PERI®

Reference Booklet

Fair-face Concrete

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Contents

Concrete for more quality in life

Only drinking water is even more in demand worldwide than concrete. More than five million cubic metres are used every year. The wish of human beings to daily extend and improve their living space will also increase in the future. This most-used building material is no invention of the 20th century, but it certainly determines the picture of our times; an artificial stone that is created from the binding medium of cement, aggregates such as gravel and sand as well as water through hardening.

Concrete has advanced to a central metaphorical expression in the past century and for many it is the "fifth element" of the 21st century just beginning.

The world is grey. Concrete is grey. But grey is not the same as grey. Grey has intermediate shades. A wall of concrete appears to be inconspicuous at first: naked and cold. When the observer comes nearer he sees the structure, design, shapes. No area is the same as the next. The appearance of the fair-face concrete catches him.

Let us look exactly around us, concrete everywhere. Almost every building, every bridge, almost every new building cannot exist without concrete. And what we see is only a fraction of what is really achieved with this building material. Most of it cannot be seen because it is buried, plastered or cladded and cannot be seen directly.

Concrete is natural because it is manufactured from natural raw materials. Concrete is an ecological building material whose main components are obtained from the surrounding region. Long transport routes with high energy use are therefore excluded. Concrete can be manufactured in a process that requires no high energy use and concrete can be recycled.

For the architects and designers concrete is a material that has no definite shape and, with its cheap raw materials, is extremely economical. When fresh it can be shaped and its mechanical (solidity), chemical (constancy) and physical (heat insulation) properties adjusted to requirements.

The unlimited ability to shape concrete is the challenge for architects and designers, for artists and engineers. Any shape of formwork is possible and thus any shape of building can be achieved. "Mix, pour, vibrate until finishing time – and the next day there is nothing more which can be done", is an old saying of foremen. That is an inestimable advantage but also a great danger. We can concrete over our living space. The result is often lack of shape if not lack of taste. Lifeless concrete silos in the suburbs of various large cities are a witness to the negative possibilities. "The ideal building artistry", said Karl Friedrich Schinkel 1834, "is only then completely achieved when a building completely corresponds with its purpose in all its parts and in spiritual and physical regard as a whole."

Increasing our quality of life with concrete is the obligation and the responsibility of everyone involved in building. All over the world we find examples of successful architecture, of interesting construction details and of harmonizing concrete surfaces that integrate into our environment. Concrete surfaces remaining visible will accompany us on our way in the future. Design, shape and process the concrete material so that it meets our aesthetic feelings, does not destroy the environment and outlives the life of our buildings.

Fair-face concrete is in demand as a styling medium and shaping form for modern architecture and is used on many buildings. Unfortunately there are very often misunderstandings and unsatisfactory results in the execution of fair-face concrete building components. This Reference Booklet "Fair-face concrete formwork" was compiled from the experience we, as formwork suppliers, have collected on many building objects with fair-face concrete.

1. Introduction

Fair-face concrete – for a long time an irritating word, not only for architects – is gaining more importance. Concrete surfaces remaining visible as a means of styling and shaping modern architecture are in demand again today. Architects have rediscovered concrete and like to design with this building material that can be shaped as wished. The following questions have to be clarified with this:

- What quality features does the fair-face concrete have to exhibit?
- What requirements are to be given in the tender documents?
- What requirements are to be stipulated for the formwork for designing the concrete surfaces?
- What is needed for the manufacture and the placing of the concrete?

Under the collective term of "Fair-face" is a designed concrete surface to be understood. Certain architectural demands regarding the appearance of the elevations are made on these concrete surfaces. There are the following design possibilities available for this:

- Structured surfaces through formwork impressions;
- Painting and coloured additives in the concrete;
- Surface treatment at a later date.

Designed concrete surfaces can be found in almost the whole range of construction, such as superstructures, piers and abutments of bridges, noise-protection walls in road construction, columns remaining visible, walls, slabs or stairway components or façade units in high-rise buildings. Despite many constructional differences these areas of application have something in common: no binding German regulations in which special requirements are determined for the quality of fair-face concrete. A clear-cut, implementable description of the fair-face concrete surfaces is therefore of special importance to avoid misunderstandings and disputes after the fair-face concrete surfaces are finished.

Aim of the Reference Booklet for fair-face concrete formwork:

A professionally founded description that takes into account what can be safely achieved under the given circumstances is the condition for realizing the required concrete surface. It provides the contractor safety in estimating, planning and execution. Exaggerated and impossible demands should therefore already be avoided in the tender documents. They increase the expenses for materials and working time, the risk in execution and thus also the costs. The rise in costs can be considerable and the result often cannot be guaranteed with certainty.

With this Reference Booklet we want to:

show the architects and those preparing tender documents
the possibilities and limits in the design of fair-face concrete surfaces. The efficiency of the formwork (formwork system and lining materials) regarding the influence on the fair-face concrete surfaces thereby stands in the forefront. The aim is to support a definite and practically executable description of the fair-face concrete ideas. Exaggerated, unrealizable and extraordinary demands on concrete construction and areas means and requires:

- Expensive formwork units specially designed to size,
- Low number of uses, i.e. high depreciation,
- High number of hours and long construction time on site,
- Qualified personnel for the execution,
- High costs altogether.

give the **contractor** support in evaluating the tender documents, working out the estimate, the selection of the necessary formwork (formwork system and lining) as well as other conditions and provisions. At the same time he should be put in the position of recognizing necessities and problems in the execution and to professionally register any demands in the tender documents that cannot be guaranteed or are wrong. He can therefore keep his estimating risk within limits.

We hope that with this booklet the disputes that often occur about fair-face concrete can be considerable reduced and the necessary awareness for what can be executed is awoken. Fair-face concrete can be designed in so many ways that this booklet only represents a selection of subjects and contents.

The regulations and documentation given are only to be bindingly and appropriately observed in the original and with the complete contents.

2 Basic conditions for the planning and execution of fair-face concrete buildings

2.1 The fair-face concrete team

The problems in the construction of buildings with designed concrete surfaces are very often a lack of coordination and agreement between the various tasks of those involved in the construction process. Construction practice has shown that the division of building tasks is also customary in erecting fair-face buildings. But coordinated team-work is especially necessary for the success of fair-face building work, as shown in Fig. 1.

Fair-face concrete team			
Design/ Supervision	**Construction**		
Client Architect Engineering Office	Contractor Concreting Engineer	Suppliers: - formwork - reinforcement - ready-mix concrete - pre-fabricated concrete	Execution: - Formw. erector - Reinforcement fixer - Concrete placer - erector

Fig. 1: The fair-face concrete team as a condition for the success of the construction work.

- The **Client** expresses his wishes and provides the financial framework.
- The **Architect** prepares the design for the building according to these wishes and thus determines the quality of the architecture.
- The **Engineer supplies** the appropriate, executable, load-bearing construction.
- The Contractor has the task of constructing the building wished by the client according to the design, the construction and with the concrete supplied.
- The **Formwork supplier** has to select and deliver the formwork according to the required concrete surfaces.
- The **Ready-mixed concrete** plant delivers the concrete with the given building material properties.

The formwork planner and the concrete engineer have a key position in the fair-face team for executing successful building work. It is thereby unimportant where their working area lies (ready-mix concrete plant, formwork manufacturer, contractor or freelance).

- The **Formwork planner** has to select the formwork system according to the ideas of the architect, and possibly with him together, regarding arrangement and type of joints, tie spacing, accuracy (deflection, returns) and the formlining with regard to the surface structure.
- The **Concrete engineer** has, because of his training, extended and deepened knowledge of the design, manufacture, placing and testing of concrete. In addition he has practical experience that he has to introduce into the circle of the fair-face team. He therefore has the task of coordinating the fair-face team. The concrete engineer has to ensure that the materials for the concrete are right and that these can be technically implemented. His task is to control and accompany all planning and execution phases. These include:

- recognizing missing information in the specification;
- discovering faults in the design;
- selecting a concrete suitable for the fair-face components;
- checking that the reinforcement can be concreted;
- ensuring a careful placing of the concrete;
- providing adequate and suitable protection for the concrete until it has sufficiently hardened.

2.2 Checking the specification

The specification forms the basis for assessing the fair-face concrete surfaces at acceptance. This means that all important influences that could affect the appearance of the concrete must be exactly described in the specification. All of the requirements that have to be shown in a specification for fair-face concrete are summarized in Fig. 2. The concrete engineer has to check whether the specification description is adequate and whether all of the points named in Fig. 2 are included to ensure that the appearance selected is achieved.

The specification should, among others, describe the type of formlining and contain a detailed illustration of all design ideas of the client in a sample formwork drawing. The construction of sample areas with a minimum size appropriate to the scale and a fixed observation distance are much more sensible for this purpose than any text description.

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Fair-face concrete – Tender documents Information in the specification or B of Q's + Extra

Surface structure
- Type of formlining
- Surface of the formlining
- Surfaces with no formwork
- Subsequent treatment

Grouping the surfaces
Sample formwork drawing with:
- Formwork units: size, structure
- Joints: type, arrangement
- Abutments: formation, sealing
- Edges: profile, width, course
- Tie holes: type, position, type of plugging

Colours
- Special cement
- Special aggregates
- Pigments
- Paints
- Repairing mortar

Assessability
- Sample areas (minimum size to scale)
- Comparable building where possible
- Usual observation distance
- Uniformity of colour
- Pores
- Nibs, joint strips

Fig. 2: Necessary information in the specification for the appearance of a fair-face concrete surface

If the specification provides no information of any kind on adequately assessing the acceptance of fair-face concrete components carried out, appropriate agreements are to be made before the work is executed. As there are still no standards for this in Germany it is recommended to agree a classification according to the Ecological Standard B 2211.

The problems of assessability are made clear on two surfaces with different pores in photographs 3 and 4.

Fig. 3: Pore formation in a fair-face concrete surface.

Fig. 4: Pore formation in a fair-face concrete surface.

When observing both photographs there is the question, for example: are these detailed photographs successful or unsuccessful examples of pores? From what distance should/must surfaces be observed? Without appropriately determining this previously in the specification there will inevitably be a discussion started on the construction site that very often ends up in court.

Through agreeing colour and structure classes as well as information on the pores according to Ecological Standard B 2211, combined with sample areas, the ideas of the client/architect can be made clear much better. The contractor has clear information of what work is necessary for the proper construction of the fair-face concrete work. In this connection it is also important that the concrete engineer clarifies in advance with the fair-face concrete team, at what distance is the usual observation to be fixed for the later user for assessing the fair-face concrete surface.

Most favourable is when the concrete engineer already consults with the designer when the specification is prepared. The usual practice today is that building contracts are mostly already placed before the concrete engineer is called in. In this case he should clarify the unclear points in the specification early enough to work out joint solutions before the construction work starts. He must recognize in good time, demands in the specification that cannot be fulfilled and refuse these as being impossible to execute. This could be, for example:

- Completely uniform colouring of all visible areas
- Completely similar pore structure
- Areas free of blooming or pores

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2.3 Fair-face concrete created by the formwork + formlining

Fair-face concrete surfaces that are created by the formwork + formlining demand appropriate knowledge of the properties of formwork and formlining materials by those designing them. The formlining is basically divided into porous and non-porous types. Porous linings provide darker and non-porous linings lighter concrete surfaces.

Porous are all natural timbers such as rough sawn or prepared boarding and planks. Uncoated derived timber panels, three-ply panels, uncoated plywoods and formwork tubes of cardboard are classified as weakly porous. All linings with a solid surface, such as film-coated or sealed plywood panels, coated boards, steel and plastic linings are non-porous.

New applications of fair-face concrete surfaces increasingly show the demand for smooth concrete surfaces that can be achieved through the use of non-porous to weakly porous linings. The danger of colour differences, increased pore formation, marbling, cloud formation and entrainment water effects is much larger than with porous and/or structured surfaces. Details are contained on the linings in Section 4.

Formwork and tie spacing, joints and edges

Apart from determining the lining material the specification must state how the grouping of the visible surfaces is to be made, if this is important for the design of the areas. The architect should define his wishes in special drawings (sample formwork drawings).

The following design requirements are to be shown in the sample formwork drawing:

- All execution details important for the optical effects;
- Arrangement and formation of the formwork ties;
- Grid system of the joints and positioning;
- Special arrangement of formwork joints.

All details of sizes (width/length) and direction of the formlining or formwork panels belong in the sample formwork drawing. The available sizes and types are to taken into account here. Special sizes can lead to considerable cutting waste and costs. If demands are made on the type of fixing for the formlining for permanent concrete impressions, these are to be exactly described, such as formlining screwed from the front, nailed, clamped at regular intervals, or if not visible screwed from the rear.

Information on the arrangement and formation of joints for the formlining and the formwork units. Formwork joints are never completely watertight and dark discolouration can occur at the joints and adjoining areas because of this. If high demands are made on the design of joints these require extra sealing of the formwork joints. These requirements are to be especially included in the specification.

A regular grid for the formwork ties can be specified, but the possibilities of the formwork system must be taken into account. It is to be determined whether and how the remaining cone-shaped depressions of the formwork ties are to be plugged, e.g. with fine concrete of the same colour or with deeply bonded stoppers. Plane making good of the cone depressions can lead to colour differences and rough edges to the areas made good.

With dummy joints and joints in the concrete it must additionally be shown whether and how profiled strips or chamfer strips can be used for example.

Edges are generally broken with > 10 x 10 mm chamfer strips. All other types are to be given in the specification. Sharp edges and corners are difficult to form. They can break off despite careful construction. There is a danger of injury to passers-by and the damage to the fair-face concrete to be considered with sharp edges.

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2.4 Other surface creations

Creation of surfaces not formed

An upper area (concrete side) always has a different appearance than a formed area. The appearance and the position of surfaces not formed that remain visible is to be given in the specification (e.g. upper sides of breast walls or parapets or the concreting side of pre-fabricated concrete panels). It is generally better to only tamp the upper side and not to smooth it. The transfer from formed to non-formed surfaces should always be separated by chamfered strips.

Creation of surfaces treated subsequently

Possibilites of creating surfaces through subsequent treatment are contained in the Standards for Cast Concrete DIN 18500. The differences between hand treatment through bushing, dressing, granulating and sharpening or technical treatment through sand-blasting, flaming, fine washing and washing out are made clear here. In these treatment processes the upper cement layer of the concrete is removed and a rough surface, mainly marked by the colour of the aggregates is exposed.

Creation of coloured surfaces

Glazing or covering sealings or coloured coatings can be applied for creative reasons and for protection against moisture penetration, dirt or pollutants.
Certain colour effects can be achieved by using lighter or darker cements, especially with very light concrete through the use of white cement or for brown colours through using Portland oil shale cement. Special effects can be achieved through colouring the fresh concrete. Iron peroxide pigments are used. Differences in colour (spots) are even more difficult to avoid with in situ concrete than in pre-fabricated concrete manufacture, especially with coloured concrete. Areas with blue or green colouring are difficult to produce.

With subsequent treatment of the surfaces coloured additives can be used, e.g. red granite or black basalt. Appropriate information according to the ideas of the architect are necessary in the specification.

The specification should contain a special item for repair mortar that can be used for construction faults in the in situ concrete or transport damages to pre-fabricated concrete panels, to compensate the coloured surface areas. Pre-trials for the repair mortar are to be paid extra.

Requirements for the concrete

Qualitatively good and simultaneously aesthetically appealing fair-face concrete surfaces can only be achieved when appropriately high demands are made on the composition, construction and placing of the concrete, and these demands are met. Practice has shown that concrete is often used where the most important demand, or even condition, independent of its suitability for fair-face concrete surfaces, is the lowest price possible. In the circle of the fair-face concrete team it is therefore the task of the concrete engineer to submit suggestions for suitable concrete mixes and to implement these against "cheap concrete".

Literature

K. Ebeling:
"Fair-face concrete – planning and execution hints – The task of the concrete engineer"
(Concrete magazine 04/98)

K. Ebeling: + G. Lohmeyer:
Fair-face concrete – Planning, specifying, assessing"
Building culture magazine, special edition 02/97)

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2.5 Regulations for fair-face concrete

2.5.1 Overview

DIN regulations – selection

DIN 1045	Load-bearing structures of concrete, reinforced concrete and pre-stressed concrete Part 3, construction work, issued July 2001
DIN 18331	VOB Part C – General Technical Contract Conditions for Construction Work; Concrete and reinforced concrete works
DIN 18217	Concrete surfaces and formlinings – requirements Plus Schmidt-Morsbach "Concrete surfaces and formlinings" – Commentary to the DIN 18217
DIN 18218	Fresh concrete pressure on vertical formwork
DIN 18202	Tolerances in tall buildings
DIN 18215	Formwork panels of timber for concrete and reinforced concrete buildings Standard sizes 0.50 m x 1.50 m, 21 mm thick
DIN 68762	Chipboard panels for special purposes in construction
DIN 68791	Large-area formwork panels of blockboard for concrete and reinforced concrete
DIN 68792	Large-area formwork panels of laminated veneer plywood for concrete and reinforced concrete
DIN 18216	Formwork ties for concrete formwork – terms, requirements, testing
DIN 4235	Compacting concrete with vibrators Part 2 Compacting with poker vibrators Part 4 Compacting in situ concrete with formwork vibrators
DIN 4421	Load-bearing scaffolding – calculation, construction and execution
Ecological Standard B2211	Concrete and reinforced concrete work – Standard contract of work

Other regulations

ZTV-K	Extra Technical Contract Conditions for Engineering Structures

German Concrete Association e.V. – Memorandums

- Fair-face concrete issued March 1997
- Release agents for concrete issued March 1997
- Ability to concrete building components of concrete and reinforced concrete issued November 1996
- Construction consultancy – cement Memorandum for concrete technology – cracks in concrete

2.5.2 Extracts from the regulations with hints for fair-face concrete

DIN 1045
Only general hints on executing formwork are given in DIN 1045. There are no conditions for designed concrete surfaces (fair-face concrete).

DIN 18331
The following conditions for formwork are contained in DIN 18331:
"The selection of the formwork according to type and materials remains with the contractor. Formed areas of concrete are to be rough from the formwork, i.e. untreated after striking, non-formed areas are to be roughly tamped.
Individual information on deviations from the general technical conditions – when a certain type or a certain material is to be agreed for the formwork, or if special requirements are to be made for the concrete surfaces, e.g. smooth upper surfaces, exposed aggregate concrete, factory cutting, broken arises, removing fins, special work for plaster adhesion and factory-made cladding."

DIN 18217 Concrete surfaces and formlining
Text of the DIN regulations (extract):

1 Area of application
This standard applies to in situ concrete and pre-fabricated concrete panels. Aesthetic hints are not given in this standard.

2 Concrete surfaces
2.1 Generally
Concrete surfaces are the mirror of the formlining or the result of subsequent treatment (see Section 2.3.3) and/or treatment (see Section 2.3.4)
The formlining is to be selected according to the requirements of the concrete surface.

2.2 Concrete surfaces with no special requirements
The type of construction and the formlining for these areas remains with the contractor. A surface treatment is not demanded, improvements are permitted.

2.3 Concrete surfaces with requirements for appearance
2.3.1 Generally
These are concrete surfaces remaining visible for which a clear and practically executable description must be available. The comparison with buildings already constructed can be an effective aid for this. Sample pieces can be agreed and used as the basis for the execution. With a comparison with sample pieces or existing buildings it is to be taken into account that the required surface areas will only be the same under the same conditions (sizes, basic materials, concrete mix, formwork, placing, subsequent treatment, weather, age of concrete etc.). Appropriate information is necessary as far as the arrangement and formation of joints and ties have an influence on the concrete surfaces. Material and proper improvements are permitted.

2.3.2 Concrete surfaces created with formlinings
Taking account of Section 2.3.1 there are creative possibilities through the use of appropriate formlinings. The concrete surface structures are to be named in the tender specification.

2.3.3 Treated concrete surfaces
These are concrete surfaces according to Section 2.3.2 and non-formed areas that are treated extra. The types of treatment are, for example, exposed aggregate, bushing, dressing, granulating, sharpening, sand-blasting, acid treatment, grinding, flaming, rolling, smoothing, brushing.

2.3.4 Subsequent treatment of concrete surfaces
These are concrete surfaces according to Section 2.3.2 and Section 2.3.3 that are treated extra with special requirements, e.g. through polishing, sealing, coating.

2.4 Concrete surfaces with technical requirements
The surfaces have certain technical functions to fulfill and/or serve following work. Each of the requirements to be met are to be clearly formulated in the specification. Material and proper improvement are permitted.

The book "Concrete surfaces and formlinings – Commentary to the DIN 18217" by Juergen Schmidt-Morsbach, Publisher Ernst & Sohn 1985, is to be observed in applying DIN 18217.

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DIN 18202 Tolerances in high buildings

4 Tolerances in plane surface
There are spot measurements as limits for plane surface tolerance laid down in Table 3; these apply to surfaces of slabs (upper and lower side), screeds, floor coverings and walls.

Table 3 and Fig. 2 give plane surface for surfaces of walls and slabs. The lowest measuring distance is 0.1 m.

Projections or steps within the formwork lining joints are fundamentally not to be excluded, because these are unavoidable due to the material, according to the relevant panel standards. This is taken into account by the measuring point distance of 0.1 m. "The permitted deviations for plane surfaces in materials are not contained in the plane surface tolerances and are therefore to be taken into account additionally." i.e. tolerances in the sizes of the formwork lining are to be taken into account or given additionally.

Table 3: Plane surface tolerances (extract)

Column	1	2	3	4	5	6
Line	Reference	Spot measurement as limit in mm With measuring distances in m to				
		0,1	1[1])	4[1])	10[1])	15[1])
5	Unfinished wall surfaces and soffits of rough slabs	5	10	15	25	30
6	Finished wall surfaces and soffits of slabs e.g. plastered walls, wall cladding, suspended ceilings	3	5	10	20	25
7	As line 6 but with increased demands	2	3	8	15	20
[1]) Intermediate values are to be taken from illustrations 1 and 2 and rounded off to complete mm						

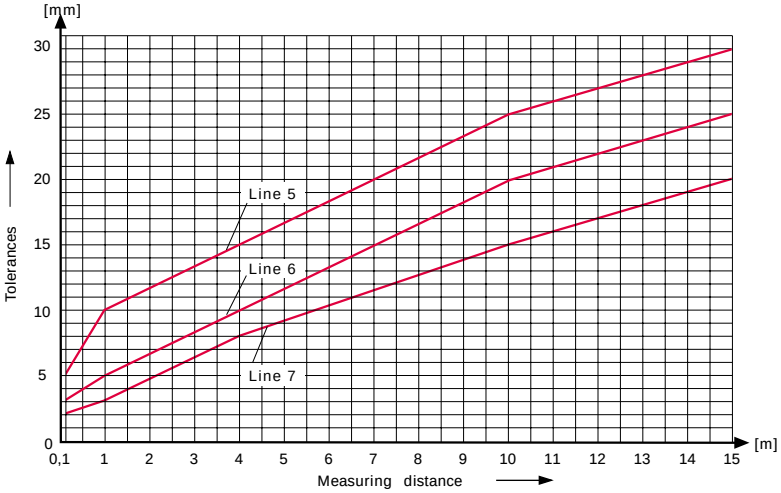
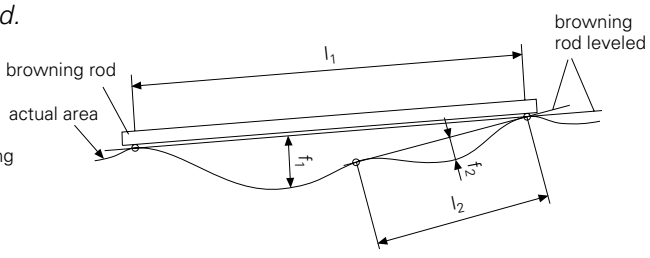


Illustration 2: Plane surface tolerances of wall surfaces and soffits of slabs (information of lines to Table 3)

The plane surface is checked by individual measurements, e.g. through spot checks, according to the illustration or through levelling over a grid area; the grid is to be measured.



l_1; l_2 = Measuring point spacing
f_1; f_2 = spot measurement

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DIN 4235

See Section 7 – Selection and influences from ....

Ecological Standard B 2211, issued 1st April 1998 Concrete – reinforced concrete and pre-stressed concrete

Section 1.2.2 ➞ Supplement to B 22110
Section 1.3.3 – 1.3.9 special information is to be given on fair-face concrete for:

a) pores;
b) structure; extra with S 3: necessity for the construction of sample areas
c) Special arrangement of the formwork panels or boarding groups
d) Special formation of necessary construction joints
e) Same colouring according to classes
f) Colour additives in the concrete mix

Section 1.3.4 ➞ in supplement to B 2110
Section 1.3.10 separate items are to be provided in the specification (B of Q's) for the following work where necessary:

(1) Surface treatment (e.g. bushing, dressing, granulating, sharpening, sand-blasting, exposed aggregate) by exactly determining the requirements
(2) Surface treatment (e.g., impregnating, sealing, coating, spraying, painting) by determining the requirements (e.g. abrasiveness) and the materials.

Structure of the specification

1.3.5.1 Basic divisions

(1) Concrete (sizes in cubic and superficial metres), formwork (superficial metres) and reinforcement (quantity) is usually to be specified and tendered for separately.
(2) If concrete, including formwork, and only the reinforcement is separately specified, the tender documents must give exact information on the sizes of the building components so that the share of formwork can be calculated simply.
(3) If concrete, including formwork and reinforcement is specified, the tender documents must enclose formwork and reinforcement drawings. This should only occur with pre-fabricated concrete units and building components of simple design and in large numbers.

2.3.4 Technical requirements; requirements for workmanship; testing conditions

2.3.4.2 Fair-face concrete and/or formed concrete surfaces on which special requirements are placed.

Sections 2.3.4.3 to 2.3.4.5 apply to the requirements for the surfaces. If no higher classes are agreed structure class S 1 and colour uniformity class F 1 are to be maintained.

2.3.4.3 Pores

Class P:
The share of open pores on the concrete surface, measured within a test area of at least 500 x 500 mm, may amount to a maximum of 0.3% of this area; pores below 1 mm in diameter are not taken into account here. The largest pore diameter may be 15 mm. The pores are to be determined on two test areas for each test. A representative part of the total area for the whole impression is to be selected as the test area.

2.3.4.4 Structure

(1) Class S 1:
smooth, plugged concrete surface
The joints between neighbouring formwork units must be tightly sealed so that a maximum of 10 mm wide nibs can occur on the surface of the otherwise smooth concrete through the exit of cement slurry and/or fine mortar. Nibs caused by this are permitted.

Class S 2:
As Class S 1 but the joints must be so tight between neighbouring units that practically no cement slurry and/or fine mortar can escape. Nibs are not permitted.

(2) Class S 1 A:
As Class S 1 but using a certain formwork according to the information in the specification (e.g. sealed surface, multiple layer panels of timber, prepared, tightly closing timber formwork, steel formwork).

(3) Class S 2 A:
As S 2 but using a certain formwork according to the information in the specification (e.g. sealed surface, multiple layer panels of timber, prepared, tightly closing timber formwork, steel formwork).

(4) Class S 3:
Structured or plastically designed concrete surface according to the type demanded (e.g. rough sawn, specially raised timber grain, exposed aggregate, special designs through moulds). The joints between the formwork units must, as far as nothing else is demanded, be plane and so tight that practically no cement slurry and/or fine mortar can escape.

2.3.4.5 Colour uniformity

(1) Class F 1:
Discolouration over an area, caused by rust, different types and previous improper treatment of the formlining, improper subsequent treatment of the concrete, aggregates from different sources as well as lines of discolouration (reinforcement marks) are not permitted. Further demands on the uniformity are not made.

(2) Class F 2:
In addition to the requirements of F 1, discolourations that are to be attributed to cements of different type or origin, or to different concrete aggregates are not permitted. Unavoidable differences occurring in the colour when maintaining these conditions and with careful placing are permitted.

ZTV = Extra Technical Contract Conditions for Engineering Structures

6.2 Formwork

6.2.2 Formwork for concrete surfaces remaining visible

The arrangement and formation of the formwork on visible areas (e.g. direction of the formwork boards, joints, joint sealing, formwork openings and blockouts) are to be shown schematically; the drawing is to be submitted to the client for agreement in good time.

The formwork is to be provided down to 300 mm below ground level.

Ties on concrete surfaces remaining visible are to be arranged to a regular grid pattern. Their number is to be restricted by suitable design of the formwork where possible.

Tie holes are to be carefully plugged with fine concrete of a fitting colour, cleanly inserted, or with deeply bonded plugs. The proposed type is to be agreed with the client.

Ties in cornices and mouldings are not permitted.

A formwork without longitudinal joints is to be used for cornices and mouldings.

6.2.2.1 Board formwork

Boards with sharp arises, undamaged, at least 80 mm and maximum 120 mm wide are to be used. Unprepared boards must be 24 mm thick and prepared boards at least 22 mm thick. Rounded edges are to be formed with fillets. Board joints are to be staggered.

6.2.2.2 Panel formwork

The joints of panel formwork must be adjusted in their grid pattern to the shape of the building and also cut to the slope where necessary. Supplements to the formwork through board strips or wedges are not permitted on visible surfaces.

Only stiff panels of the same type may be used as formwork panels, and only thin panels of the same type on a stiff base formwork.

6.2.4 Release agents

Only proven release agents (formwork oils etc.) may be used that leave no spots on the concrete. They may also not have disadvantageous effects on the following surface protection systems. The instructions for use of the manufacturer are to be observed.

Timber formwork is to be treated with release agent in such good time that it has penetrated into the timber when the reinforcement is fixed, so that reinforcement steel and pre-stressing members are not soiled.

New formwork for fair-face concrete not coated with plastic is to be treated with cement slurry before the first use and to be cleaned and sprayed or painted with release agent at least twice.

DBV Codes of Practice

See Section 7 – Selection and influences from ….

3 Tender document wording and contractual aspects

3.1 Tender document wording

In evaluating a number of tender document wording for building projects carried out it can be seen that principally text blocks or tender descriptions from other building projects were used as a basis. A clear description of the required concrete surfaces that can be definitely estimated and executed is missing in nearly all of these tender documents. Very often a demand is made in such a way that it is very difficult and indefinite to understand in order to gain as much space for decisions as possible for the client. The contractor is given the risk and the responsibility for the indefinite description of the required concrete surface. Unfortunately the present market situation forces contractors to accept such tender documents, without or with only slight objections. Sometimes the client also does not have the necessary knowledge to recognize the problems when placing the order.

In the VOB (Contract Procedure for Building Work) Part A it is laid down, among others:

Clause 9 (1) "The work is to be described so definitely and exhaustively that all tenderers must understand the description in the same meaning and be able to calculate their prices safely and without extensive preparatory work.

Clause 9 (2) The contractor may not be given any unusual risk for circumstances and events over which he has no influence and that he cannot estimate the effects of for the prices and deadlines in advance."

We, as formwork suppliers, are usually only called in after the contract is made. Unfortunately we then often have to explain to our customers that one or other demand cannot be technically guaranteed or only with increased working and material expenses.

If we say that we cannot technically guarantee a demand, this means that influences can occur that, under the execution conditions that were completely unknown at the time of the tender and placing of the order (e.g. weather), can produce a different result. Through unforeseen moisture entering the timber formlining there can be swelling at the edges of the lining etc. Unfortunately these unforeseen influences are partially ignored in the tender documents and it is hoped by chance that only positive influences will affect the results.

With the chance that only positive influences will affect the execution of a fair-face concrete wall and the sentence in the ZTV "If the contractor does not produce the fair-face quality demanded, the client retains the right to demolition and renewal at the cost of the contractor.", the quality of execution cannot be guaranteed.

Apart from the legal consequences (see Section 3.3) the cooperation of all those involved in the "fair-face concrete team" (see Section 1.2.1) is urgently necessary here.

The tender document wording should be clearly divided in its requirements, into:

Requirements for:

- The design and execution
- The formwork and formlining including tie system and grid
- The reinforcement plus spacers
- The concrete and its placing
- The parts to be installed
- Other influences.

The Austrian Association for Concrete and Concrete Technology has determined, in guidelines "Formed Concrete Areas" (basic print in December 2001), GK Classes for Requirements for Visibly Remaining formed Concrete surfaces (Table 1).

The requirements on structure, pores and uniformity of colour are thereby taken from B 2211 (see Section 2.5.2).

The following division is made for the construction joints:

AO Offset of areas between two concrete sections ≤ 10 mm

A1 Offset of areas of two concrete sections ≤ 10 mm
Fine mortar escaping from the above concrete sections must be removed in good time.
Triangular lath is recommended.

A2 Offset of areas of two concrete sections ≤ 5 mm
Fine mortar escaping from the previous concrete sections must be removed in good time.
Chamfered strips are recommended.

A2 S Offset of areas of two concrete sections ≤ 3 mm
Fine mortar escaping from the above concrete sections must be removed in good time.
Chamfered strips or others are permitted / not permitted.

The following division is made for the plane surface:

EO DIN 18202, Table 3, line 5
E1 DIN 18202, Table 3, line 6
E2 DIN 18202, Table 3, line 7

3 Tender document wording and contractual aspects

Requirement Class	Requirements for formed concrete areas[1]						Requirements on formwork[2]	Requirements on concrete, release agent	Applications Application examples
	Structure[2]	Pores	Uniform colour	Construction joint	Plane	Sample	Formwork Class	Concrete Standard[3][4]	
GB 0	S 0	5 P	–	A 0	–	–	SK 01		Concrete areas with no special architectural design or technical requirements
GB 1	S 1	4 P	–	A 0	E 0	–	SK 01		Concrete areas with principally technical concrete requirements, e.g. basement walls, garage walls, retaining walls
GB 2	S 1	3 P	–	A 1	E 1	recommended	SK 02	BS-GB	Concrete areas with high technical concrete requirements, e.g. infrastructures with exposure class XF2, XF3 and XF4, sewage plants
GB 3	S 2	3 P	–	A 2	E 1	recommended	SK 02	BS-GB	Concrete areas in high-rise buildings with special technical and concrete requirements, e.g. walls and slabs in high-rise buildings, sewage plants for industrial waste water
GB S Special Class	S 2	P	F 2	A 2 S	E 1	Specified	SK 02	BS-GB	Architecturally designed areas with of special importance, e.g. concrete areas for representative building components

The following division is to be made for the Formwork Classes:

SK 01 Type of formwork as selected, e.g. framed panel formwork with lower requirements than SK02

SK 02 Formwork system such as framed panels, girder formwork or special formwork

SK 03 Formwork system such as framed panels, girder formwork and special formwork with higher requirements than SK 02.

The formwork classes are described in detail in the guidelines.

The check-list contained in 3.2 is an aid in formulating the ideas in the tender documents, to assess the implementation on site and to calculate the choice and expense in the execution.

3.2 Check-list for tender document wording for concrete surfaces with demands on appearance

Demands on	Explanation, alternative, hints	Special choice demanded
1. Concrete surface		
Smooth concrete surface	Smooth formlining, large-area formwork unit with inconspicuous joints – formwork joints visible	
Rough concrete surface	Rough formlining, structured lining, large or small-area formwork, formwork joints visible	
Structured concrete surface	Type and shape of the structure - through the formlining - through treating the concrete surface	
Surface with few blowholes or pores	A few blowholes and pores on the surface Size of pores and blowholes Pores and blowholes distributed over the area.	
Colour of the concrete surface	As few colour differences as possible - colour of the concrete through cement, aggregates - colour of the concrete absorbent /non-absorbent formwork colour mixed (pigments) in concrete Additives	
2. Formwork **2.1 Type of formwork**		
Materials	Boards, formwork boards or panels, structured unitsor linings, plastic coatings – Absorbent/nonabsorbent surface – Steel etc.	No specification/ Specification:
Surface quality	Natural, sealed, film-coated, oiled, waxed etc.	No specification/ Specification:
Surface structure	Prepared, ground, smooth, rough, structured through brushing Screen printing scars, sand blasting etc.	No specification/ Specification:
Sizes of formlinings	Panel size (standard sizes, special sizes) Boards: board width (80 – 120 mm) length up to approx. 4.5 m Formlining thickness – from 20 mm self supporting, below 15 mm on a base formwork.	No specification/ Specification:

Demands on	Explanation, alternative, hints	Special choice demanded
Formlining fixing	Fixing from the front (concrete side) from the rear Type of fixing: nailed, screwed, tacked Fixing: projecting, flush, sunk, filled (warning: even sunken and filled fixings remain visible on the concrete surface) Fixing spacing free or specified	No specification/ Specification:
Formlining joints	Abutting, tight (sealing strip, joint filling) tongued and grooved Cross joints in one line/or overlapping	No specification/ Specification:
Number of uses for the formlining	New, used with damaged places used but improved permissible number of uses 1 or n	No specification/ Specification:
Absorption properties of the formlining	Formlining not absorbent Formlining weakly absorbent Formlining absorbent (Drain-fabric	No specification/ Specification:
2.2 Formwork System		
Girder formwork system Walls/ slabs Framed panel formwork	Specified grid of units (length/width) Tie spacing Specified unit size of formwork system Tie spacing Standard formlining, special lining	No specification/ Specification:
Formwork ties	Tie spacing provided by standard formwork Special tie spacing horizontal vertical Type of tie DW 15, 20, 26 PVC tube with cone and PVC plugs Recoverable ties, concrete cones (colour, shape) Non-recoverable watertight ties	No specification/ Specification:
Unit joints	Joint formation with girder formwork Joint formation with framed panels Standard with formlining attached System tolerances at joints Special items: joint strips, chamfers etc.	No specification/ Specification:
Filler areas	Filler area lining Filler area arrangement and construction Striking play	No specification/ Specification:

Demands on	Explanation, alternative, hints	Special choice demanded
2.3 Erection of the formwork		
Pre-assembly	Factory assembly - unit size restricted by transport sizes Site assembly has hardly any restrictions on unit size Site assembly means lower quality, special adjustments Formlining change at factory (site)	No specification/ Specification:
Accuracy of sizes	DDIN 18202 Table 3 Line 5 Line 6 Line 7 Warning: no higher accuracy can be guaranteed Tolerances in the formlining also to be considered Tolerances in the area at formlining joints at unit joints	Specification:
Joint construction Vertical and horizontal	– Expansion joints: show positions Formed with Chamfered strip, double-chamfer lath, joint insert Stopend formwork, expansion joint band etc. – Construction joints: possible arrangement formed with Chamfered strip, double-chamfer lath, joint insert Stopend formwork, expansion joint band etc. – Formwork base Flush, tight, joint emphasized by use of a lath	No specification/ Specification: No specification/ Specification: No specification/ Specification:
3. Concrete surface – Influences		
Discolouration from formlining Joints in the lining Release agent	Formlining (boards) artificially aged Grind, fill, seal No concrete discolouration, sanding, formation of spots etc. No effects on adhesiveness of following coatings No recognizable residues Biologically degradable	No specification/Specification: No specification/Specification: No specification/Specification:

Demands on	Explanation, alternative, hints	Special choice demanded
Fittings to be assembled	Type of fitting, quality (rusting/non-rusting) Fixings, securing position (nailing, screwing, binding or welding)	
Blockouts	Type of blockout, fixings Accuracy of position, other requirements such as chamfer strips etc.	No specification/ Specification:
4.	**Concrete**	
Concrete placing	Size of concrete sections Concrete output Concreting speed Concrete mix (w/c value, type of cement, consistence, additives, liquefying agent) Concrete compaction (poker vibrator, external vibrator)	
5.	**Planning Construction**	
Formwork planning	Extent of the planning, submission of drawings Working documentation availability	
Construction sequence plan/Time schedule	Preparation/controls	
Transport and inter-mediate storage Loading/unloading Stacking		
Accessories	Requirements: Release agents Filler formlining (type and fixings) Tie-holes and later closure	

3.3 Fair-face concrete – legal tender and contractual aspects

There is no binding definition in the technical or legal meaning (e.g. in the DIN standards) by means of which the extent of work involved in constructing a building or part of a building in fair-face concrete is more closely determined. One reason why there are differences between contract parties is whether the contractor has met his contractual obligations in constructing a building/part of a building in fair-face concrete.

Tender documents and form of contract

What a contractor has to perform is determined by the agreements between the parties. They should be fixed in writing and consist of the following:

- Contract conditions
- Specification
- Bill of quantities
- Drawings

Tender documents / Making a contract

With public contracts as well as with some private clients, making a contract is preceded by tender documents according to the VOB/A. If the tender documents are subject to the VOB/A the person writing the tender is bound (VOB/A Clause 9 (1 + 2) to write the tender in such a manner that the tender documents exactly specify the work to be carried out as far as possible. The documentation should therefore define, for example, what construction requirements (formwork, concrete) are to be used and/or how the final product should appear.

According to Clause 9 (2) VOB/A, a contractor may not be subjected to any unusual risks. Such unusual risks are present, among others, when the client does not disclose considerable circumstances that cannot be recognized by the tendering company and later contractor. If the contractor is subjected to an unusual risk this can result in a claim for compensation of the contractor for faults in negotiating the contract. The tendering company has an obligation to check. With recognizable faults, irregularities and similar the client must be questioned. If he omits to do this there are no grounds for a claim for compensation. The contents of the contract will therefore not be adjusted because the VOB/A contains no imperative contractual rights that the contract contents provided in Clause 9 VOB/A may be assumed instead of the agreement made.

The tender documents concerned are also not invalid because of a breach of any legal prohibition according to Clause 134 BGB. When writing the contract, especially the tender documents, care should be taken, simply because of the possible threat of claims for compensation, that the contractor or the tendering company is not subjected to unusual risks.

Comparable buildings and sample areas

The work to be carried out can be determined through the verbal description by sample areas and comparable buildings. Sample areas and comparable buildings are to be agreed. With comparable buildings it is to be observed that the construction conditions (time of year, cement, aggregates and others) can never be reproduced and the building to be constructed will never be a 100% duplicate but can only be constructed with differences to the comparable building. Sample areas cannot be made available before or during the tender period because they are only constructed at each site. After construction the sample area should be observed and approved by both contract partners. For the later assessment of whether the other fair-face concrete areas correspond with the sample area, an observation distance should be agreed, both for the sample area and for the other areas. This should correspond with the later observation distance to the fair-face area in later use. By this means the danger is especially reduced that when accepting the whole of the work individual criteria such as the aesthetic feelings of the client being decisive for assessing the faultiness or acceptability.

Sample areas have the advantage that the parties are agreed during the construction work as to how the fair-face areas to be constructed are to appear. Agreed sample areas or comparable buildings avoid the contractor being subjected to an unusual risk.

Contractually indebted work and faults

If work is faulty this also means that the contractually indebted work was not fulfilled. According to Clause 633, par.1 BGB the work is to be carried out so that it has the assured properties and no faults. Faulty work is present when the finished work deviates from the normal quality of the work indebted, as provided for by the parties. This also means that the contractor has to carry out the work on the building or part of the building according to the recognized rules of the trade. The recognized rules of the trade include, among others, the DIN standards. But these only help very little in the specification of fair-face concrete. They refer to tolerances, types of construction and construction techniques etc. The DIN standards also do not show how the terms that are often used in specifications, "ready for painting" or "ready for papering", are to be understood. Exactly the use of these terms in the specification often results in the contract partners having different ideas from that which is contractually indebted.

Assured properties

Also missing, so-called, assured properties represent a fault. A property is assured when this is seen to be important for the client and the contractor has promised to fulfill this. As long as an assured property is agreed, this is indebted by the contractor, no matter whether the construction is technically possible in this manner or not. When a sample area is agreed this applies as an assured property according to Clause 13 (2) VOB/B. In no case should anything be contractually agreed which cannot be technically constructed, because the contractor is liable for fulfilling the contract. He is therefore subject to claims for fulfillment or guarantee from the client such as mitigation or withdrawal from the contract.

In one case the BGH (Federal High Court) has decided that assured tolerances are contractually owed by the contractor, even if keeping to these tolerances is impossible from a technical point of view. The defendant was supposed to construct a binder formwork for the client. Size tolerances were contractually agreed that according to the professional expertise were impossible to meet. With assured properties the plaintiff can demand the defendant to construct the contractually agreed work. That also applies when this is technically impossible, hardly possible or only with very considerable expense.

No legal misuse is seen in the plaintiff insisting on the assured properties. The contractor is also not released from his special liability if he objects according to Clause 4 (3) VOB/B. He already knew when signing the contract that it was especially important for the client to fulfill these properties. Before signing the contract the contractor should therefore have checked whether such an assured property could be carried out. If sample areas or comparable buildings are agreed this problem does not usually arise, because when this is constructed the technical implementation is proved.

Observing the guarantee and liability questions shows how important it is to exactly determine the contract content according to the wishes of the contract parties. Especially the use of indefinite terms such as "able to be papered", "able to be painted", "suitable for painting" or "ready for painting" should be avoided because each party can understand these terms differently. There is no legally binding definition that the contract parties can call upon. As there is also no High Court judgment on the question of how the above terms are to be understood there remains a free interpretation. The parties should therefore write down as exactly as possible what they understand by agreeing tolerances for example and determining who will pay for the costs of any necessary making good. In addition recording quality and evidence should be made during the construction to avoid disputes.

Contractual inclusion of Codes of Practice

Both the German Concrete Association (DBV), the Federal Network of the German Cement Industry (BDZ) as well as the Federal Network of German Concrete and Pre-fabricated Concrete Industry (BDB) have issued Codes of Practice for use in tender documents and contracts for fair-face concrete. These Codes of Practice should make it easy for the parties to write their contracts and avoid disputes. As these Codes of Practice do not number among the recognized rules of the trade it must be agreed by the parties when making the contract which recommendations shown in these Codes are to be used and thus a part of the contract. A general reference to the Codes of Practice is not expressive enough.

3. Tender document wording and contractual aspects

DBV Code of Practice “Fair-Face Concrete”

The DBV has issued a Code of Practice named “Fair-face Concrete”. Under 2.4 of the Code of Practice it is said what is to be observed, especially in the tender documents, i.e. what performance features are to be absolutely exactly determined. This concerns on the one hand the surface structure, colouring, division of areas, constructive details, appearance and position of non-designed areas, as well as on the other hand any watertight formwork joints etc. The preparation of sample areas is also recommended in this Code of Practice.

The Code of Practice can serve as a check-list for preparing tender documents, but is no generally valid instruction for the tender documents for every building. In the tender documents of every building there should therefore be specific criteria, separated in requirements for the formwork, reinforcement and concrete, taken into account and included in the specification and Bills of Quantities etc.

The Code of Practice also contains what is to be considered when accepting fair-face concrete. According to this only the whole optical impression and not a single part should be the deciding factor for acceptability of the work. Avoidable deviations in the appearance of the elevation areas and possibly avoidable or unavoidable, or constructionally difficult demands on the elevation area, are differentiated with regard to the question of faults.

As exactly the question of acceptability of fair-face concrete depends upon individual aesthetic feelings, rules for acceptance should be drawn up by the parties. That applies especially to fixing the criteria of when the work concerned is acceptable. This could be, for example, that the contract parties agree on the appropriate rules of the Code of Practice. The Code of Practice can only be an orientation for the acceptance rulings however, and not necessarily be valid for every building.

Securing evidence of quality

To be able to check the implementation of the contractual agreements there should be securing evidence of quality agreed between the parties for work such as fair-face concrete, which can be executed very differently. The standard of quality is determined by sample areas or comparable buildings. The contract parties can check, again and again, by means of these reference objects, whether the executed work corresponds with the contractually indebted work.

The sample area or comparable building should be exactly localized and possibly defined in photographs. It will thus be avoided that the contract parties dispute which areas have been determined as sample areas. Securing of evidence can be made by taking photographs and or expert surveys for example. Calling in a professional expert is advisable for assessing whether the executed fair-face concrete corresponds with the contractually indebted work. To obtain the most objective expert comments, court evidence proceedings (independent evidence proceedings) or arbitration expert proceedings should be introduced. An expert only instructed by one contract partner (out-of-court) will be seen in a later court dispute as an interested party, whilst an expert in independent evidence proceedings or an arbitration expert is to be seen as impartial.

Literature

Prof. H. Franke and B. Schaarschmidt:
Fair-face concrete – an assured property?
Tender document and contractual aspects (concrete 4/2000).

3.4 Formwork planning

Presentation of engineer's working drawings for agreement on formlining joints, ties etc. It should be clear to the author of the tender documents that formwork is almost exclusively carried out with system formwork and appropriate formlining materials. Standard or system sizes of the formlining and formwork units, as well as tie spacings, are therefore already given.

A deviation from these given circumstances means, for example:

- Use of special formlinings (sizes) with appropriate cutting to waste
- Assembly of special formwork to achieve the required unit grid
- Assembly of special formwork units or arrangement of extra walings and ties to obtain the tie grid required.
- And others

These extra demands require more material and work and thus also higher costs.

3.5 Tolerances

The basis for accuracy in formwork construction is DIN 18202 "Tolerances in high-rise buildings" (see section 2).

The tolerances laid down in the DIN apply to the execution of buildings on the basis of DIN 18201, independent of the building materials. The size limits and angle tolerances laid down are to be maintained in the formwork assembly on site and are influenced by the erection. The formwork used must be so constructed and assembled to manufacturing tolerances that the size limits and angle tolerances can be maintained. In addition fillers can be used for example on site.

Much more important for fair-face concrete, and directly influenced by the formwork, are the plane surface tolerances. These are given in DIN 18202, Table 3 and Fig. 2. The demands here, especially line 7, are very high and require special care and measures in the execution. The tolerances given by the formwork suppliers refer to the formwork units (e.g. framed panel units) and their connections in undamaged condition and with proper assembly.

On site there are additional tolerances such as: erection inaccuracies, measuring tolerances

- Slight soiling in the area of unit joints
- Timber swelling through moisture influences, also with formlining panels
- Inaccuracy in the standing area
- Column deformation
- Erection play of push-pull props
- Tie expansion
- And many more

Demands that lie above the DIN 18202, line 7, cannot be guaranteed with the formwork appliances on the market at present. The contractor should especially observe here:
If other tolerances are demanded in tender documents and are not refuted in the contract, the tolerances in the tender documents are valid.

A special problem and also frequent points in dispute are the formlinings and formwork unit joints. As these usually concern steps between neighbouring panels there is no ruling in DIN 18202. In DIN 18202 tolerances are only determined from a basis measuring length of 100 mm. Offsets or steps within the formlining joints cannot be excluded because they are according to the relevant panel sizes (DIN 68762, 68791 and 68792) and unavoidable as a result of moisture fluctuations.

DIN 68792 provides a permissible deviation of + 0.2 mm to – 0.9 mm for the thickness of a 21 mm formwork panel. This value applies upon leaving the factory and a timber moisture content of about 7%. Despite surface treatment and edge sealing the panels quickly absorb moisture from the edges and swell up. With fair-face concrete formwork for high demands a supporting panel or open spaced boarding is often used on which the fair-face lining is attached. Two formwork panels are therefore involved in swelling and shrinking and double the tolerances. A different degree of moisture in each unit cannot be excluded and thus steps in the formlining of several mm cannot be avoided.

DIN 68792 gives analogous tolerances for the length and width of the panels at the time of delivery from the factory:

Tolerance	Length	± 3.0 mm
	Width	± 3.0 mm

These tolerances are to be absolutely observed in assessing the joint space or step in the formlinings. A higher accuracy than the material has when leaving the factory cannot be guaranteed.

Before Table 3 in DIN 18202 it is written: “The deviations permissible for plane surfaces in building materials are not contained in the tolerances for plane surfaces and are therefore to be additionally taken into account”, i.e. that the permissible size tolerances of formlining panels are to be additionally recognized in the effects on their dimensions according to DIN 68791 and 68792.

3.6 Examples of tender document wording

In the following tables there are some extracts taken from an extensive collection of tender document wording. These extracts are intended to show how tender document wording should not be formulated. In the second column there are comments provided that explain them and give necessary hints.

Tender document wording (quotations)	Comments
The arrangement and construction of the formwork for fair-face surfaces (e.g. direction of formwork boards, joints, joint sealing, formwork openings and blockouts) are to be shown schematically; the drawing is to be submitted to the client in good time.	The contractor is given complete freedom in designing the formwork. He will only obtain the ideas of the client when the first draft is submitted. The costs for formwork planning and execution cannot be calculated.
Concrete areas that are marked as “Fair-face FF” are to be constructed as far as possible without steps or pores, including special measures when concreting.	How is, as far as possible without steps or pores, to be defined? Concrete cannot be constructed without steps or pores.
With fair-face concrete the reinforcement – especially for slabs and beams – is to be protected from rust before concreting. The formwork is to be cleaned of release agents before using to avoid rust marks on the concrete.	How is the reinforcement to be protected from rust? Why remove release agents from the formwork before use? How can the formwork be separated from the concrete? Better to spray on a fast-drying release agent and remove surplus release agent with a rubber scraper.
A new large-panel formlining to DIN 68792, so far unused, is required both for slabs as well as wall areas in high-quality fair-face concrete. The tenderer is free to use multiplex panels or blockboard panels. The panel thickness may not be less than 21.5 mm. The Module of Elasticity in both directions should be almost the same. In addition it is demanded that the formwork panels be coated and this coating is approx. 500 g/m^2 on both sides. All edges are to be sealed and protected.	Colour differences on the concrete surfaces cannot be avoided in the first use of a new formlining. The formwork panels have a standard thickness of 21 mm. A thickness of over 21.5 mm usually means special manufacture. The thickness of the formlining is dependent on the spacing of the supports. The coating thickness of 500 g/m^2 is not justified because this is dependent on the panel timber and usually has no influence on the concrete surface. A coating of up to about 240 g/m^2 is ideal. Thicker coatings crack easily, e.g when nailing. Moisture can then penetrate, make the panels swell and the thick, brittle coating breaks off.
The highest demands are made for all fair-face concrete work required by the specification. The contractor must guarantee a perfect fair-face concrete to DIN 18331. The finished concrete surfaces should have a completely dense structure; sanding, nests, clouding and streaks may not appear.	How are the areas to appear? What are the highest demands? DIN 18331 does not govern fair-face concrete. These demands cannot be guaranteed in executing the work and professional doubts should be registered.
The fair-face concrete will not be given any other treatment and the skeleton construction in this case is absolutely the final product. Reference is explicitly made to VOB A Clause 4.7. The site supervision retains the right to have all work demolished that is not perfectly executed.	The possibility of demolition represents an arbitrary act of intervention, because the requirements and the distance of observation are not exactly defined. There is no exact acceptance criteria.

3. Tender document wording and contractual aspects

Tender document wording (quotations)	Comments
All construction sizes are to be exactly constructed to an accuracy of ± 3.0 mm. Inaccuracies in sizes will be altered at the cost of the contractor.	There is no reference to the tolerances contained in DIN 18202. Lower tolerances than are given in DIN 18202 cannot be guaranteed. ± 3.0 mm without any reference to a basic length is a demand that cannot be met.
All fair-face concrete areas of the building are to be constructed in fair-face quality. The fair-face areas are to be constructed with prepared timber formwork. Boards with different absorption are to be excluded.	Fair-face quality is not an exact description of the concrete surface. Boarded formwork has different absorption because natural products such as knots absorb more heavily.
Only formwork oil may be used that does not discolour the concrete surface, causes no sanding and permits subsequent painting, making good or plastering. Formwork oil must be biologically degradable (CE-Text) Water Hazard Class 0. Quality scale: Deitermann Relax Bio 1 or similar.	Rather use a release agent than formwork oil. Biologically degradable release agents easily lead to dusting of the concrete surfaces. There is thus a contradiction in the requirements for the surface. There is no Water Hazard Class 0. A release agent can, at best, only be classified as Class 1 for low water hazard.
Joints/abutments/stopper arrangements are to be agreed with the architect and engineer – also formally. Difficulties in formwork or concreting work are not especially described. They are to be calculated and included in the unit prices.	This is not a clear and implementable demand. Any possible costs arising for this cannot be definitely calculated.
There is extra work necessary for constructing perfect fair-face concrete, compared with a concrete with no special requirements for the surface. This extra work is to be taken into account in the estimate and included in the appropriate formwork items. Subsequent objections about more difficult conditions are therefore basically excluded.	Remarks as above. The client is simply trying to prevent extra costs from the contractor.
The contractor is to submit formwork drawings to the client for checking in good time, to agree on the arrangement of ties and joints. These drawings are to be altered by the contractor where necessary and submitted to the client in triplicate for release. The formwork drawings are paid for in the lump-sum price. Sample formwork drawing: The architect appointed by the client will prepare a sample formwork sketch for the design of the fair-face concrete areas that will serve only the purely architectural demands. The sketch will be prepared when the architect is appointed, together with the contractor.	These demands represent no clear basis for an estimate. How is the estimate to be prepared when the sample drawings are only to be prepared and handed over when the architect is appointed?
The formwork is to be constructed in joinery quality, e.g. with mitres, bevels etc.	What is joinery quality? Even the different timber moisture content in the whole process and thus the swelling and shrinking contradicts this. The tolerances are made larger by mitres and bevels.

Formwork systems are divided into two groups according to their principal construction units

- Framed panel formwork
  (panel formwork for slabs)
- Girder formwork
  (flexible formwork for slabs)

The effects of these systems on the concrete surface will be described in the following.

4.1 Wall formwork

4.1.1 Framed panel formwork

The principle of framed panel formwork is shown by the example of the PERI TRIO Framed Panel Formwork. Other framed panel formwork is similar in the concrete impression. The grid system of the framed panels and ties is different.

Formwork units = Framed panels = Frames of metal profile sections with the lining inserted.

The frames are connected to each other with formwork couplings. The framed panels are arranged in a measured system according to size. The tie holes in the framed panels are fixed, i.e. there is a rigid tie grid. The lining has protected edges and is placed in the metal frames. The projecting frame edge is pressed into the concrete. The lining is riveted to the frames and the joint between lining and frame is elastically sealed. Smooth, film-coated, non-absorbent formwork panels are used for the lining.

Example of a framed panel formwork PERI – TRIO

The standard panels of the TRIO are collected in the two following illustrations and the tie spacing measurements shown for each panel. The formwork is made up of these units. The units can be arranged horizontally or vertically. The plan shows how a corner and an abutting wall are formed. The framed panels are divided inbetween and a filler used to compensate the remaining measurement and as a striking aid. It should be observed that the panels have to be arranged opposite each other because of the ties. Two tie holes come together at panel joints, of which one tie hole is used for the tie. The corner with the impression of the framed panel joint, the tie holes with and without tie, and stacking of the units can be seen in the photograph.

The panels are stacked above each other for larger formwork heights.

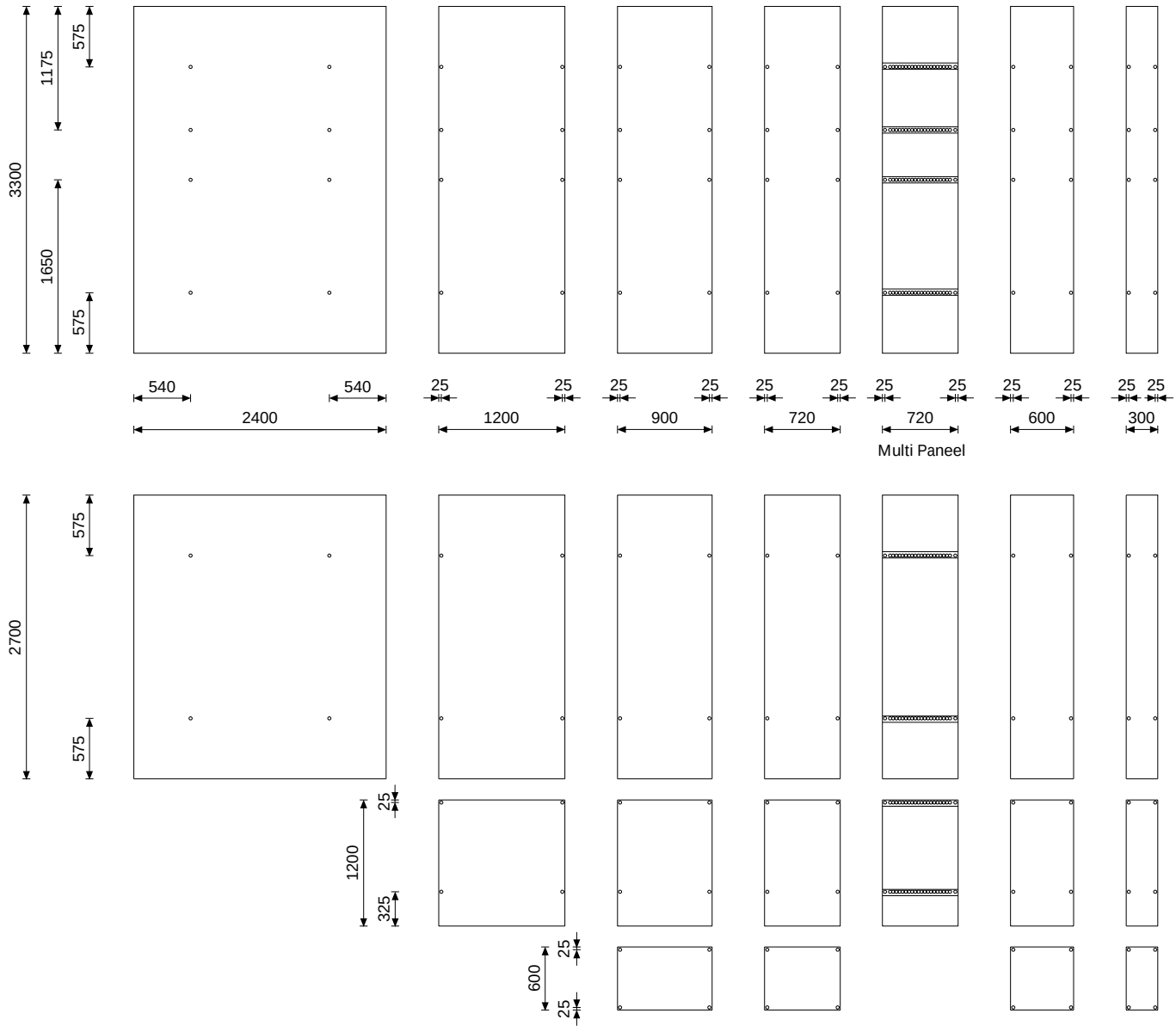
Special solution for TRIO Structure

TRIO as above, but the formlining is replaced by a supporting panel. An individual lining must be fixed to this supporting panel, i.e. the lining can be freely selected according to the requirements for the surface. By observing the possibly pre-assembled formwork sections the formlining size can also be freely selected. The unit joints are determined by the formlining. The lining is usually fixed from the front (concrete side), with linings of > 21 mm this can also be made from the rear. As two linings are arranged on top of each other there can be steps in the joint areas (swelling and shrinking) which cannot be compensated.

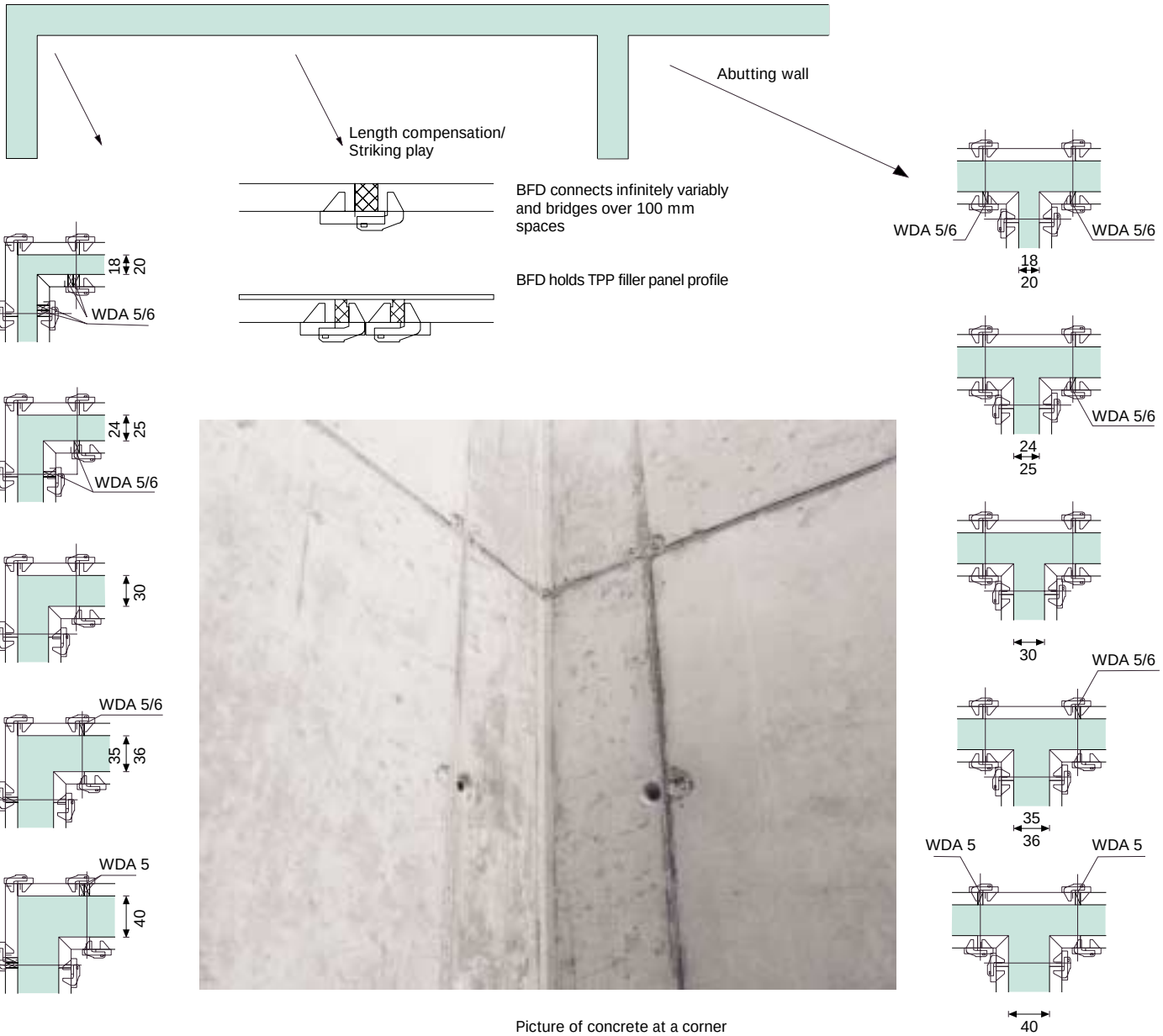
The tie grid of TRIO remains the same.

TRIO Framed Panel Formwork – Overview of units

(sizes in mm)

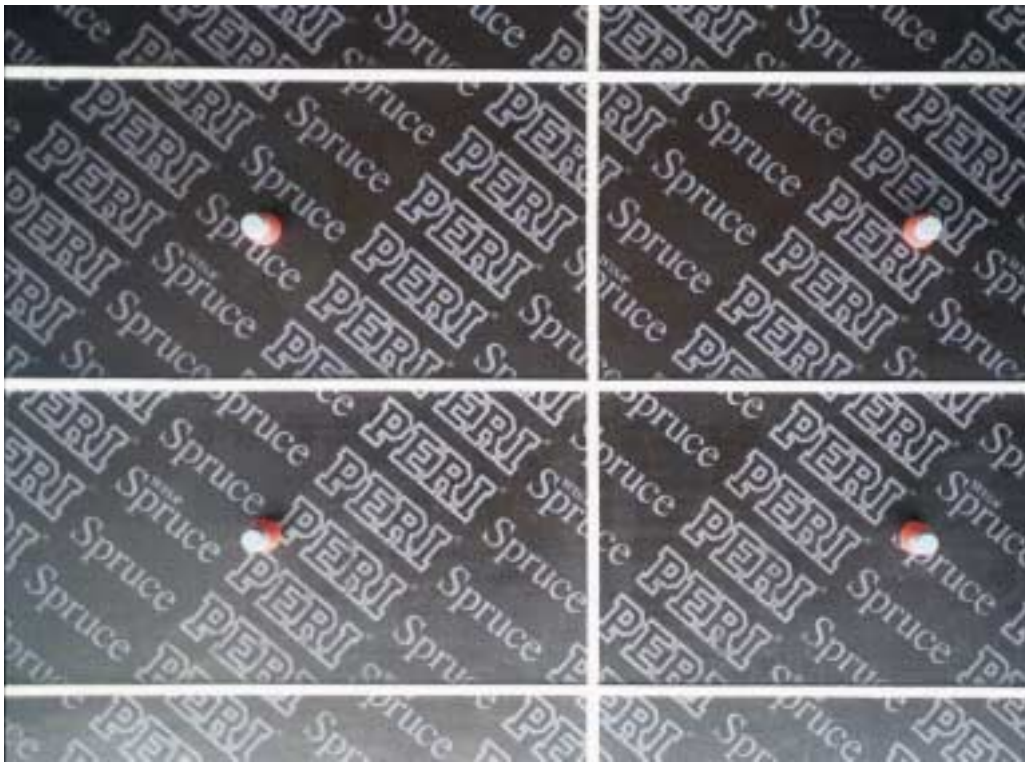


Plan of a wall – Formwork principle



Picture of concrete at a corner constructed with TRIO framed panel formwork. Units stacked.

Fair-face areas with double-chamfer laths



Type of formwork:
VARIO formwork

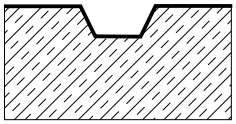
Formlining:
21 mm PERI Spruce

Type of fixing:
with Torx screwed from the rear

Type of formwork:
PERI Spruce lining screwed from the rear, tie spacing provided and extra dummy cones

Picture of concrete:
Tie spacing with extra concrete cones

Section through the joint.



Example of the outer wall of a hall formed with PERI TRIO Framed Panel Formwork

Front with door and gate openings

Uniform framed panel arrangement
2.40 m x 2.70 m horizontal panels with filler strips between.

Outer wall formed continuously with a symmetrical joint arrangement, tie holes plugged with PVC plugs

Example of the outer wall of a hall formed with PERI TRIO Framed Panel Formwork

Details of the façade:

Joint impression of the framed panel formwork including filler areas
Impression of the formwork tie positions

Example of the outer wall of a hall formed with PERI TRIO Framed Panel Formwork

Details of the façade:

Joint impression of the framed panel formwork including filler areas
Impression of the formwork tie positions

Fair-face concrete areas with structure

Type of formwork:	TRIO Structure
Formlining:	21 mm 3-S panels
Type of fixings:	Torx screwed from the rear and tacked from the front at joints

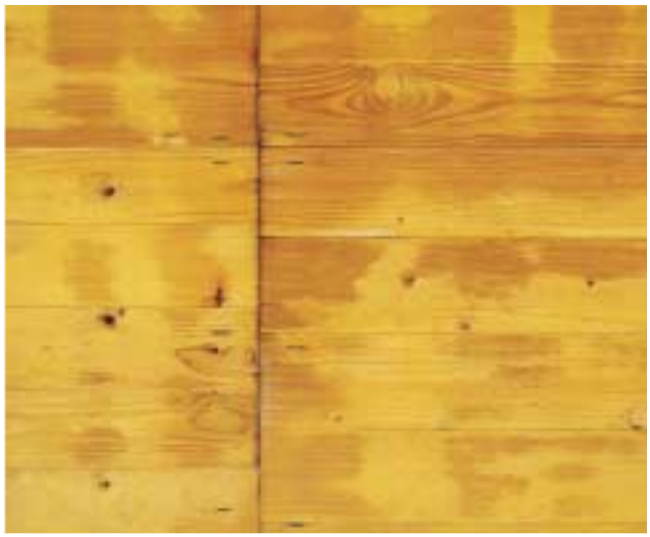
Picture of the formlining:

TRIO Structure units covered with 3-S panels

Picture of the concrete:

Forming of a door opening with chamfer strips

Picture of the concrete with unit and lining joints



Forming the lining joint

4.1.2 Girder formwork

The principle of girder formwork is shown in the example of PERI VARIO. Other girder formworks have a similar concrete picture. The grid system of the formwork sections and ties are different.

There are standard formwork sections in fixed sizes or they are especially assembled for appropriate projects.

They consist of:

- Formlining (freely selected) – a supporting formlining or open boarding is necessary for fixing a non-load-bearing formlining or fixing the lining from the rear
- Girder position (usually vertically) – girder spacing can be selected depending on the loading and deflection, consisting of GT 24 timber girders
- Walings as connections and tie bearings

Standard VARIO GT 24 elements

The standard units are kept in the hire plant depot in fixed sizes (see illustration). The units have a supporting formlining. With special requirements for the concrete surfaces a formlining can be fixed to this especially for the project. The tie spacing is fixed for the standard VARIO elements.

If the standard VARIO elements cannot be used, units especially assembled for the project can be supplied according to the same construction principle. These provide the following grid possibilities for the units and the ties:

Formwork section sizes

- Height = girder length = 0.90 m .....
  (n x 0.30 m) ..... 6.00 m
  (larger heights possible by stacking sections)

- Standard widths: b = 1.00 m; 1.25 m; 1.50 m; 1.875 m; 2.00 m; 2.50 m; 3.00 m;
  (other unit widths possible by assembling walings of special lengths for specific projects)

- Tie spacing vertically:

0.46 m + n x	0.89 m
	1.18 m
	1.48 m
	1.78 m
	2.07 m
	2.37 m

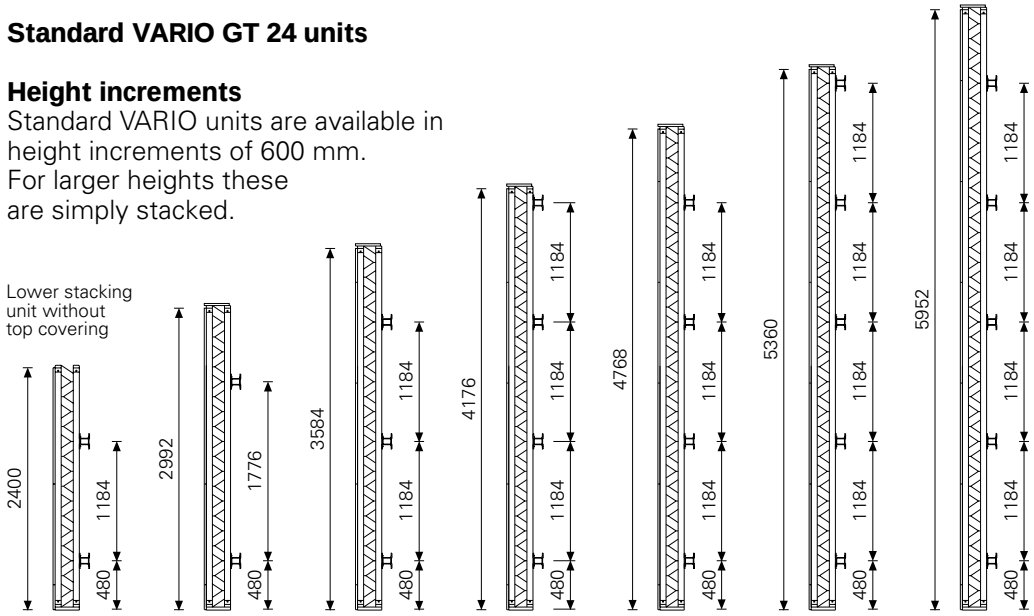
  The waling spacing is selected according to the static requirements (grid intervals of 0.296 m)

- The horizontal tie spacing can be freely selected within the waling position.

Standard VARIO GT 24 units

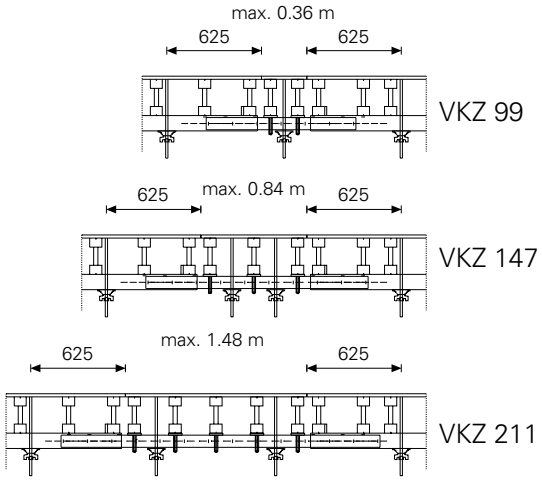
Height increments

Standard VARIO units are available in height increments of 600 mm. For larger heights these are simply stacked.



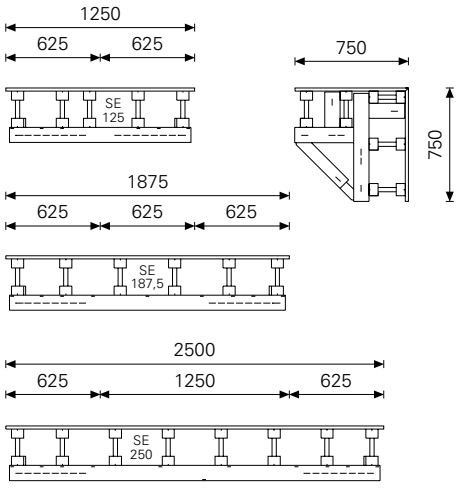
Fillings / Striking play

Maximum compensation widths with VARIO VKZ Couplings:

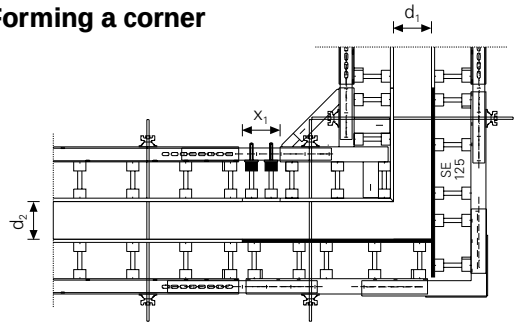


Width increments

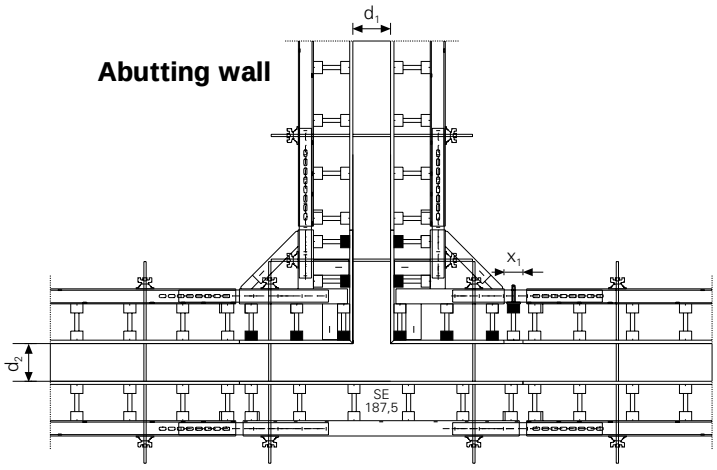
There are standard VARIO units in 3 widths:



Forming a corner



Abutting wall

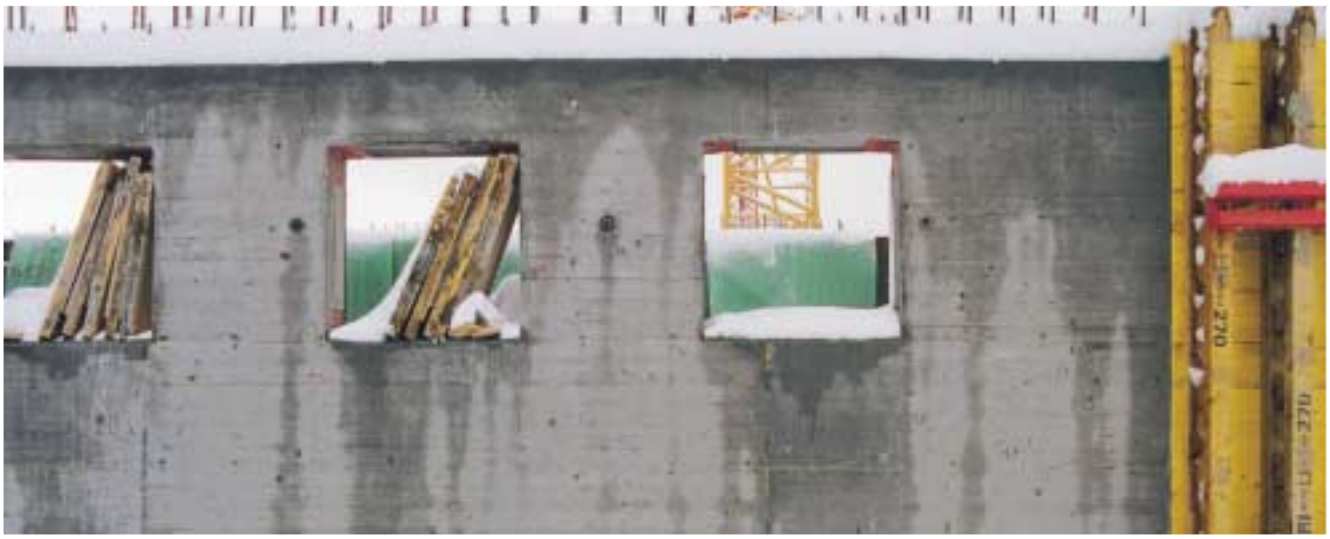


Fair-face concrete area with 3-S panels

Type of formwork:	VARIO for specific projects
Formlining:	21 mm 3-S panels
Type of fixing:	Torx screwed from the rear

Type of formwork:
Standard VARIO

Picture of the concrete:
Standard tie spacing



Print: formlining joint in the concrete

Formlining joint

Fair-face concrete area with VKS Coupling
Type of formwork: TRIO formwork
Formlining: 21 mm Finnply
Type of fixing: Torx screwed from the front

View from the rear:

With **VARIO Fair-Face Coupling** installed

Picture of the concrete:

Picture of the unit and lining joints

Unit joint in the concrete

Unit joint with the **VKS** coupling

Aligned unit joint with the **VKS** Coupling

Fair-face area with nibs
Type of formwork: TRIO formwork
Formlining: 21 mm PERI Beto
Type of fixing: Torx screwed from the rear on boarding

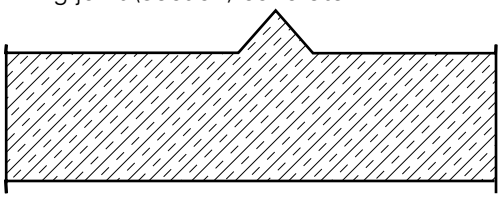
Picture of the concrete:
Tie spacing provided

Type of formlining:
Formlining screwed from the rear

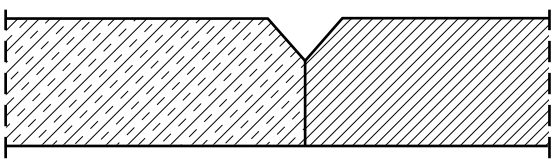
Picture of concrete at unit and lining joints

Formation of the nibs and lining joint

Detail of the lining joint (section) concrete



Formlining



4.2 Slab formwork

Slab formwork is divided in the same way as wall formwork into

- Girder formwork =
  the flexible systems such as PERI MULTIFLEX
- Framed panel systems =
  the panel systems such as PERI SKYDECK

4.2.1 Slab formwork – flexible systems

In flexible systems the formlining is supported by a number of girders and props or towers. The spacing of the girders and props is calculated and selected according to the static requirements. The formlining exclusively determines the picture of the concrete surface.
This can principally be selected independently of the supporting system. The formwork panels selected should not be too large however because these present a problem with striking by hand and can be easily damaged.

Formwork tables have a special position with regard to the formlining grid. Formwork tables are ready-made formwork units in a fixed grid, or tables made to measure for the project. The size of the tables has an influence on the picture of the grid on the soffit. Exact planning of the formlining and table grid is imperative here. The formlining is screwed or nailed from the front onto the supporting girders.

4.2.2 Slab formwork – panel systems – PERI SKYDECK

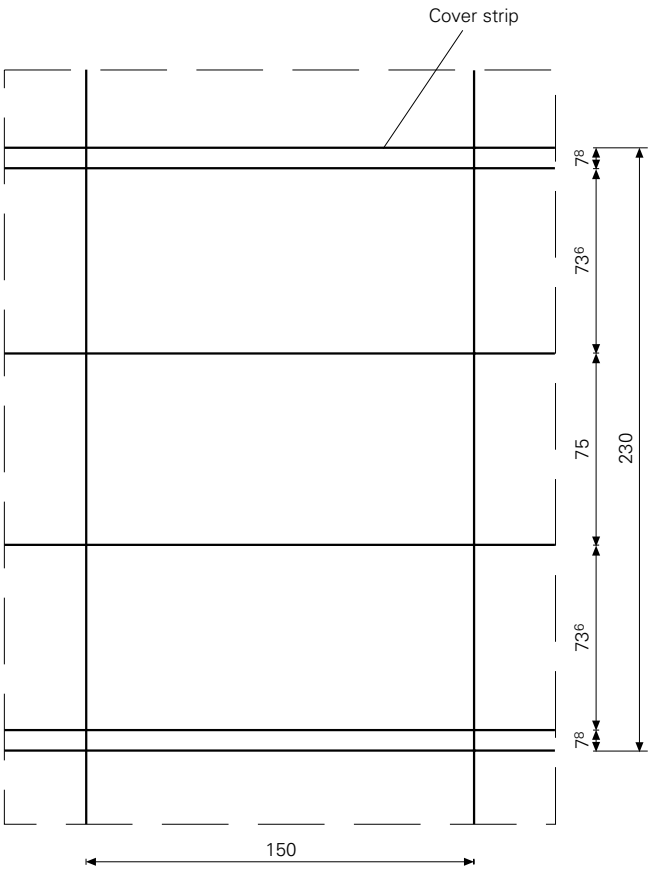
The panel systems form a fixed grid on the concrete soffit in the same way as framed panel formwork. The grid is determined by the panel size and is different for each of the systems on the market. For the PERI SKYDECK system there is a basic panel size of 750 x 1500 mm. These are supplemented by filler units of

750 x 750 mm
750 x 500 mm 1500 x 500 mm
750 x 375 mm 1500 x 375 mm

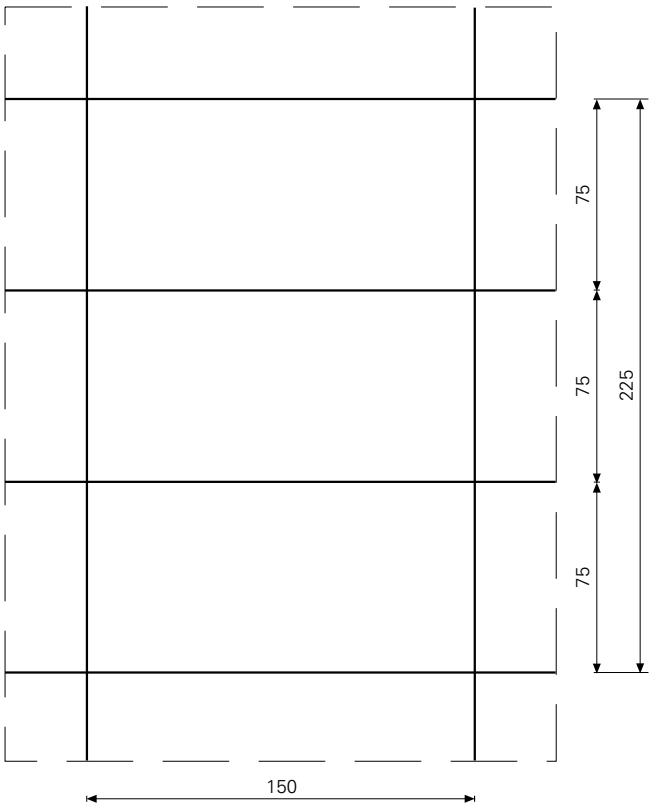
Fillings are made with these filler units at the edges as well as at interruptions (e.g. columns). The arrangement and formation of the fillings has to be planned for the project. The basic grid for SKYDECK, determined by the girders, is

- With the drophead system 1500 x 2300 mm
- Without the drophead system 1500 x 2250 mm

Basic grid system for SKYDECK



Basic SKYDECK grid with drophead
1.50 m x 2.30 m



Basic SKYDECK grid with grophead
1.50 m x 2.25 m

Formlining rivet fixings also show on the concrete.

SKYDECK with drophead 1.50 x 2.30 m

SKYDECK with prophead 1.50 x 2.25 m

4.3 Column formwork

Column formwork is divided into two basic systems in the same way as wall formwork.

PERI VARIO GT 24 girder formwork

With girder formwork the picture of the concrete is principally determined by the formlining selected and its fixings to the girders. Formwork ties may be necessary with large column cross-sections.

PERI - QUATTRO framed panel formwork

Column cross-sections of up to 600 x 600 mm can be constructed in 50 mm stages. The framed formwork panels are erected in windmill fashion. The formwork height is achieved by combining unit heights of 2.75 m; 1.25 m; and 0.50 m.
The horizontal formlining joints are shown in the concrete when stacking the units. The QUATTRO units have film-coated, multiple-layer panel lining as standard.

PERI TRIO column formwork

Column cross-sections of up to 750 x 750 mm can be constructed in 50 mm stages. The framed formwork panels are erected in windmill fashion. Through the special connections of the framed formwork panels with each other, the row of holes required for these is impressed in the concrete. The formwork height is achieved by a combination of unit heights of 2.70 m; 1.20 m; and 0.60 m. When stacking there is a horizontal joint shown in the concrete, similar to the unit joints in framed panel formwork.
The TRIO panels have a film-coated, multiple-layer panel lining as standard. Corners are formed by specially attached plastic chamfer strips.

PERI RAPID

The formlining for this column formwork can be freely selected (21 mm). The column cross-section of up to 600 x 600 mm can also be freely selected. The formlining is spanned over chamfer strips at the corners. The concrete surface is only influenced by the formlining.

Corners

All column formwork is constructed for the use of chamfer strips. Columns without chamfer strips, i.e. sharp arrises, raise problems.

VARIO GT 24 =
There can be slight bleeding at the corners through low deflection and movement between the units.

QUATTRO and TRIO =
No clean arrises can be formed without chamfer strips because of the framed panels.

RAPID =
Sharp arrises are possible with the RAPID system when using formlinings of more than 27 mm in thickness.

Columns with VARIO GT 24 column formwork

Columns with TRIO column formwork

Columns with QUATTRO column formwork

Lining: film-coated plywood panels screwed from the rear

Columns with RAPID column formwork

Corners broken with chamfer strips

Lining freely selected

without any visible fixings because it is clamped by the chamfer strips.

Arrises with sharp edges through a special lining (30 mm thick)

Circular column formed with SRS circular column formwork in steel

4.4 Formlining

4.4.1 Concrete surfaces created by the formlining

There are possibilities of design for the structure of the concrete surface through the use of appropriate formlinings. Other possibilities are provided by colouring (pigments) or the use of coloured basic materials.

The formlining determines the surface character of the concrete here – independent of any subsequent processing or treatment. The person writing the tender documents must exactly know the formlining itself, its influences on the concrete, the materials – if necessary in connection with the release agent – and the placing, and take this into account in the design. As a result the specification – alone for the concrete area – must be so clear that the contractor can take into account all the points of view relevant to the materials and applications without any risk.

Possible unclearnesses oblige the contractor and, where necessary the formwork supplier, to register professional doubts; for example with "no pores" and "uniform colour", that contradict both the formlining as well as the concrete. In such cases it is purposeful to leave the investigation into application limits and design possibilities to the sample areas appropriate to the project, i.e. the sample area must agree with the building to be constructed and the concrete area according to materials, dimensions, placing, weather etc.

Designed concrete areas are the mirror of the formlining. The clearly demanded choice of an "appropriate" formlining by the contractor must therefore be able to be deduced from the specification, both according to type as well as in special cases the make. Constructive (tongued and grooved) or processing (release agents) requirements remain basically with the contractor, but are to be interpreted from the specification.

Concrete consists structurally of a binding medium and aggregates of different sizes, whereby its surface is determined by hardened cement paste. The structure – mostly determined by the formlining – density and uniformity of the hardened cement paste determines the grey colouring of the concrete area. As a completely uniform cement paste density is impossible, both with regard to the formwork as well as the concrete, from the technical processing point of view – quite apart from the materials themselves – a uniform grey colouring is also not even partially to be achieved.

The same applies to the formation of pores. In this sense it can only be spoken of "uniformity" in design in connection with concrete areas, that mostly depends on the observation distance.

A uniform grey colouring of concrete structures, whose surfaces run at different levels to each other, are poured in one working sequence and are intensively compacted to technological concrete requirements, cannot be guaranteed by the contractor. The technical application causes, especially for formwork with smooth surfaces, lie in the following factual situations:

1. If the percentage of reinforcement in three-dimensionally formed concrete structures is so high, i.e. the spacing of individual reinforcing rods, above all among each other, are so close that the amount of play necessary for a homogenous concrete structure in the course of compacting – especially the freedom of movement for the largest aggregates – is difficult or even impossible. There is therefore a sieving effect.

2. The task of the contractor is to safely provide the required concrete consistency and a plugged structure free of nests. The compulsion to provide intensive compaction is therefore given.

3. With this compaction intensity on the one hand and the sedimentation tendency caused by the reinforcement on the other hand, there are unavoidable concentrations, especially of the fine and finest aggregates – powdered aggregates (0 – 0.25) – which can, in certain circumstances, result in a considerable reduction of the water/cement ration, hydration effects and thus heavy, grey colour shading. In addition the powdery aggregate content, as referred to the large aggregates, is recommended in DIN 1045 and, in connection with slender cross-sections, thus has a maximum aggregate of 16 mm and amounts to about 450 kg/m^3. It can therefore be assumed that about 2/3 of the optically visual powdery aggregate consists of cement.

4. This vibration effect, that is caused under certain circumstances by the smoothness of the absorbent or non-absorbent formwork surface, additionally affects the formwork levels, i.e. there is a much more uniform distribution of the fine aggregates on horizontal areas than with vertical or even sloping areas for example. In the latter case, according to the water retention properties of the cement, degree of water/cement ratio and structure of the concrete aggregates – especially with lightweight concrete – it can lead to entrainment water effects, formation of stripes and purely and simply to shading of grey colours, the extent and contrast of which only appear after striking.

4.4.2 Formlining groups

4.4.2.1 Concrete surfaces with timber texture

Fair-face concrete – Boarded formwork

Selection:
Surface: rough/treated with artificial resin
rough (type of cutting)/smooth (prepared)
profiled
Arrangement: board arrangement – vertical, horizontal according to instructions
any board width/ ….mm
any arrangement of joints/regular/ alternate/according to instructions

With the above timber-constructed or profiled surfaces the tolerances for plane surfaces are subject to the material through swelling and shrinking differences and are to be allocated to the area of DIN 18202, Table 3, lines 5 – 6. Deviations cannot be excluded with heavy moisture differences. Unsealed timber surfaces have an absorbent effect and produce a dark grey colouring on the concrete surface.

Boards as formlining should have a moisture content of about 18% so that water can be absorbed from the concrete and also be returned according to the hydration requirements. Moisture alterations together with volume alterations are connected in this area of moisture.

New boarded formwork with unsealed (e.g. artificial resin) surfaces is to be neutralised/aged before the first use. Freshly boarded formwork, whether sawn or prepared, basically requires neutralising with a single or double surface treatment with cement or lime slurry, which is to be brushed off again when dried. The xylose in the timber is alkaline neutralized, the pores in the boards filled by the cement/lime slurry and the moisture requirements of the boards reduced by this. Powdering or sanding of the concrete surface is considerably reduced. The concrete surface has a darker shade of grey.

Rough-sawn surface – with the use of the term "rough-sawn" the type of cutting is to be specifically given.

e.g. rough-sawn – rift-sawn (cross-cut with similar stripes)
rough-sawn – circular-sawn (circular saw cut visible)
rough-sawn – band-sawn (very smooth, uniform surface)

Rough-sawn formwork boarding is absorbent and provides a rough, heavily structured surface for the concrete with an increased rough effect. This property helps, among others, the excess water in the surface areas to penetrate into the porous formwork, i.e. it prevents sanding and streaking effects and many more in the fair-face concrete.

The concrete picture of a properly erected fair-face concrete formwork of sawn boarding, with the correct materials and workmanship, guarantees an appealing structure and a uniform dark grey shade of colour compared with a non-absorbent formwork.

Boards are from growing timber and have structural differences that are made clear by the acceptance of moisture and thus in the formwork through small alterations in dimensions as well as partially different shades of grey.

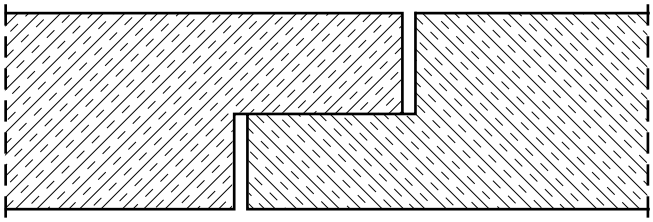
Prepared surface – provides an optically expressionless flat structure as fair-face concrete. The low roughness has the risk of streaks forming, sedimentation and thus partially different shades of grey. Otherwise the same applies as for sawn boards.

Joints

Butt joint = boards with no tongues or grooves = easiest method → formation of nibs, sanding, nests and many more are due to this type of jointing.
With jointed boards the joints are sealed against cement slurry escaping. The choice of jointing should be left to the contractor because it has hardly any effect on the fair-face concrete surface.

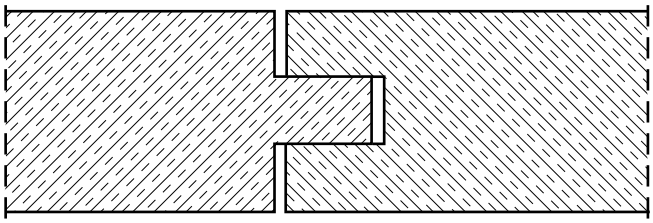
The important types of jointing and their assessment

Rebated joint



With a proper moisture content, neither slight steps nor nibs can be completely avoided. The boards can deflect slightly differently. Sanding, formation of nests etc., on the other hand, are not to be expected because the horizontal joint of the rebate is a proper seal. The rebated joint can be easily assembled and taken apart, even over arched areas

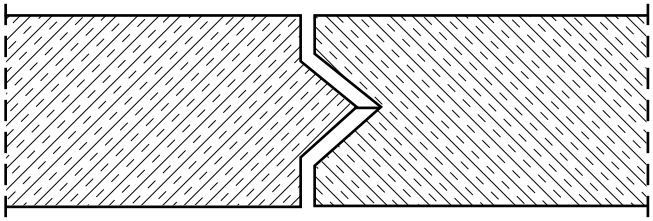
Tongued and grooved joint



This most well-known and often used type of joint has the same appearance as the rebated joint, i.e. nibs and steps are hardly avoidable, but a little less. Different board deflections are avoided.
Disadvantages of tongued and grooved joints:

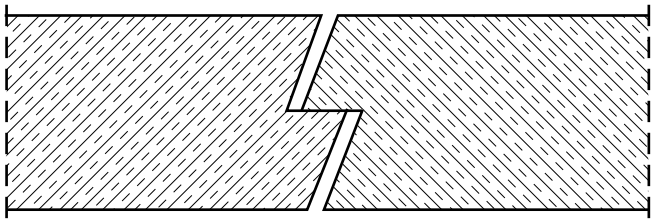
- Expensive to assemble and remove
- The tongue usually breaks off when taking apart and cannot be used again
- Use on arched areas is only possible under certain conditions.

Triangular tongued and grooved joint



This joint is hardly better than the butt joint.
This type of joint cannot be professionally recommended.

Wedge-shaped rebated joint



This type of joint is the most suitable for use. The advantages of the above types of joints are all included here. This joint should be used to achieve a clean and uniform boarded fair-face concrete surface.

Uses for boards

Rough-sawn boards
3 – 5 uses
with artificial resin coating up to 10 uses

Prepared boards
6 – 10 uses
with artificial resin coating up to 20 uses

Mechanically treated boards
3 – 5 uses
with artificial resin coating up to 30 uses.

Boarded panels
Boarded panels are panels made up of single boards. Boarded panels usually have a finger joint on the end to achieve an offset board joint when joining panels. Board widths, finger joint lengths, panels widths and lengths are different with each supplier. The type of joint can sometimes be selected. The board finish can be selected from rough sawn to prepared, whereby the panels are principally supplied with a coating (artificial resin). The panels then have a non-absorbent surface and treating the boards with a cement slurry to neutralize the xylose is unnecessary. The number of uses is considerably increased.

A good concrete quality and board moisture content can usually be expected by manufacturing in special companies who have adequate experience. A uniform concrete picture can be achieved with these boarded panels. With some types of boarded panels the jointing system of the panels can cause the panel joint to be larger in width than the board joints in the panel through swelling and shrinking. This means that these joints are shown and visible in the concrete surface.

Otherwise the same applies as for single boarding.

Three-ply panels (3-S panels)
Three-ply boarded panels are standardized in DIN 18215 "Formwork panels of timber for concrete and reinforced concrete". They consist of 3 layers of boards cross-bonded together. Panel thicknesses are 21 and 27 mm.

Panels sizes are different according to the manufacturer and up to 2.50 m wide and 6.60 m long.

Surfaces:
Coating: Natural or coated/with resin/sanded
Structured/brushed

To simulate a single boarded structure, extra V or U grooves can be cut at selected spacings (100 – 120 mm). A U groove is to be preferred because the concrete nibs occurring are more stable and not so easily broken off when striking.

The 3-S panels are to be classified constructively between a solid boarded panel and a plywood panel. According to the coating the panels can be classified as weak to averagely absorbent. The surface quality is the same as for boards. The panels swells and shrinks altogether through the cross-bonding. The panels joints are shown on the concrete surface. The surface of the concrete is marked with a slight boarded structure.

Number of uses:
8 – 15 uses with untreated surfaces and fair-face requirements
20 – 40 uses with coated surfaces and fair-face requirements.

Uncoated coniferous plywood panels
Coniferous plywood panels have 5 or 9 veneers, are water resistant and have a high-strength bonding (e.g. BFU 100).
One side is made good and lightly sanded.
They are suitable for concrete surfaces with low fair-face requirements. A timber structure is shown on the concrete surface.

The number of uses for uncoated panels is about 5 in fair-face concrete.

4.4.2.2 Plane concrete surfaces

Fair-face concrete, plane and smooth, plugged pores/open pores

"Plugged pore" concrete areas are formed with treated, or non-absorbent formwork, where no water is required and the water that is added is fully used for hydration. For fair-face concrete this means there is a lighter shade of grey, but in connection with sedimentation there can be more intensive shades of grey affecting the uniformity.

Open pore areas are formed with untreated or rough timber formwork – including chipboards as well as plywoods – that cannot be seen as an absorbent material in the meaning of rough sawn boarding, but nevertheless have a minimum water requirement, so that the concrete area structures are "screened" and provide the concrete with a broken, dark shade of grey. The area appears more uniform.

Plane areas according to DIN 18202, Table 3, line 6 or 7, are also dependent on the tolerances of the formwork system as supporting unit. Steps or nibs within the area of the formlining joints cannot basically be excluded in this tolerance area because these are unavoidable as a result of moisture absorbed or released due to the materials. There is no such thing as warp-free timber or panel materials.

Plane fair-face – rough
Timber panels in grid form provide a so-called screen print formwork. The surface is enlarged by this, which can be of purpose when painting (reducing the formation of streaks, aggregate signs are less apparent). There is the danger that too much release agent remains on the surface. The concrete areas show a closed pore dark effect in the light and rough according to the grid. The make of formwork or at least the grid unit is to be named here to exactly establish the grid.

Plane as before.

Plywood formlining
Blockboards of thin or thick laminations (to DIN 68791) and veneered plywoods (to DIN 68792)
Because of the large number of suppliers, the different constructions, the various sizes, the timbers used, the processing and bonding qualities, as well as the coating qualities, comments can only be given to a certain extent.

They are usually plywoods manufactured to appropriate quality standards that are coated with a resin coating of different thicknesses. The coating of 120 – 240 g/m^2 on each side is adequate for about 50 uses in monolithic concrete construction. A higher coating thickness can have unfavourable effects in site use, because moisture can penetrate into the panels through nail holes and similar damages and thus the thicker and more brittle coating will break off more easily.

Film-coated panels belong principally in the area of non-absorbent formlinings. Thus, when compacting the concrete, fines will collect on the surface of the formlining and cause a higher water/cement ratio in this area. Air and water pores are not "absorbed" and remain on the concrete surface.

The smooth, non-absorbent formwork surface causes slight sanding, streak effects, sedimentation and others that are visible on the surface. These formwork surfaces provide a lighter grey shade of concrete, whereby shades of grey and thus an effect on the uniformity can occur.

Film-coated panels are always sealed at the edges in the factory. Cut edges should also be sealed to keep the swelling at the edges as low as possible and to avoid increased water absorption effects at joints (darker concrete stripes).

Some panel manufacturers now supply panels with an absorbent film coating. The absorbency in the first and subsequent uses is low. There are no exact comments on this. The concrete surfaces appear to be dull. Grey shading occurs.

Veneered plywoods consist of at least 3 veneer layers that are so bonded with each other that they remain together in any weather for the whole time in use. They all provide a smooth, non-structured concrete surface.

Differences are made between:

A facing formlining	4 – 12 mm thick
A self-supporting formlining	15 – 30 mm thick

The sizes are different according to the manufacturer, a standard size being 2.50 m x 1.25 m. The first measurement of the size always gives the direction of the cover veneer. The panels sizes are to be selected according to the type of formwork and the joints required. The largest sizes of laminated panels without joints are 12.10 x 2.70 m.

4.4.2.3 Profiled fair-face concrete

Both the type as well as the make, depending on the instructions for use of the manufacturer, are absolutely necessary here. Special formwork is to be exactly described with regard to the concrete surface quality. With regard to the concrete surface quality it is advisable to concrete a sample area appropriate for the project in any case.

5 Concrete surfaces – photographic documentation

5.1 Wall formwork – framed panel formwork

Examples of concrete surfaces that were formed with framed panel formwork from the hire depot.

This is used formwork, the formlining of which may show properly repaired places. Nail-holes, small scratches in the face veneer etc. are not repaired and represent no faults. The joints are not absolutely sealed, a small amount of water and fines can escape. (see GSV Guidelines “Quality criteria for hired formwork”)

TRIO from the hire depot

Large panel 240/270 stacked with 90/120

TRIO from the hire depot

Formlining properly repaired with plugs. Scratches in the face veneer permitted. Face veneer not broken through. Some tie-holes used and others not. Closed panel joints cleanly formed.

Wall formwork – framed panel formwork

TRIO from the hire depot

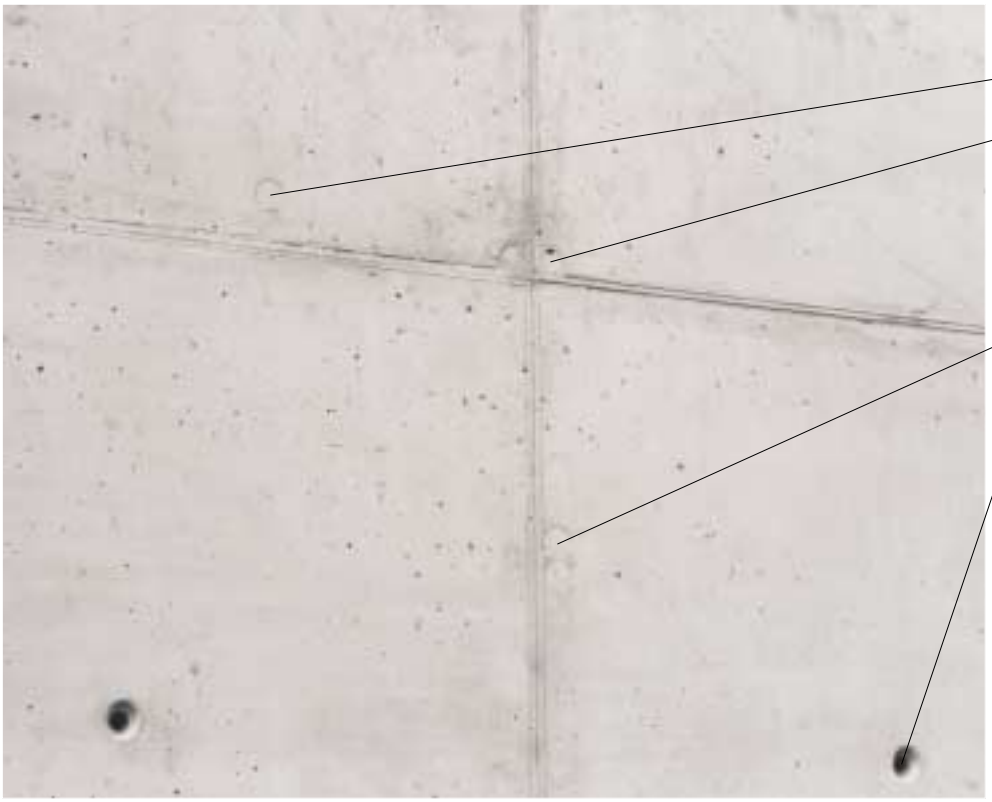
TRIO from the hire depot

Detail of the upper wall elevation

Repair point in the formlining with a plug

Blowhole percentage in the concrete too high because of poor and improper concrete placing and compacting, some tie-holes used, others not but plugged. Panel joints cleanly formed.

Wall formwork – framed panel formwork



TRIO from the hire depot

Formlining plug

Tie-holes in the framed panel formwork are unused and closed with plugs. Frame profile marks normal.

Repair plug

Tie-holes after striking PVC cone removed

TRIO from the hire depot

Tie-hole arrangement

Wall formwork – framed panel formwork

TRIO from the hire depot

Internal corner formed with internal corner unit, normal formlining used and repaired.

Colouring caused by TRIO frames or similar during storage.

Colour differences in the concrete through dissimilar absorption properties of the formwork panel, i.e. the phenol-resin film is worn differently

TRIO from the hire depot

External corner
Edges formed with framed panels
Frames show marks.

Wall formwork – framed panel formwork

TRIO from the hire depot

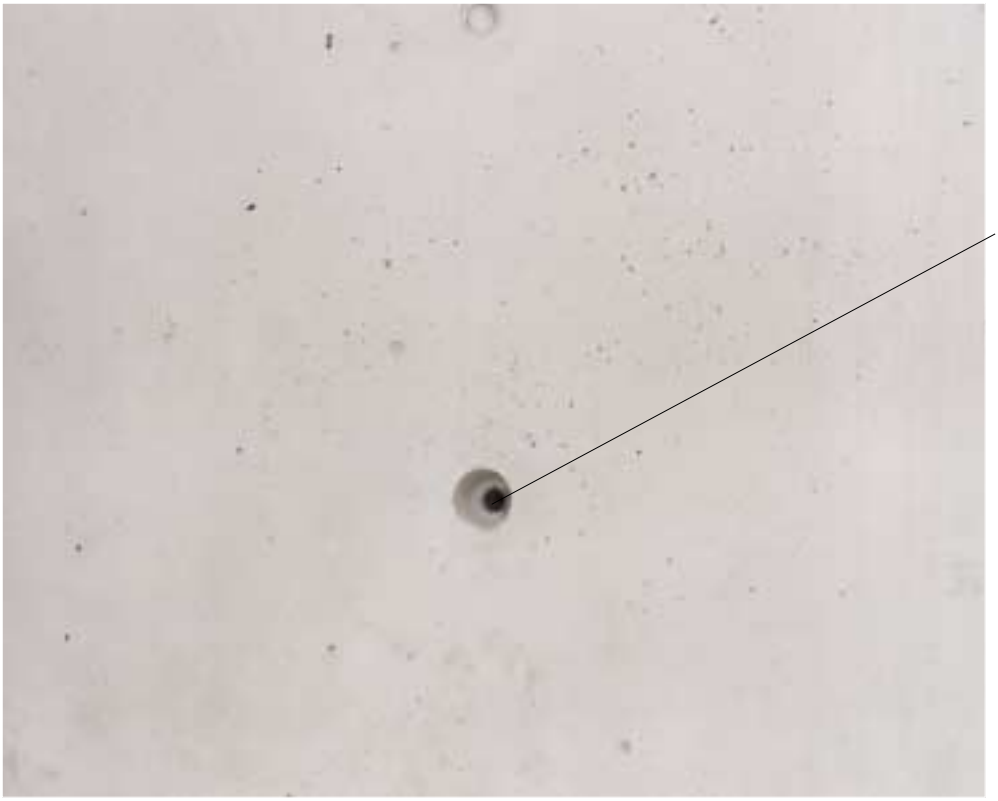
TRIO from the hire depot

Panels with different degrees of use

Wall formwork – framed panel formwork

TRIO from the hire depot

Formlining joint on a large panel



TRIO from the hire depot

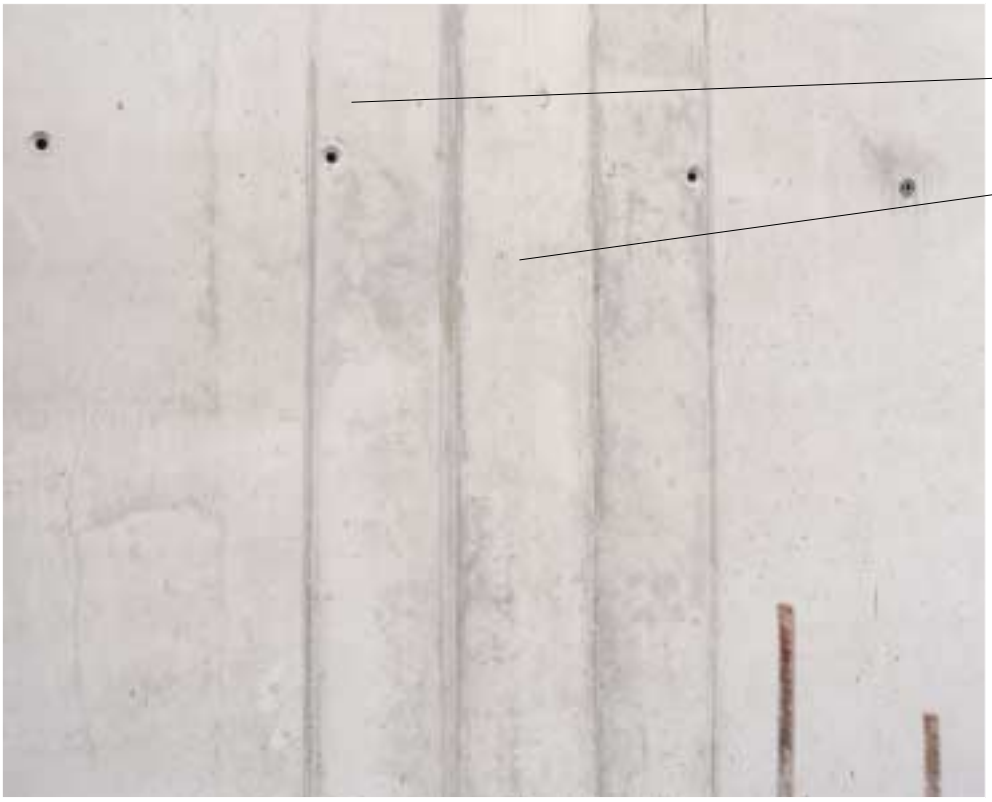
Heavy blowhole formation through inadequate compaction

Tie-hole of the watertight tie 35 mm cone removed

Tie-hole unused

Bolt-head impression from the fixing bolt of the supporting frame.

Wall formwork – framed panel formwork



TRIO from the hire depot

With new formlining

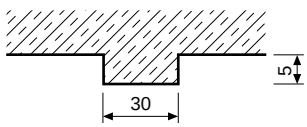
Pier projection about 50 mm formed with internal corner units and stopend formwork

Stacking

Unused row of tie-holes plugged with plugs in the formlining

Used row of tie-holes Lower panel 2.70 m high

Section



Used row of tie-holes

Wall formwork – framed panel formwork

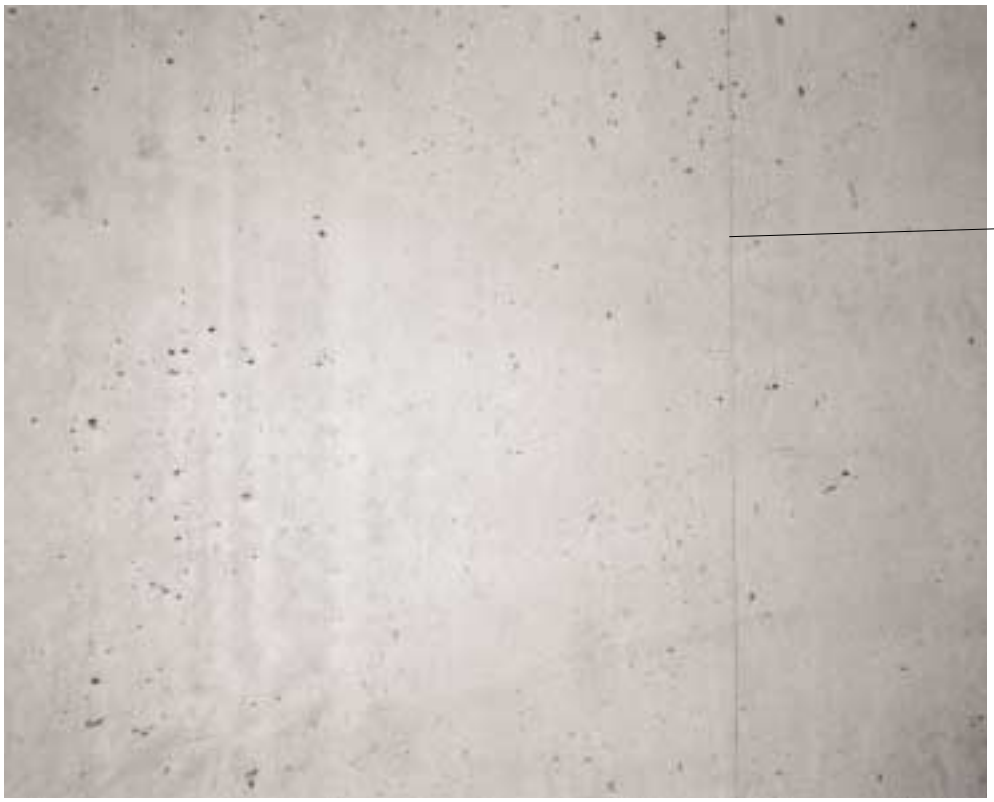
TRIO from the hire depot

with a new formlining

tie-holes formed with watertight cones, not yet plugged

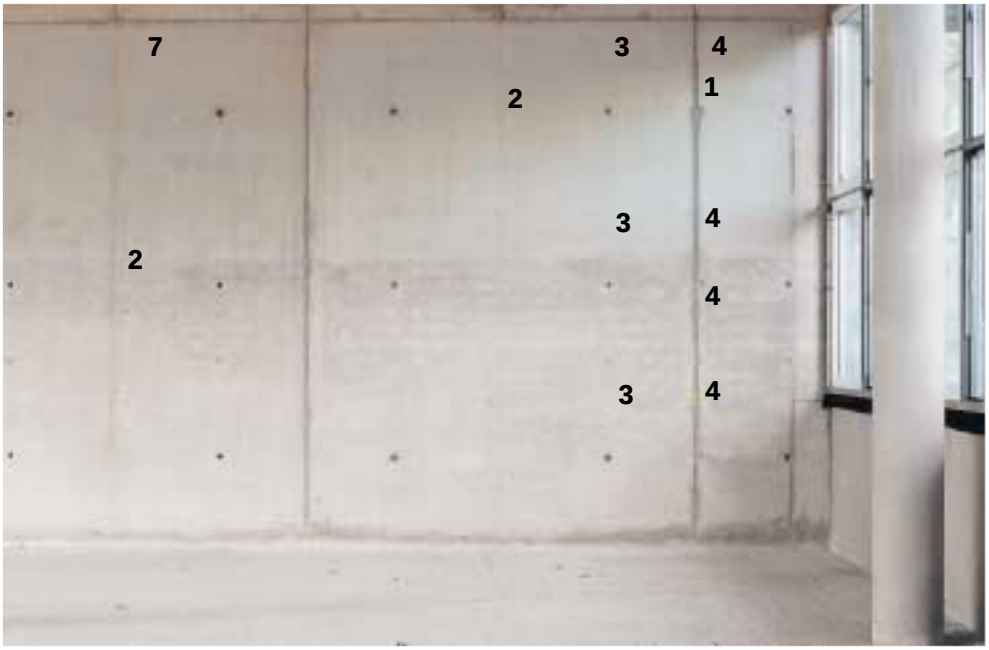
concrete not properly placed or compacted

panel joint with frame impression



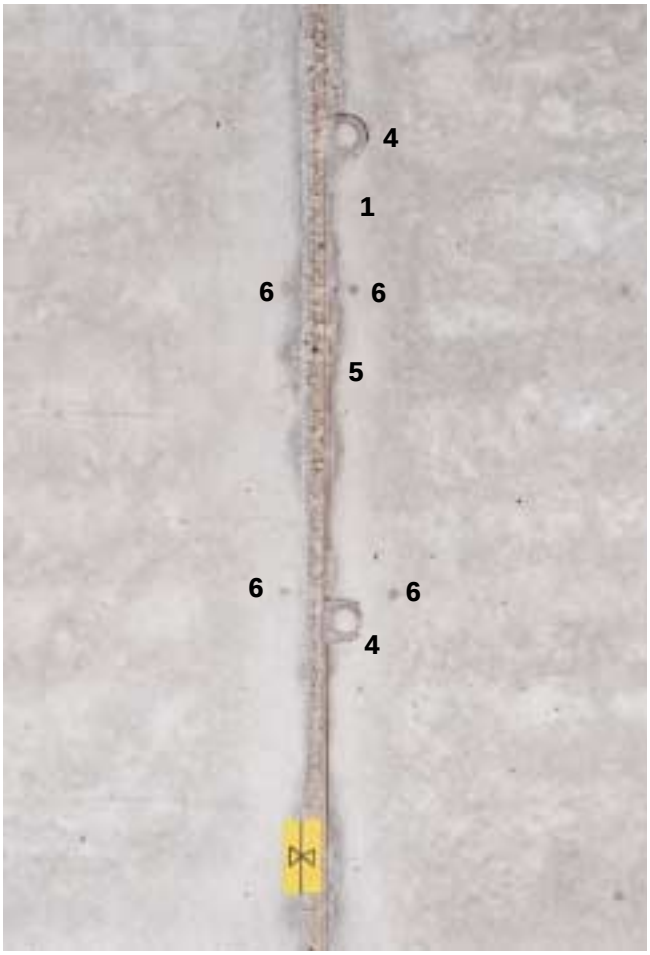
Formlining in the large unit

Wall formwork – framed panel formwork



TRIO from the hire depot with a new formlining

TRIO 3.30 m



Details

1 Joint between units

2 Formlining joint in the large unit

3 Tie-hole used

4 Tie-hole plugged

5 Unit joints normal without extra sealing, slight water and fines escape possible

6 Rivet impression of the formwork lining fixings

7 Rust plumes from connecting reinforcement

Wall formwork – framed panel formwork

TRIO from the hire depot with new formlining
Industrial fair-face concrete of a sewage plant
PERI watertight ties

5.2 Wall formwork – VARIO GT 24 girder formwork

Formlining – Derived timber panels
Size 2.00 x 4.00 m

Formlining chamfered at the joints and not extra sealed, therefore slight escape of water and fines, tie-hole positions are fixed.

Wall formwork – VARIO GT 24 girder formwork

Formlining – film-coated plywood panels (PERI Beto)

Formlining chamfered at the joints, thus nibs formed in the concrete, tie-hole positions fixed

View of wall with joints and tie pattern

Formlining joint

Wall formwork – VARIO GT 24 girder formwork

on a climbing scaffold

formlining – film-coated plywood panels with a board structure
horizontal concrete joints emphasized with double-chamfer laths

Wall formwork – VARIO GT 24 girder formwork

Industrial fair-face concrete

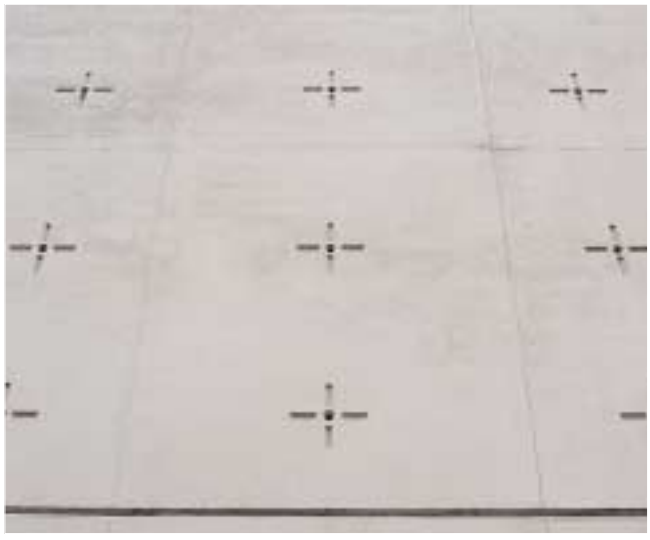
Formlining – film-coated plywood panels

Surface structure through plastic mould placed in the formwork

Wall formwork – VARIO GT 24 girder formwork

Formlining – film-coated plywood panels

Joints formed with Vario fair-face couplings so that there are no joint steps in the formlining
Joints and tie patterns, as well as window openings, are correlated.

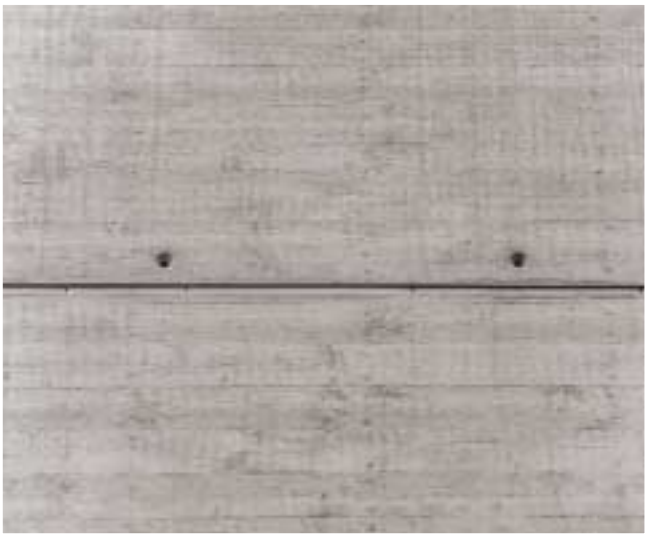


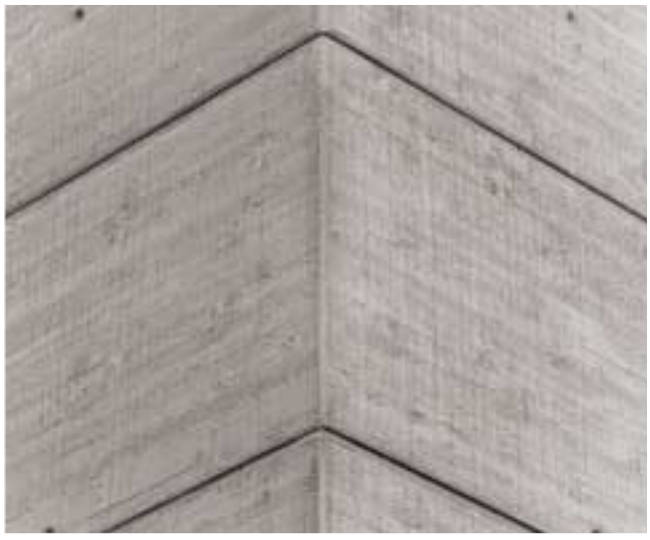
Wall formwork – VARIO GT 24 girder formwork

Tower – climbing formwork

Formlining – rough-sawn boards (rift sawn) tacked from the front, arranged horizontally

Horizontal construction joints with emphasized joint profile, vertical arrises of the walls broken by chamfered strips, low water and fines escape unavoidable through elasticity of the formwork



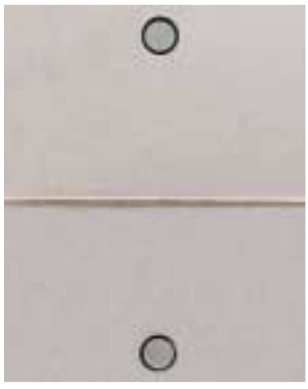


Wall formwork – VARIO GT 24 girder formwork

Formlining – made to measure film-coated plywood panels of Betoplan top, screwed from the rear

Unit width 3.84 m, joint grid in the height 820 – 1050 mm and tie grid strictly specified by the architect, thus expensive arrangement of extra walings and DW 20 ties necessary

Watertight ties with cones and shadow joints
Some formwork joints chamfered to form a concrete nib
Ties and concrete nibs



5.3 Circular walls

Formwork for a multi-storey car parking spindle

PERI RUNDFLEX girder formwork from the hire depot

Formwork height 3.90 m, formwork divided into
horizontal wall cycles and placed on a bracket scaffold

5.4 Slab formwork

SKYDECK panel slab formwork with dropheads
Slab soffit with joints arranged symmetrically

Slab soffit formed with modular tables from the hire depot
Formlining of film-coated plywood panels screwed from the front
Filler strips arranged between the columns

Vertical construction joints in wall formwork
Formation of joints

Wall formwork can be manufactured for any plan areas. The formwork systems have standard solutions for right-angled, obtuse and acute wall corners, abutting walls and stepped walls (see section 4.1). The picture of joints and tie spacings is affected by special formwork units for internal, and sometimes external corners, which appear on the concrete surface through the formlining.

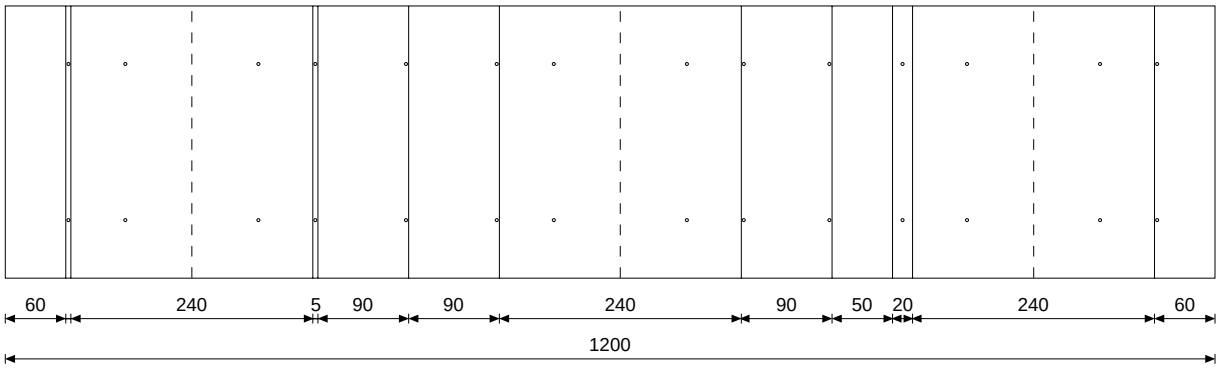
The principle is shown in the following with a wall formwork from the TRIO framed panel formwork system:

Section of a wall completely formed with wall corners and wall abutments. The influence of the formwork on the other side of the wall can be seen in the elevation of the continuously smooth external side of the wall, through the arrangement of formwork joints, filler strips and tie spacing.

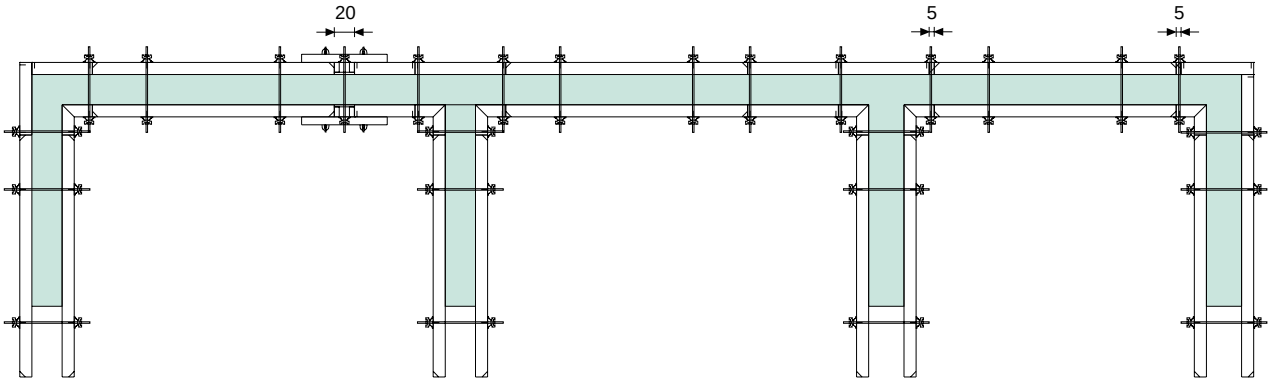
An orderly, possibly symmetrical picture of joints and ties, can be achieved if the fair-face concrete wall is formed straight through in a first cycle. After concreting and striking the abutting walls are then formed against the first wall in a second cycle. But there is the constructive problem of the reinforcement connections here as well as the arrangement of the joints to be clarified with the structural engineer. In addition the formwork connection to an existing wall is difficult to make and can lead to leaking joints.

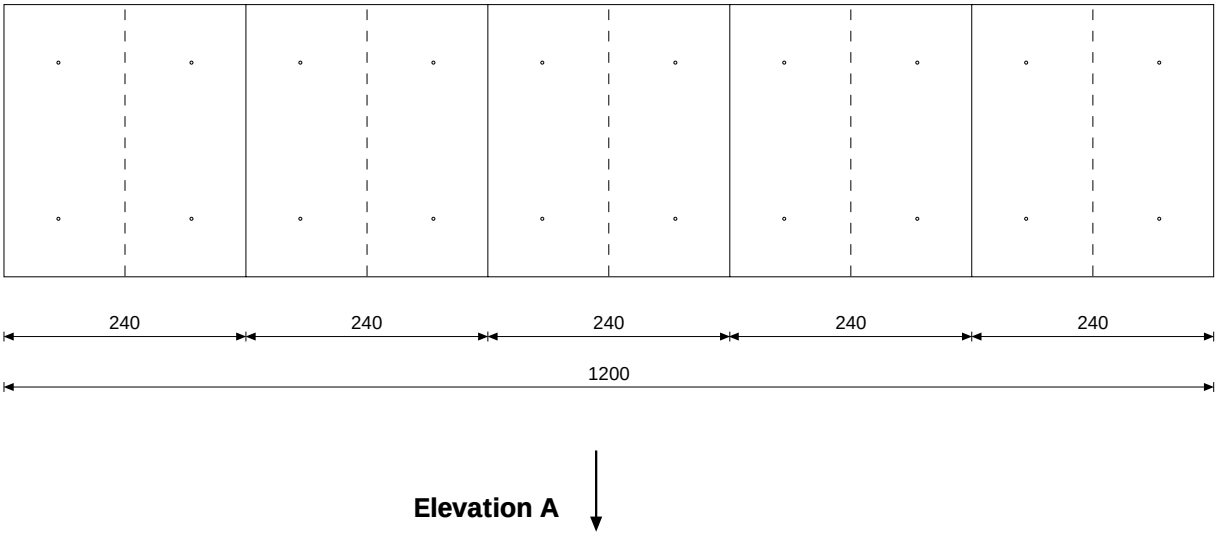
The example shows that an effective and aesthetically satisfying solution can only be achieved jointly between the architect, formwork planner and structural engineer.

Elevation A



Elevation A





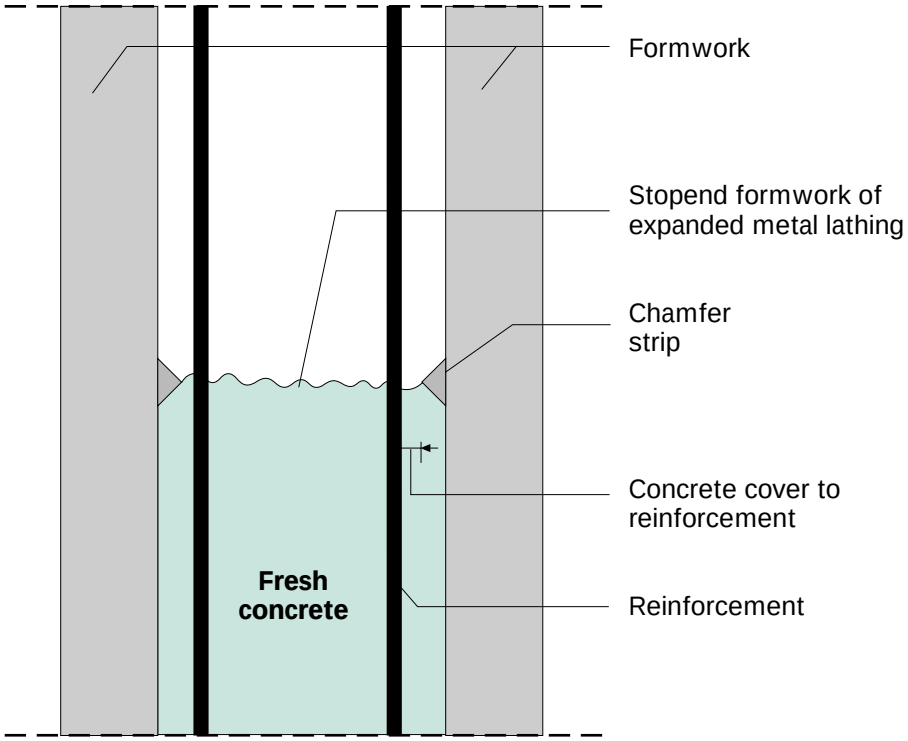
Cycle 1:
Continuous fair-face concrete wall
(Example with TRIO framed panel formwork in large panels)

Cycle 2:
Abutting walls
(Problem of sealing the connections to the existing wall)

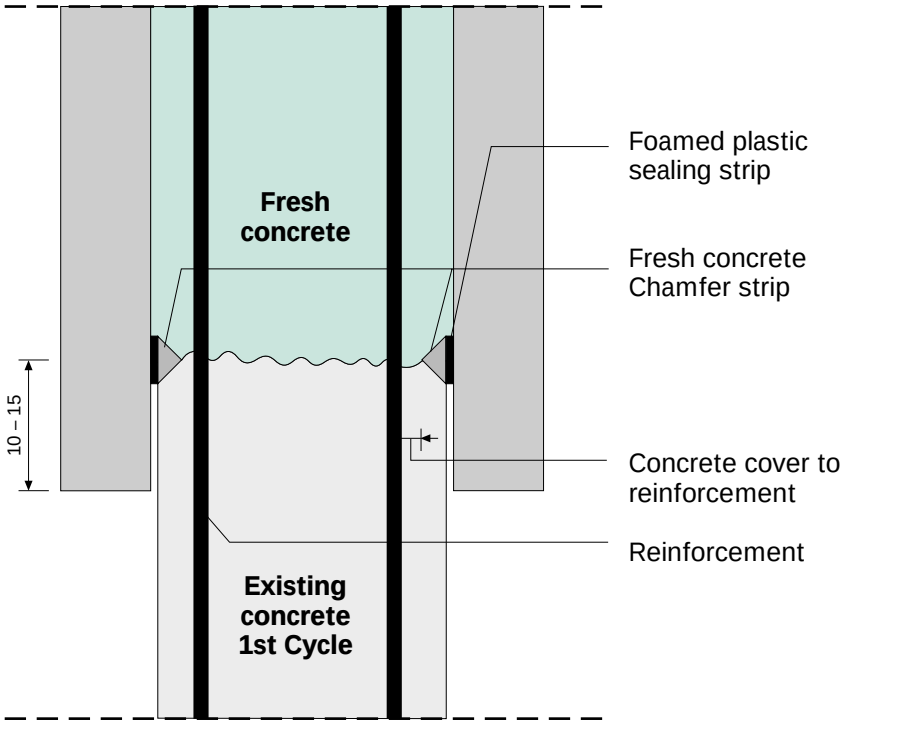
Wall formwork – vertical joint construction

Construction joint emphasized with chamfer strips
Plan view

1st Concreting cycle



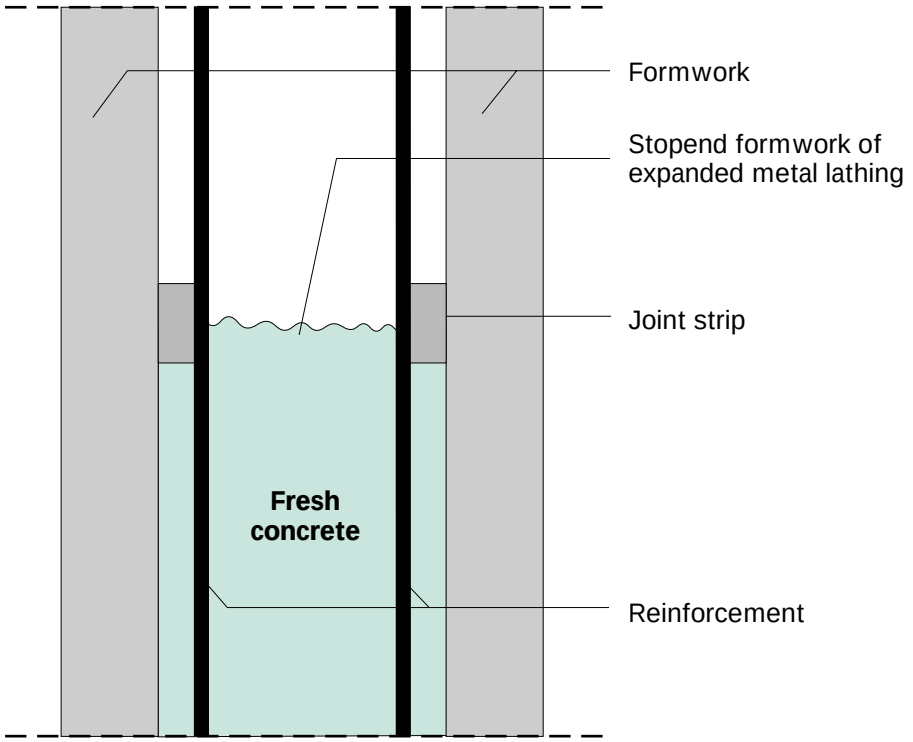
2nd Concreting cycle



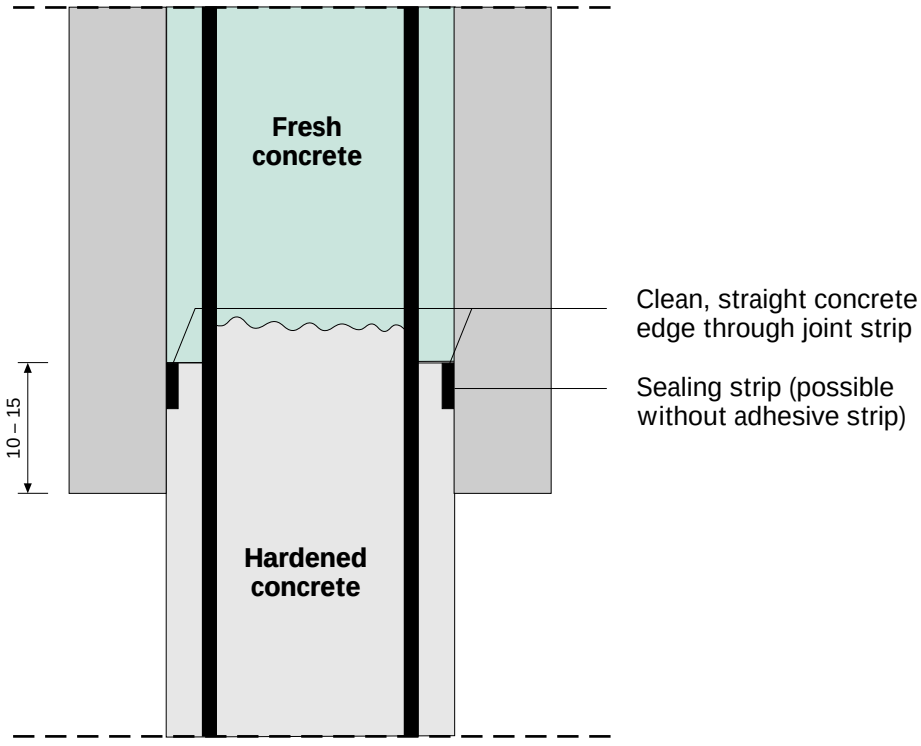
Wall formwork – vertical joint construction

Joint formed with a joint strip – joint visible in concrete
as a straight edge
Plan view

1st Concreting cycle



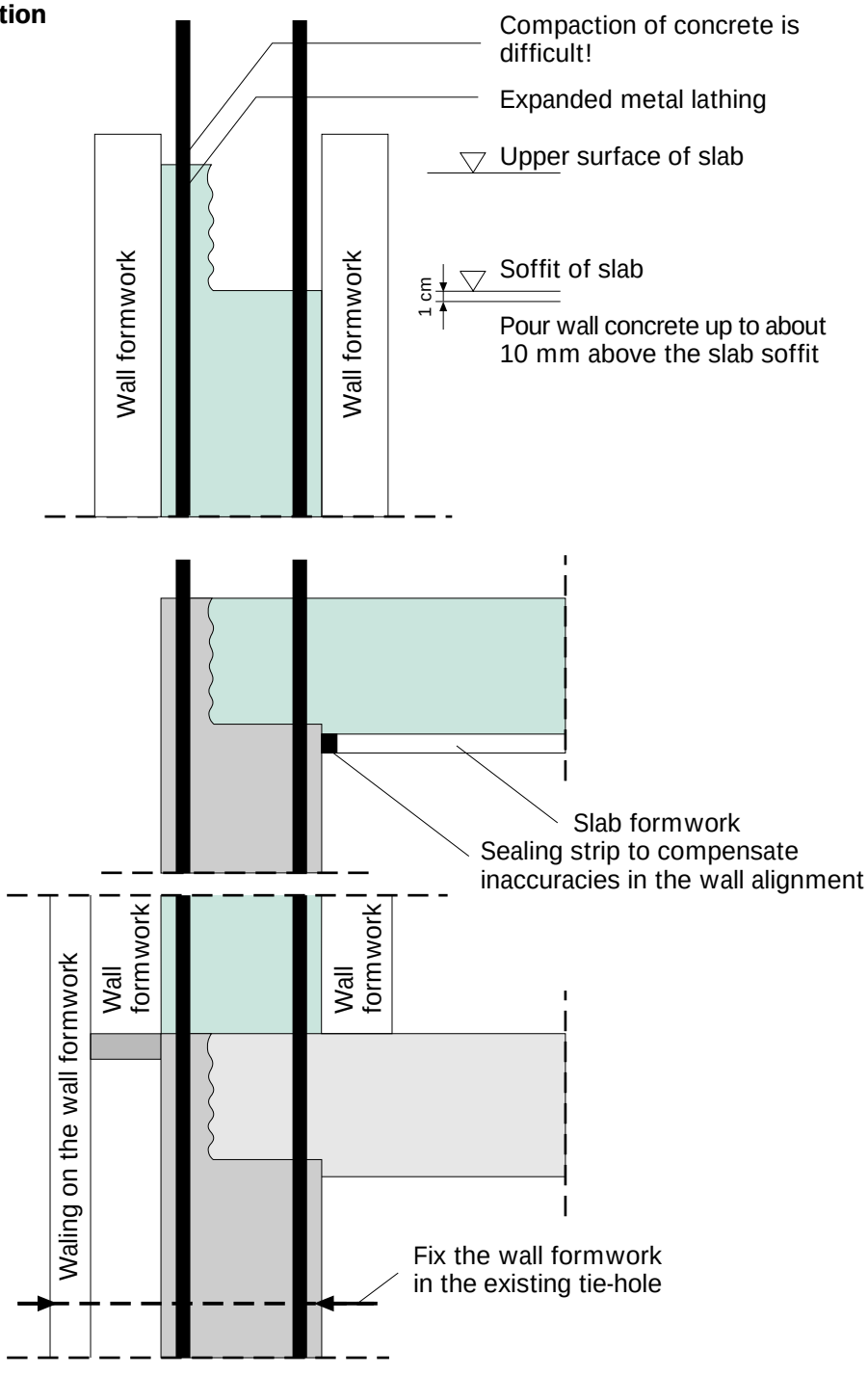
2nd Concreting cycle



Wall formwork – horizontal joint construction

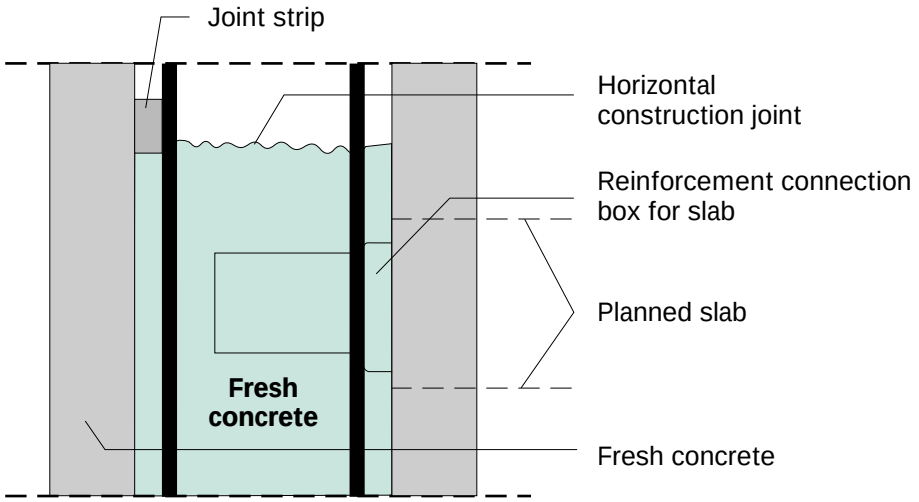
Joints formed as with vertical joints. There should be a drop arranged in the joint which falls away from the fair-face side. Rust water from the reinforcement will then be led away by this fall. Discolouration from escaping rusty water will then be prevented on the fair-face side.

Section
Joint formation
at the wall/slab connection

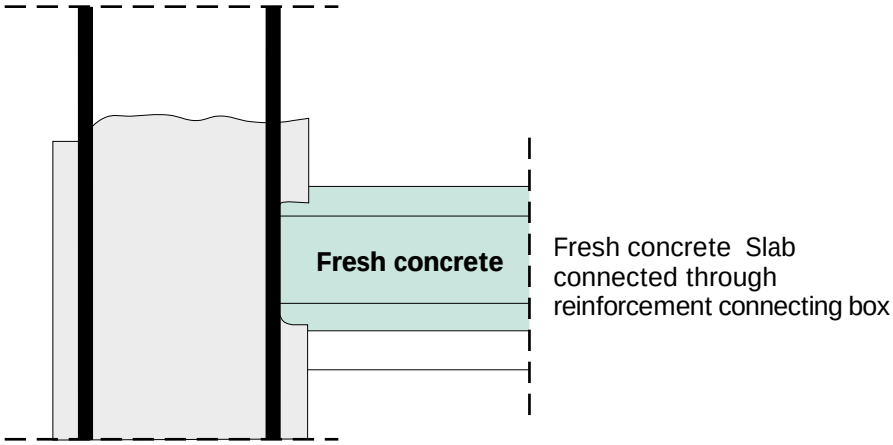


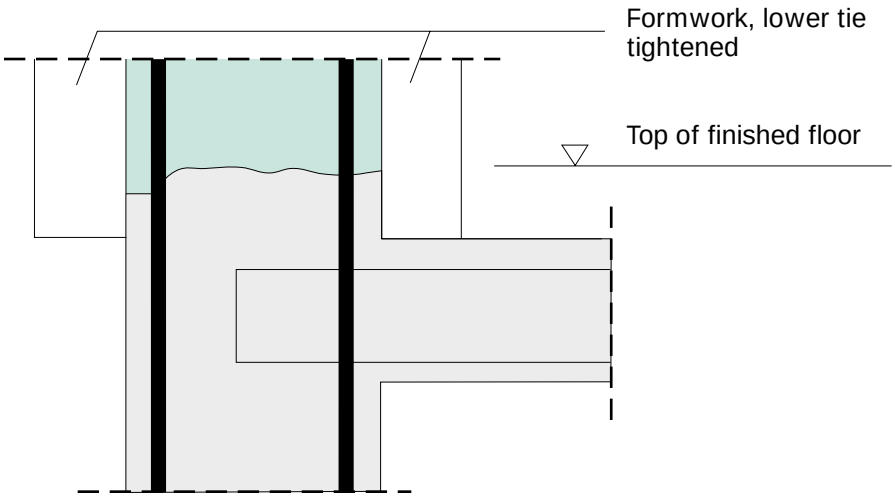
Connection of wall/slab through reinforcement connection

1st Concreting cycle



2nd Concreting cycle





7 Selection and influences from …

The following sections, "Selection and influences from ….", represent only a brief supplement to the whole complex of fair-face concrete, because these subjects do not directly concern the formwork. They are an introduction into each of the complex of subjects and make no claim to completeness. A detailed study of further literature is necessary.

7.1 DBV Code of Practice

In the following some hints from the DBV Code of Practice on fair-face concrete will be collected, as far as these were not included in the previous or following sections and those concerning fair-face concrete formed with formwork.

Sample formwork drawing

The planner should establish in this drawing, supplementary to the written description and the structural drawings, special features in the formwork (and the elevations), such as board widths, board direction and joints, arrangement of laths, tie cones and similar.

Basic construction rules

If visible areas are constructed, the high demands on their quality can only be fulfilled if the correct technical conditions for placing and compacting the concrete are present.

In arranging the reinforcement there are the following criteria to be considered:

- Maintain a minimum spacing of the construction components
- Provide sufficient concrete openings if necessary
- Ensure there are the necessary vibrating paths, and
- Select suitable spacers

Undercut formwork and cover formwork, as well as horizontal edges of laths and installation components can seriously prevent air escaping from the concrete under certain circumstances, which inevitably leads to the collection of larger air pores.

The shape of the concrete components suitable for the materials (height, thickness, installation components) must be made possible by proper forming of the edges and joints. When planning and specifying acute-angled walls, sharp arrises, edges and the like, it should be considered that despite great care when striking, edges can break off.

With constrictions and depressions, as well as with subsequent treatment, an adequate concrete cover is to be taken into account to protect the reinforcement from corrosion.

With weathered visible areas there must be a controlled outlet planned for the rainwater to prevent dirty plumes on the concrete surface.

Assessment and acceptance

Architectural design demands are made for visible areas that represent the individual aesthetic feelings of the planner or observer. Demands for the appearance in the specification must therefore have been described so exhaustively that a subsequent assessment is possible. Comparative buildings or sample areas are then to be taken into consideration in the assessment if they were contractually agreed. An objective assessment provides that there is the same knowledge in the areas of concrete technology, formwork techniques and building construction.

Every visible area is unique because of the permissible tolerances according to DIN 1045 in the concrete mix, the effects of the formlining, release agent and weather conditions on the appearance. Each building component of a structure can therefore only fulfill certain individual criteria within the framework of building materials over a permissible range. The assessment of a visible area is only reasonable when the concrete has gained a similar appearance after striking, depending on the concrete mix and environmental conditions. The concrete "ages" and is soiled as any other building material, i.e. the structure and colour can alter in the space of time.

The total optical impression of a building or part of a building should be assessed from a suitable distance. The following observation distances have proved to be correct in practice:

Building: The suitable distance corresponds with the distance that allows the important parts of the building to be seen. Important design features must thereby be recognizable.

Building: The suitable distance corresponds with the usual observation distance of the user.

There should be a total harmonious picture. Haphazard irregularities in the structure or the colour are characteristic for the technology of fair-face concrete and to be considered in the assessment of the total impression. Deviations, such as differences in colour shades in neighbouring formwork or concreting sections, or irregular pore distribution within an area, for example, may not be so large that they are felt to be disruptive with objective observation.

Individual criteria

With a definite construction task it may be necessary to call upon individual criteria for assessing concrete surfaces with demands on the appearance. But it is explicitly pointed out that the total impression is decisive for assessing these areas.

In the assessment it is to be checked whether the result of the work is typical for the type of building and materials on the basis of the contractually assured properties.

It is to be negatively assessed if certain avoidable deviations have systematically occurred that could have been avoided with a reasonable amount of work and none of these corrections was made during the construction period.

Avoidable deviations in the appearance of the visible areas are:

- Compaction faults (e.g. nests of aggregates, uncompacted places)
- Collections of rust signs
- Remains of mortar (“noses”) in vertical parts of the building on construction joints
- Arbitrary arrangement of formwork ties
- Unworkmanlike edges formed
- Heavily marked layers of concrete pours
- Large steps at the joints of formwork units and building component connections
- Heavy leakages (open aggregate structure through exit of cement paste) at formwork board and unit joints as well as at tie-holes (use of PERI tie cones with lip sealing)
- Heavy water streaking effects
- Heavy clouding and marbling
- Colour differences as a result of dirty or improperly stored formwork, formlining not “aged” or repaired formlining with new boards
- Closing of tie-holes is not clean or irregular, if demanded

Deviations in the appearance of the visible areas that could be avoided are those that can be avoided through certain measures, but the success of which does not always occur, such as:

- Clouding and marbling formations
- Colour differences between successive concrete pour layers
- Accumulation of pores in the upper part of vertical building components through missing concrete load for removing air.
- Reinforcement or large aggregate markings as a result of touching the reinforcement when compacting (different water/cement ratios). Single reinforcement rods are to be preferred to fabric reinforcement because the vibration transfer is lower
- Slight leaking at formwork board and unit joints as well as at tie-holes (tie cones)
- Water streaking effects in low numbers and extent
- Single lime and rust plumes on vertical building components
- Discolouration of soffits of horizontal building components through rust deposits on the formlining from the reinforcement
- Small breakages on edges in executing sharp edges

Demands on the visible area that cannot be safely fulfilled in the construction work are:

- Completely similar shade of colour on all visible areas
- Completely similar pore structure (pore size and distribution), visible areas free of pores
- In situ concrete components free of leakages

Improvements

Despite the greatest care there can be faults in executing concrete areas with demands for the appearance,. DIN 18217, section 2.3.1, therefore provides for material and workmanlike improvements for such areas.

Improvement places usually remain visible as such, even with the greatest of workmanship ability. It should therefore be carefully checked and considered whether an improvement of small optical faults can be waived.

7.2 Selection and influences of the release agent

In DIN 1045, part 3, it is required for the use of release agents that:

(1) Only release agents that neither damage the concrete, the reinforcement or the formwork may be used.

(2) Release agents may not detrimentally affect the surface quality of the concrete.

(3) The manufacturers instructions for applying the release agent are to be applied.

The DBV Code of Practice (DBV = German Concrete and Construction Technology Association e.V.) "Release agents for concrete – Part A – Hints on selection and application", issued March 1997 and "Part B – Testing", issued August 1999, should be used as a working basis for selecting and assessing the release agent.

The release agent selection is above all dependent on the type of formwork used, according to the construction conditions for the concrete (e.g. heated concrete) and according to the special requirements for the building component to be constructed (e.g. drinking water container, fair-face concrete etc.).

The selection of a suitable release agent should be absolutely left to the contractor. Only release agents should be used that comply with the general requirements of the above Code of Practice:

"Release agents should, as far as possible, make the striking from concrete components easy without unwanted secondary effects, by reducing the adhesion between the formlining and the hardened concrete."

Unwanted secondary effects are, for example:

- **Effects on the concrete surface**
  – increased formation of spots and pores
  – sanding, heavy dusting, disruptions in the hardening
- **Effects on the adhesion properties of subsequent building materials (e.g. plaster, adhesive, paints) through release agent residues**
  – slow weathering
  – residual chemical effects
- **Effects on the formwork**
  – promotes rust on steel formwork
  – swelling or buckling of timber formwork or coated timber materials
  – etching of plastic formwork

Further special requirements for the release agent are to be named in the tender documents, such as:

- Increased abrasion resistance to ZTV-BEL-B (Extra Technical Contract Conditions and Guidelines for Constructing Bridge Coverings on Concrete)
- Suitability for drinking water containers

The contractor should have the suitability confirmed by the manufacturer. Sample concrete areas are basically to be constructed before each use of a release agent to prove the effectiveness and compatibility of the release agent with the formwork, the formlining and the concrete. This sample is absolutely necessary for fair-face concrete.

A thin, equal application of the release agent with an adequate release effect is especially important for fair-face concrete. After the release agent is applied, surplus release agent should be removed with a rubber scraper or similar. This is to be carried out especially on non-absorbent formlinings (film-coated panels) to obtain an equal application of the release agent.

The use of biologically well-degradable release agents on the basis of plant oils or ester can form a good culture medium for micro-organisms. This can lead to an increased growth of microbes on the concrete surface and thus to effects on the appearance.

Both release agents of PERI

PERI – Clean
PERI – Bioclean

are products on a mineral oil basis and fulfill the above general requirements for a release agent according to the DBV Code of Practice. They are suitable for all normally used formlinings and formwork.

PERI – Bioclean also fulfills higher demands, such as:

- Fast biologically degradable (RAL-ZU 64 = blue angel environmental sign)
- KTW recommendation (plastic - drinking water)
- Multiplication of micro-organisms on materials for the drinking water area to Working Paper W 270 of the DVGW (German Association for Gas and Water Trades e.V.)

Other hints and product features can be seen in each of the product informations on release agents.

7.3 Reinforcement and ability to concrete building components

DBV Code of Practice "Ability to Concrete Building Components of Concrete and Reinforced Concrete – Planning and Execution Recommendations for Concrete Placing" (issued 11/96).

7.3.1 Basic rules

Building component cross-sections are to be so sized, and the reinforcement so arranged, that the placing of the concrete is possible with the best possible complete compaction without separation. Formwork, reinforcement and installation components may not prevent the exit of the air that collects on the surface of the fresh concrete through compaction. Information is to be given on openings in the concrete, vibrator holes and concrete cover in the working drawings. A reduction in the large aggregates and/or the use of flow concrete can be necessary for narrow cross-sections and where reinforcement is concentrated. This information is to be fixed in the working drawings.

7.3.2 Arrangement of reinforcement for placing concrete

Concreting openings
The concreting openings in the reinforcement are to be designed at least 40 mm larger than the diameter of the concrete placing tubes or hoses. According to this the minimum wall thickness of the building component, apart from the static requirements, is provided by the diameter of the placing tube or hose + Σ of the reinforcement diameter lying above each other + concrete cover.

The spacing of the concreting openings, that are dependent on the building component sizes and the density of the reinforcement, should usually lie between 2.0 to 2.5 m. With closer reinforcement, e.g at intersections of high beams or secondary beams, a smaller spacing of about 1.0 to 1.5 m is recommended. For slab-types of building components of up to 0.5 m thick, with a close grid of upper reinforcement, vibrator holes are usually adequate as concreting openings.

Vibrator holes
According to DIN 1045, part 3, section 6.4, the reinforcement is to be so arranged that a poker vibrator can be introduced from all necessary sides. To estimate the spacing of immersion points there is the following rule of thumb: spacing of vibrator immersion points in mm = diameter of the poker vibrator in mm x 10. For lightweight concrete this spacing is to be reduced by half. For thin and heavily reinforced building components the spacing of vibrator holes of about 250 mm is recommended. The width of the vibrator hole is 60 to 100 mm, preferably 100 mm.

The use of individual rod reinforcement is to be preferred to fabric reinforcement because vibrations are not transferred so easily.

Minimum spacing of rods

The minimum spacing of rod reinforcement is to be maintained. Independent of concrete openings and vibrator holes, according to DIN 1045, part 1, section 9.2, the minimum spacing is max. diam. d_s or 20 mm, with the largest aggregate > 16 mm = max. d_s + 5 mm.

With a crossed arrangement of reinforcing rods the minimum spacing in the upper layer should be enlarged to the size s = d_k 10 mm, whereby dk is the largest aggregate diameter. The largest aggregate diameter is usually 32 mm. If another aggregate is used this must be clearly noted on the reinforcement drawings (e.g. d_k = 8 mm or d_k = 16 mm).

Concrete cover
The nominal size C_{nom} of the concrete cover is composed of the minimum size C_{min} and a leading size Δc

$$c_{nom} = c_{min} + \Delta c$$

The type and number of spacers and supporting cages for the upper reinforcement are to be given in the reinforcement drawings.

7.4 Fresh concrete – project management, manufacture, transport and placing

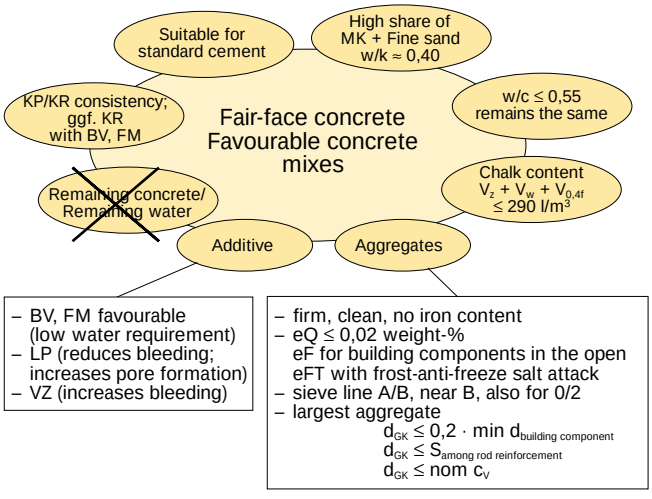
Qualitatively good, and at the same time aesthetically appealing fair-face concrete surfaces can only be achieved if appropriately high demands are made on the mix, manufacture and placing of the concrete, and these are also fulfilled.
The whole problems of concrete cannot be exhaustively treated here and therefore there are a few hints in the following as suggestions for further investigation and determination. The principal person responsible for the project management, manufacture, transport and placing of fair-face concrete should be the concrete engineer demanded for the fair-face concrete team in Section.

Concrete planning

The concrete engineer has to select a suitable concrete from the types of concrete of the ready-mixed concrete supplier or design an appropriate concrete mix according to the requirements. The following hints apply to this:

- the concrete should not tend to bleed nor have too much adhesion
- low shrinkage with low water content, favourable particle size distribution curve and an adequately high mortar content
- use the DIN 1045 for the maximum values of fine aggregates and sand
- cement affects the colour of the concrete, but this is covered by
- differences in the water/cement ratio
- waiting times between individual layers when placing
- irregular and inadequate compaction
  typical grey shade through Portland cement
- with increasing iron oxide content darker, with blast furnace cement lighter with increasing content of blast furnace sand
- concrete liquefier or flow medium reduces the water content. Carry out trials when using flow mediums to avoid unwanted colour differences
- coal ash (f) can reduce the water content of the concrete, but its use for fair-face concrete has problems.

For hints on concrete mixes see illustration:

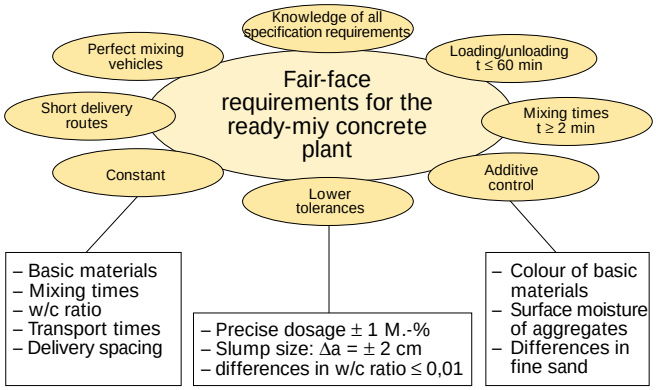


Favourable concrete mixes for fair-face concrete

Ready-mixed concrete plant

The ready mixed concrete plant must not only have knowledge of the concrete mix and the delivery address but also be informed of all demands made in the specification and peculiarities of the fair-face concrete areas.

The demands for the ready-mixed concrete plant are summarized in the following illustration:



Fair-face requirements for the ready-mix concrete plant

To be observed are:

- peculiarities of transport times, delivery spacing, accurate dosage and mixing times
- extra controls on the materials supplied
- Uniformity of the concrete consistency
- Continual supervision of the concrete on site
- Ready-mixed concrete plants with short delivery routes to site to be preferred
- Do not change the type or supplier of the basic materials during concreting and supervise the cement and aggregates for uniform colours
- Continually take into account the surface moisture of the aggregates
- Regular control of the differences in the fine sand area
- Completely empty ready-mixed concrete vehicles before taking on new concrete (also remaining water)

Concrete placing

- An experienced concreting team is to be used for fair-face concrete, which has to be properly instructed. The fair-face concrete quality should be practiced by the placing team on a subordinate part of the building.
- Time differences in placing are to be avoided.
- Large drop heights and concrete heaps when placing concrete lead to separation of the aggregates and leave many blowholes.
- It is recommended to place concrete in layers of < 500 mm (with rebars close together < 300 mm).
- Limiting the free drop height of the concrete in high building components to a maximum of 1.50 m is to be ensured by using concrete chutes or pipes.
- The concrete is to be filled in the middle and not against the formwork.
- High building components are to be constructed with a connecting mix as a drop buffer.
- Workmanlike compaction to DIN 4235
- Subsequent treatment of the concrete to protect against drying out and cooling by hanging up waterproof tarpaulins at a short spacing, thus avoiding "chimney effect" in the intermediate space.
- Do not strike the formwork in rain. There is the danger of blooming through rainwater running down.
- Placing concrete in high or low outside temperatures is to be avoided.

Installation components and blockouts

Installation components must have ventilation openings to avoid blowholes on the cover side, or these are to be formed sloping for ventilation. With large blockouts (blockout width larger than the penetration spacing of the vibrator) the use of flow concrete is sensible.

Construction joints

The forming of construction joints and sealing them with the help of metal or rubber joint strips, injection hoses, swelling bands etc., is determined by the planner, whilst the position of construction joints is usually determined together with the contractor.

7.5 Concrete compaction

Fair-face specifications often demand a concrete surface free of pores or with only a slight percentage of pores. These are air and water pores that are present in the fresh concrete and their percentage can be reduced by compacting. Vibrators (poker or formwork vibrators) are used for this.

DIN 4235 "Compaction of concrete by vibrators"

governs the use of these appliances.

The following extracts on the proper use of vibrator appliances to achieve an ideally compacted concrete are from
Part 2 – Compaction with poker vibrators and

Part 4 – Compaction of in situ concrete with formwork vibrators.

Part 2 – Poker vibrators

… The vibrator is to be quickly submerged in the concrete and, after a short time at the deepest point, slowly withdrawn so that no holes remain behind the vibrator. The escape of any trapped air is made easy by this method.

In fresh concrete that is practically completely vibrated there are still air pores. Some such pores are also on the formwork surface. Fresh concrete that is practically completely compacted generally contains a natural air pore content of about 1.5% volume.

As the remaining pores are not connected and their volume is low they have no importance for the strength of the concrete and its permeability.
As far as the conditions of the building component allow, the concrete is to be poured as compact and horizontal on the surface as possible. The height of each layer should not be larger than 0.50 m

Even with higher concreting speeds, individual pours that follow each other should be separately compacted and not higher than 0.50 m.
The poker vibrator may not be submerged too near the formwork surface, especially when the formwork is weak and can be heavily vibrated. The best spacing of the vibrator from the formwork is dependent on its effective radius. It should be a little smaller than the effective radius.

Air can be drawn in at unsealed joints through the different vibrations of concrete and formwork, e.g. when placing powerful vibrators too near the formwork. The results are a structure full of holes and sandy places in the area of the unsealed formwork joints.

The reinforcement is to be arranged so that poker vibrators can be introduced at the necessary spacing. Long contact of the vibrator with the reinforcement is usually to be avoided because watery cement paste can then collect on the reinforcing rods.

Vibrating on visible concrete surfaces

To obtain the best possible and similar surfaces, the concrete is to be of the right mix, and to be especially equally poured and compacted. The height of each pour should not be more than 0.30 m. The vibrator is always to be immersed at the same depth in the lower, already compacted layer. The period of vibrating is to be restricted to the minimum. The submerging points of the vibrator are to be distributed evenly. It can be useful to use vibrators of Group 1 < 40 mm diam. along the formwork. Touching reinforcement lying near the formwork can result in this showing on the concrete surface.

Part 4 – Formwork vibrators

The vibrator is fixed to stiffeners so that a large area of the formwork is vibrated. Attaching directly to the formlining is to be avoided. With vibrators of Group 1 there is often a spacing of 1.5 to 2.5 m.

It is recommended to set vertical formwork walls on rubber strips so that the vibration is less reduced. This also serves to seal better.

The vibrator should only be operated when the formwork is filled with concrete a little above the point where the vibrator is fixed. The height of other layers should be 0.25 to 0.30 m.

High building components that are quickly concreted, especially concrete surfaces that remain visible, should be subsequently compacted with formwork vibrators or hammering the formwork to remove islands of water that leave sandy streaks on the formwork area and air pores on the concrete surface.

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