate layering either on vertical or horizontal cast surfaces.

It should be remembered that like most chemical processes, retardation is very temperature-sensitive. Also, retarder should not be applied to formwork in low temperatures. It is important to test retarder to make sure that it is suitable for the conditions in which it will be used when final casting takes place.

The retarder should also be tested in relation to the material of the formwork being used. The absorption properties of such materials can have a significant effect on retardation depth. When using wooden formwork for the first time, it can be necessary to apply the retarder twice.

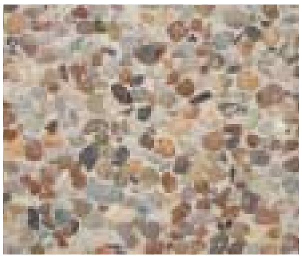
During final brushing and flushing, it must be remembered that the penetration depth also depends to a certain extent on how much power is used.

Treatment must be completely finished in one operation without stopping. A final mild acid etching can be applied a few days after exposure if the cement slurry has diminished the brilliance and colour of the exposed aggregate.

Exposure by mild acid etching. Mild acid etching of plane or profiled surfaces the day after casting will remove cement paste. It is important to thoroughly wet the surfaces with water before acid etching to prevent the surface from absorbing hydrochloric acid. Acid etching is usually performed using a 1:10 acid solution (30% commercial hydrochloric acid). After acid etching, the surface must be thoroughly flushed with water. Normally, this form of treatment only exposes the sand grains.

Grinding is a surface treatment method normally used for terrazzo floors in bathrooms, on stair elements, or on terrazzo tiles. The method has also been adopted for use on facade elements. If a terrazzo surface is required, it is best to carry out machining work at a factory used to dealing with horizontal grinding. There is however another method merely consisting of grinding away the top layer of cement paste. This gives the same result as acid etching. Grinding should normally be carried out after 3-4 days' hardening time, otherwise there is a risk of tearing aggregate out of the concrete. In planning such work, it is imperative to take account of the fact that the grinding process necessitates the provision of a drain to take away the large amount of water involved. It is also important to use aggregate that is suitable for grinding (marble, granite, etc.).

Exposed surface with Hardeberga granite.



Exposed surface with fine pebble gravel 16/32.

Exposed and acid-etched surface with Lahn quartz 5/8 (German aggregate).

Polished, acid-etched and exposed surface with Glen Sanda 4/8 (Scottish aggregate).

Sand blasting wears away the concrete surface and is used especially for the treatment of cast-in-situ concrete. The object is to wear away the cement paste on the surface so that the aggregate and coarse sand grains are left in a relatively uniform texture. With sand blasting, the natural colour of the surface becomes slightly greyish or mat.

Like grinding, sand blasting requires a reasonably uniform concrete surface strength, otherwise it will tear out sand grains and aggregate. If sand blasting is used too late, the result will either be poor or the cost will be too high be-

– give life to the concrete

cause of the time needed to treat thoroughly hardened concrete. Dry sand blasting develops large quantities of dust and involved personnel must use masks or special equipment.

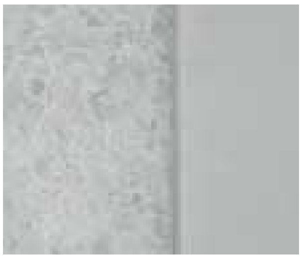
If sand blasting is to result in a relatively coarse texture, it is an advantage to use gab-graded grading based on coarse aggreate fractions 8-20 mm. When cast-in-situ concrete is involved, the vibrator poker must not come too close to the visible surface, otherwise the movements of the concrete around the vibrator poker might easily lead to patches with reduced amounts of aggregate.

As previously mentioned, sand blasting must be performed at a time when the strength of the concrete has not developed too far, therefore formwork should be removed relatively early. The careful planning and control of hardening conditions are therefore necessary.

Hammering and pick chiselling. This is a relatively expensive finishing method.

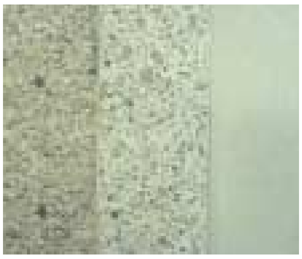
In hammering it is most common to use a pneumatic bush hammer. Depth penetration with this method is fairly modest, which means that casting blemishes, etc. cannot be completely concealed by the surface treatment. To facilitate this kind of treatment, formwork should contain the fewest possible joints. Plywood is suitable, for example.

A stronger effect can be achieved with a pick chisel bit. Surfaces become coarser and in general the appearance is more uniform, i.e. a more monolithic overall effect when used on cast-in-situ concrete. Normally the intention is to create an appearance similar to that of split granite. It is therefore an



Polished and acid-etched surface with lysite.

White concrete with exposed calcined flint.



Exposed, polished and acid-etched surface with Blauschwartz (7/15 (German aggregate).

Acid-etched surface with Bayergrün 10/20 (German aggregate).

advantage to use granite in the aggregate when making up this type of concrete.

Account must be taken of the fact that hammering and especially chiselling remove substantial amounts of material (with chiselling up to 2-3 cm). Other considerations arise: final treatment in relation to the position of reinforcement rods, determination of covering layer thickness. Chiselling is work for stonemasons; skilled craftsmen should therefore be engaged for the task. Because of the relatively large depth of material removal, a skilled stonemason can only deal with about 3 m^2 surface per day.

A further factor is that sharp lines are very difficult to achieve. Thus, beams and column edges will appear a little uneven. This is why such treatment is often reserved for surfaces that are to be framed with smooth-cast concrete, so that all corners and edges can be left untreated. Hammering and especially chiselling require strong concrete and should not be started until a hardening time of about 14 days has elapsed.

Hammering and chiselling are normally only used for cast-in-situ concrete.

Lightly treated surfaces

A special way of finishing the surface is to treat the fresh concrete where, for example, the concrete element is cast with the facade upwards. Good effects can be obtained by brooming, felt floating, rolling, scouring with wood or sacking, etc. These forms of treatment all involve retaining most of the surface slurry and giving the surface a special texture. The effects produced can be enhanced by varying the steps in particle size when making up the concrete.

In general, these surface treatments must resemble the outcome of chance, but must at the same time have a uniform appearance, i.e. the process demands skill. The treatment must be commenced immediately after casting and is therefore conditional on there being no water segregation (bleeding). The treatment must not be confused with cement washing or applying an extra layer of cement slurry. On the contrary, it removes superfluous water and leaves a relatively uniform cement paste in an appropriately thin layer.

A further and highly important rule is that each time the treatment is used, it must be applied at the same time in the concrete hardening process. Variations in "uniformity" will result if this rule is not observed.

Coloured concrete

In recent years architects have shown much interest in the use of coloured concrete, whether for facades, paved areas, or roof tiles. The desired architectural effects have been achieved by using pigments or aggregates, or combinations of these materials.

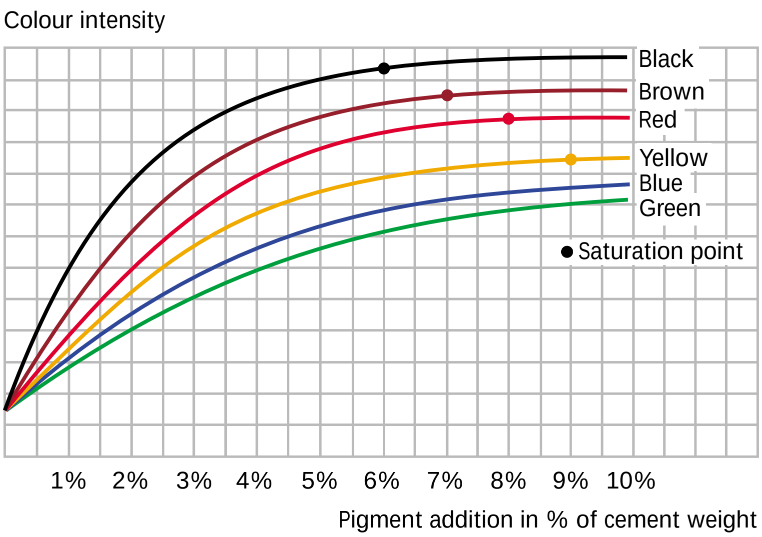
All pigments are not equally suitable for producing coloured concrete. Here, special requirements apply and pigments must be lime-proof, light-fast, and alkali and weather-resistant. Previously, the pigments used were mainly natural mineral pigments complete with their impurities and colour variations. The pigments used today are synthetic, inorganic substances of well-controlled uniformity as far as colour and reflectivity are concerned. There are a number of pigments that cannot be used – concrete is strongly basic and as such is able to break down some of them. If concrete is mixed using a pigment that is not lime-proof and light-fast, there is a risk of the resulting surface not being the correct colour.

Furthermore, pigments must not be used if they contain substances that might impair the strength and hardening properties of the concrete.

The colouring process normally involves pigments that colour the concrete right through. Clean, pure colour tones can often be obtained by using AALBORG WHITE® as the basis, possibly with coloured aggregate. It is also important to ensure uniform filler. It is best to make sure that the constituent materials used in producing coloured concrete have a colour as close as possible to the colour required. Difficulties can arise if there are large colour variations in aggregates, especially when the construction has been exposed to normal wear. Initially, the outer layer of coloured cement paste covers all aggregate particles, but will in time be worn away – thus allowing the colour of the aggregate material itself to become dominant. This condition will, primarily, concern those engaged in paving.

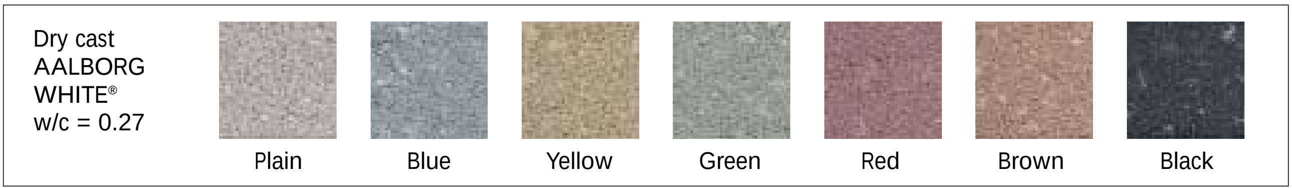
It is seldom possible to obtain aggregate in precisely the colour required. This might not be necessary anyway, but there must be no sharp contrasts; the amount of reflected light being the most important factor. Here the "grey scale" can help in selecting suitable materials, in that it provides a basis of comparison in determining how much light the individual colours actually reflect.

For financial reasons, the use of coloured concrete (especially in sandwich facades) is limited



Colour intensity depending on dosage quantity with associated colour shade scale.

to facings. This is not normally the case in tiling and paving work. In paving, the production conditions are the same as for homogeneous coloured concrete. With modern block machines it is however possible to produce paving stones with coloured facing on ordinary grey



Dependence of colour shade on w/c number for AALBORG WHITE®.

concrete backing. Most used are black, red, yellow and brown pigments based on synthetic iron oxides.
Water-repellent substances can be added to coloured concrete for facades and paving. Examples are zinc stearates in powder or liquid form. The dosage is about 0.3-0.4% of cement weight. An advantage of using such substances is that they reduce the tendency towards efflorescence.
The stearates also give improved workability and lower water absorption. The risk of algae growth is also eliminated, for algae spores are not compatible with zinc combinations.

The use of yellow iron oxides means increased water requirement because the colour particles are needle-formed. The water does not become bound by the oxides, therefore the increase in water requirement necessitates increased cement content in order to maintain the required w/c ratio.

Figure 1 shows the pigment dosage quantities necessary for creating a required shade of colour. Figure 2 is an overview of choices of pigment combinations in relation to white base cements.
The degree of pigmentation is dependent on the shade of colour required.

The following practical guidelines can be used:

- For light colouring, i.e. pastel colour based on AALBORG WHITE®, for example, 1-2 kg pigment per 100 kg cement.
- For middle colouring, 3-5 kg pigment per 100 kg cement.
- For strong colouring, dosage is 6-8 kg pigment per 100 kg cement.

When using black or brown pigments, dosing is the same as for light colouring; for yellow and especially blue pigments the figures for strong colouring apply; for red-pigmented concrete the middle colouring figures. With 8-10 kg pigment per 100 kg cement, no extra colour effect can be expected.

In general, the tolerances on dosages of the constituents used in coloured concrete lie within ±5%.
In connection with dosing ratios, differences can arise depending on whether pigment is added in powder or liquid form.

The dosing sequence of constituents, including pigments, has great significance in obtaining uniformity in the finished, coloured concrete surface. In this way, streaks or "comet tracks" as they are sometimes called, and the lumping of cement paste and pigments can be avoided.
The combinations are given in the table below.

Mixing sequence				Cement lumps	Pigment lumps
1	2	3	4	Σ	Σ
sand	+ pigment	+ cement	+ water	0	12
sand	+ slurry	+ cement	+ water	10	0
sand	+ cement	+ pigment	+ water	3	36
sand	+ cement	+ slurry	+ water	4	124
sand	+ water	+ pigment	+ cement	4	11
sand	+ water	+ slurry	+ cement	8	0
sand	+ cement	+ water	+ pigment	3	8
sand	+ cement	+ water	+ slurry	21	27
sand	+ water	+ cement	+ pigment	12	8
sand	+ water	+ cement	+ slurry	5	145
sand	+ pigment	+ water	+ cement	10	0
sand	+ slurry	+ water	+ cement	0	0
sand/pigment/cement/water*				200	200
sand/slurry/cement/water*				64	136

*All constituents added simultaneously.
Mixer type: Panmixer, Zyklos
Mixing time: 1+2 = 15 s, 1+2+3 = 30 s, 1+2+3+4 = 60 s
Moisture content: 8%

Pigment and cement dispersal depending on the order in which (sequence) they are fed into the mixer.

Formwork technique

Formwork oils

It is difficult to select the most suitable formwork oil beforehand. Therefore it is always important to try out formwork oil on one or two test casts and in this way find the best oil. Much difficulty can be saved by choosing a formwork oil for the particular work in hand. One job might be different from another and it must be remembered that different formwork often has to be chosen. An oil that has proved very satisfactory for one job, will not necessarily be satisfactory for other jobs. The selected formwork oil must be able to work together with the matrixes involved. Some will dissolve or rot the matrixes.

The following requirements must be met by the formwork oil:

- Frost-free storage before use.
- Easy formwork stripping, i.e. good release capacity.
- No pore formation in or discoloration of the concrete.
- Easy formwork cleaning, i.e. minimum slurry residue on formwork surfaces.
- No retardation of concrete surface (dusty surface).
- Rust protection of formwork (steel), i.e. on stripping, the side that has been in contact with the concrete must be free of rust.
- The formwork oil must not be hazardous to personnel and must therefore meet working environment legislation.

Wooden formwork.

In practice, formwork oils can be categorised into the following main groups:

Pure mineral oils

These are oils containing no additives whatsoever, neither to make application easier nor to make the oil emulsify in water.
Provided the oil is light in colour, it will not discolour the concrete surface and only slightly affect the hardening characteristics of the concrete. However, these oils can increase the number of pores and even though the oil is suitable for the surface, it can subsequently cause blotching.

Pure mineral oils with additives

Additives producing chemical effects. These are substances (acids) added to mineral oil, which react with the alkalis in the concrete and usually produce lime soaps.
Because this is a chemical bond, the result is often a very strong carrying oil film that means only a minimum amount of oil is necessary. It is important to use the correct dosing, typically around 1/3 of the quantity of formwork oils traditionally used. If too much oil is used, the chemical reaction will lead to softening of the concrete surface. These oils can be improved by the use of other additives, e.g. rust inhibitor.
The oils normally remain undamaged by frost and if the formwork is erected in a humid environment the chemical effect of these oils can be supplemented by additives that repel water, i.e. oil can be applied to a wet form without prior drying off. The oil repels the water by penetrating under it and adhering to the formwork.
The use of the additives just mentioned makes these formwork oils particularly suitable as cleaning agents.

Additives with physical effects

Formwork oils containing these additives, also known as emulsions or “oil-in-water emulsions“, can in principle be considered as an improvement on pure mineral oils, in that they give better adherence between formwork surface and oil film, which in turn means a stable and coherent oil film.
These oils can usually be used without thinning. That is to say, their primary task is to emulsify the water forced out to the oil film when the concrete is being cast. However, a distinction ought to be made between the use of plastic concrete and earth-moist concrete. When using the formwork oil where earth-moist concrete is cast, it is usually necessary to further emulsify it with water before it is used. Such dry concrete does not release moisture along the form-work surface, whereas plastic concrete does.

Formwork oil paste – wax

Because of its consistency, wax is usually difficult to apply. It requires very comprehensive and lengthy rubbing in, but in return ensures a very thin and uniform wax film that is beneficial in all respects. The use of wax enables the production of exceptionally smooth surfaces, largely without pores.

Synthetic oils

As a rule, synthetic oils are based on a combination of synthetic ester oils and water. Here, synthetic vegetable oil is to be understood as vegetable oil artificially produced. During production, the vegetable oil is chemically treated to eliminate the limitations which it would otherwise have when applied to concrete formwork. It is a stable formwork oil which unlike ordinary vegetable oil does not easily become rancid and react with the concrete.
Synthetic oils are much easier to break down than mineral-oil-based products. They have low viscosity, they are easy to apply and they do not give off odour. They also have slight retardation characteristics. Generally, these oils remain usable for up to 6 months. They can thus be used under winter conditions and when warm concrete is poured. The oils should be stored in normal temperatures.
Synthetic oils can be applied to formwork in the normal way. i.e. mainly as a thin, sprayed-on film. After application, the surface must not be touched. The combination of water and oil improves the concrete surface finish; to a large extent it will be free of pores. The use of super-plasticisers in the concrete gives further benefit. These oils do not lead to discoloration when, for example, white or coloured concrete is used.

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Application of formwork oils

Formwork oil must be applied as a thin film, but to ensure the best release characteristics the film must be unbroken and the formwork clean. The method of application must also be correct, e.g. manual or machine spraying, brooming with a soft broom, sprinkling and spreading by rubbing, or application by oil-soaked cloth.

In most cases superfluous oil must be removed. There can be wide variations in covering capacity, but 1 litre of oil can normally be expected to cover about 30-80 m^2.

Application is largely unrelated to formwork material, but the method of application will depend on the type of oil used. Pure oil can be applied using all the methods named, whereas emulsions are best applied by brooming or rubbing, wax only by rubbing.

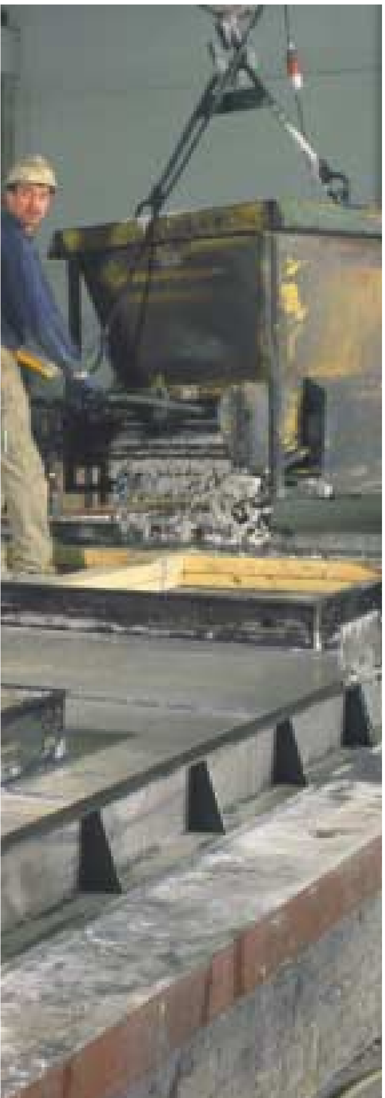
Where exposure is concerned, pure mineral oil is used prior to the application of retarder. It is important that the oil be dried off after application. Thick films of oil often make it difficult to control retarder application. Where exposed facades are combined with smooth-cast facade sections, synthetic oils are used to avoid air pore formation.

In addition to the above, there are a few relevant factors that can have an influence on concrete surface quality:

1. The physical and chemical properties of formwork oil:
   - Lubrication properties (release capacity).
   - Emulsification characteristics (rust spots).
2. Concrete type:
   - Cement content and content of fine materials that in general affect concrete surface quality.
3. Concrete consistency, workability and tendency to bleed, which all affect concrete surface quality.
4. Vibration and deposition of concrete.

Further factors having an effect on concrete surface quality must also be taken into account:

1. Oil film thickness and possibly age, i.e. some oils oxidise quickly.
2. Temperature variations during the period in which the oil must remain effective.
3. Formwork type. Here, the geometry and material play a role.
4. Direction of casting: horizontal and vertical surfaces. There is a risk of streaks with air pores appearing in vertical surfaces.



Formwork materials

The two most common faults in concrete surfaces, discoloration and pores, arise to a large extent from the absorption capacity of formwork material. The number of pores decreases concurrently with any increase in formwork surface absorption capacity, and at the same time the concrete becomes darker.

Only a few surface pores will appear in those cases where a relatively high surface pressure forces free air and water pores upwards.

Wooden formwork. Formwork in wood or plywood varies widely in absorption capacity. Used correctly however, formwork oils will counter the associated difficulties. All new wood can be lacquered twice with a 24-hour interval between applications or, prior to use, oil can be applied two or three times at 48-hour intervals.

The object is to fill the pores in the wood throughout the more absorbent areas and thereby ensure more uniform porosity. When treating wood in this way, the oil must be applied copiously and superfluous oil removed so that the formwork is saturated before the material is used. Then, when the material is used subsequently, only a thin film of oil need be applied from casting to casting. During weather which subjects the wood to severe drying out, it is often necessary to apply extra coats of oil in order to prevent formwork shrinkage.

Steel formwork.

Steel formwork will as a rule tend to produce a lighter shade of concrete surface, in that no absorption takes place and the w/c ratio is thus higher at the surface.

If the concrete has a tendency to bleed, consideration must be given to a third factor that can give rise to unfortunate surface problems, i.e. rust. The risk of rust on formwork and consequent concrete surface discoloration is of course increased by bleeding. Mineral oils with additives can reduce the tendency, and reduce the number of pores.

Plastic formwork. Different types of plastic formwork are used, but the omission of formwork oil is not recommended. Gradually, as the formwork is used repeatedly, the concrete surfaces produced will change. Wear takes place every time the formwork surface is cleaned, and cement slurry adheres to the formwork.

There are other formwork materials, two examples being rubber and expanded polystyrene. Mineral-based oils cannot be used here since they react with the formwork material; special products are necessary.

Concrete production

Concrete production

The production of high-quality, strong and durable concrete which at the same time has the desired surface texture, is conditional on the correct utilisation of the properties of its constituents. This can be ensured by using an appropriately combined grain curve and concrete composition.

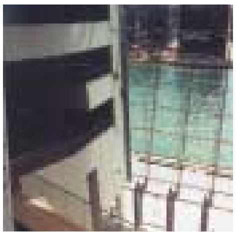
As the following proposals show, concrete recipes for different surfaces (including the choice of texture and profiling) are largely based on experience. In general, the underlying principles for working out the grain curve and concrete composition are the normal guidelines.

In determining aggregate composition, it is important when making up facade concrete – whether for smooth-cast surfaces or exposed surfaces – to keep to the narrow tolerance limits of the combined grain curve. Experience shows the advantages of setting up guidelines that will ensure good control of the grain curve. For example, it is recommended that a tolerance of ±5% be applied to screen meshes of 1/4 mm and 4 mm, and to the mesh corresponding to half the value of the selected maximum grain size. If this is 16 mm for example, the tolerance for 8 mm screen mesh applies. See also the examples of aggregate composition.

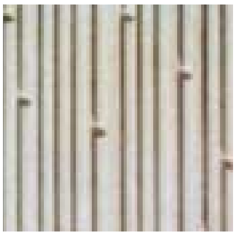
The keywords and values used in the following proposed concrete recipes are based on experience gained in surface technique. The illustrations showing the build-up of front panels in facade elements and for matrixes must be considered as examples of how such work is carried out.

Concrete element facades

Exposed



Smooth, moulded



Profiled

Smooth, moulded acid-etched

Polished

Concrete composition

Surface	Grading	Cement type	Cement kg/m³	Fine aggregate kg/m³	Coarse aggregate	Fine/ coarse	Admixtures	w/c_{max}
Exposed	Gap graded	Rapid hardening	330-350	400-500	1350-1450	25-75%	WRA HRWRA colour (AEA)*	0.55
Smooth, moulded	Even tendency to small sand humps	Rapid hardening	330-350	650-800	1000-1150	40-60%	WRA AEA HRWRA colour	0.55
Profiled	Even tendency to small sand humps	Rapid hardening	330-350	650-800	1000-1150	40-60%	WRA AEA HRWRA colour	0.55
Smooth, profiled, acid-etched	Even tendency to small sand humps	Rapid hardening	330-350	650-800	1000-1150	40-60%	WRA AEA HRWRA colour	0.55

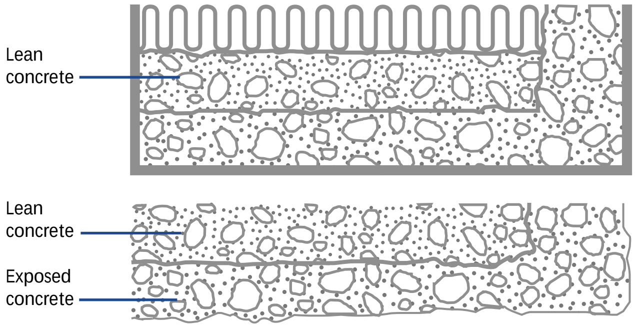
* It can however be quite difficult to mix air in exposed concrete, because of its composition.
WRA = Water reducing agent
HRWRA = High range water reducing agent
AEA = Air entraining agent

Examples

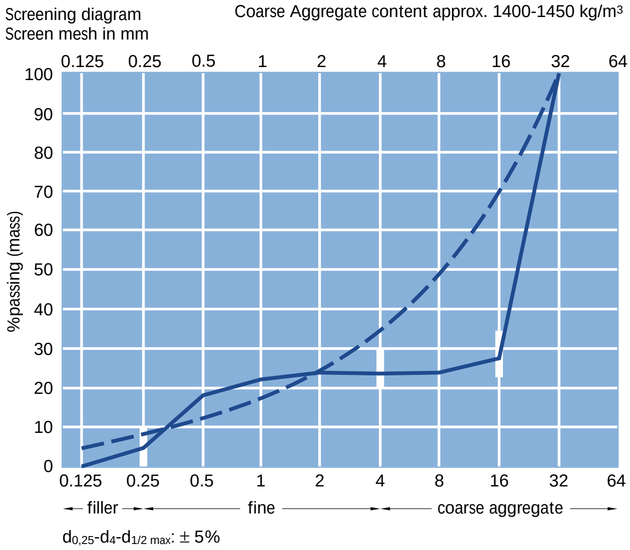
Exposed surfaces

Exposure
Chemical retardation of cement paste in the concrete surface.

Other methods
Sand in the form, washing fresh concrete, positive casting.

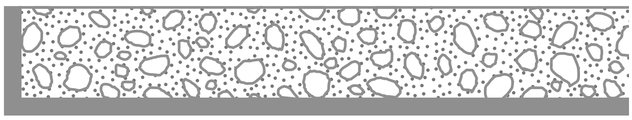


Combined grading for "exposed concrete"
Fine/coarse: 25/75%
Coarse Aggregate content approx. 1400-1450 kg/m³



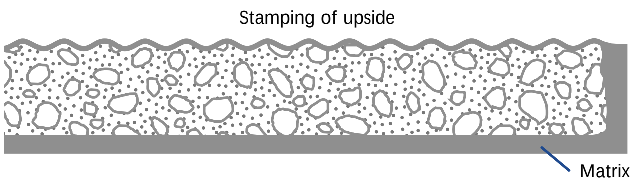
Smooth cast

Smooth casting imposes heavy demands on formwork, on vibration, and makes repair work difficult. The surface is vulnerable and has a tendency to crack because of the increased w/c ratio in the cement paste in contact with the formwork.



Profiled concrete

Stamping the upside and/or casting against matrixes.
Stamping the upside: changes in form easy, but variations in uniformity of appearance; drying out requires special methods.
Casting against matrix; changes in form more difficult, but appearance more uniform.
Repair can be very difficult.

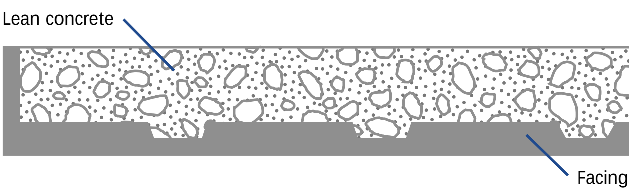


Smooth, profiled, acid-etched

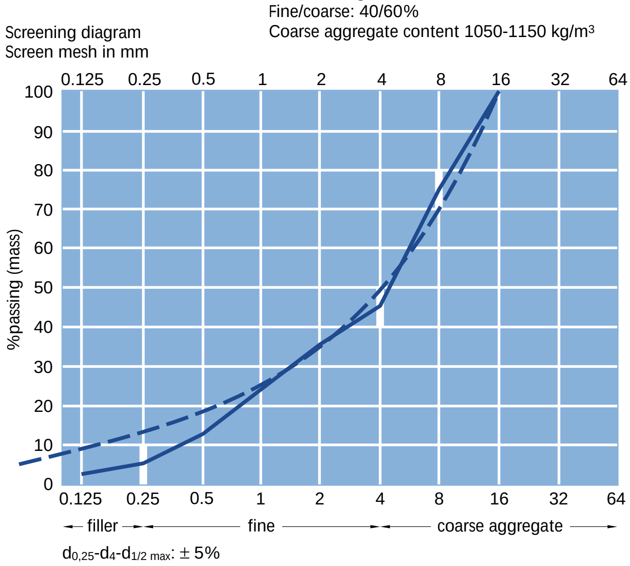
Sand fraction often composed of several types to take account of colour effects in the concrete. Acid etching 5-10% HCL (37%).

Why acid etching?
Reduces nuisances previously mentioned in connection with smooth surfaces, the"cement skin" disappears. As far as colour is concerned, the fine parts of aggregate come into their own.
Colour pigmentation effects reduced through acid etching.
Chloride risk (prewatering and post-watering essential).

Alternative to acid etching
Weak chemical retarder, but it is not possible to achieve such slight surface retardation as with acid etching.
Phosphoric acid, acetic acid leave uneven white blotches.



Combined grain curve "smooth, acid-etched"
Fine/coarse: 40/60%
Coarse aggregate content 1050-1150 kg/m³



Concrete vibration

The colour of the finished concrete surface depends on many factors, including vibration.

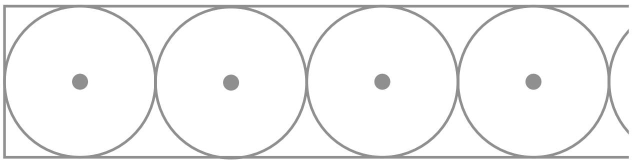
Ordinary concrete often contains a large amount of entrapped air from the mixing process and from pouring into the form. To prevent many and large pores, this air must be removed. The process used for this purpose is vibration which removes the larger and irregular air bubbles. The greater the distance the air has to travel to the surface, the more the concrete has to be worked, therefore it is often difficult to limit the number of pores in walls and pillars in relation to deck constructions. The upper parts of walls and pillars are normally where most pores appear and therefore these parts of the construction require special treatment.

The concrete must normally be poured continuously in layers at an even rate. Pauses between layers often give rise to discoloration and pore formation. In general, the dumping height for poured concrete must not exceed 1 m. If this maximum is exceeded, there is considerable risk of separation.

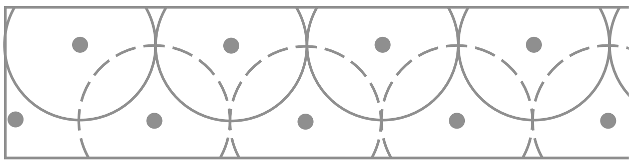
Concrete is vibrated during casting in order to ensure denseness and homogeneity. The surface of the finished concrete is much dependent on the method of vibration used. Incorrect vibration can cause honeycombing, extensive colour variations, and, with loose formwork, cement slurry leakage. There are several methods of vibration, examples being poker vibration where a poker is pushed down into the cast concrete, or external vibrators mounted on the formwork so that the vibration produced is disseminated through the formwork and into the concrete.

With vibration it is important to use formwork that does not leak. When system formwork is used, the sections when assembled must be capable of withstanding stress. The forces generated by the pressure of poured concrete plus the vibration from vibrators can open joints.

Use of poker vibrator.



No overlap leaves areas uncompacted.



Overlap ensures full compaction.

When using a poker vibrator, it must be taken down into the concrete rapidly, then, after allowing it to operate for a short time at the deepest point, withdrawn slowly again so that no cavities form behind it. The whole process should take 15-30 seconds. This process helps the upward movement of entrapped air bubbles. Experienced concrete casters are able to judge when concrete has been sufficiently vibrated by looking at the surface. It should be closed by cement slurry, with just an occasional air blister appearing. When casting constructions of limited cross-sectional area, pillars for example, rapid insertion of the vibrator is important. If it is allowed to operate for too long in the upper layers the fine-grained constituents pack, so blocking the escape of larger air bubbles. This in turn leads to the formation of more pores in the finished concrete surface.

Concrete should, as far as construction-site conditions allow, be poured into formwork in horizontal layers of equal thickness. Under no circumstances should any layer be more than half a metre thick. The aim is to cast the same layer thickness all the time. The poker vibrator must not be used to distribute the concrete as this will result in surface defects, and the concrete might separate. Pouring and vibrating must be timed in harmony so that the poured concrete becomes compacted correctly. In the case of very strict surface requirements as regards denseness and least possible number of pores, a reduction of the poured layer thickness to 30 cm is recommended. Layer thicknesses greater than 50 cm must be expected to give increased pore formation. There is also a risk of the appearance of layer division lines. A reduced layer thickness can be difficult to maintain, especially when thin walling is being cast.

If vibration is to be performed only in thin layers, e.g. when pouring floors, it is advantageous to insert the poker vibrator into the concrete at an angle. This compacts the concrete better, i.e. vibration is directed more towards the supporting structure than with a vertically inserted poker vibrator. When

Vibrating table for concrete elements for facings.

this method is used, the angle and direction of the poker vibrator should be the same throughout the process.

When producing wall elements in horizontal moulds, poker vibrators, beam vibrators or form vibrators are suitable. Combinations of these types can also be used, depending on the shape of elements, reinforcement placing, and element thickness. Form vibration is most common for producing wall elements.

To ensure a minimum of air pores and to avoid "acoustic patterns" it is important to aim at mounting a few large vibrators on a correctly braced form. That is to say, it is advantageous to use four large RZ 165 K form vibrators which give a centrifugal force of 16,500 N at a speed of 3000 rev/min. Such vibrators are usually mounted at form ends.

If many, small form vibrators are used they can so to speak "cancel each other out" and give rise to poor compaction with the accompanying risk of too many air pores in the concrete surface.

Poker vibrators with long drive shaft or vibrators with built in motor and long cable are ideal where high, vertical walls and pillars are involved. These vibrators can be inserted through "ports" in the sides of forms. Uniform vibration throughout the entire height and uniform concrete are preconditions for a successful result and uniform concrete surface.

When using a vibrator in the vicinity of formwork, it must not be inserted down too closely to the surface of shuttering boards, etc., especially if the shuttering is so slender that it might begin to vibrate synchronously with the vibrator. The correct distance from formwork will depend on the radius of action of the vibrator. With thin concrete walls, poker insertions should be closer together to ensure even compaction. If the relationship between vibrator and formwork vibration does become badly distorted, e.g. if a powerful poker is brought too close to shuttering, air might be sucked through joints in the formwork. The result will then be a surface with too many holes and sandy areas. If vibrators can come into contact with formwork, the possibility of such surfaces becoming damaged must not be overlooked. If very thin concrete constructions are involved, the vibrator can be fitted with a rubber cap.

With reinforced concrete, it is important that the reinforcement be positioned to allow insertion of the vibrator at the correct distances. If very close-pitched reinforcement makes pouring in uniformly thick layers impossible, it can become necessary to distribute the concrete with the poker vibrator. To prevent the relatively long vibration time giving rise to separation, each layer must here again be no more than 50 cm thick. The concrete must have a composition that gives "self-contained" flow without releasing water.

If pumped or liquid concrete is poured into narrow forms with close-pitched reinforcement, the vibrator used must have a diameter of 40 mm and the vibration time must be shorter than with stiffer concrete, i.e. 10-20 s per insertion. The precise sequence should be established by trial casting.

Where there are strict surface requirements, the height of each pouring layer must not exceed 30 cm. The vibrator must always be inserted to the same depth in the underlying, already vibrated, layer. The insertion points should be in a regular pattern of distribution. It might be advantageous to use a poker with a diameter of 40 mm.

Contact between poker and reinforcement close to shuttering can result in marks being left in the concrete surface, i.e. the appearance of the concrete surface is directly related to the condition of the formwork surface. It might be necessary to use a different method of vibration, depending on the formwork surface. It is therefore recommended that one or several trial castings be made in order to establish the most suitable method and the correct concrete composition.

Treatment of concrete

To ensure durability, concrete must have good curing/ hardening conditions.

Good curing/hardening conditions in this context means that drying out of the newly-cast concrete is prevented and that it is not exposed to unfavourable temperature effects such as premature exposure to frost, large temperature variations, etc.

Protection against drying out is particularly vital within the first 24 hours of curing time. See the future European standard ENV 13670-1, Execution of Concrete Structures, etc.

Drying out can be prevented by:

- allowing formwork to stay in place,
- covering with vapour-proof membrane (plastic film, sealing agent),
- keeping the concrete surface wet.

Formwork

Formwork itself will prevent a certain amount of drying out.

Formwork consisting of lacquered or oiled plywood and steel acts in the same way as plastic film, in that these materials are waterproof and non-absorbent.

With ordinary wooden shuttering, the actual moisture content of the wood is of great significance. Therefore it should be saturated with water before pouring. Fresh wood will retain moisture much longer than wood that has dried out and then been saturated repeatedly.

Plastic

Plastic film laid or brought close to the concrete surface is an effective way of preventing evaporation. This however assumes that the form of the construction is regular without inward projections and corners, and that reinforcement bars, etc. do not protrude above the concrete surface.

Casts that are completed with substantial horizontal areas such as floors, facade and deck elements, are applications where plastic film is ideal.

It is important to ensure that film is held in position and cannot be blown off or lifted in folds that might create a wind tunnel effect. Torn plastic film should not be used again.

For the sake of the final surface finish, it might be necessary to delay covering until the concrete surface has gained a certain degree of strength and cannot be marked or deformed in any way by the application of plastic film. This problem can be avoided by using a sealing agent.

Preserving the surface appearance might also mean laying the plastic film so that it is in close contact with the concrete to prevent blotches and discoloration arising because of non-uniform protection or condensation on the underside of the film.

A plastic film lying direct on a wet/soft concrete surface will often result in shiny, smooth patches. This problem can be eliminated by using, for example, a covering of felt or geotextile before laying the plastic film.

Establishing effective protection with plastic film is difficult where walls, pillars, etc. are involved and great care is needed to avoid tearing the film and to ensure good joints. Strong adhesive tape is ideal for joining and repairing film.

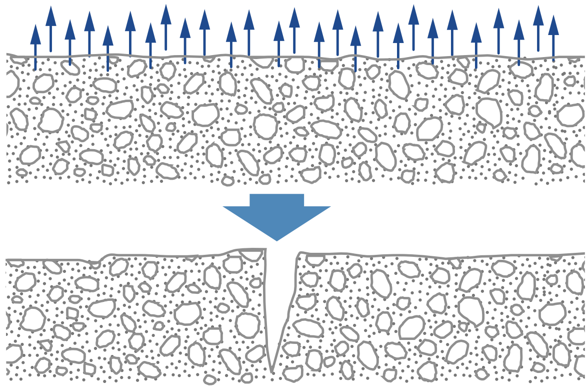
Sealing agents

Sealing agents are used primarily to protect fresh concrete, but can also give protection when formwork is removed.

It can be difficult to apply the appropriate amount of sealing agent to vertical surfaces and undersides. The risk is that it will run down and lead to uneven protection and permanent discoloration. Application by spraying several times solves such problems.

The main area of use for sealing agents, an area in which they have become widespread, is the protection of fresh horizontal concrete surfaces. Their most obvious advantage is that they can be sprayed on without leaving marks in the hardening concrete. However, they do have a tendency to produce various shades of discoloration if spraying is not uniform or the concrete surface is uneven, etc. Information on the effectiveness of these agents should be obtained from the supplier before use.

It is important that the sealing agent used is applied in the prescribed quantities. Some products contain a colour pigment so that users are able to judge from the colour of the surface whether the correct quantity is being applied. In practice however, where large surfaces are involved, it can be difficult to ensure uniform and complete coverage without suitable spraying equipment.



Plastic shrinkage may lead to cracks caused by the negative pressure found in the pore liquid when the concrete dries out.

Theory

Cement and water (cement paste) react and create a binder (cement gel) which cement the aggregates in the concrete.

Provided that sufficient water is available the reaction will run until the cement has reacted. For ordinary portland cement "sufficient water" means 40-45% by mass water in proportion to the cement (w/c ratio 0.40-0.45).

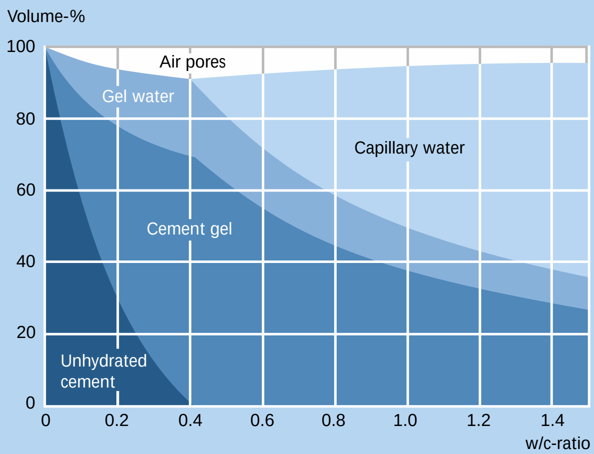
During the reactions part of this water (approx. 26% by mass) is bound chemically in the reaction products (cement gel), and the remaining part (19% by mass) is bound physically on the surfaces of the reaction products as well as in small pores. This water is called gel water. At normal temperatures the gel water will not be available for further reactions.

The ratios will often be as shown graphically in figure 4. At a w/c ratio over 0.40 a water surplus is seen which means that even with full hydration pores filled with water will be found, so-called capillary pores. The water in these pores can evaporate without causing any reduction in quality.

At high w/c-ratios with water surplus a certain water loss during the hardening will thus be possible without changing the final porosity. However, this should not be exploited deliberately, but is to be regarded as an extra safeguard.

At low w/c-ratios (e.g. 0.35) there will not be sufficient water to obtain a 100% hydration of the cement. At this w/c-ratio there are no capillary pores and the porosity which exists only as very thin gel pores is less than with a higher w/c-ratio. The reduced porosity (and the thin pores) explains the importance of the w/c-ratio in respect to strength and density.

Occasionally it is said that it is disadvantageous to produce concrete with a "deficit" of water. However, this is a misunderstanding as the final porosity of the cement paste is the most important while it is of secondary importance that the cement has not hydrated 100%. When you work with very low w/c-ratios you should however be aware that the concrete would be particularly sensitive to water loss, as the concrete does not contain surplus water. Even a modest water loss might therefore cause a significant reduction of the quality compared to the quality, which could have been obtained under favourable hardening conditions.



The volume ratios for hydrated cement paste.

Blotching...

Efflorescence

Most white discoloration on concrete surfaces is ordinary efflorescence – the result of a chemical reaction that leaves behind calcium carbonate. When construction takes place in warm, dry air, drying out will begin, the evaporation zone being transferred to the inner transverse section, i.e. the surface becomes dry and no lime-bearing moisture reaches the surface of the concrete. Conversely, if the ambient air is humid, it is highly probable that the lime solution will diffuse right up to the surface of the concrete, where evaporation can only occur slowly. Both warm and cold air can be humid, but in tempered zones the humid spring and autumn months are the worst where efflorescence is concerned, because in both seasons there are long uninterrupted periods of high humidity.

Other observations also suggest that efflorescence on new facades after longer periods of humidity can be eliminated or diminished if the humid period ends with rain that washes off the efflorescence before drying out and carbonisation take effect.

Sometimes, efflorescence is soft and rubs off. It can be removed dry with a stiff broom, followed by rubbing with a dry cloth and finally flushing with water. This kind of treatment should be performed in mild, good-drying weather.

Efflorescence can be a thin, even film or a thicker layer of salt bloom. It often appears as a powdery layer on concrete surfaces. It need not necessarily be white, but often assumes pastel-like shades. This phenomenon is particularly common to white concrete surfaces.

Calcium carbonates are sparingly soluble in water and are not readily dissolved by driving rain on facades. They often adhere to a surface quite firmly and cannot be completely dislodged by heavy showers, by flushing or by washing off. Calcium carbonate appears when moisture is present and is a chemical compound of calcium hydroxide and atmospheric carbon dioxide. The phenomenon of efflorescence is thus linked with the evaporation or drying conditions in and around the construction.

It should be mentioned that efflorescence on concrete surfaces can occur as the result of unfavourable storage conditions for concrete elements and other concrete items, and unfavourable site conditions. If concrete surfaces are exposed to draught combined with low temperature and high humidity, severe efflorescence will often appear. In connection with coloured concrete, such efflorescence often distorts or diminishes colour. It can therefore be wise to treat the surface of the concrete with a weak solution of hydrochloric acid (the concrete must be at least 24 hours old). Thorough flushing before and after acid flushing is necessary to make sure that acid is not sucked into the concrete.

Coloured concrete with coloured efflorescence.

Efflorescence caused by casting during the cold and rainy time of the year.

– and discoloration

Discoloration of concrete facades

Discoloration in the form of yellowing on white and light surfaces is often a problem. It is difficult to determine the causes of such discoloration; the phenomenon is often complicated. It is also difficult to eliminate this discoloration, irrespective of whether it occurs early or late. There are many conditions that can give rise to yellowing problems, e.g. in production (from concrete constituents), during pouring, from storage and transportation.

Yellow impurities can appear when facade elements are being erected. These can be the result of solutions created by rain and moisture on reinforcement and metal objects stored on floors. Such yellow-brown solutions penetrate element joints and lead to yellowing problems in the form of streaks and spots.

In recent years, yellowing problems have arisen in connection with soluble substances in insulating materials and have resulted in uniform yellowing over the entire facade element. This is because the material has to some extent become slightly moistened while being kept in a damp room or storage space. Certain chemical reactions can be initiated even as early as the pouring stage when impurities penetrate down into the freshly-poured white facings. This applies to all forms of mineral wool insulation and experience shows that although such discoloration does disappear, the process can take from 1 to 3 years.

During the storage of facade elements with insulating materials, unfortunate discoloration can occur at the storage facility or on the building site. If they are stored for longer periods in wet weather, the insulating materials will as a rule absorb much moisture. In time, water soaks through the material across the whole width and height of elements so that it eventually acts as a sponge. When the elements are used and building heating starts to take effect, drying out of the outside walls leads to yellowing of the facade. As just described, the discoloration will disappear.

Yellowing can also occur later on already erected facades. This can usually be attributed to sulphurous and acid combinations that arise in polluted industrial areas. As a rule this kind of discoloration can be removed by high-pressure washing down.

Strong discoloration can be avoided by rainwater being appropriately drained off.

Pore formation

A special phenomenon in casting untreated surfaces is air pores. These are created by air and water which during compaction remain adhered to the surface. The number and size of air pores will depend on the composition of the concrete, not least on its water content, the surface of formwork, the formwork oil used, and compaction. Where wallpaper is to be used, surface air pores of up to 1 mm can often be permitted, but if surfaces are to be painted, the pores must not be larger than 0.5 mm. Where surfaces are to remain untreated, air pores can be unsightly when they are concentrated in spots or streaks.

Experience shows that air pores are often more likely to appear in vertical rather than horizontal surfaces, and that they appear less seldom where the pressure of concrete on formwork is high, i.e. in the lower parts of the form. The concentration of surface pores often seen in the upper parts of a poured layer of concrete can be reduced by the artificial application of overpressure at the conclusion of casting. A particular point of interest here is that air pores can be avoided by, for example, using shuttering with a coarse surface. The indication is thus that the use of smooth formwork contributes to the formation of air pores. Therefore the oil used to "smooth out" formwork is also a contributory factor.

The conditions that promote pore formation are, first and foremost, formwork materials that are too dense and the use of mineral oil without additives. A lean, particularly soft concrete gives significantly more pores than rich, soft concrete.

Example of pore formation from the incorrect choice or pre-treatment of formwork material.

Example of pore formation from pouring and vibration.

Water pores are formed by water concentrations being entrapped between formwork and concrete. When the water disappears, the pore remains in the surface. Water concentrations come mainly from the concrete, but entrapped water from formwork, reinforcement and transportation equipment can also give rise to pore formation. Compared to air pores, water pores are large. It is not uncommon to see water pores up to 5 mm. They are irregular in shape and the bottom of the pore is often covered by a thin layer of cement slurry. Pores are often characterised by the presence, immediately under the pore, of streaks left by water.

Pores can also be created by formwork oil. During vibration, superfluous formwork oil can form into drops that create surface pores in hardened concrete. These usually appear in the lower parts of forms, in that superfluous oil percolates down along the form sides. The pores are uneven, characterised by discoloration in and around them. They are usually 1-3 mm in size.

Pore formation can be caused by different factors. The fineness of the cement and the dispersal of cement paste have an influence on the flow characteristics of the concrete. During compaction, the cement paste acts as a lubricant for aggregates so that they can be packed and fill voids. The water/cement ratio also plays a large role. Concrete with a high w/c ratio will separate if over-vibrated, thus giving rise to a large risk of water pores on the surface against formwork. The use of water reducing and high range water reducing agents will reduce the w/c ratio and give concrete which is more workable. Concrete with a relatively low w/c ratio quite often requires strong compaction to achieve a suitable density. Intense compaction by vibration, etc. increases the risk of pore formation. It is therefore advantageous to use additives that give better flow characteristics which in turn permits a reduction in the use of intense vibration.

The aggregate composition has much influence on pore formation. A well-defined grain curve with a suitable content of filler grain (<1/4 mm) gives concrete good compaction characteristics. Furthermore, it does not leave much space for free water and free air in the concrete, i.e. it reduces the risk of pore formation. The maximum grain size in aggregate and grain shape are also significant. The general rule is that coarse aggregate, i.e. large maximum grain size, increases pore formation, compared to smaller grain size. Coarser aggregate materials with irregular shapes absorb far more air at the surface than natural, rounded, smooth aggregate. Some causes of pore formation on concrete surfaces must also be looked for in the way the concrete is transported, poured and compacted. For example, air can be whipped in during transport and drawn in during pouring; the thickness of poured layers can vary; degrees of compaction from vibration can differ. These factors all to some extent promote pore formation.

Experience shows that the content of filler for smooth-cast surfaces should occupy between 5 and 10% of the grain curve. It is important to keep the screening value within very narrow limits. Filler material should consist of cubic and rounded grains.

Environmental effects

The appearance of a concrete surface will change in the course of time, the main cause being rain and pollution. Because of contaminants in rain, many buildings change in this way after just a few years.

Dirtying

In this context, dirtying is to be understood as the distribution of visible dirt on facades. Particle-formed contaminants are deposited on horizontal or inclined surfaces where they then become distributed by heavy rain. Areas exposed to much rain are in fact cleaned relatively thoroughly. Where rainfall is less, contaminants and weathering agents are transported down over the facade. Here the water evaporates leaving the dirt behind. The direction in which heavy rain is driven gives variation in dirt patterns. Looking at the direction of water flow down a facade it can be seen that the upper third and associated corners become cleaned first. The next third is often cleaned very unevenly.

If the facade is porous, rain will initially be absorbed by the construction.
In the case of a closed smooth structure which is non-absorbent, rainwater flows down the surface very quickly. Here, dirt manifests itself much farther down.

How quickly dirt patterns emerge depends on climatic conditions and the degree of pollution. Because of pollution caused by traffic, etc. the problem is common in larger conurbations. Typically, south and west-facing facades are more badly affected than those that face north and east.

Facade cleaning

In principle, it must be assumed that all cleaning damages a concrete facade. It must therefore not be used until the damage caused by cleaning is less than that caused by dirt deposition on concrete surfaces.

With regular maintenance however, the degree of dirtying can be kept at an absolute minimum so that cleaning can be performed using gentle methods. When dirt is allowed to accumulate its acidity increases, i.e. rain carries the acid. When the water evaporates the acid concentration is increased.

Facades exposed to such conditions over long periods can be so badly affected by dirt that severe corrosion can be seen on their surfaces.

There are many ways of cleaning facades, from the use of pure water, neutral alkalis, acidic cleaning agents, mechanical equipment where dirt is removed carefully using small brushes and scalpels, to more powerful forms such as sand-blasting.

With facade cleaning, cooperation between architect and contractor is essential. Cleaning to give a clean appearance to the building is often not necessary as a means of protection against damage from pollution. Moreover, satisfactory cleaning can often leave the building with darker surfaces where dirt has been allowed to remain for several years. The contractor is therefore obliged to inform the architect or the consulting engineer of the consequential damage that might ensue from washing to achieve a high degree of optical cleanliness. The contractor must of course be familiar with the chemicals to be used and the types of concrete surfaces that require cleaning.

The most gentle form of cleaning is obtained when pure water is used. Effectiveness can be improved by operating with high pressure and coarse brushing (large automatic equipment perhaps). The brushes must not be so coarse that they damage the concrete surface.

The next step in increasing cleaning effectiveness is to add neutral cleaning agents, as used in the home for example. The most important function of these agents is to reduce the surface tension of the water so that it is better able to penetrate surface deposits and dissolve the dirt.

Steam cleaning was once a widespread method, but is becoming increasingly unpopular in Europe because the additives used in the water – soda and phosphates – can damage concrete surfaces. Hydrofluoric acid or cleaning agents based on this substance are often used. Such agents are particularly good.

Another substance often seen is hydrochloric acid. It should be emphasised here that surfaces to be washed with this substance must be made very wet before it is applied so that only the surface comes into contact with the relatively strong acid. The solution recommended is 1:15
(1 part 37% hydrochloric acid to 15 parts water).

On only slightly dirty surfaces, oxalic acid is a possibility. This substance is gentler with lime compounds than many other acids.

Finally, cleaned facades can be given a protective surface treatment, e.g. transparent mat silicone which also allows the facade to breathe, i.e. it allows diffusion.

Dirt on a gable because of shadowing from a neighbouring gable.

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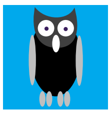

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Refresher courses for architects, consulting engineers, contractors, skilled bricklayers, and students.

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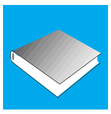
Tests of gravel and other aggregates, suggestions for concrete mix design, trial mix, test of concrete properties.



Research and Development

Aalborg Portland is constantly working with further development of materials and techniques: New types of cement, alternative raw materials, new applications, high strength concrete, test methods, etc.

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