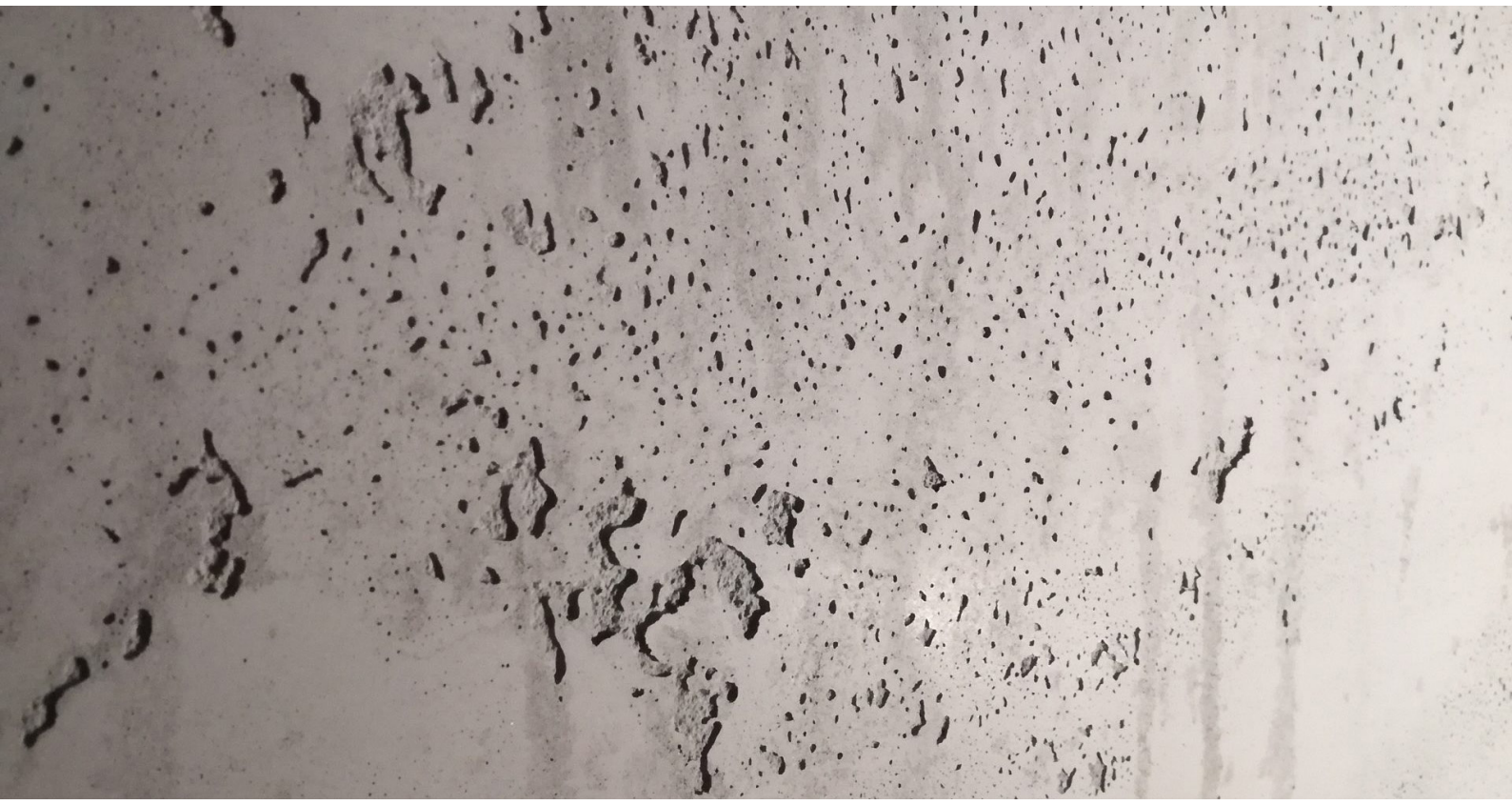
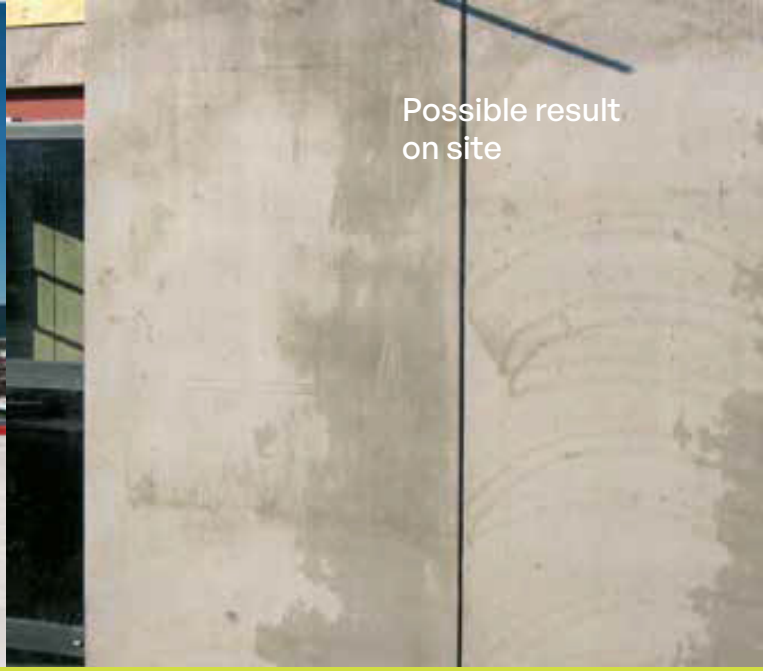
Guide to architectural concrete

Guidance on planning and production



formee

Expectation of the client or designer



Possible result on site

INTRODUCTION

Architectural concrete – beauty and technology in one

Architectural concrete has inspired architects, clients and contractors for years. It is a material that combines an exceptional visual character with durability and structural solidity. Everyone, however, perceives concrete in their own way – some appreciate its aesthetics and noble rawness, others focus on function and technical parameters.

Although more and more buildings in architectural concrete are being completed in Poland, clear, uniform guidelines and standards that would make its design, execution and acceptance easier are still lacking. The result is frequent misunderstandings and diverging expectations of the appearance or quality of the surface.

Imagine a process in which:
it is known how many pores a concrete surface may have and how large they may be,
the permissible colour differences are precisely defined and it is clear from the outset when a reference element is to be produced,
the cost estimate and the schedule leave no room for guesswork.

Setting the requirements out in this way makes it possible to:

- avoid unnecessary disputes and complaints,
- speed up delivery of the project,
- ensure high quality and repeatability of the result,

plan the budget and the technology precisely.

Other countries have extensive regulations and standards – here they are still rarely applied because of the lack of translations and their limited availability. Meanwhile, millions of cubic metres of concrete are produced in Poland every year, a substantial part of it architectural concrete whose quality determines the image of buildings and the satisfaction of clients.

That is why this document has been prepared – to help everyone involved in the construction process to work together on clear rules and high standards. It is a step towards a more professional, predictable and inspiring use of architectural concrete in Polish architecture.

Definitions and basic terms

Architectural concrete
This is concrete that is specifically planned and defined at the design stage with a view to the appearance of the surface. Its aesthetics – texture, colour, uniformity – have a key influence on the visual character of the building.

Architectural concrete means not only surfaces left in their natural form after striking the formwork, but surfaces produced with the appropriate technological discipline – so that

Classes and requirements
for architectural concrete

Architectural concrete is a material specifically designed at the documentation stage. The requirements for its appearance – texture, colour uniformity or porosity – significantly affect the visual character of the building. Architectural concrete can take various forms:

- left in its natural state after striking the formwork,
- coloured throughout,
- mechanically treated (e.g. grinding, bush-hammering, flaming, sandblasting, polishing),
- with exposed aggregate.

Whatever the finish, success depends on maintaining the technological discipline that makes it possible to avoid surface defects – pores, runs or discolouration.

Categories of architectural concrete
The surface quality of architectural concrete is assigned to three categories, depending on the visual requirements and the use:

- **Low requirements (BA1)**

Surfaces where appearance matters less – e.g. basement walls or underground car parks.

- **Medium requirements (BA2)**

Typical visible surfaces – e.g. staircases, common areas.

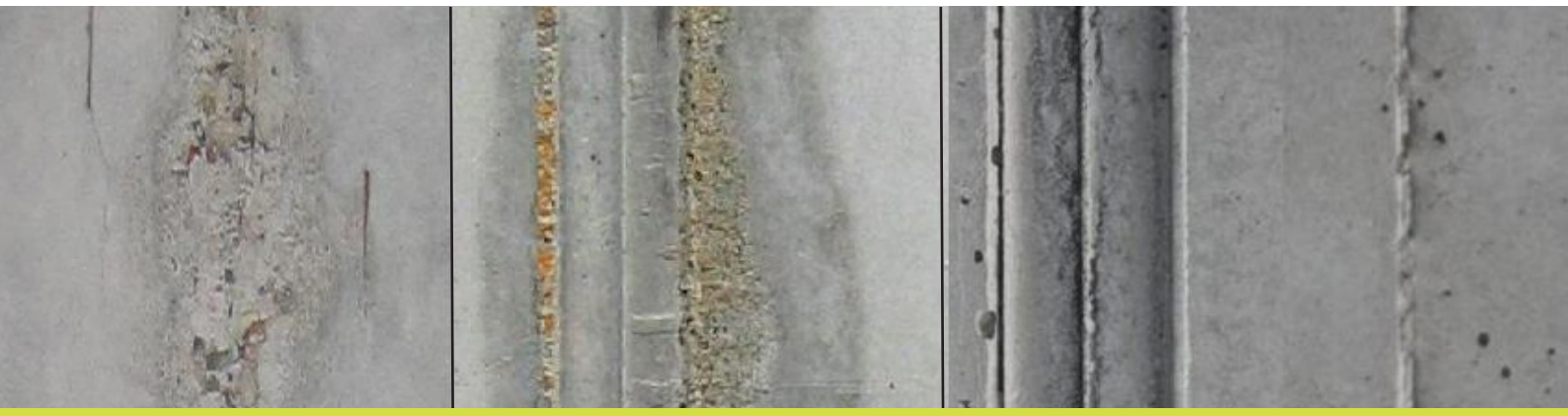
- **High requirements (BA3)**

Representative elements – facades and exposed walls in interiors.

Category	Texture	Porosity	Uniformity of colour	Reference element	Category of formwork	Costs
BA1 – Low requirements	F1	P1	RZ1	Free choice	KD1	Low
BA2 – Medium requirements	F2	P2	RZ2	Recommended	KD2	Medium
BA3 – High requirements	F3	P3	RZ3	Required	KD3	High/very high

Table 1 – Categories of architectural concrete

Detailed guidance for each category is given in Table 1 (above). It should be stressed that these requirements apply to concrete shaped before placing, that is, reproducing the formwork. They do not apply to surfaces shaped while the mix is setting (e.g. floating) or worked after hardening.
A distinction is made between edges chamfered with a triangular fillet and sharp edges. Sharp edges generally have a radius of about 3 mm resulting from the production technology. Elements should be lifted carefully to avoid damaging the edges.
Careful, complete execution of the edges contributes substantially to perfect architectural concrete – and attention must be paid to a suitable consistency of the concrete mix.



Texture category		Description
Texture, joints of formwork elements, Interruptions	F1	• largely uniform concrete surface, • cement paste/mortar at the joints of formwork elements should not exceed: width up to approx. 20 mm and depth up to approx. 10 mm [T1-T3], • imprint of the formwork element frame permitted, • offsets of planes – maximum up to 10 mm
	F2	• largely uniform and closed concrete surface, • cement paste/mortar at the joints of formwork elements should not exceed: width up to approx. 10 mm and depth approx. 5 mm (T1-T3), • imprint of the formwork element frame permitted. • Additional requirements: • ensure the same type of formwork and its preparation, • ensure the cleanliness of the formwork and even application of the release agent, • the method of sealing formwork joints must be established, • the type of spacers must be established, • formwork of the same surface quality is recommended, • preparation of a trial surface is recommended. • offsets of planes at the interruption – maximum up to 10 mm
	F3	• smooth, closed and largely uniform concrete surface, • cement paste/mortar at the joints of formwork elements should not exceed: width up to ok.3 mm [T1-T3], • further requirements regarding e.g. formwork joints or frame imprint must be established in detail. • Additional requirements: • as for F2, • detailed design of the formwork is required (joints, seals, arrangement of panels, etc.), • the formwork must be protected against the effects of weather, • a short interval between erecting the formwork and placing the concrete is recommended, • guidance for forming construction joints must be defined (trapezoidal fillet, connecting joint, etc.), • an execution instruction must be drawn up, • the finished elements must be protected (corner protection, protection against soiling), • offsets of planes at the interruption – maximum up to 5 mm

Table 2 – Requirements for architectural concrete surfaces produced by reproducing the formwork

Offset of plane – horizontal joint.

Offset of plane – vertical joint.

Reveals

The execution of the reveals and the character of their surfaces must be defined in detail (e.g. window rebate, window sill, solar shading).
Note:
Using Zemdrain® liners makes it possible to remove air and considerably reduce the formation of honeycombing,
It must be borne in mind, however, that in a precast plant with daily production such an operation involves considerable effort and should be agreed and remunerated separately.

Joint layout and division

With economical execution in mind, the designer should consider the planned or possible dimensions of the building elements as early as the concept stage.
Installing precast concrete elements creates joints whose deliberate arrangement can be used as a design feature – possibly combined with false joints. The joint width depends on the dimensions of the elements.
on large facade areas, horizontal and vertical joints must be designed.
Depending on the intended visual effect, the wall elements are produced in appropriate dimensions. Butt joints must be allowed for in all buildings, in line with the size of the walls.

Category porosity	Description
P1	maximum pore area approx. 3000 mm^2 **, ***
P2	maximum pore area approx. 2350 mm^2 **, *** [Fig. 8]. Additional requirements: • check the interaction between the type of concrete, the release agent and elements, • the same type and preparation of formwork must be ensured, • the cleanliness of the formwork and even application of the release agent must be ensured, • preparation of a trial surface is recommended.
P3	maximum pore area approx. 1600 mm^2 **, *** [Fig. 9] Additional requirements: • as for P2, • any change in the concrete composition must be excluded, • the use of recycled water and aggregate must be excluded, • the preparation of at least 2 trial surfaces is recommended.

Table 3. Surface porosity
* Area of pores with a diameter Ø in the range 2 mm < Ø < 15 mm.
** Pore area on a standard control area of 500 mm × 500 mm.
*** Where absorbent formwork is used, the maximum pore area should be taken as P1 – up to 3000 mm2, P2 – up to 2000 mm2, P3 – up to 1000 mm2.

Colour differences

For technological reasons, precast concrete elements may show colour differences. There are many causes of this. Many precast plants work in shifts, so the “human” factor with all its influences plays a large part. In addition, the elements spend different lengths of time in curing chambers or on formwork tables. Striking times are always technically different, which can affect the colour of the surface. Ambient temperature, the temperature of the concrete mix and the temperature of the formwork tables also affect the shade. The cooler it is, the greater the risk that the concrete surfaces will be patchy or darker.

Formwork tables that are properly maintained and kept clean are reflected in high-quality surface structures. Even different concrete consistencies have a fundamental influence on the final result. This is why the “human” factor and the “equipment” factor play an equally key role.
Any change – whether to the cement, the aggregate, the additions or the admixtures – can under certain conditions lead to a change in the appearance of the surface. The release agent is of very great importance.
Above all, the way it is applied is decisive for obtaining a uniform, pore-free surface.

Category	Description
RZ1	– a change of shade and a lighter/darker colour are permissible, – rust and dirty runs are not permissible.
RZ2	• uniform, large-area changes of shade towards light/dark are permissible, • rust and dirty runs are not permissible, • different types of formwork face (different plywoods) as well as different finishing materials are not permissible. **Additional requirements:** • as for P3, • the concrete mixing time must be set at not less than 60 seconds, • a greater number of trial surfaces must be provided for.
RZ3	• large-area changes of colour caused by various finishing materials, different types of formwork face and different final treatment of the concrete are not permissible, • slight changes of colour are permissible, • rust, dirty runs, clearly visible individual layers of the placed mix as well as changes of colour are not permissible, • the choice of a special and suitable release agent is required. **Additional requirements:** • as for RZ2, • the change in striking time resulting from different weather conditions must be taken into account, • the reinforcement should be arranged so as to prevent the poker vibrator from touching the formwork and the reinforcement, • points for discharging the mix into the formwork must be provided at equal spacing, • the geometry of the structural elements and the reinforcement layout must allow rapid placing of the concrete, • the w/c ratio must be kept to ± 0.02 or the consistency maintained accurately do + 20 mm.

Table 3. Requirements for architectural concrete surfaces regarding colour

Note! Even with the greatest care and observance of the rules, changes in the shade

of the concrete cannot be
entirely avoided!

Element / feature	KD1	KD2	KD3
Drilled holes	Permitted	Permitted for repair	Not permitted
Holes from nails and screws	Permitted	Permitted without spalling	Permitted as repair points subject to agreement
Damage from the vibrator	Permitted	Not permitted or subject to agreement	Not permissible
Scratches	Permitted	Permitted as repair points	Permitted as repair points subject to agreement
Concrete residues	Permissible in recesses without adhering concrete	Not permitted	Not permitted
Soiling with cement paste	Permitted	Not permitted	Not permitted
Creases, ripplings of the plywood	Permitted	Not permitted or subject to agreement	Not permitted
Local repairs	Permitted	Permitted	Not permitted or subject to agreement
Reference element	Any	Execution recommended	Execution required

Table 5. Formwork categories

* All repairs to the formwork must be carried out by qualified and competent personnel,

and the formwork must be checked before use

Nail imprint of the plywood

To avoid deviations as far as possible, the concrete must be stable. It must neither segregate nor bleed. An appropriate cement and binder content is of great importance for the robustness of the concrete. The consistency of the concrete must under no circumstances be changed by adding extra water. If the amount of water specified in the mix design is not sufficient to achieve the required consistency, the concrete must be produced using suitable admixtures. Robust, stable concrete is the basic condition for successful architectural concrete.

Ordering – the details needed for a good result

At the tender stage, detailed recommendations and good practice are a valuable aid in planning and specifying the requirements for architectural concrete. The guidance they contain helps to avoid typical errors and misunderstandings between the designer and the contractor. The most important information to be taken into account as early as the preparation of the technical specification is set out below:

- Rough and textured architectural concrete surfaces show a far lower tendency to clouding, marbled discolouration and micro-cracking.
- Joints dividing the elements and false joints can act as features shaping the appearance of the surface.
- Chamfering the edges of precast elements is recommended, as it reduces the risk of spalling during transport and installation.
- For surfaces exposed to the weather, the influence of the weather must be taken into account – among other things through controlled drainage of rainwater and the use of water repellent treatment, which prevents the accumulation of dirt and the formation of runs.

In the tender specification, a general requirement for “architectural concrete” is not sufficient. To achieve the expected visual and qualitative result, an unambiguous and practically feasible description of the scope of work must be prepared. It should include, among other things:

Choice of the architectural concrete category, according to the BA1, BA2 or BA3 classification:

- BA1 – low requirements (e.g. basement and underground garage walls),
- BA2 – medium requirements (e.g. staircases, common spaces),

- BA3 – high requirements (facades and representative surfaces).

Definition of the required surface parameters according to the tables:

- texture (F1, F2, F3),
- porosity (P1, P2, P3),
- colour uniformity (RZ1, RZ2, RZ3).

Precise guidance on the formwork – including the formwork category (KD1–KD3), the execution of formwork joints, the arrangement of tie and nail holes, and the permissible surface repairs.

The execution of the unformed surface, if any, and the requirements for the edges (e.g. sharp edges require more work and must be described specifically in the documentation).

The obligation to produce a trial surface and a reference element to be approved before the start of the main production, which will serve as the benchmark at acceptance.

Formwork

Formwork is the basic element of precast technology and shapes the appearance of the architectural concrete surface directly and decisively. The quality of the formwork, its preparation and the way it is used are of key importance for achieving the expected aesthetic and technical results.

Type of formwork and surface structure

Precast concrete elements are most often produced in the following formwork:

- steel – smooth and non-absorbent, giving uniform, closed surfaces with a distinct imprint of the mould,
- timber – giving a more natural grain and a subtle texture,
- matrix – making it possible to reproduce structural patterns (e.g. grooves, stripes, geometric motifs).

The type of formwork directly determines the texture of the element surface and is one of the most important factors identifying the visual character of the concrete.

Condition and preparation of the formwork

The formwork face must be perfectly clean, free of concrete residues and damage. Even slight contamination, scratches or traces of earlier work can cause discolouration, streaks and unwanted imprints.

Before placing the concrete it is necessary to:

- check the condition of all formwork panels,
- verify the tightness of the connections,
- apply a suitable release agent in a uniform layer,
- protect the surface against excessive heating or cooling.

Influence of the formwork on colour and texture

Smooth steel formwork gives a very even surface but can at the same time reveal the finest differences in colour. Even under identical production conditions, concrete surfaces in smooth formwork may show:

- slight variation in shade,
- marbled discolouration,
- differences arising from the setting and hardening of the concrete.

With matrix formwork the surface texture dominates visually over the shade, which makes colour differences less noticeable.

Formwork imprint and formwork joints

The quality of the formwork connections has a significant influence on the imprint of the divisions, joint lines and any offsets of planes:

- the width and depth of the technological joints must be limited in accordance with the architectural concrete category (e.g. to 3 mm in the high class BA3),
- all gaps should be carefully sealed to prevent cement paste from leaking out,
- the surfaces of matrices and connections should be designed so as to achieve an aesthetic result consistent with the intended architectural concept.

Fig. 3.2 “Living” concrete caused by segregation of the mix

Colour uniformity

Concrete with a smooth surface from the mould, with all its irregularities, is not comparable with a painted surface – it is “living” concrete. Greater colour uniformity of the surface can be achieved through light, textured or treated surfaces (e.g. light washing, acid etching, grinding, etc.).

Formed and unformed surfaces

The formed surface (in contact with the formwork) shows greater uniformity and repeatability of texture than the unformed surface (the side where the mix is poured in).

For high-quality architectural elements, the key factors are:

- the type of formwork,
- the way the mix is compacted,
- the striking time.

Maintenance and use of formwork

Repeated use of formwork requires systematic maintenance:

- cleaning of the working surfaces,
- removal of rust and contamination,
- checking the tightness and technical condition of the connections.

A lack of proper care of the formwork results in a drop in surface quality and visible defects whose repair is often not possible without impairing the visual result.

Release agent

Release agents serve the following purposes:

- optimum separation of the formwork from the concrete,
- faultless reproduction of the formwork surface,
- care and protection of the formwork material,
- prevention of stains and marbled discolouration,
- avoidance of dusting (loss of grains) and lime efflorescence,
- easier release of air bubbles,
- no adverse effect on the adhesion of paint coatings, plasters, adhesives, etc.

Applying the release agent

When choosing a release agent, attention must be paid to the interaction between formwork and concrete. The recommendations of the formwork manufacturers are very helpful here.
There are various types of release agent: solvent-based and solvent-free (both based on mineral oil), as well as oil-in-water emulsions.
Experience shows that the best results in architectural concrete are obtained when as little release agent as possible is applied and the excess is drawn off with a rubber squeegee or – better still – wiped off with a cloth.
If the release agent is applied with a nozzle (Fig. 4.1), the nozzle must atomise it finely to ensure even coverage. Correctly set pressure and suitable nozzles are of key importance.
Surfaces covered too generously with release agent may show distinct discolouration in brownish-yellow shades (Fig. 4.6) as well as pronounced pores or surface dusting. Excess release agent remains clearly visible on the concrete surface.
Correct application of the agent and wiping the surface with a cloth produce a concrete surface with few pores.

Fig. 4.1. Applying the release agent

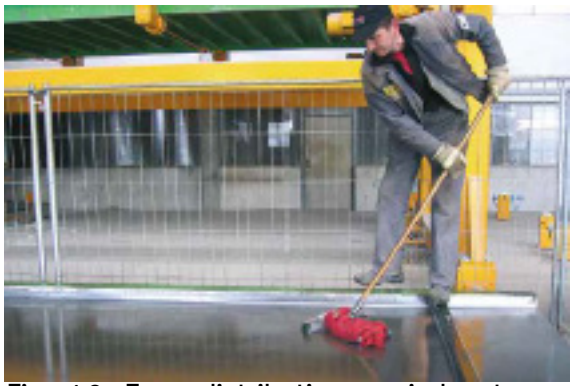


Fig. 4.2. Even distribution carried out with a cloth

Fig. 4.3
Note, footprints remain visible

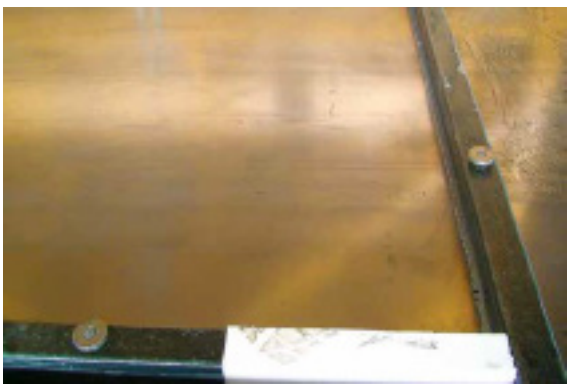


Fig. 4.4
Surface correctly covered with the agent

Flash-off time

The current market offer provides the user with a range of different release agents.
Besides the classic formwork oils, which are ready for use immediately after application to the formwork surface and require no flash-off time, there are many products whose release properties develop only after a certain time.
This group includes all solvent-based products and emulsions whose release effectiveness stabilises only after the solvent has evaporated.
The appropriate flash-off times are usually given in the manufacturer's technical data sheets or on the packaging and must be strictly observed.
At low temperatures, high air humidity and excessive application they may be considerably longer.
In every case the condition of the release film must be checked before concreting.
Since precast elements are mostly produced on steel tables, not only the release effectiveness matters but also the corrosion protection of the formwork.
If the release agent is chosen incorrectly, corrosion may occur, especially in places where the concrete
– as a result of drying – begins to detach from the formwork surface.
Condensation forms at these points, which can lead to corrosion.
This process can be further intensified by the temperature in the curing chamber.
The formation of rust usually depends on many factors.
Proper matching of release agent, concrete and steel table is of key importance.

A release agent with strong anti-corrosion properties may in turn cause deposits on the steel table, which can lead to the concrete surface tearing off.

It is advisable to carry out trials with different release agents.

Ultimately, precise matching of the release agent to the formwork table, the concrete mix and the ambient conditions is necessary.

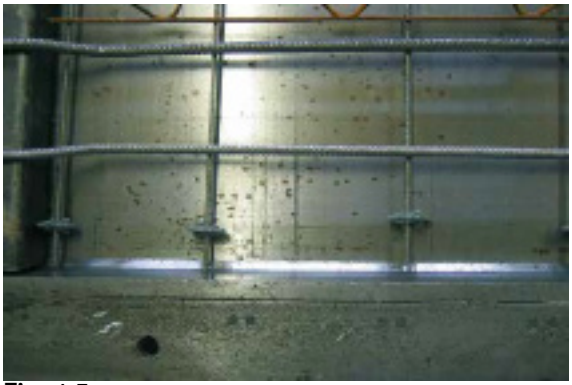


Fig. 4.5
Rust on steel tables

Fig. 4.6
Discolouration caused by overdosing the release agent

Fig. 4.7
Tearing off at the concrete surface

Production and curing time

Production process

Many precast manufacturers work on so-called circulation lines. Such usually fully automated production lines generally ensure that the process always follows the same course. The steel table is cleaned and robots apply the position markings for the formwork and cast-in components, after which the formwork is set. The release agent is then applied – by machine or by hand. The next stage is placing the reinforcement and the concrete. The concrete is compacted with external vibrators or by vibration and shock technology. A combination of these methods is also possible. Production carried out by different crews placing the concrete mix can affect the quality of the concrete and the concrete surface.

Curing time

Storage of the elements during hardening (store, curing chamber, etc.) lasts different lengths of time – depending on whether the plant works one, two or three shifts. If walls are produced in the morning, they are usually struck in the afternoon. Elements concreted in the afternoon have a longer curing time. Consequently, different curing times may cause colour differences on the concrete surface. Often a different concrete mix design, which gains early strength more quickly, is used for production with a shorter curing time. This entails different cement contents and different water-cement ratios, which affects the colour of the concrete.

Influence of temperature differences

Air temperature also affects the shade of the surface. If an element is produced in summer, its colour is usually lighter and more uniform than with winter production. The influence of the steel tables on the colour of the concrete, the marbling and the effectiveness of the release agent is highly temperature-dependent. The action of release agents is also sensitive to temperature.

Fig. 5.1
Circulation line

Influence of temperature – summary:

- At different temperatures the steel table leaves different visual effects on the concrete surface
- The setting of the concrete proceeds differently depending on the temperature
- Release agents react in a temperature-dependent way
- At low temperatures the reinforcement placed in the concrete is distinctly visible on the surface
- With cold aggregate, coarser grains may show dark on the concrete surface
- At low temperatures the curing time of the concrete becomes longer
- The action of admixtures (FM/BV) differs depending on the

Fig. 5.2
Coarse aggregate imprints itself on the surface

Fig. 5.3
Imprinting of the reinforcement

Fig. 5.4
Unprotected storage: water marks

Imprinting of the reinforcement

The possible causes of this phenomenon are:

- excessive temperature differences between the concrete and the reinforcement
- excessively intensive compaction of the concrete mix
- soiling of the surface due to a longer curing time Such visual effects generally do not result from insufficient concrete cover.

Fig. 5.5
Protected storage in a hall

Storage

After drying in the curing chamber, precast concrete elements are often stored directly in the open air. Under such conditions there is a risk of significant cracks caused by excessive temperature differences and by drying of the elements. In addition, precipitation may cause efflorescence on fresh concrete.
It is therefore recommended that concrete elements be protected against drying, cooling and moisture.

Fig. 5.6
Colour differences caused by

Loading

Precast concrete elements should be loaded and transported only after sufficient strength has been reached.
In some cases the elements are loaded and transported immediately after striking. If their strength is not yet sufficiently high, this may lead to cracking.

Concrete “cosmetics”

During transport, installation on site or setting in place, the elements may be partially damaged. Such damage is usually repaired on site by a concrete cosmetics specialist. The repaired areas remain visible, especially on elements of coloured concrete. Colour differences between the original concrete surface and the repaired areas cannot be avoided.

Varied possibilities of surface design

Matrices
With structural matrices placed in the formwork, almost any surface texture and/or division of the surface can be achieved. This produces concrete surfaces with a uniform appearance and relatively few pores. Marbling and clouding are practically eliminated. In addition, the surface texture, through the play of light and shadow, gives the whole visible surface greater optical uniformity. When planning, the dimensions of the precast elements must be matched to the available matrix sizes. If necessary, the joints where the matrices meet must be designed in consultation with the manufacturer. The design options range from surfaces imitating rough board formwork to images created by the shading effect of the surface.

Surface treatment
Once the element has hardened and can be struck, there are various methods of secondary shaping of the concrete surface.
The required concrete cover must, however, be strictly maintained.

Fine washing
The top layer of cement paste is removed to a depth of 1–2 mm, which gives the surface a sandstone-like structure. Depending on the depth of removal, both the cement paste and the aggregate affect the colour.

Coarse washing
The coarse aggregate grains are exposed almost to half their depth (more than 2 mm). The result is a very rough, coarse-grained surface known as washed concrete. The dominant colour is given by the aggregate. This surface is produced by applying a retarder paste to the fresh concrete and removing the retarded layer with a water jet.

The dominant colour is given by the aggregate.
This surface is produced by applying a retarder paste to the fresh concrete and removing the retarded layer with a water jet.

Acid etching
Removing the top layer of cement paste with acid slightly exposes the aggregate grains. Depending on the depth of etching, the surface appears moderately rough.

High-pressure water jet
Treating the surface of hardened concrete with a water jet proceeds similarly to fine washing but without a retarder paste. Depending on

Matrix concrete

the intensity of the water jet, surfaces of varying roughness are produced.

Sandblasting
Sandblasting gives an effect similar to fine washing. In addition, the aggregate grains are matted and lose their gloss. The surface becomes matt and rough. The depth of treatment can be adjusted to the requirements.

Flame treatment
Under a flame of about 3000 °C the top layer of cement paste melts and the aggregate grains crack and spall off. The result is a very rough and strongly articulated concrete surface.

Grinding and polishing
If the surface is only lightly ground and the aggregate grains are barely visible, the colour of the cement remains dominant. When grinding goes deeper, so that the aggregate grains become clearly visible, the aggregate gives the dominant colour. In both cases the surface becomes very smooth and glossy. Additional polishing increases the gloss of the surface still further.

Washed surface

Sandblasted surface

Acid-etched surface

Concrete coloured throughout

Coloured
concrete surfaces

Besides surface treatment, colour can also be a feature shaping the appearance of concrete. Very light concrete is usually produced with white cement which, with pigments added in accordance with DIN EN 12878, allows practically any colour to be obtained. The colouring can be further reinforced by using coloured aggregate. Concretes made with grey cement can also be coloured, but the effect is less expressive and less saturated. Darker shades are more easily obtained precisely with grey cement. The intensity of the colour depends on the dosage and quality of the pigment. Pigments can be added in powder or liquid form.

Production guidance:

- When using white cement, the cement silo, the mixer and all equipment used to prepare and transport the concrete must be thoroughly cleaned before production starts.
- Pay attention to the curing time – all elements should remain on the formwork table (or in the curing chamber) for the same length of time.

- Concrete in dry and warm weather where possible – the risk of efflorescence and discolouration is then considerably lower.
- Ensure that surface water evaporates and, if necessary, apply a water repellent treatment.
- Coloured surfaces are best protected with a glaze.
- Protect the elements against precipitation.
- Produce trial surfaces in order to assess the colour and the overall visual result.
- Keep the raw materials constant as possible and ensure uniformity during production and treatment.

Even with the greatest care on the part of the manufacturer and the contractor, variations in shade or white efflorescence may occur.

Water repellent treatment

For grey, coloured and especially dark concretes exposed to the weather, water repellent treatment is recommended in order to reduce the tendency to efflorescence.

Surface protection

A pigmented glaze can be used to make the appearance of concrete surfaces more uniform. A glaze makes practically any colour possible, and the whole concrete surface takes on a uniform shade. This technique also allows repair areas to be covered simply and attractively in the same colour. The structure of the concrete remains visible, the surface acquires no gloss, and the walls retain the character of the material while becoming more uniform in colour. Figures 6.17 to 6.20 show examples of the use of pigmented glazes. The coating can be applied either in the plant or later on site.

The glaze additionally protects the elements against water, oil- and grease-based soiling and against graffiti. Various manufacturers offer suitable products and application technologies.

Protection and prevention

Special measures carried out in the factory on precast concrete elements include surface treatments intended to protect them and preserve their quality against external influences (e.g. weather or graffiti).

In principle, protective coatings can be applied at any point during service, but for architectural concrete intended for outdoor use it is recommended that the protection be applied in the factory – before delivery and installation of the elements.

Types of protective treatment:

Water repellent treatment

This is a treatment in which the concrete surface is worked with a liquid, water-resistant silane-based agent.
It does not form a coating but penetrates the near-surface pore system of the concrete. As a result, the capillary rise of water is inhibited and the transport of moisture and harmful substances into the concrete, as well as the migration of dissolved minerals (e.g. free lime) to the surface, is limited.
Water repellent treatment is easy to apply and its effect can last up to 10 years.

Glazes

They penetrate the near-surface structure of the concrete in a similar way to water repellent treatment but do not form a closed lacquer layer. They are usually invisible. Experience to date shows that glazes are more labour-intensive to apply but considerably more durable and more effective in protecting the surface against external factors.
Efflorescence, weather-related loss of material and the growth of micro-organisms (algae, lichens, mosses) are largely limited. For architectural concrete, especially coloured and treated surfaces, the glaze is now the technical standard of surface protection. Coloured glazes are best applied after the elements have been installed on site, which makes it possible to cover the repair areas at the same time.

Anti-graffiti systems

These are partial or full-surface coatings which, after graffiti has been applied, can be removed with steam or a high-pressure water jet. After the protective coating has been removed, most systems require it to be applied again. These coatings are more or less visible – they may look “greasy” or matt-glossy and change the shade of the surface. Because of the cost and the visual effect, they are used mainly on surfaces particularly exposed to graffiti.

Transport
installation

General

The transport of precast concrete elements from the plant to the site and their installation in their final position in the building are obligatory organisational processes in construction with precast elements. All the works, activities and stages of this process, as well as the successive “stopping points” of the concrete element up to the moment of installation, must therefore be analysed and planned with particular care in the case of precast elements with high architectural requirements. Every storage and handling operation carries a risk of damage or soiling.

Before production of the elements begins, the following must be established:

- how the elements are to be cured in the plant and stored thereafter until dispatch,
- how high-quality architectural surfaces are to be protected during loading, transport, unloading and installation on site.

If temporary storage of the precast elements is envisaged on site, the same matters must be taken into account and organised as apply to storage at the production plant.

To protect quality, it is worth discussing the handling of the precast elements at every stage in advance with all the project participants.

Transport

What matters is not only the way of storing at the production plant, but also storage during transport to the site.
If the elements are stacked, the timber or plastic separating strips used to keep them apart may show on the surface.
Solar radiation or rain may cause colour differences on the concrete surface around window openings and recesses.
For example, the outline of a window opening may show as a lighter mark on the element lying below.

Installation

Precast walls are usually set in place with a crane. The lifting sockets provided for raising the elements remain partly visible. If the elements are handled improperly, damage, spalling and cracking may occur.
The risk of damage is particularly high when setting the elements in place, and dirty hand and shoe marks leave permanent traces. No objects may be leaned against the wall and no markings for the following trades may be made on the concrete surface. Architectural concrete walls should be marked with information signs. It is generally recommended that concrete walls be protected against soiling – e.g. in the factory by water repellent treatment or by covering with film.

Repairs
to concrete on site

General
For cosmetic treatment of architectural concrete surfaces that deviate from the requirements, show defects or have been damaged, two types of measure are currently distinguished:

- Cosmetic repairs carried out by the precast manufacturer or the contractor. Work of this kind is usually sufficient to remedy technical damage to structural elements or small, limited aesthetic deviations. Such repair crews, however, often quickly reach the limits of their capabilities.

- Cosmetic treatment of architectural concrete surfaces by specialist firms. Today, very high-quality cosmetic corrections are provided mostly by well-qualified conservators and easel painters who deliver such services thanks to considerable artistic skill.

Only a few years ago many kinds of deviation in architectural concrete surfaces were regarded, from the point of view of contractual requirements, as “unrepairable”. With the emergence of firms offering an entirely new quality of concrete cosmetics, there is now only a small group of defects or faults that cannot be corrected.

Although a qualified surface repair carried out by a specialist firm considerably extends the possibilities of improving the appearance of architectural concrete, it can also be costly and should therefore be limited to the smallest possible areas.

Repair areas
During installation of precast elements with a crane, damage to the elements frequently occurs. This may result from improper handling or from accidental events on site. Such damage is then repaired more or less professionally. Filler is usually used for this purpose. Its colour is most often not identical to the colour of the concrete, so the repair area usually remains visible. In many cases the damage is more conspicuous after repair than it would have been if left alone. The moisture absorption capacity and the ageing process of such repaired areas are also usually different from those of the original concrete.

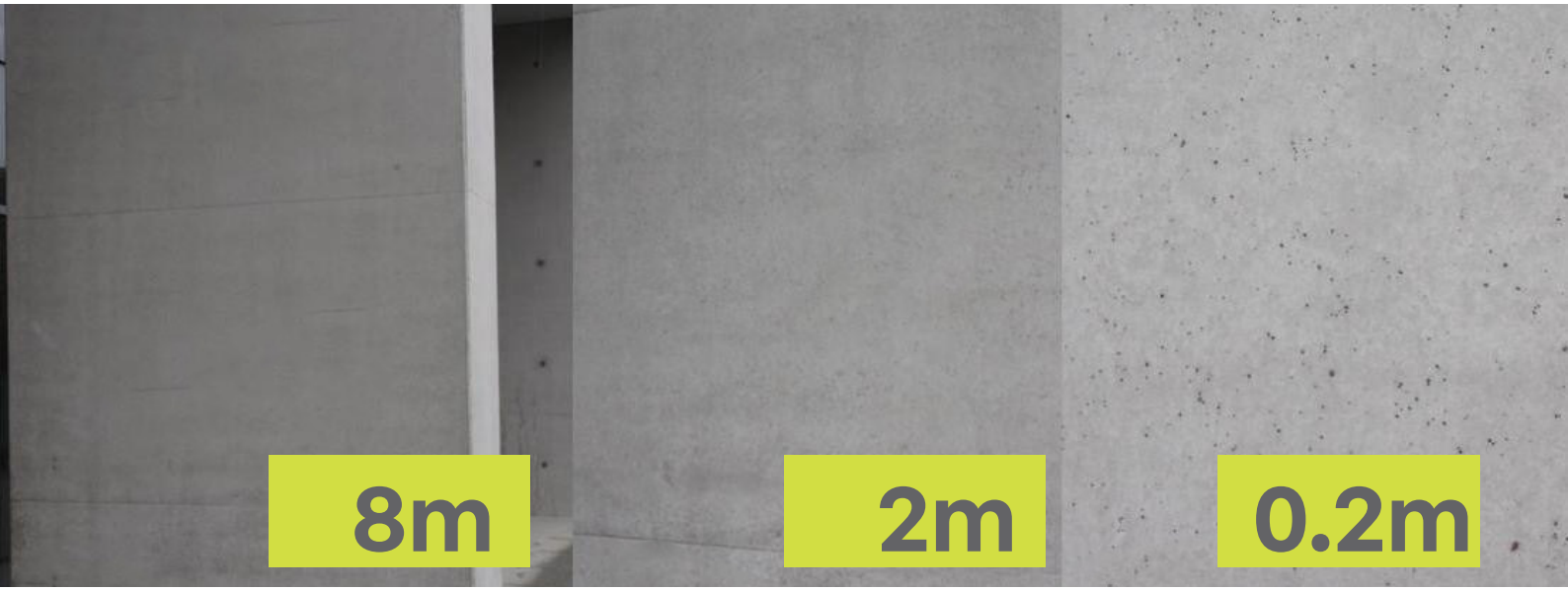
Trial surfaces
In order to check the colour and quality of the filling, a trial surface must be produced before repairing the element itself. Such a trial surface also serves as a reference surface for the client – on its basis the client can decide whether to accept this method of repair. It also makes it possible to assess the quality of the repair work in advance. In every case it is recommended that repairs be carried out professionally, carefully and cleanly, because at the acceptance of architectural concrete surfaces it is precisely such repair areas that are often decisive for the final assessment.

Acceptance of the surface
for architectural concrete

Viewing distance

It is extremely important to assess architectural concrete from the agreed viewing distance.

A very frequent error during acceptance of surfaces is that the observer stands at a **short distance** from the structure being assessed



Different distances for viewing and assessing concrete.

Every structural element should be assessed from the distance envisaged as standard for the later user. Elements inside buildings will be assessed from a different distance than facades. The correct distance is one that allows the whole building, or its significant parts, to be taken in visually. In the case of a building, the correct distance is one from which the building can be seen as a whole. In the case of a building wall, the distance should allow the whole wall to be viewed.

The lighting conditions are of key importance. Acceptance should be carried out during the day but without direct sunlight. Evening light, casting sharp shadows, makes imperfections more clearly visible. On damp, rainy days too the facade surface gives a different visual impression.

General principles of acceptance

During the assessment it must be remembered that each element was produced in different weather conditions and that there may have been differences in the quality of the materials used (within the permissible range provided for). Slight differences in texture, porosity or colour are permissible in each of the described categories of architectural concrete. There is therefore a need for individual assessment of every structural element

Order of assessment

The general impression from the agreed viewing distance should be assessed first, relating the result to the appearance of the reference element. Only when the overall image fails to meet the requirements should the individual parameters be assessed.

The following principles are defined for the acceptance of the surface:
- The general impression is more important than any single criterion.
- An appropriate viewing distance and typical lighting conditions must be used.
- For a building: the distance that allows the whole structure to be taken in visually in its significant parts.
- For elements: the distance normally taken by an observer, or the functional distance arising from normal use of the building.

Architectural concrete surfaces – requirements at acceptance

In assessing the surface, the general impression seen from the typical viewing distance is decisive. Individual criteria are assessed only when the overall appearance of the surface does not meet the agreed requirements.

Permissible deviations in the appearance of the surface:
- slight differences in structure on treated concrete surfaces,
- clouding, marbling and slight colour differences,
- clusters of pores,
- visible spacers and reinforcement,
- dark streaks and slight efflorescence at the joints of formwork elements,
- a small number and area of runs from water flowing down,
- individual lime streaks and efflorescence,
- edge damage where sharp edges are formed,
- slight deformation of the surface.

Requirements that are technically impossible to achieve or cannot be ensured in a fully controlled way:
- a uniform shade of colour on all visible surfaces of the building,
- surfaces completely free of pores,
- a homogeneous pore structure (uniform size and distribution of pores),
- a surface without micro-cracks.

Assessment criteria

The assessment of architectural concrete surfaces should be based on objective and, as far as possible, measurable criteria, taking into account the appropriate viewing distance resulting from the dimensions of the building. Properly executed repair work is permissible.

Unformed architectural concrete surfaces

Surfaces worked by hand show visible traces of the working technique and may be characterised by clouding and colour differences.

Assessment of cracks

Reinforced concrete is a form of construction in which cracking is a property of the material and cannot be entirely avoided. An aesthetic assessment of cracks is possible only where specific requirements in this respect have been formulated in the construction or supply contract. Otherwise cracks are assessed in accordance with the general technical criteria for reinforced concrete structures.

Cracks with a mean width of the following are regarded as harmless:
- 0.3 mm in external elements,
- 0.4 mm in internal elements.

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