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Execution of Concrete Structures

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National foreword
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0 Foreword

The Standards DS 481, Concrete Materials, and DS 482, Execution of Concrete Constructions, are prepared to substitute BBB (Basic Concrete Specifications) and supplement DS 411, Norm for Concrete Constructions.

0.1 Transition provisions

For a period of 1 year from the issue of this standard, use of DS 411, 3rd Edition1984, BBB or DS 411, 4th Edition 1999, and this standard will be allowed.

The standard is prepared under the precondition that the Building Material Directive is fully operational, i.e., that the affiliated harmonised standards, with matching systems for attestation of conformation, exist.

In the hitherto editions of the norms and BBB, reference has been made to approved control arrangements.

To ensure continuity between the hitherto norms and BBB and until the harmonised standards are available, the products in this standard must be subject to the stated control arrangements or it must be possible to document that the requirements in this standard have been observed, until the aforementioned harmonised standards are available.

Premixed Concrete: The Fabricated Concrete Control, Dansk Beton Certificering
Sand and gravel materials: The Sand and Stone Control, Dansk Grus Certificering
Normal Concrete in Lightweight Elements: The Lightweight Concrete Control
Concrete Elements: Danish Concrete Certification (Dansk Beton Certificering)

As an alternative to the aforementioned control systems, control or certification systems that have been established with a view to achieving the requirements in the forthcoming harmonised standards can be used. These control systems must be pre-notified.

Note: Attestation Method S in this standard is equivalent to the European System 2+, which will be the most likely attestation system for building materials within the area of concrete, including aggregate materials, premixed concrete, concrete elements, concrete repairs and concrete additives.

1 Introduction

The Standard, DS 482: Execution of Concrete Constructions, is used for the execution of buildings and civil engineering constructions, including the manufacture of concrete elements.

The standard is valid for the execution of concrete constructions in accordance with DS 411, Norm for Concrete Constructions, with the affiliated standard DS 481: Concrete – Materials.

DS 411 refers to Sections 5 to 9 and Section 12 in DS 482.
Text that is written as notes are guidance notes.

2 References

The list of standards, testing methods and other documents listed below are referred to in the present standard. For the stated standards, where a date year is not given, the current edition is valid.

DS 409	Norm for safety provisions for constructions
DS 410	Norm for loads on constructions
DS 411	Norm for Concrete Constructions
DS 423.17	Fresh Concrete. Setting
DS 423.37	Curing Concrete, Development of Heat
DS 481	Concrete - Aggregate
DS/EN/ISO 9001	Quality Assurance Systems. Requirements for development, construction, production, installation, and service.
DS/EN/ISO 9002	Quality Assurance Systems. Requirements for production and installation.
DS 13080	Reinforcement Steel. Reinforcement bars used for non pre-stressed concrete constructions.
DS 13082	Reinforcement Steel. Machine-welding (automatic) of reinforcement units.
DS 13083	Reinforcement Steel. Manual welding of reinforcement units.
DS 13084	Reinforcement Steel. Reinforcement steel in coils used for non pre-stressed reinforcement in concrete constructions.
DS/EN 523	Thin steel pipe lining for pre-stressed cables. Terminology, requirements and quality control.
DS/EN 446	Injection mortar for pre-stressed cables. Requirements for execution.
DS/EN 447	Injection mortar for pre-stressed cables. Requirements for ordinary injection mortar.
ISO 8501-1	Preparation of steel substrates before application of paints and related products; visual assessment of surface cleanliness; Part 1: Rest grades and preparation grades of uncoated steel substrates and of steel substrates and of steel substrates after overall removal of previous coatings.
DS/EN 10025	Hot rolled products of unalloyed constructions- and machine steel. Technical Delivery Stipulations.
DS 10601	Heat treatment of metallic materials in solid state. Nomenclature and definitions.
DS/ENV 1992-1-1	Eurocode no.2, Concrete Constructions. General rules and regulations for building constructions.
DS/ISO 2859-1	Methods for random inspections during measuring with alternative variation: Part 1: Random Inspection Plans set up after satisfactory quality level (AQL) for inspection of quantities in consecutive order.

DS/ISO 2859-1	Methods for random inspections during measuring with alternative variation: Part 1: Random Inspection Plans set up after non-satisfactory quality level (LQ) for inspection of single quantities.
ISO 3951	Sampling procedures and charts for inspection by variables for percent non-confirmation.
TI-B33	Gauging of concrete sealing materials´ effect, October 1992

3 Definitions

Accreditation Authority:
National Authority that is authorised to accredit certification agencies and, which is covered by a Multilateral Agreement (MLA) that also includes DANAK.

Basis placement:
Expression for module-lines or levels, etc.

Concrete Elements:
Elements made of concrete that are produced under uniform conditions, cast and set at a place other than the place of their use.

Cover Layer:
Note: Cover Layer is defined in DS 411

Post-stressed:
Stressed concrete, where the reinforcement is stressed after the concrete has set (cured).

Factory Concrete:
Concrete that is produced at a stationary mixing plant and delivered in fresh condition to the operatives on site.

Fresh Concrete:
Concrete that is premixed and in such a condition that it is still adaptable and formable.

Pre-stressed Concrete:
Pre-stressed concrete, where the reinforcement is stressed before the concrete sets.

Cured Concrete:
Concrete, which has set and hardened and has developed strength due to a reaction between cement and water.

Identification Control:
Is a control of whether the delivery is without visible flaws and in accordance with the information stated in the delivery note.

Control Section:
Splitting-up of a project’s activities in relationship to time, quantity or construction component.

Control Class:
Note: Control Class is defined in DS 411

Delivery:
The process whereby the product is delivered to the recipient.

Load:
Two or more shipments of the same concrete recipe (mix), which are homogenised in a concrete mixer truck and delivered together.

Environmental Class:
Note: Environmental Class is defined in DS 411.

Recipient:
The contractor, who is responsible at delivery.

Rise:
The construction's surplus height.

In-situ mixed concrete:
Concrete, whose aggregate is mixed on site by the contractor.

Product Certification Agency:
An agency, which is accredited by an accreditation authority to certify in accordance with defined product standards.

Product Certificate:
Certificate issued by a product certification agency.

Project Specification:
The total project materials, which specifies the technical requirements for the construction.

Shipment:
The amount of concrete, which has been mixed in one operation.

Stressed Concrete:
Reinforced concrete where there, due to the stressing (tension) of the whole or parts of the reinforcement, a condition of pre-stressing has been established. The tensioned reinforcement is called stressed reinforcement.

Tension (stressing) Lists:
List that states the sequence, etc., for stressing/tensioning of the stressed reinforcement.

Stressing/Tension Systems:
The total equipment/plant/auxiliary equipment required to stress reinforcement, including anchorage, wedges and wedge-housing, stressing/tension machinery and stressing bench, for pre-stressed constructions.

Symbols:
Note: Symbols is defined in DS 411.

System Certification Agency:
An agency, which is accredited by an accreditation authority to certify in accordance with defined quality control standards.

System Certificate:
A certificate issued by a system certification agency.

Contractor:
Company executing the construction.

Execution:
All activities that are put into motion to execute a construction, for example, scaffolding, formwork, reinforcement work, pouring of concrete, post-treatment of the construction, element mounting, etc., with affiliated control and documentation.

4 Documentation

The present standard presumes that the following are available:
- Project Specification
- Quality Plan
- Documentation for Execution
- Chosen method for attestation of conformity

4.1 Project Specification

The project specification must contain all the necessary information for execution; including technical requirements with matching accept criteria and requirements for documentation.

The project specification must, as a minimum, state:
- The construction's geometry
- Shape for reinforcement
- Identification of reinforcement
- The form and identification of permanent inserts and fittings
- The identification of the concrete type
- Environmental Class
- Control Class
- Cover layer of concrete

Note: The project specifications can also contain requirement for:
- The content of the Quality Plan
- Control Sections
- Type and extent of documentation
- Trial/Sample (concrete) pours and their purpose
- The formation of casting joint and their location in the construction
- Material specification in connection with casting together of components
- Limitation of the formation of cracks at casting joint and between cast cross sections with different dimensions.
- Electrical contact between reinforcement and inserts and fittings, which are cast into the construction, etc.
- Surface treatment of reinforcement
- Programme/plan for pouring concrete
- Spacers (distance spacers)
- Tension Lists
- Tension Systems
- Under what conditions welding of reinforcement is allowed
- Special requirements to the cover layer, due to special reinforcement materials or constructive design
- Tolerances (geometry, reinforcement and cover layer, and requirements for verification)
- Air-pore analysis and/or frost testing of samples taken out of the pours during construction.
- Protection against drying-out in Passive Environmental Class, and requirements for measuring of heat development.
- Maximum permissible temperature difference during curing of concrete.
- Strength at striking of formwork, with regard to both strength and rigidity.
- Characteristic Concrete Strength at time of pre-stressing.
- Requirements for surface structure
- Requirements for measuring of cover layer after pouring
- Rise, for example, at delivery of concrete elements and after removal of formwork.
- The building's stability, temporary shoring/supporting

- Other material specifications, for example for repair and finish.
- Other special conditions.

The works contractor must ensure that all necessary information, for the execution of the building component, is available at execution.

NOTE: The project specifications should stipulate requirements for distribution and filing of documents, which are used for execution of the construction.

4.2 Quality Plan

The works contractor must establish a quality plan for the execution of the construction or works. The extent of the quality plan must be adjusted to the project specifications.

NOTE: See section 11.1

4.3 Documentation for execution

The execution must be documented, see Chapter 12.

NOTE: The project specification should establish the type and extent of documentation for the execution. The documentation should include:

- Certificates for materials or suppliers´ attestation of compliancy with specifications.
- Possible alterations to the project specifications
- Drawing materials for the whole construction inclusive concrete elements, with as built data.
- Control data
- A description of the corrected actions with documentation for their implementation.
- A description of repair work and control data for said works
- All the above points can be reported individually, for example as separate documents.

4.3.1. Attestation of conformity for concrete elements

With production of concrete elements based on random sample control, the methods stated below for attestation of conformity should be used:

Method A

Attestation of conformity comprises:

- an accredited system certificate, which shows that the quality system is in compliance with DS/EN/ISO 9001 or 9002, and
- an accredited product certificate that, based on a 2 yearly audit and 2 yearly report of results from own control, shows that the demands for execution are in compliance with DS 482. All demands in DS 482 must be audited in the course of a 3 year period.

Method B

Attestation of conformity includes an accredited product certificate which, on the basis of a 2 yearly audit and 2 yearly reporting of results from own control, shows that the demands for execution comply with DS 482. All demands in DS 482 must be audited during the course of a period of 3 years.

Method S

Attestation of conformity encompasses:

- an accredited system certificate that states conformity for the relevant production control system with DS/EN ISO 9001/9002

NOTE: Attestation method S will be equivalent to the European System 2+, which will be the most likely attestation system for building materials within the concrete area, including aggregate, pre-mixed concrete, concrete elements, concrete repairs and additives.

Method C

Attestation of conformity includes the executing contractor’s own declaration that states the construction’s conformity with DS 482.

NOTE: The 4 possible attestation methods will give the recipient of concrete elements the assurance for conformity with DS 482 under the condition that the methods described in DS 482, about Material-, Delivery- and Execution Control, are implemented.

5 Scaffolding and Formwork

5.1 Materials

Materials, being used for the formwork, must not damage the concrete.

5.2 Tightness, strength and rigidity

The formwork must be so tight as to ensure the characteristics of the concrete.

The formwork's individual parts, joints, supports and scaffolding and their foundation must be made secure with due consideration to the loads that they can be subjected to, and with a view to achieving the requirements for the concrete's geometry and its affiliated tolerances.

Formworks´, supports´ and scaffoldings´ load bearing capacity must conform to current construction norms.

NOTE: When dimensioning the strength of formwork, supports, and scaffolding, etc., the following should be taken into account:

Basis for the calculation
Formwork and scaffolding should be evaluated for both serviceable limit state and ultimate limit state.
When establishing the demands for serviceable limit state, the requirements to the finished construction's geometry should be observed. Special consideration should be taken to eccentricities.

Loads
When calculating the formwork and scaffolding, the following calculatory loads should be considered:

- Dead load, including that of cured concrete
- Fresh concrete
- Local piling up of fresh concrete, inclusive supplement for shunting/knocking
- Payloads
- Lateral pressure on the formwork
- Natural loads (naturlaster)
- Horizontal Mass Loads

Fresh concrete is categorised as a free variable load. The concrete's density, with consideration to the inlay of reinforcement, is established in each individual case.
Unless it can be otherwise documented as secure, the load for piling up of concrete, inclusive supplement for shunting/knocking should be not calculated at less than 3 kN/m2. Only forms and form-carrying elements must be calculated to be effected by this load.

Payloads are considered to be free variable loads and are fixed in each individual case. The payload ("flat load") on the formwork should normally not calculated as less than 2 kN/m2.

The concrete's lateral pressure should be fixed with due consideration to casting firmness, the consistency of the concrete, temperature at pouring and vibrating. The load is fixed in accordance with a securely documented calculation method.

The size of natural loads must be considered in each individual case.

Horizontal Mass Action, which can take effect in a random horizontal direction, can be set to 1% of the simultaneously effective permissible vertical load. Horizontal Mass Action must be considered to be effective with the other occurring horizontal loads. The total horizontal load should, for an arbitrary horizontal direction, in no case be less than 2,5% of the simultaneously effective calculated vertical load.

The load reduction factor ¥ should be set to ¥ = 1,0

5.3 Slip Materials

The treatment of the forms must not result in discolouration of visible concrete surfaces or, in other ways, have harmful effects.

5.4 Striking Formwork

Striking of formwork must be implemented in such a way and at such a time that the construction is not damaged or deformed to a greater degree than expected.

NOTE: The project specifications should contain information about when striking the formwork should be initiated earliest. The requirement should be related to the concrete's pressure strength and/or rigidity (E-modul). Unless otherwise stated in the project specifications, constructions that are effected by bending have their formwork struck when the concrete everywhere on the surface has a pressure strength of minimum 10 MPa, and constructions that are not subjected to bending can have their form struck when the concrete over the whole surface has reached a pressure strength of minimum 5 MPa.

When the form has been struck, its protective effect on the concrete is removed. The time for striking the form must, therefore, be matched with the required post treatment of the concrete, in accordance with Section 9.7.

6 Cast-in parts

6.1 Materials

6.1.1 Lifting devices

When designing lifting devices and calculating the loads on such devices, consideration must be taken to all the effects that the lifting devices can be subjected to in connection with striking the formwork, transport and mounting.

NOTE: Special consideration should be taken to shunting and slantwise pulling.

6.1.1.1 Lifting brackets of smooth reinforcement bars

Lifting brackets made of smooth reinforcement bars must be made of the following types:

A. Lifting brackets made of "killed steel" (steel with Al/Si content) in accordance with DS/EN 10025, with knock testing implemented at 0 ºC.
B. Lifting brackets made of half-killed steel in accordance with DS/EN 10025.

After bending, the brackets must be normalised (annealed at 950ºC, dependent on the steel's composition) in accordance with DS 10601. During this process, one must ensure that minimum 100 mm of the bracket outside the bent section achieves the specified temperature. Cooling after the heating process must happen in an even and slow process.

NOTE: For lifting brackets, where normalisation after bending has been necessary, one should ensure that the brackets do not again be cold deformed, for example due to uneven pulling during striking the formwork. A new pull or shunt, for example during mounting, can subsequently result in rupture in the deformed steel.

C. Lifting brackets that can tolerate repeated deformation with skiftende fortegn, without resulting in rupture.

The lifting brackets´ characteristic strength must be documented with tests after the brackets have been deformed repeatedly with changing fortegn.

NOTE: "Repeatedly" and "deformation" are variable quantities that are dependent on the use of the brackets.

6.1.1.2 Special Lifting Systems

When using specially fabricated lifting systems, it must be documented under which lifting direction the lifting system can be used.

The lifting systems strength must be documented.

6.1.2 Other cast-in parts and fittings

Permanent cast-in parts and fittings must be identified.

NOTE: Requirements for permanent cast-in parts and fittings should be clearly stated in the project specifications.

For cast-in parts and fitting for temporary use, one must ensure the following:

- that they do not damage the concrete or its reinforcement.
- that they do not damage the concrete's surface.
- that they don not damage the function or durability of the construction.

6.2 Transport and storing

Transport and storing of cast-in parts and fittings on site must happen in such a way that labelling is clear and the mixing of different dimensions and types is avoided.

The cast-in parts and fittings must not be damaged and must be kept free of substances that can damage or destroy them or the concrete, or the adhesion between the parts and the concrete.

6.3 Placing and fixing in the formwork

Cast-in parts and fittings must be fixed so that their position is maintained during and after pouring of concrete, so that the location of them is as required in the construction.

The cast-in parts and fittings must not placed by immersion into the wet concrete, unless the suitability of this method can be documented.

NOTE: The project specifications should state where the cast-in parts and fittings:
- may not be placed in electric contact with reinforcement or
- must be in electric contact with the reinforcement.

7 Slack Reinforcement

7.1 Materials

7.1.1 Reinforcement

NOTE: Requirements for the quality of reinforcement are given in DS 411

Reinforcement must be delivered to site marked in such a way that the reinforcement's quality and origin is clear. Only reinforcement with rust grade A, B or C, in accordance with ISO 8501-1, can be used.

7.1.2 Tie Wire and distance holders

Tie Wire and distance holders must not be made of materials, which can damage reinforcement or concrete.

NOTE: Tie Wire can be softened steel wire with a diameter ≥ 1.5 mm

Distance holders must have a sufficient strength and rigidity and be formed in such a way that the requirement for the cover layer of concrete and an effective casting-in is ensured. Distance holders must, furthermore, not reduce the cover layer's quality.

7.2 Transport and storing

Transport and storing of reinforcement steel on site must happen in such a way that labelling is clear and the mixing of bars, dimensions and types is avoided.

Reinforcement must not be damaged and must be kept free of substances that can destroy the bars or the concrete, or reduce the adhesion between concrete and reinforcement.

7.3 Execution

7.3.1 Reinforcement steel in coils

Straightening out of reinforcement steel from coils should be done in such a way that after straitening, the steel will live-up to requirements of DS 13080.

NOTE: Reinforcement steel in coils should be delivered in accordance with DS 13084.

7.3.2 Cold-bending

When cold-bending reinforcement steel, the bending radius must be minimum 1.5 times the bend test values stated in DS 13080.
If cold-bending happens at temperatures below 0 ºC, the security of such a procedure must be documented.

NOTE: *Bundled reinforcement.* Only 2 reinforcement bars may be bundled and bent simultaneously, and in such a way that they both achieve the same bend radius.

7.3.3 Cold bending back, hot bending and hot bending back

Cold bending back must fulfil the requirements of DS 13080.

When cold bending back of reinforcement with a diameter ≤ 12 mm, the bending diameter must be minimum 3 times the value stated for cold bending, and back bending must fulfil the requirements in DS 13080.

If hot bending or hot back bending is used, the execution must be done with consideration to the documented characteristics of the steel in question.

NOTE: Heating and cold back bending can decrease the reinforcement steel's characteristics substantially.

7.3.4 Fixing of reinforcement

Reinforcement must be fixed in such a way that its placement in the final construction is in accordance with requirements. Provisions for fixing of reinforcement must not prevent good and complete envelopment of reinforcement by concrete.

7.3.5 Hooks and stirrups

NOTE: Requirements for the forming of hooks and stirrups are stated in DS 411.

7.3.6 Welding

Single welds, in this context fastening (point) welds, executed in workshops or on site must fulfil the requirements of DS 13083

Automatic welded units must fulfil the requirements of DS 13082.

NOTE: fastening welds are normally used for the same purpose as binding reinforcement together with tie wire, i.e. for fixing of the reinforcement during transport and the pouring of the concrete. These point welding seams can, just like other welding seams on reinforcement, alter the characteristics of the steel's strength and toughness.

7.3.7 Anchorage and overlapping of reinforcement bars

NOTE: Requirements for anchorage overlap when binding and direct joints of slack reinforcement are given in DS 411. With consideration to a safe work environment, it should be evaluated to what extent vertical starter-bars should be terminated with hooks or similar safe provisions.

7.4 Placing in formwork

Before pouring of concrete, reinforcement must be free of loose rust, oil, soil, dirt, mortar, etc.

Reinforcement must not be placed or stuck down into concrete which has been poured into the formwork, unless the suitability of this process can be documented. The safe and sufficient fixation of the reinforcement against movement must be provided for during pouring of concrete.

NOTE: The requirement for the covering layer of concrete and the placing of the reinforcement is stipulated in DS 411. If nothing else is mentioned, distance spacers with a thickness minimum equivalent to the cover layer´s thickness, should be used. These should be spaced with a distance so that the minimum required cover layer of concrete can be assured. It must be assured that the reinforcement bars are sufficiently fixed during the pouring of concrete.

The reinforcement work should normally be completely finished before pouring of concrete for the construction in question is initiated.

8 Stressed Reinforcement

Stress-reinforcement, lining pipes, anchors and auxiliary parts and fittings must be documented as being able to live up to the stipulated requirements.

NOTE: The stipulated requirements are stated in the project specifications.
Work with pre-stressing, and auxiliary processes, should be implemented with special attention to safety.

Stress-reinforcement must not be welded or exposed to weld-splashing and droplets.

8.1 Materials

8.1.1 Stress-reinforcement, anchors and auxiliary parts

Stress-reinforcement must meet the requirements in Annex A.

Only stress-reinforcement with rust of Rust Grades A or B, in accordance with ISO 8501-1, may be used.
Stress-reinforcement, anchors and auxiliary parts must be labelled in such a way as to display origin and quality.

8.1.2 Lining pipes in steel must meet the requirements of DS/EN 523

NOTE: Lining pipes in other materials can be used if documentation for their usability is available.

8.1.3 The system for fixing

The system for fixing must be rigid enough to ensure a stable fixation of the cables to be stressed in the desired position, and must not damage the reinforcement or the concrete.

8.1.4 Injection Mortar

Injection mortar must meet the requirements in DS 481.

8.2 Transport and storage

Stress-reinforcement must be kept free of substances that can damage it or the concrete/injection mortar and reduce the adhesion between the reinforcement and concrete/injection mortar.

Cement and additives for injection mortar must be delivered, transported and stored in such a way as to be protected against water, in accordance with DS/EN 446.

8.3 Placement in formwork

The pre-stressing system must be placed in the formwork in the designed position.

NOTE: If nothing else is mentioned, distance spacers should be used. Their thickness should be minimum equal to the stipulated thickness of the cover layer of concrete. These spacers should be distributed in such a way that the minimal requirement for the cover layer is maintained and the reinforcement should be sufficiently fixed against movement during the pouring of the concrete.

8.4 Pipe-liners

Lining-pipes and joining of these must be tight.

There must be venting of lining-pipes in all places in the construction where there is a possibility for the collection of water, but minimum in both ends and in all top points of the lining-piping.

NOTE: Venting should be clearly marked/labelled so that it can clearly be decided, which lining-pipe can be vented.

Lining-pipes must be fixed in such a way that they stay in place during pouring of concrete and vibrating.
Fixing of lining-pipes in a specified routing must happen with the aid of brackets with matching bracket holders. Lining-pipes must be fixed solid to each bracket and have an even spacing.

8.5 Tensioning/Stressing of reinforcement

Documented procedures must be available for the tightening/stressing and stressing strength, or the pre-stressed reinforcement's extension must be controlled.

Tightening must be implemented in accordance with tension lists.

For pre-stressed constructions, the consecutive values of tension strength and extension must be documented.

NOTE: The limit for tension for tensioning of reinforcement is stated in DS 411.
If there is a documented coherence between the utilised concrete's development of strength and the maturing of the concrete, this can be used to fix the point of tensioning/stressing of the reinforcement. The maturity of concrete is ascertained through the temperature measured in the concrete at the stress-reinforcement's anchorage points and representative points in the construction.

8.6 Injection

Injection into the lining-pipes with injection mortar must be implemented in accordance with DS/EN 446.

9 Casting/Pouring of concrete

9.1 Specification of concrete

Before pouring, one must secure that the chosen concrete's production and user characteristics are consistent with the intended method of implementation.

NOTE: DS 411 states the requirements for the concrete.
Further requirements can be set in the project specifications.
The following must be specified with regard to method of implementation:

- Concrete consistency
- Temperature
- Retardency
- Setting time
- Pumpability
- Development of strength
- Other technical conditions

9.2 Delivery and Reception of Concrete

Concrete must be delivered with a delivery note, in accordance with DS 481.

NOTE: Regarding the latest time for pouring of concrete into formwork, see DS 481.

9.3 Casting/Pouring Schedule

A casting/pouring schedule must be established before any pouring takes place.

NOTE: The Casting/Pouring Schedule can contain:

- Manning Summary
- Material Summary
- Summary of plant/reserve plant
- Provisions for aftercare
- Provisions for ensuring a continuity for casting/pouring

9.4 Test Casting /Pouring

Test castings must be executed if required.

NOTE: The purpose of test casting is to establish a baseline for the concrete construction with regard to execution. The purpose of the test casting should be concretised in the project specifications. The test casting should be implemented with consideration to the conditions in the construction, including the following:

- the formwork's and reinforcement's geometry
- equipment and methods
- the characteristics of the fresh concrete.

The thickness of layers, vibration time, sink-depth for rod-vibrators and vibration time for form vibration should be established for test castings.

The setting/curing process should be evaluated by comparing of temperature simulations of the test body with recorded temperatures in the test body.
A trial casting can, if it is stated in the project specifications, be integrated into the permanent construction.

9.5 Preparing for casting/pouring of concrete

When planning for casting, consideration must be taken to possible variation in the conditions for execution of the construction.

NOTE: Planning should ensure that persons that are directly involved in the work of pouring, compressing, and after care and protection of the concrete are instructed in the methods for the works implementation.

Preparatory work must be completed, controlled and documented before casting/pouring can be initiated, among other things, because of:

- Washing-out of concrete, for example due to rain, water pressure, water streaming or due to casting of concrete underwater, cannot happen.
- That the fresh concrete is secured against pollution and damaging water-transport.
- That casting against frozen under layers does not happen
- That casting joints are clean and water-saturated but surface dry before casting of new concrete pours.

NOTE: Regarding definition of casting joints´ surface characteristics, see DS 411.

9.6 Handling, placing and compressing (vibrating)

Handling, placing and compressing of concrete must happen in such a way that the concrete:

- does not separate
- forms a uniform, homogonous and tight mass, which completely envelops reinforcement and cast-in parts and fittings.
- completely fills out the formwork.
- achieves the intended strength, appearance and durability.

NOTE: In constructions with reinforcement, or similar, concrete normally should not fall freely for a height of more that 1 m.
If this is not possible, the pouring should take place with the aid of pipes or concrete-hoses, unless it can be documented that other methods are secure.
Concrete should not be subjected to damaging horizontal relocation.

Compressing of the concrete should happen mechanically if the correctness of other methods is not documented.

NOTE: Vibration is executed in a systematic fashion until all in capsulated air is expelled from the concrete, but with proper consideration to the in capsulated air's stability.
Where demands have been made to the air content and/or frost constancy in the cover layer, one should not vibrate the concrete's cover layer directly against the formwork. This can normally be secured if the rod vibrator does not come closer to the formwork's edge that 3 times the rod's diameter.

Concrete should normally be poured/cast in layers.

When vibrating concrete with a rod vibrator, the layer thickness of concrete should not be more than 80% of the vibrator´s rod length.

The rod vibrator´s in-stick depth should be fixed via a test casting. The in-stick depth is typically within the interval of 3-10 times the rod's diameter. The in-stick depth and vibration time is dependent on geometry, quantity of reinforcement and cast-in components and the concrete's consistency.

Special attention should be paid to areas where the cross section is altered, at rebates, bound reinforcement, tight reinforcement and casting joints.

Underpinning joints (grouting) can be finished by being stamped.

Vibration time and method must be determined.

Reinforcement, lining-pipes, anchorage elements and casting-in parts and fittings must not be displaced or suffer harm during vibration.
During levelling and floating of free surfaces, no water, cement of other materials may be added to the concrete.

NOTE: In Passive Environment Classes, however, this can be permitted if the correctness of the action can be documented.

9.7 The concrete's protection during the setting/curing process

Concrete must be protected against the harmful effects of the curing process.

NOTE: Damaging and harmful effects can, for example, be sunlight, strong winds, and water and washout erosion. These effects can occur during the handling, placing, compressing of the concrete and until the setting process is completed.

Exposed surfaces must be protected against critical drying out, and the construction as a whole against the harmful temperature effects.

Drying-out protection in Passive Environmental Class must, however, only be established if required.

NOTE: Demands should normally be stated for protection against drying-out of indoor floors and coverings.

9.7.1 Drying-out

Concrete must be protected against critical drying out during the setting and curing process so that the formation of cracks and crevices, due to plastic shrinkage, does not occur and so that the necessary water quantity for the cement's hydration is available.

NOTE: This requires the latest point in time for establishing protection and the duration of this protection. Plastic shrink cracks can occur until time for the concretes setting. The concrete's setting time is determined in accordance with DS 423.17, or based on the concrete's heat development in accordance with DS 423.37.

9.7.1.1 *Time schedule for establishing of protection*

As earliest as possible, after the pouring of the concrete, the free surfaces must be protected against critical drying out as shown in Table 9.7.1.1.a.

Table 9.7.1.1a – Maximal permissible water evaporation before the establishment of protection against drying-out.

Concrete's content, X of FA[1]+MS[2] in weight-% of C[3]+FA+MS	Concrete's content, Y of MS in weight-% of C+FA+MS	Max. evaporated amount of water from surface.
X>15%	Y>5%	1.5 kg/m²
15%≥ X> 5%	5% ≥ Y>0%	3.0 kg/m²
5%≥ X	Y>0%	6.0 kg/m²

The water content given in Table 9.7.1.1a is equivalent to the lay thickness greater than or equal to 0.2m. For thicknesses less than 0.2 m, the water content should be reduced proportionally, but the drying-out protection should be established at the beginning of the setting of the concrete.

[1] FA = Fly ash

[2] MS = Micro Silica

[3] C = Cement

NOTE: If no documentation for the fulfilment of demands in Table 9.7.1.1a is available, the protection of the surfaces should be established before the Table 9.7.1.1a shown time for casting has progressed.

NOTE: **Table 9.7.1.1b – Latest time for establishing of protection against drying-out for wind velocity of maximum 5 m/sec.**

Concrete's content, X of FA+MS in weight-% of C+FA+MS	Concrete's content, Y of MS in weight-% of C+FA+MS	Outdoor works	Indoor work		
			Concrete temperature		
			>30ºC	15-30 ºC	<15 ºC
X>15%	Y>5%	1 hour	1 hr.	1.5 hrs.	2 hrs.
15%≥X>5%	5%≥Y>0%	2 hours	2 hrs.	3 hrs.	4 hrs
5%≥X	Y=0%	4 hours	4 hrs.	6 hrs	8 hrs

The time figures in Table 9.7.1.2a are valid for layer thicknesses greater than or equal to 0.2 m. For thicknesses smaller than 0.2 m, the time must be reduced proportionally.

9.7.1.2 Duration of protection

To ensure sufficient hydration and, therefore, the tightness of the concrete's surface, the surface must be protected against critical drying-out, as shown in Table 9.7.1.2a.

Table 9.7.1.2a – Minimum duration of protection against drying-out expressed at relative hydration (Expressed on the basis of concrete's adiabatic heat development)

Environmental Class	P	M	A	E
Relative Hydration %	40	60	85	90

NOTE: The duration is calculated based on the concrete's measured adiabatic heat development parameters. If the heat development parameters have not been decided, the values in Table 9.7.1.2a are normally sufficient to avoid critical drying-out.

NOTE: Table 9.7.1.2b – Minimum duration for protection against drying-out

Concrete's age[4] measured in ripening time[5] at earliest removal of protection (covering)				
Environmental Class:	P	M	A	E
w/c[6] > 0.55	15	-	-	-
0.55≥ w/c > 0.45	15	36	-	-
0.45≥ w/c > 0.40	12	24	120	-
0.40≥ w/c	12	24	96	120

[4] If setting starts later than 5 hours after mixing, the stated ripening times must be increased proportionally.

[5] Documentation of the concrete's ripeness happens through measuring its surface layer at a depth of max. 10 mm. The required protection against drying-out can be established by:

- Let the formwork stay and cover the concrete's free surface.
- Cover with a moisture-tight membrane
- Maintain sufficient high relative moisture content in the environment.
- Constant watering of the surface, but changing watering and drying of the surface must not occur.
- Use sealing agent, if the sealing agent has an affectivity of minimum 75% based on Test Method TI-B33, unless otherwise required in the project specifications.
- Watering must only be initiated when the fresh concrete surface can stand up to it.

[6] The water/cement ratio

Sealing agents must not be damaging for the concrete, cause discolouration or reduce adhesion of the application of future moisture insulation, coverings or paintwork.

NOTE: If the form is struck before the concrete has achieved the necessary surface ripeness, immediately after this happens, and within an hour, the surface must be protected. This protection should be maintained until the required ripeness has been achieved.
When casting concrete in winter conditions (i.e., temperature under 5ºC), it should be ensured that the concrete does not freeze before it has attained a frost-safe condition due to its curing process.
Before the pouring/casting process is initiated, safety provisions against the freezing of the concrete should be documented.
Concrete can be expected to be safe against frost when it reaches a ripeness of 15 – 20 hours.

9.7.2 Temperature process and deformation during curing

The temperature process and deformation during curing must not result in damage to the construction.

NOTE: Damage can be avoided if:

1) The concrete's temperature during curing does not exceed 70 ºC for concrete in the moderate, aggressive and extra aggressive environmental classes.
2) The maximum permissible temperature difference during the concrete's curing between the construction cross section's mean temperature and the surface temperature should not exceed 15 ºC. See figure 9.7.2.1.

Parts of constructions, where the temperature profile can be assumed to be parabolic, and the aforementioned temperature limits must be substituted with a limit of 20 ºC for the maximal temperature difference between the mean (middle) and the surface (measured at a depth of 10 mm).

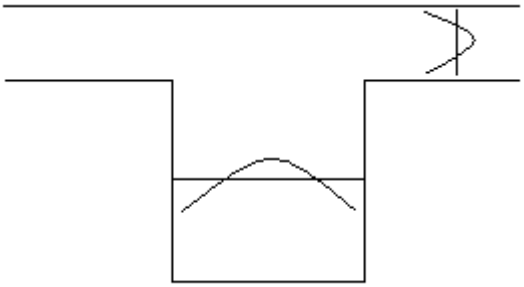
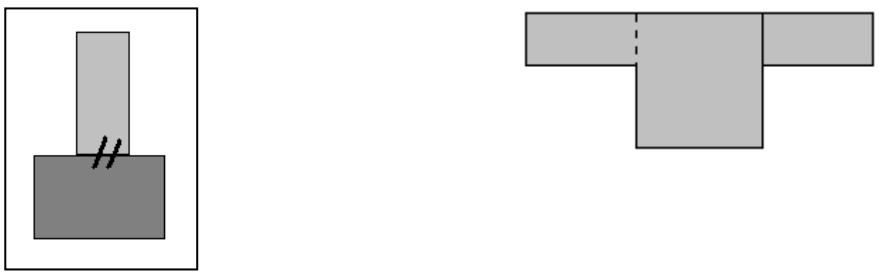


Figure 9.7.2.1

3) For construction parts, which cannot move freely, the project specifications can also contain requirements on limitation of the formation of cracks due to the temperature difference between the cured and curing concrete (a) or between simultaneously poured construction parts with different thicknesses (b). See figure 9.7.2.2.



(a) (b)

Figures 9.7.2.2a and 2b

For requirements to construction parts´ (which are cast together) relative temperature movements, there can be limits for the greatest permissible utilization of the concrete's actual tensile stress or limits for what temperature differences that normally can occur.

The project specifications can state requirements for documentation regarding the fulfilment of temperature differences, including methods of monitoring and/or calculation.

The project specification should establish which concrete characteristics that must be defined when prescribing the calculation of temperatures and tension.

The limits for the maximum permissible temperature difference that is found by calculation of tension can be based on the following:

- mean temperature
- temperature difference between well defined points in the construction.

Limits for the maximal permissible temperature difference can result in the curing process using one or more of the following provisions:

- concrete, with an adjusted pouring temperature
- insulation of concrete surfaces and/or formwork
- proportional form periods
- cooling pipes cast into the concrete
- heating coils/pipes cast into the concrete

When heating or cooling, no crack forming temperature differences may occur.

9.8 Striking the formwork

See Section 5.4

9.9 Conditions after formwork is struck

Surfaces must be protected against damage and pollution from subsequent construction work.

9.10 Repair and finish

When choosing materials and methods of execution for repair and finish, it must be documented that demands for the construction's durability and function can be maintained.

10 Mounting of concrete elements

When placing, shoring and underpinning elements, it must be assured that they are secured properly.

NOTE: The project specifications must show when shoring/and supports can be removed with consideration to the stability of the building.

Documented procedures must be available for placing and adjusting.

NOTE: Procedures for placing should contain information about the following:
- Safety conditions
- Lifting
- Placing, shoring and underpinning
- Fixing

Procedures for adjusting should contain information about the following:
- Vertical and horizontal adjusting
- Control of support points
- Control of joints
- Control of the total construction
- Evaluation of deviations beyond the permissible tolerances.

11 Quality Control

Quality must be ensured by systematic control.
The quality control system must contain or refer to documented procedures for the requirements shown below.

11.1 Quality Plan

The executing contractor must work out a quality plan for the execution of the concrete constructions.

NOTE: The quality plan should contain:

- the execution contractor's organisation plan and the project's organisation plan
- document control plan
- control plan for ensuring that the advance documentation/advance testing, delivery control, execution control, final control and handing-over exist for all requirements.
- plans showing distribution into control sections
- list of subcontractors /suppliers
- inspection programmes and inspection reports for subcontractors/suppliers
- list of project alterations
- adjusted actions
- specification of the execution of the works
- operation and maintenance manuals.

11.2 Organisation

Authority and mutual relationships for personnel that lead, execute and verify works, which have influence on quality, must be described in the quality handbook.

Authorization for the handling of deviations must be fixed.

11.3 Personnel

The executing contractor must ensure that all personnel have the necessary education and training in executing the functions that are required.

11.4 Control of documents

Documents, to be used during the production, must be controlling.

NOTE: The executing contractor should have a main summary of the documents, tables, forms, etc., for use during the production, and which are necessary to fulfil the present standard with statement of the valid edition.
All documents should be stamped with number and date of issue.
The executing contractor should ensure that only valid issues of documents are available for the personnel who are to use them.

11.5 Purchase

Purchase specifications must be available.

11.6 Execution

The executing contractor must have documented procedures for the following processes:

- making ready for casting/pouring, including the reinforcement works
- casting and compacting
- striking the formwork
- the concrete's protection during the setting period
- tensioning

- mounting of elements, including placement and adjustment.

11.7 Inspection-, measurement and proofing equipment

For all inspection, measurement and proofing equipment, there must be procedures for control, maintenance and calibrating.

The executing contractor must document the equipment's control, maintenance and calibration.

11.8 Deviations and corrective actions

There must be documented procedures for ensuring that constructions and elements with deviations are prevented from being used, unless documented agreements about their use are available.

NOTE: Procedures for treatment of deviations should result in identification, documentation, evaluation, separation from other constructions (when this is technically possible in practice), disposition regarding concrete constructions and concrete elements with deviations and information regarding production areas.

If deviations are of such a character, that there is a likelihood for other concrete constructions and concrete elements being charged with the same deviations, these building elements should be separated and subjected to new control. The result of this separation and new control should be documented. The reason for the deviations should be investigated. If the reason can be ascertained, corrective action should be taken to avoid a repetition, and this should be documented.

Repaired and/or retreated constructions and elements must be controlled.

12 Control

Control comprises Material Control, Delivery Control and Control of the Execution.
The control must be sufficient as to document that the construction has been executed in accordance with the stipulated specifications.

Control must be implemented in accordance with the relevant Control Classes.
In intense or normal control, the data from material and delivery control, and from execution control, shown in Table 12.3, must be stated in a Control Journal. For relaxed control, a Control Journal is not required.

12.1 Material Control

Material Control comprises beforehand documentation of materials
Sample taking should be implemented in accordance with the requirements in these, or affiliated, standards.

NOTE: If no demands for sample taking are stated, the following standards should be used, dependent on the sample taking methods: DS/ISO 2859-1, DS/ISO 2859-2, DS/ISO 3951.

Evaluation of sample results must happen as stated in DS 409.

12.1.1 Slack reinforcement

For slack reinforcement, all Control Classes must have documentation for agreement with DS 13080.

Welded reinforcement
Welded reinforcement must have documentation for agreement with DS 13083.

Mechanically welded reinforcement mesh
Mechanically welded reinforcement mesh must, for all Control Classes, have documentation for agreement with DS 13082.

Reinforcement from coils
Reinforcement from coils must, for all Control Classes, have documentation for agreement with DS 13080.

NOTE: For slack reinforcement, certified in accordance with the aforementioned standards, the documentation is regarded as being satisfactory.
The certificate should unambiguously account for the coherence between the labelling of the reinforcement and the reinforcement's quality.

12.1.1 Stressed/Tensioned reinforcement

For stress/tension reinforcement there must be documentation for tight and normal Control Classes in accordance with DS 411 and Annex A. Stress/tension reinforcement must not be used in connection with relaxed control.

NOTE: Documentation should unambiguously account for the coherence between labelling of the reinforcement and the reinforcement's quality.

12.1.2 Concrete
All Control Classes for concrete must have documentation for compliance with Chapter 5, 6 and 7 in DS 481.

NOTE: For concrete attested in accordance with Method A, B and S, of DS 481, documentation is regarded as being satisfactory.

12.1.3 Other materials
Documentation for materials that make up the construction must be available.

12.1.4 Concrete elements
NOTE: For concrete element, attested in accordance with Methods A, B and S and Section 4.3.1, documentation is considered as being satisfactory.

12.2 Delivery Control
At delivery control, materials and products are checked to find compliance with the specified requirements.

NOTE: The control can be documented with the delivery note.

12.2.1 Slack reinforcement
Delivery control of slack reinforcement is implemented as identification control on site.

NOTE: It should be ensured that the labelling used is unambiguous.

12.2.2 Stress/tension reinforcement
Delivery control of stress/tension reinforcement is implemented as identification control on the building site.

NOTE: It should be ensured that the labelling used is unambiguous.

12.2.3 Concrete
At delivery control, it must be ensured that a delivery note is available for each delivery of concrete to the site. Delivery control must be implemented immediately before pouring of concrete into the formwork. The time of pouring must be noted.

NOTE: If the concrete manufacturer is the same judicial person as the recipient, the delivery note can be omitted if it is secured in another way that exchange of the individual concrete loads cannot occur.

The following must be controlled for delivered concrete:
- That the concrete consistence, temperature and air content lives up to the agreed value.
- The concrete's ripeness.

The control can be reduced to include delivery notes if the supplier can document coherence between the concrete's ripeness and the fresh concrete's characteristics.

NOTE: for concrete attested in accordance with Method A, B or S, after DS 481, the delivery control can be reduced to ensure that the delivery note's information is in accordance with the required.

12.2.4 Other materials
Delivery control of other materials is done as identification control on site.

12.2.5 Concrete elements

Delivery control of concrete elements is implemented as identification control on site.

NOTE: at delivery of concrete elements, it must be ensured that all necessary information for handling is available.
For concrete elements attested in accordance with Method A, B and S for Section 4.3.1, the delivery control can be limited to ensuring that the delivery note's information is in agreement with the required.
For concrete elements attested in accordance with Method C for Section 4.3.1, it must be documented that the concrete elements fulfil the requirements.

12.3 Execution Control

A summary of the extent of the control in the 3 control classes can be found in Table 12.3.

NOTE: Sample Control for concrete elements, as an alternative to Table 12.3, is described in Annex B in its entirety.

For tight and normal control classes, all control data must be entered into the control journal.
Control before and at injection must minimum be documented in accordance with EN 446.

Table 12.3 - Control of Execution

	Tightened Control Class	Normal Control Class	Relaxed Control Class
Formwork	Formwork must be controlled before each pour is implemented.		Formwork is controlled at: - first pour and per 20th repetition - substantial alterations
Reinforcement works	Reinforcement works must be controlled before each pour.		Reinforcement work must be controlled minimum at: - first pour and per 20th repetition - substantial alterations
Tensioning reinforcement	Reinforcement, tensioning system, the system for tensioning is controlled for each pour and each control is done in accordance with the tensioning list.		Stress/tensioning reinforcement must not be used
Injection	Injection to be controlled before and at each injection.		Stress/tensioning reinforcement must not be used
Casting-in parts and fittings, etc.	Parts for casting-in, etc., to be controlled at each pour.		Casting-in fittings to be controlled minimum at: - first pour and per 20th repetition - new casting-in parts, fittings, etc. - altered placements.
Casting of concrete	Control of the whole casting	Casting is controlled at minimum: - first pour and per 10th repetition. - critical activities, e.g., at rebates close to reinforcement and complicated geometry - substantial alteration, e.g., for alteration of method and design.	The pour is controlled minimum at: - first pour and per 20th repetition. - critical activities, e.g., at rebates, close reinforcement and complicated geometry - substantial alterations, e.g., to methods and design.
Curing and after care	Curing and after care is controlled minimum at: - first pour and per 5th repetition. - altered pours - altered methods - altered construction types - substantial alterations, e.g., weather conditions and concrete types	Curing and after care to be controlled minimum at: - first pour and per 10th repetition. - altered pours - altered methods - altered construction types - substantial alterations, e.g., weather conditions and concrete types	No control
Mounting of concrete elements	Mounting of elements controlled before and after each mount.		No control

NOTE: **Formwork**
Control of formwork before casting should comprise:
- geometry
- stability and anchorage
- tightness
- cleanliness
- cleanliness, roughness and moisture and casting joints.
- keeping moist the formwork made of absorbent materials
- appearance
- rebates, casting-in parts and fittings, and similar
- applied anti-adhesive materials (slip materials)

Before striking the formwork, the concrete's strength, temperature difference and ripeness/degree of hydration should be verified.

NOTE: **Reinforcement**
Control of reinforcement before pouring of concrete should comprise:
- that the reinforcement is of the specified type
- the reinforcement is clean, i.e., free of rust, old concrete, oil, grease, painting and other damaging materials
- the amount, dimensions and placing is as specified
- the reinforcement is correctly bent and fixed
- the cover layer on the reinforcement lives up to the specified requirements
- the concrete is placed, cast and vibrated correctly.

Stress/tension reinforcement, tensioning and injection
Control of tension reinforcement should comprise:
- cable geometry and placing
- tension system and anchorage equipment
- vent.pipes, including tightness against seeping in of cement paste
- coherence with stipulated tension lists
- tensioning equipment's calibration
- amount of injection mortar

Before transferral of the tension force to concrete, the concrete's strength should be verified.

Casting-in parts and fittings
The control before pouring should comprise:
- checking that casting-in parts and fittings are as specified
- placing and fixing of parts
- checking that concrete is placed, cast and vibrated correctly.

Concrete, pouring, setting and curing and after care
Control should include the following:
- the concrete's age at the beginning of pouring/end of pouring the concrete
- separation and compression
- registering of the process of casting and floating, including the time process, possible interruptions and disturbances
- temperature conditions, including temperature differences in the concrete
- after care, including methods and progress
- registering of climatic conditions at pouring, ie., wind speed, air temperature, relative air moisture content, sunshine and rain
- time of striking of formwork

After striking of formwork, the concrete should be inspected.

Concrete elements
Control before mounting should comprise:

- that the elements are as specified

Control after mounting should comprise:

- placing
- bearing depth
- joints/casting together of elements

13 Evaluation of whether structure conforms with specifications

The control sections size must be chosen in such a way that the material characteristics and production conditions are constant within the control section.

Agreement is reached if it can be documented that the specified requirements are fulfilled for each control section.

NOTE: See Section 11.8 in case of deviations and corrective action
At execution control and concrete element production in accordance with Annex B, the evaluation of agreement is also in accordance with Annex B.

14 Geometric tolerance

Unless otherwise stated in the project specifications, the following tolerances must be observed.

14.1 Tolerance for in situ cast concrete constructions and for concrete elements

The project specifications must state the rules for evaluating agreement with specs.

Foundations

Placing of the foundation's centre line in the plan must observe the following limits: ± 30 mm
Levels: + 5/-15 mm

NOTE: for foundations, the plus deviation can permissibly be increased by + 15 mm.

Columns and walls

Placing in plan:	± 10 mm
Plumb:	± 0.4%
Level:	± 10 mm
Jump between neighbour surfaces:	± 5 mm

Beams and decking

Placing in plan:	± 10 mm
Levels:	± 10 mm
Jump between neighbour surfaces	± 5 mm

Linear interpolation between the given limits is allowed

14.2 Tolerances for slack reinforcement

Placing of main reinforcement in cross section, depth:
It is generally valid: ± 10 mm for each individual reinforcement rod.
For secondary reinforcement: ± 20 mm.

NOTE: Secondary reinforcement is understood as being, for example, the mesh dimension of reinforcement mesh.

For the given tolerances, it is valid that the minimum cover layer of concrete must be observed.

For plus deviations shown below, it is valid that the mean value is decided over a length of 1 m.

Measurement ≤150 mm	+5 mm
Measurement =500 mm	+15 mm
Measurement ≤ 2500 mm	+30 mm

Linear interpolation between the limits is allowed.

14.3 Tolerances for concrete elements

Rules for evaluation of agreement with specs is shown in Annex B

Facade- and wall elements, slack reinforced		Normal
Thickness (T)		± 5 mm
Width (B)	B≤ 2.4 m	± 5 mm
	B≤ 7.2 m	± 8 mm
	7.2 m < B≤ 9.6 m	± 12 mm
Height (H)	B≤ 7.2 m	± 8 mm
	7.2 m < B≤ 9.6 m	± 12 mm
Hollow core slab elements, etc., with slack reinforcement		
Thickness (T)		± 8 mm
Width (B)	B≤ 2.4 m	± 5 mm
	4.2 m < B≤ 7.2 m	± 8 mm
Length (L)	L ≤ 7.2 m	± 12 mm
Hollow core slab elements, pre-stressed		
Thickness (T)		± 8 mm
Width (B)	B≤ 2.4 m	± 5 mm
Length (L)	L ≤ 7.2 m	± 12 mm
	7.2 m < L≤ 14.4 m	± 20 mm
Beams and column elements, slack reinforced or pre-stressed		
Height (H)	H≤ 0.6 m	± 8 mm
	0.6 m < H≤ 2.4 m	± 12 mm
Width (B)	B≤ 2.4 m	
	For H≤ 0.6 m	± 8 mm
	at 0.6 m < H≤ 2.4 m	± 12 mm
Length (L)	L≤ 14.4 m	± 20 mm
	14.4 m < L≤ 28.8 m	± 30 mm
Large plate-like elements, slack reinforced or pre-stressed		
Height (H)		± 12 mm
Width (B)	B≤ 2.4 m	± 8 mm
	2.4 m < B≤ 7.2 m	± 12 mm
Length (L)	L≤ 14.4 m	± 20 mm
	14.4 m < L≤ 28.8 m	± 30 mm
The project specifications can state the tolerances for warped, bent, angle deviation and rise		

15 The Standard's creations

In the spring of 1996, Danish Standard established, after recommendation from the Planning Committee for Concrete, PLU 8, which is a sub committee (S 329/U-01) under the Standardising Committee, S-329 Execution.

The subcommittee got the task of preparing a proposal for DS 482, comprising a revised compiling of the section regarding execution in DS 411 and Basic Concrete Specification (Dk:BBB) for building constructions.

The revision work was to be coordinated with the European standardising work so that the European standards would be utilized as far as possible.

The subcommittee has, during its work, had the following members:

Akademiingeniør *Marlene Haugaard*
Ingeniør *Per Fogh Jensen*
Akademiingeniør *Jens Frandsen*
Akademiingeniør *Gunnar Hansen*
Akademiingeniør *Erik Jørgen Pedersen*
Akademiingeniør *Lasse Løvgren*
Civilingeniør *Jens-Christian Bernhardt*
Civilingeniør *Bent Feddersen*
Civilingeniør *Finn Bach*
Projektleder *Jens G. Rasmussen*

The subcommittee's proposal was presented in S 329, which, during the period had the following participants:
Ingeniør *Per Fogh Jensen (chairman)*
Akademiingeniør *Gunnar Hansen*
Civilingeniør *John Bjerrum*
Akademiingeniør *Jan Graabek Knudsen*
Akademiingeniør *Jens Fransen*
Ingeniør *Niels Jørgensen*
Civilingeniør *Ulla Kjær*
Akademiingeniør *Erik Jørgen Pedersen*
Projektleder *Jens G Rasmussen*

After discussion and consideration in S 329, PLU 8 and The Norm Committee, the proposal was presented to a representative committee with the following composition:
Per Fogh Jensen, S 329 (chairman)
John Bjerrum, S 329 and Vejdirektoratet
Knud Christensen, Banestyrelsen
Bent Feddersen, PLU 08, S 411
Carl de Fontenay, S 328
Mette Geiker, ATV
Gunnar Hansen, S 329
Chr. F Justesen, Cementfabrikkernes Tekniske Oplysningskontor
Peter Birchløv, Betonelementforeningen

Niels Jørgensen, S 329
Ulla Kjær, FRI and S 329
Steen Lykke, IDA, Dansk Betonforening
Jesper Høy, Dansk Betoncertificering
Lasse Løvgren, Entreprenørforeningen
Knud Christensen, Banestyrelsen
Charlotte Michelsen, By-og Boligministeriet
Robert Nielsen, Entreprenørforeningen
Hans Nyvold, Ingeniørhøjskolen Horsens
Knud Arne Nørgaard, Ingeniørhøjskolen Århus
Chr. Munch-Petersen, Teknologisk Institut
Jørgen Skårup, Dansk Betonindustriforening, Dansk Fabriksbetonforening, IDA
Finn Bach, teknisk sekretær
Jens Gorm Rasmussen, projektleder

After discussion and consideration in the representative committee and the Norm Committee, the proposal was sent to a public hearing in the period 15 July to 15 September, 1998.

Based on the incoming critique, the proposal went through final consideration in the representative committee and the final proposal with presented to DANISH STANDARD for approval.

Annex A (normative)
Reinforcement for stressing/tensioning

The requirements stated in DS 411 for stress/tension reinforcement must be documented.

In addition, there are demands to testing of relaxation, which must be executed as stated below:

a) The test sample and the temperature in the room where the test is done must be 20 ºC ± 2 ºC for the duration of the test.
b) The test sample must not have been subjected to loading of any type before the test itself.
c) The start load, which is equivalent to 60%, 70% and 80% of the characteristic break force of the test sample, must be applied as an even and increasing forcer over a period that must not exceed 5 minutes. Hereafter, the prolongation is kept constant and the measurement of forces for the test sample's relaxation must be initiated 1 minute after the total beginning load is applied.
d) The overrun of the load on the test sample equivalent to the initial load, mentioned under c), must not occur in the test period.
e) The test's duration must be 1000 hours. Relaxation is stated as the percent power reduction between the first and last power determination at a constant length alteration.
f) For liner, the measuring length must be greater than or equal to the linens increase (slålængde). Testing is implemented as a trial test and subsequently minimum once a year for the same reinforcement type.

Annex B (informative)
Control of execution and evaluation of conformability with production of concrete elements

B.1 Control of execution

Control of execution comprises visual control and verification of production of concrete elements.
Visual control comprises:

- Visual control before pouring
- Visual control of post cast concrete elements

Verification comprises:

- Verification before pouring
- Verification of post cast concrete elements

Verification is implemented as documentation for that the processes are controlled, and the visual control is qualified and implemented.

B.1.2 Visual Control

Visual control is undertaken independent of environmental classes and control classes.
Visual control must be done for all concrete elements before casting and for all finished concrete elements.
Visual control is normally done without the use of measurement apparatus. In cases where it is not visually decidable that the demands are met, measurement apparatus must be used.

The result of visual control requires no documentation, unless the rules for treatment of deviation of products tread into function.

B.1.2.1 Visual control before pouring comprises the following points:

- Formwork in accordance with Section 12.3
- Reinforcement in accordance with Section 12.3
- Stress reinforcement in accordance with Section 12.3
- Casting-in parts in accordance with Section 12.3

During pouring and casting, it must be controlled that the concrete does not separate and that the concrete is compressed sufficiently and that vibration is systematically done.
After the casting is finished, it must be seen to that the drying out protection is established in accordance with requirements.

B.1.2.2 Visual control of completed concrete elements is implemented after striking the formwork, and the following points are looked through:

- Surfaces are in accordance with demands
- protruding reinforcement is placed correctly
- Drying-out protection is still established in accordance with requirements
- Any additional requirements in the project specifications

B.1.3 Verification

Verification is done independently of control class and environmental class.

Concrete element production must be divided up into the following product groups:

- Walls
- Facades
- Slack reinforced columns and beams
- Slack reinforced cellular slab
- Pre-stressed cellular slabs
- Pre-stressed rib-slab elements
- Piles
- Staircases
- Tank elements
- Tunnel elements
- Balcony elements

NOTE: if the concrete element cannot be categorised in the above, it is considered as a independent product group.

Verification must be done for each product group in minimum the extent shown in Table B1. Verification must be done with the help of calibrated measuring apparatus and/or templates to an extent required in Table B2.

NOTE: EEC-Class 1 tape measures and callipers can be used for verification without previous calibration, if they are unscathed.

The result of implemented verification must be documented for each concrete element for the control points shown in Table B2.

Table B1 - Extent of verification

Tightened Control Class Size of lot ≤	Normal Control Class Size of lot ≤	Method A ≥	Method B ≥	Method C + S ≥
3	3	100%	100%	100%
50	100	10%[7]	10%[8]	10%[9]
100	200	13 samples	13 samples	13 samples
200	500	13 samples	13 samples	20 samples
500	1000	13 samples	20 samples	30 samples
1000	2000	20 samples	30 samples	40 samples
2000	4000	30 samples	40 samples	50 samples
4000	8000	40 samples	50 samples	65 samples
8000	10000	50 samples	65 samples	80 samples
10000	12000	65 samples	80 samples	95 samples
12000	20000	80 samples	95 samples	110 samples

- The size of the lot must be chosen in such a way that the control section does not exceed 6 calendar months for Method A, 3 colander months for Method B and 1 colander month for C and S.
- Tested units must be representative with regard to the actual production
- The control section must be chosen so that the material characteristics and production conditions are constant in the period.

[7] But minimum 3 samples
[8] ditto
[9] ditto

Table B – Verification[10]

Process	Control points	Characteristics	Measurement required	Executed in accordance to
Before casting	Formwork	Geometry/appearance Stability/anchorage Tightness Rebates Slip materials	No	Section 12.3
	Reinforcement/ Stress reinforcement	Placing of reinforcement Bar diameter Geometry of reinforcement Cover layer of concrete Tension force	Yes	Section B.2.2.1
		Steel type No. of bars Fixing /surface	No	
	Casting-in parts and fittings	Type and number Fixation/ surface	No	Section 12.3
Casting/pouring	Casting	Consistence Pouring out/distributing Casting characteristics Separation Compressing Reinforcement fixed	No	Section B.2.2.2
After Casting	Conditions for curing	Establishing Removal Method	No	Section B.2.2.3
	Main measurement	Length Width Height/thickness	Yes	Section B.2.2.4
	Reinforcement	Protruding reinforcement	No	Section 12.3
	Casting-in parts and fittings	Placement	Yes	Section 12.3
	Surface	Appearance	No	Section 12.3

[10] If the project specification requires further testing, the extent, method, and requirements and demands for documentation must be stated.

B.1.3.1 Reinforcement/stress reinforcement before pouring

Before casting/pouring of concrete, 3 nos of reinforcement is chosen from the total reinforcement lot for verification. Each of these is checked for steel type, diameter, length and number of the reinforcement bars in question.
It is also checked that the reinforcement is placed in accordance with the drawings.

NOTE: measurement can be omitted if the reinforcement is placed in the formwork and so that it is measured where doubt occurs.

Before pouring of concrete, the cover layer is measured by checking at all critical locations. The cover layer is measured at minimum 3 different locations in the formwork.

When verifying the tensioning, the tension force is measured at a number of arbitrarily chosen cables/lines, but minimum at 2 cables/lines per form or track. Testing must be done using of measuring apparatus, which is independent of the track in question's tensioning equipment and its measuring apparatus.

NOTE: Measurement of the extension can be used as an alternative to tension force measurement.

B.1.3.2 Casting/Pouring

Part of the pouring must be monitored, and it is registered whether the concrete's pouring, distribution and vibration is correctly executed, and whether the concrete is considered to have an acceptable consistence and casting characteristics and the concrete does not separate.
It is also registered whether the reinforcement is sufficiently fixed during the pouring.

B.1.3.3 Conditions for setting and curing

Verification is done by registering the time for establishing and removal of the specified drying-out protection. It is registered whether the type of the drying-out protection is correct. Any alteration or temporary removal of the drying-out protection for more than 1 hour is registered.

There must be documented procedures (methods) for how the demands in Section 9.7 are observed. At control of curing and setting conditions, the registration must point out that the method is observed.

B.1.3.4 Main measurements

Verification must primarily be aimed at the dimensions, which have importance for the construction's use. Verification must include measuring the length, width and height. It may be necessary to take several readings for each main measurement.

B.2 Evaluation of observance with rules

B.2.1 Criteria for approval

The result of each tested characteristic, before correction of deviation, must be judged in accordance with Table B3. If the verification result for each characteristic does not observe the criteria for "approved", the said verification result must be considered a deviation.

The executing contractor must prove that the processes have been controlled within the control section. This is proved for each individual characteristic separately in the production group. The

number of deviations for each characteristic is counted and proved to be acceptable for each characteristic (max. number of deviations) in accordance with Table B4.

Table B3 - Approval Criteria

Process	Control point	Characteristics	Random sample Accept figure (max. no. deviations)	Single results Approved
Before Casting/pouring	Formwork	Geometry/appearance Stability/anchorage Tightness Rebates Slip materials	Table B4/II	Demands Evaluation Observed
	Reinforcement/ Stress reinforcement	Placement of reinforcement	Table B4/I	Tolerance observed
		Bar dimension		Demands observed
		Reinforcement geometry		Demands observed
		Cover layer		Demands observed
		Tensioning force		Tolerance observed
		Steel type, no. og bars, Fixation/surface		Demands observed
	Casting-in parts	Type	Table B4/I	Demands observed
		Number/fixation/surface	Table B4/II	Demands observed
Casting/pouring	Casting/pouring	Consistence Pouring/distribution Casting characteristics Separation Compressing Fixing of reinforcement	Table B4/I	Demands Evaluation Observed
After casting/pouring	Conditions for curing	Establishing Removal Method	Table B4/I	Demands observed
	Main measurement	Length Width Height/thickness	Table B4/I	Tolerance observed
	Reinforcement	Protruding reinforcement	Table B4/I	Demands observed
	Casting-in parts and fittings	Placement	Table B4/II	Tolerance observed
	Surfaces	Appearance	Table B4/II	Demands observed

Table B - Accept figures (maximum number of deviations)

Random sample taken at	Accept figures	
	Level I	Level II
3 – 12	0	1
13-19	1	3
20-29	2	5
30-39	3	7
40-49	4	9
50-64	5	11
65-79	6	13
80-94	7	15
95-109	8	17
110-124	9	19
125-144	10	21

B.2.2 Consequences when deviations occur

B.2.2.1 Non-approved characteristics

Concrete elements with non-approved characteristics must be treated in accordance with point 11.8, unless it can be documented that the deviations are without importance for concrete elements´ use and durability in the finished construction.

B.2.2.2 Non-approved control sections

A control section cannot be approved, if:
- the testing extent for the individual product group does not live up to the demands in Table B1
- the accept figures, in accordance with Table B4, are not observed for the individual product group's control sections.

Reasons for non-approved control must be examined and corrective action be taken to bring back control in production, which is documented by verification as shown below.

If a control section cannot be approved fore one or more characteristics in a product group in the verification period, the subsequent verification period for that product group must not exceed one calendar month for Method A and B, and a half calendar month for Method C and S.

For subsequent non-approved control sections for the product group, a continued halving of the verification period must be undertaken in comparison to the previous verification period.

NOTE: The verification period is not required reduced to less than 5 production days

Reduced verifications periods must be maintained, until the control section for the product group can maintain the accept figures in accordance with Table B4.

When the control section for the product group is approved, the subsequent verification period can be extended to the double until the verification period is equivalent to the demands shown in Table B1.