



**BUREAU
VERITAS**

Design and Construction of Offshore Concrete Structures

February 2017

**Guidance Note
NI 594 DT R00 E**

Marine & Offshore
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Bureau Veritas Marine & Offshore General Conditions



General Conditions

1. INDEPENDENCY OF THE SOCIETY AND APPLICABLE TERMS

1.1 The Society shall remain at all times an independent contractor and neither the Society nor any of its officers, employees, servants, agents or subcontractors shall be or act as an employee, servant or agent of any other party hereto in the performance of the Services.

1.2 The operations of the Society in providing its Services are exclusively conducted by way of random inspections and do not, in any circumstances, involve monitoring or exhaustive verification.

1.3 The Society acts as a services provider. This cannot be construed as an obligation bearing on the Society to obtain a result or as a warranty. The Society is not and may not be considered as an underwriter, broker in Unit's sale or chartering, expert in Unit's valuation, consulting engineer, controller, naval architect, manufacturer, or any other legal entity of Bureau Veritas Group as may be specified in the relevant contract, and whose main activities are Classification and Certification of ships or offshore units.

2.1.2 "Services" means the services set out in clauses 2.2 and 2.3 but also other services related to Classification and Certification such as, but not limited to, ship and company safety management certification, ship and port security certification, training activities, all activities and duties incidental thereto such as documentation on any supporting means, software, instrumentation, measurements, tests and trials on board.

2.1.3 "Society" means the classification society, 'Bureau Veritas Marine & Offshore SAS', a company organized and existing under the laws of France, registered in Nanterre under the number 821 131 844, or any other legal entity of Bureau Veritas Group as may be specified in the relevant contract, and whose main activities are Classification and Certification of ships or offshore units.

2.1.4 "Unit" means any ship or vessel or offshore unit or structure of any type or part of it or system whether linked to shore, river bed or sea bed or not, whether operated or located at sea or in inland waters or partly on land, including submersibles, hovercrafts, drilling rigs, offshore installations of any type and of any purpose, their related and ancillary equipment, subsea or not, such as well head and pipelines, mooring legs and mooring points or otherwise as decided by the Society.

3. SCOPE AND PERFORMANCE

3.1 The Society shall perform the Services according to the applicable national and international standards and Industry Practice and always on the assumption that the Client is aware of such standards and Industry Practice.

3.2 Subject to the Services performance and always by reference to the Rules, the Society shall:

- review the construction arrangements of the Unit as shown on the documents provided by the Client;
- conduct the Unit surveys at the place of the Unit construction;
- class the Unit and enters the Unit's class in the Society's Register;
- survey the Unit periodically in service to note that the requirements for the maintenance of class are met. The Client shall inform the Society without delay of any circumstances which may cause any changes on the conducted surveys or Services.

The Society will not:

- declare the acceptance or commissioning of a Unit, nor its construction in conformity with its design, such activities remaining under the exclusive responsibility of the Unit's owner or builder;
- engage in any work relating to the design, construction, production or repair checks, neither in the operation of the Unit or the Unit's trade, neither in any advisory services, and cannot be held liable on those accounts.

4. RESERVATION CLAUSE

4.1 The Client shall always: (i) maintain the Unit in good condition after surveys; (ii) present the Unit after surveys; (iii) present the Unit for surveys; and (iv) inform the Society in due course of any circumstances that may affect the given appraisement of the Unit or cause to modify the scope of the Services.

4.2 Certificates referring to the Society's Rules are only valid if issued by the Society.

4.3 The Society has entire control over the Certificates issued and may at any time withdraw a Certificate at its entire discretion including, but not limited to, in the following situations: where the Client fails to comply in due time with instructions of the Society or where the Client fails to pay in accordance with clause 6.2 hereunder.

5. ACCES AND SAFETY

5.1 The Client shall give to the Society all access and information necessary for the efficient performance of the requested Services. The Client shall be the sole responsible for the conditions of presentation of the Unit for tests, trials and surveys and the conditions under which tests and trials are carried out. Any information, drawings, etc. required for the performance of the Services must be made available in due time.

5.2 The Client shall notify the Society of any relevant safety issue and shall take all necessary safety-related measures to ensure a safe work environment for the Society or any of its officers, employees, servants, agents or subcontractors and shall comply with all applicable safety regulations.

6. PAYMENT OF INVOICES

6.1 The provision of the Services by the Society, whether complete or not, involve, for the part carried out, the payment of fees thirty (30) days upon issuance of the invoice.

6.2 Without prejudice to any other rights hereunder, in case of Clients' payment default, the Society shall be entitled to charge, in addition to the amount not properly paid, interest equal to twelve (12) months LIBOR plus two (2) per cent as of due date calculated on the number of days such payment is delinquent. The Society shall also have the right to withhold certificates and other documents and/or to suspend or revoke the validity of certificates.

6.3 In case of dispute on the invoice amount, the undisputed portion of the invoice shall be paid and an explanation on the dispute shall accompany payment so that action can be taken to solve the dispute.

7. LIABILITY

7.1 The Society bears no liability for consequential loss. For the purpose of this clause consequential loss shall include, without limitation:

- Any loss and/or deferral of production, loss of product, loss of profit, loss of revenue, loss of profit or anticipated of whether direct or indirect;
- Indirect or consequential loss;

7.2 In any case, the Society's maximum liability towards the Client is limited to one hundred and fifty per-cents (150%) of the price paid by the Client to the Society for the performance of the Services. This limit applies regardless of fault by the Society, including breach of contract, breach of warranty, tort, strict liability, breach of statute of limitations, or any other legal theory.

7.3 All claims shall be presented to the Society in writing within three (3) months of the Services' performance or (if later) the date when the events which are relied on were first discovered by the Client. Any claim not so presented as defined above shall be deemed waived and absolutely time barred.

8. INDEMNITY CLAUSE

8.1 The Client agrees to release, indemnify and hold harmless the Society from and against any and all claims, demands, lawsuits or actions for damages, including legal fees, for harm or loss to persons and/or property tangible, intangible or otherwise which may be brought against the Society, incidental to, arising out of or in connection with the performance of the Services except for those claims caused solely and completely by the negligence of the Society, its officers, employees, servants, agents or subcontractors.

9. TERMINATION

9.1 The Parties shall have the right to terminate the Services (and the relevant contract) for convenience after giving the other Party thirty (30) days' written notice, and without prejudice to clause 6 above.

9.2 In such a case, the class granted to the concerned Unit and the previously issued certificates shall remain valid until the date of effect of the termination notice issued, subject to compliance with clause 4.1 and 6 above.

10. FORCE MAJEURE

10.1 Neither Party shall be responsible for any failure to fulfill any term or provision of the Conditions if and to the extent that fulfillment has been delayed or temporarily prevented by a force majeure occurrence without the fault or negligence of the Party affected and which, by the exercise of reasonable diligence, the said Party is unable to provide against.

10.2 For the purpose of this clause, force majeure shall mean any circumstance not being within a Party's reasonable control including, but not limited to: acts of God, natural disasters, epidemics or pandemics, wars, terrorist attacks, riots, sabotages, impositions of sanctions, embargoes, nuclear, chemical or biological contamination, laws or action taken by a government or public authority, quotas or prohibition, expropriations, destructions of the worksite, explosions, fires, accidents, any labour or trade disputes, strikes or lockouts.

11. CONFIDENTIALITY

11.1 The documents and data provided to or prepared by the Society in performing the Services, and the information made available to the Society, are treated as confidential except where the information:

- is already known by the receiving Party from another source and is properly and lawfully in the possession of the receiving Party prior to the date that it is disclosed;
- is already in possession of the public or has entered the public domain, otherwise than through a breach of this obligation;
- is acquired independently from a third party that has the right to disseminate such information;
- is required to be disclosed under applicable law or by a governmental order, decree, regulation or rule or by a stock exchange authority (provided that the receiving Party shall make all reasonable efforts to give prompt written notice to the disclosing Party prior to such disclosure).

11.2 The Society and the Client shall use the confidential information exclusively within the framework of their activity, underlining these Conditions. Confidential information shall only be provided to third parties with the prior written consent of the other Party. However, such prior consent shall not be required when the Society provides the confidential information to a subsidiary.

12. INTELLECTUAL PROPERTY

12.1 Each Party exclusively owns all rights to its Intellectual Property created before or after the commencement date of the Conditions and whether or not associated with any contract between the Parties.

12.2 The Intellectual Property developed for the performance of the Services including, but not limited to drawings, calculations, and reports shall remain exclusive property of the Society.

13. ASSIGNMENT

13.1 The contract resulting from to these Conditions cannot be assigned or transferred by any means by a Party to a third party without the prior written consent of the other Party.

13.2 The Society shall however have the right to assign or transfer by any means the said contract to a subsidiary of the Bureau Veritas Group.

14.3. In case of doubt as to the interpretation of the Conditions, the English text shall prevail.

15. GOVERNING LAW AND DISPUTE RESOLUTION

15.1 The Conditions shall be construed and governed by the laws of England and Wales.

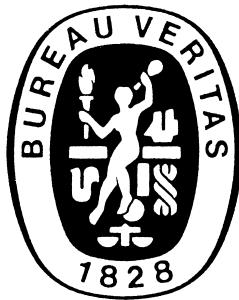
15.2 The Society and the Client shall make every effort to settle any dispute amicably and in good faith by way of negotiation within thirty (30) days from the date of receipt by either one of the Parties of a written notice of such dispute.

15.3 Failing that, the dispute shall finally be settled by arbitration under the LCIA rules, which rules are deemed to be incorporated by reference into this clause. The number of arbitrators shall be three (3). The place of arbitration shall be London (UK).

16. PROFESSIONAL ETHICS

16.1 Each Party shall conduct all activities in compliance with all laws, statutes, rules, and regulations applicable to such Party including but not limited to: child labour, forced labour, collective bargaining, discrimination, abuse, working hours and minimum wages, anti-bribery, anti-corruption. Each of the Parties warrants that neither it, nor its affiliates, has made or will make, with respect to the matters provided for herein, any offer, payment, gift or authorization of the payment of any money directly or indirectly, to or for the use or benefit of any official or employee of the government, political party, official or candidate.

16.2 In addition, the Client shall act consistently with the Society's Code of Ethics of Bureau Veritas. <http://www.bureauveritas.com/home/about-us/ethics-and-compliance/>



GUIDANCE NOTE NI 594

NI 594

Design and Construction of Offshore Concrete Structures

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SECTION 2 **CONTROL OF MATERIALS AND EXECUTION OF CONCRETE
WORKS**

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SECTION 1

GENERAL

1 General

1.1 Application

1.1.1 This Guidance Note provides guidelines for the design and construction of offshore concrete structures.

1.1.2 This Guidance Note is applicable to offshore structures made of reinforced or prestressed concrete.

1.1.3 For steel structural parts, reference is made to the applicable parts of the Offshore Rules and other associated Rule documents.

1.2 Referenced documents

1.2.1 Recognized standards

Reference is made to technical standards listed in Tab 1.

In particular, ISO 19903 "Petroleum and natural gas industries - Concrete offshore structures" is adopted for the application of the present Guidance Note.

1.2.2 Other standards

Technical standards, other than those stated in Tab 1, may be used on a case-by-case basis, upon the acceptance of the Society.

1.2.3 Combined use of technical standards

The full list of standards which are specified and used for a given project are to be submitted to the Society before the review of documents is started.

The Society will give a particular attention to combined use of technical Standards. The consistence of combined criteria and the global level of safety are to be demonstrated.

1.2.4 Offshore Rules

Offshore Rules means Bureau Veritas Rules for the Classification of Offshore Units (NR445). When reference is made to the Offshore Rules, the latest version of these ones is applicable.

Table 1 : Recognized standards

Standard		Comments
ISO 19900	Petroleum and natural gas industries - General requirements for offshore structures	General requirements applicable for offshore floaters
ISO 19903	Petroleum and natural gas industries - Concrete offshore structures	A large part of requirements are adopted for the purpose of the present Guidance Note: materials, loads, concrete works
EN 1992-1-1	Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings	Structural checks and materials
American Concrete Institute (ACI) set of publications		In particular: ACI 357.2R - Report on barge-like concrete structures ACI 546.2R - Guide to underwater repair of concrete
American Society for Testing Materials (ASTM) set of publications		In particulars, standards on concrete material and components testing methods
ISO 6934	Steel for prestressing of concrete	Requirements for prestressing steel and associated equipment
ISO 6935	Steel for the reinforcement of concrete	Requirements for reinforcing steel
ISO 1920	Testing of concrete	In particular: • making and curing test specimens • strength of hardened concrete
ISO 4463-1	Measurement methods for building - Setting-out and measurement - Part 1: Planning and organization, measuring procedures, acceptance criteria	Measuring procedures and acceptance criteria

2 Definitions

2.1 Offshore concrete structure

2.1.1 Splash zone

The splash zone is the area of the structure which is situated in the vicinity of the sea surface, being frequently wetted due to environmental effects (waves).

2.2 Concrete terms

2.2.1 Aggregate

The aggregate is a granular mineral material used as a component of concrete product. The aggregate can be natural, artificial or recycled from material previously used in construction.

2.2.2 Cement

The cement is the binder component of a structural concrete mix.

2.2.3 Admixture

The admixture is the material added during the mixing process of concrete, in small quantities relating to the mass of cement, in order to modify the properties of fresh or hardened concrete.

2.2.4 Addition

Additions are finely divided materials used in concrete mixture in order to improve certain properties or to achieve specific properties.

Two types of addition are considered:

- nearly inert additions (type I)
- pozzolanic or latent hydraulic additions (type II).

2.2.5 Concrete

Concrete is the material formed by mixing cements, coarse and fine aggregate and water, with or without the incorporation of admixtures and additions, which develops its properties by hydration of the cement.

2.2.6 Reinforcing steel

Reinforcing steel are all steel elements incorporated in structural concrete in order to provide additional strength, and in particular tensile strength, and which give the ductile characteristics of concrete.

2.2.7 Prestressing steel

Prestressing steel defines all steel elements and their related equipment used to apply a prestress (compression) on structural components, in order to avoid or to reduce regions of the structure loaded in tension.

3 Documents to be submitted

3.1 General

3.1.1 Documentation is to be prepared for all activities that are to be performed in the design, construction, installation and inspection of offshore concrete structures.

Procedures and manuals are to be prepared to ensure that the construction and installation are performed in a safe manner, fully compliant with all assumptions of the design.

3.2 Documents and drawings

3.2.1 Project specification

Prior to commencement of the review of drawings, the complete list of Rules, Codes and Statutory Requirements to be complied with must be submitted for information. This list is to detail the requirements to be complied with:

- International Rules
- Flag state requirements
- Coastal state requirements
- Owner standards and procedures
- Industry standards

The project specification is also to specify the list of Owner requested statutory certificates.

3.2.2 Construction

Procedures and detailed schedules for construction at each construction site together with transit, installation, anchoring and commissioning activities are to be submitted to the Society for information. These documents are also to indicate the possible interfaces between the various Contractors. The design review and survey program is to be based on these information.

3.2.3 General documents

- General arrangement
- Overview of concrete structure
- Description of construction and installation phases
- Description of the connections of the subsea systems with the unit

3.2.4 Layout and structure

- Structural arrangement
- Structural details including structural modelling
- Structure orientation
- Details of connections between concrete structure and equipment
- Details of concrete structure discontinuities
- Inspection and survey plans
- Storage/containment systems
- Corrosive characteristics of storage compartments (hydrocarbon, chemical products, sea water, etc)
- Corrosion protection measures and equipment
- Protective equipment against collisions
- Mooring systems, including lines, anchors and relating devices on the unit

3.2.5 Metocean data

- Storm, wave and current conditions for the intended operating site and for towing routes
- Data relating to water and air temperatures
- Specific meteorological conditions of the intended operating site
- Relevant wind data: velocities, directions
- Corrosive characteristics of air and water
- Ice and snow data, when relevant.

3.2.6 Documents for design and construction

- Procedures and manuals for the control of construction, transportation and installation
- Description of all products used for construction, material specifications, product standards
- Certification of prestressing systems and grouting products
- Material works certificates and test reports, defined in [3.3] and as required in Sec 2
- Reports and certificates for qualification process of concrete production
- Drawing issued for all construction phases, with information on geometry, amount and position of reinforcing and prestressed steel, tolerances and inserts
- Construction work procedures
- Design calculation reports, including all assumptions made for calculation
- Loading manual, including all loading conditions for transit phases and operations on-site
- Installation procedure and relevant drawings
- Quality control procedures.

3.3 Material certificates

3.3.1 Works certificates

Works certificates are documents submitted by the producer of construction material and giving the following information:

- test method, specifications and criteria
- all relevant test data
- certification that the tests have been carried out on samples taken from the delivered products
- all necessary information for identification of product, producer and purchaser.

Note 1: Works certificate may be waived when the material product is concerned by a National or International certification scheme and all required test data are documented based on statistical data from the producer, at the satisfaction of the Society.

3.3.2 Test reports

Test reports are documents issued by the producer of construction material containing the results of tests carried out on current production.

4 Design

4.1 General

4.1.1 The offshore concrete structure is to be designed in accordance with recognized standards specified in Tab 1 and Offshore Rules.

4.1.2 For concrete structures supporting marine renewable energy technologies, reference is made to the following guidance notes, as applicable:

- NI 631 - Certification scheme for Marine Renewable Energy technologies
- NI 603 - Current and tidal turbines
- NI 572 - Classification and certification of floating offshore wind turbines

SECTION 2

CONTROL OF MATERIALS AND EXECUTION OF CONCRETE WORKS

1 General

1.1 Application

1.1.1 The present Section provides guidelines for the control of materials and execution of concrete works as applicable for offshore concrete structures.

1.1.2 The present Section details the inspection activities relating to materials and execution, and provides additional guidelines for related documentation.

1.1.3 The requirements of the present Section are mainly based on those of ISO 19903.

1.2 Project specification

1.2.1 The project specifications are to include drawings, technical descriptions and specifications that describe how the structure is to be constructed.

1.2.2 Project specifications are to include:

- material grades
- particular requirements for materials and execution of works
- geometrical dimensions of the structure mentioning explicitly the tolerances
- inspection classes defined in [2.1]
- size of aggregate
- identification of any structural element of particular importance with respect to the inspection of the execution
- whether the strength properties of the structure is to be verified by test using specimens taken from the structure
- durability classes for individual structural members
- chloride class
- whether sulphate resistant cement is to be used
- testing methods and compliance standards
- significant construction joints
- nominal concrete cover to the reinforcing elements
- dimensions for cutting, bending and placing of reinforcing steel, including tolerances
- special provision to be made during the construction period

- locations of end anchorages and positions for the pre-stressing unit
- programme of prestressing including:
 - required concrete grade during prestressing
 - prestressing sequence
 - prestressing forces
 - elongations
 - specification of injections, injection inlets, location of ventilations, pump pressure limitations
- connections and positions of prefabricated elements, when relevant
- special requirements for the erection of prefabricated elements.

2 Inspection, testing and correcting actions

2.1 Classes of inspection

2.1.1 In order to differentiate the requirements for control and inspection according to the type and purpose of structural elements, three classes of inspection are defined:

- Class 1 - simplified inspection
- Class 2 - normal inspection
- Class 3 - extended inspection.

2.1.2 Inspection classes are to be defined by the applicant, as specified in [1.2].

2.1.3 By default, Class 3 - extended inspection apply for all structural elements which are important for structural strength. Class 1 and Class 2 will be specially considered for each project.

2.2 Inspection and testing

2.2.1 General requirements for inspections and documentation for each class are given in Tab 1.

2.2.2 Control of material and products is to comply with the requirements of Tab 2.

2.2.3 Control of the execution is to comply with the requirements of Tab 3.

Table 1 : General requirements for inspection and documentation

Item	Class 1	Class 2	Class 3
Inspection	Random inspection	Frequent but random inspection	Continuous inspection of each casting
Documentation	<ul style="list-style-type: none"> Records from all inspections. All non-conformities and corrective actions reports 	<ul style="list-style-type: none"> All planning documents Records from all inspections All non-conformities and corrective actions reports 	

Table 2 : Control of materials and products

Item	Class 1	Class 2	Class 3
Materials for formworks	Not required	In accordance with project specification	
Reinforcing steel		In accordance with the present Guidance Note, referenced and recognized standards	
Prestressing steel	Not relevant	In accordance with the present Guidance Note and ISO 6934	
Fresh concrete, ready mixed or site mixed		In accordance with the present Guidance Note	
Embedded elements		In accordance with the present Guidance Note and the project specification	
Precast elements		In accordance with the present Guidance Note and ISO 19903	
Inspection reports	Not required		Required

Table 3 : Control of execution

Item	Class 1	Class 2	Class 3
Scaffolding, formwork and falsework	Random checking	Major scaffolding and formworks are to be inspected before concreting	All scaffolding and formworks are to be inspected before concreting
Ordinary reinforcement	Random checking	Major reinforcements are to be inspected before concreting	All reinforcements are to be inspected before concreting
Prestressing reinforcement	Not relevant	<ul style="list-style-type: none"> All prestressing components are to be inspected before concreting, threading, stressing. All materials are to be identified by appropriate documentation. 	
Embedded items		According to ISO 19903 and project specification	
Erection of precast elements	Not relevant		Prior to completion and at the completion
Site transport and casting of concrete	Occasional checking	Basic and random inspection	Detailed inspection of entire process
Curing and finishing of concrete	Occasional checking	Occasional checking	Regular inspection
Stressing and grouting of precasting reinforcement	Not relevant		Detailed inspection of the operation, including evaluation of stressing records prior to cutting permission
Geometry of final structure	Not relevant		According to the present Guidance Note, ISO 19903 and project specification
Documentation of inspection	Not relevant		Required

2.2.4 Inspection of falsework and formwork

Inspections before casting, according to relevant classes, are to include the followings:

- geometry of formwork
- stability of formwork and falsework and their foundations
- tightness of formwork and its parts

- removal of detritus and remains from the formwork
- treatment of construction joints
- wetting of formwork
- preparation of formwork surface
- openings and blockouts

After formwork removal, it is to be checked that temporary inserts are removed.

2.2.5 Inspection of reinforcing steel

Before casting, inspections according to relevant classes are to confirm that:

- the reinforcing steel is positioned at the specified spacing, in accordance with design drawings
- the concrete cover is in accordance with the specifications
- the reinforcing steel is not contaminated with oil, grease or paint
- the reinforcement is tied and secured against displacement during concreting
- the space between bars is sufficient to place and compact the concrete.

2.2.6 Inspection of prestressing works

Before casting operations, inspections will confirm that:

- the position of tendons, sheaths, vents, drains, couplers, anchorages, etc, is in accordance with design drawings, including the cover of tendons and spacing of tendons
- the tendons and sheaths are fixedly secured and their supports are stables
- the sheaths, vents, drains, anchorages, couplers and their sealing are not damaged
- the tendons, anchorages and couplers are not corroded
- the sheaths, anchorages and couplers are clean.

Prior to tensioning or prior to releasing the pretension force, the actual concrete strength is to be checked against the requested strength. The calibration of jacks is to be checked.

Before the start of grouting operations, the inspections are to ensure that:

- the qualification of grout is done, as required
- the results of trial grouting are as required
- ducts are clean and opened for grout through their length
- vents are prepared and identified
- materials are batched and sufficient for overflow.

During grouting, the inspections are to include:

- check of the conformity of fresh grout tests for fluidity and segregation
- check of the characteristics of equipment and grout.

2.2.7 Inspection of concreting operations

The inspection of concreting operations is to be performed and documented in accordance with the requirements of the present Guidance Note, according to the allocated class.

3 Materials

3.1 General

3.1.1 The approval of materials and concrete components and reinforcements is based on material testing, chemical composition, mechanical properties and other specified requirements given in the present Guidance Note.

3.1.2 Material specifications are to be established for all materials that are used in the production of concrete.

3.1.3 Material can be rejected at any stage of execution if it is established that the conditions upon which the approval was based were not fulfilled.

3.2 Concrete components

3.2.1 General

Concrete components are to be sound, durable and suitable for making concrete that will attain and retain the required properties.

Concrete components are not to contain harmful ingredients in quantities that can cause corrosion of reinforcing steel or be detrimental to the durability of concrete.

3.2.2 Cement - Certificates

Cement is to be delivered with works certificates, giving at least the chemical and mineralogical composition of the product and the test values for all required properties.

Works certificates are also to state the type/grade of the cement, the batch identification and the tonnage, and are to demonstrate compliance with other specified requirements, when relevant.

Note 1: Works certificates may not be requested when the cement is produced and tested under a national or international certification scheme, and all required properties are documented based on statistical data from the producer.

3.2.3 Cement - Testing

Cement is to be tested in accordance with an approved method as defined in recognized standards such as ASTM ones.

The following type of test may be required:

a) Physical properties

- Strength in mortar
- Soundness
- Fineness
- Initial settling time
- Normal consistency
- Volumetric stability.

b) Chemical composition

- Oxide composition
- Sulphate content
- Chlorite content
- Loss of ignition
- Pozzolanicity
- Insoluble residue.

3.2.4 Cement - Chemical composition

Mineral composition of cement is to be calculated using accurate methods, such as Bogue method.

The content of tricalcium aluminates (C_3A) is to be evaluated. The content of tricalcium aluminates will be kept, preferably, between 5% and 10%.

Note 1: A content of C_3A lower than 5% may adversely affect the corrosion protection of embedded steel.

3.2.5 Types of cement for marine environment

The cement used for offshore concrete structures is to have an established suitability for use in marine environment.

The following types of cement are considered as suitable for offshore concrete structure operating in marine environment, if unmixed with other types of cement:

- Portland cements
- Portland composite cements, with silica, fly ash or slag and minimum 80% clinker.

Provided that the suitability is demonstrated, the following types of cement may also be considered:

- other Portland composite cements, with other pozzolanas or clinker below 80%
- Blast-furnace cements (less than 64% clinker)
- Pozzolanic cements with less than 64% clinker
- Composite cements with less than 64% clinker.

Cements are to be specified in grades based on the 28 days strength in mortar and are normally categorized as normal hardening, rapid hardening and slow hardening cements.

3.2.6 Mixing water

The sources of mixing water are to be investigated and approved for their suitability and dependability for supply.

The mixing water is not to contain chemical constituents in quantities that can be detrimental to setting, hardening or durability of the concrete, or can cause corrosion of reinforcing steel.

Drinking water from public supply can normally be used without further investigation. Exceptionally, the Society may request specific investigations for the acceptance of public supply water.

The following types of mixing water are not to be used for concrete production:

- water resulting in a concrete strength less than 90% of that obtained using distilled water tested at 7 days
- water reducing the setting time to less than 45 minutes or changes the setting time by more than 30 minutes relative to distilled water.

Salt water is not to be used for concrete production or curing.

3.2.7 Aggregate - General

Aggregate is categorized as follows:

- normal weight aggregate is the aggregate with an oven-dry (105°C) particle density between 2000 kg/m³ and 3000 kg/m³
- light weight aggregate is the aggregate with an oven-dry (105°C) particle density less than 2000 kg/m³ or a loose oven-dry bulk density less than 1200 kg/m³.

Aggregates are not to become soft, excessively friable, expand or shrink. They are not to react with the products of hydration of cement and are not to affect the concrete adversely by their composition.

Aggregates from sea bed are normally not to be used, except when they are properly washed to remove chlorites.

3.2.8 Aggregate - Documentation

Aggregate is to be delivered with a test report, as defined in Sec 1, including at least the following information:

- description of the source
- description of the production system
- particle size distribution/grading including silt content
- particle shape, flakiness
- porosity and water absorption
- content of organic matter
- density and specific gravity
- potential reactivity with alkalis in cement
- petrographical composition and properties than can affect concrete durability.

The sources of aggregate are to be investigated and approved for their suitability and dependability for supply. Aggregates of different grading will be stockpiled and transported separately.

3.2.9 Aggregate - Testing

Testing of aggregate is to be carried out at regular intervals, both at quarry and at the construction site during concrete production. The attendance of a surveyor may be requested by the Society, on a case-by-case basis.

The frequency of testing will be defined based on the quality and uniformity of the supply and the volume of concrete production, in accordance with the applicable standard.

An appropriate grading of fine and coarse aggregate is to be established. The grading and shape characteristics are to be consistent throughout the concrete production.

3.2.10 Normal weight aggregate

Normal weight aggregate, as defined in [3.2.7] is to be of natural mineral substances resistant to decomposition when wet.

Relevant properties of aggregate are to be defined, such as:

- type of material
- shape
- surface texture
- physical properties
- chemical properties.

Harmful substances such as claylike and silty particles, organic materials, sulphates and other salts are to be in quantities that will not affect the properties and durability of concrete adversely.

Maximum aggregate size is not to be less than 16 mm. Maximum aggregate size is to be specified, based on considerations of concrete properties, spacing and cover of reinforcing steel.

The risk of alkali aggregate reaction in concrete is also to be evaluated, using accepted test methods.

3.2.11 Lightweight aggregate

Lightweight aggregates, as defined in [3.2.7] are to be made from expanded clay, expanded shale, slate or sintered pulverized ash from coal-fired power plants or from other aggregates with corresponding documented properties.

Lightweight aggregates are to present uniform strength properties, stiffness, density, degree of burning and grading. The dry density is not to vary more than 7,5%.

3.2.12 Additions

Additions used for concrete production are to have a chemical composition which is compatible with all other concrete components. Combinations of additions and admixtures are to be specially considered with respect to the overall requirements of the concrete. The effectiveness of the additions are to be checked by trial mixes.

Additions may be constituted from latent hydraulic or pozzolanic materials such as:

- silica fume, in quantities not exceeding 10% of the weight of Portland cement clinker
- fly ash or other pozzolanas, in quantities not exceeding 35% of the total weight of Portland cement and additions
- granulated blast furnace slag, in quantities for which the clinker content is not less than 30% of the total weight of cement and slag.

The total amount of chlorides in the fresh concrete, calculated as free calcium chloride, is not to exceed 0,3% of the cement weight.

3.2.13 Admixtures

Admixtures used for concrete production are to be tested on the production site together with the cement and additions, in order to check that their combination will yield the required effect without affecting adversely the properties of the concrete.

The following properties are to be tested:

- consistence, such as at 5 and 30 minutes after mixing
- concrete strength in compression, tension and bending at 28 days.

Risks relating to overdosage events are also to be assessed. A test report is to be prepared and submitted for such checks.

3.2.14 Repair materials

Repair materials are to be compatible with adjacent material, particularly from the point of view of elasticity and temperature dependent properties. The documentation, testing and approval of such materials is to be done on a case-by-case basis.

3.3 Concrete

3.3.1 General

Material specifications for fresh and hardened concrete are to be established and submitted. Concrete properties are to be verified by testing methods, based on recognized standards.

The following concrete properties are concerned:

- compressive strength
- tensile strength
- modulus of elasticity
- fracture energy
- properties influencing cracking of the concrete, such as:
 - creep
 - shrinkage
 - heat of hydration
 - thermal expansion
- properties related to the durability of concrete, such as:
 - permeability
 - absorption
 - water/cement ratio
 - other properties related to physical and chemical attacks resistance.

3.3.2 Water / cement ratio

Water/cement ratio is the ratio of the mass of water to the mass of cement used in a concrete mix. A low water/cement ratio leads to higher strength and durability, but affects adversely the plasticity of fresh concrete.

The effective water/cement ratio is calculated by deducting the mass of absorption water for aggregate 24 hours saturated in dry surface condition.

Type II additions (pozzolanic or latent hydraulic additions) may be taken into account for the calculation of effective water/cement ratio, when used in combination with Portland or Portland composite cement. The following formula is to be used:

$$m = \frac{w}{(c + ka)}$$

w : Mass of water

c : Mass of cement

k : Efficiency factor for type II additions, to be determined with respect to durability in the given environment; except when duly justified, the values of this factor are to consider the limits given in Tab 4.

a : Mass of type II addition.

The maximum effective water/cement ratio values to be used for structural concrete of offshore barges is given in Tab 5.

Table 4 : Efficiency factors for type II additions

Type II addition	Efficiency factor k
Silica	1 to 2
Slag	0,5 to 0,7
Fly ash	0,2 to 0,4

Table 5 : Effective water/cement ratio

Structural zone	Maximum values of effective water/cement ratio m
Outside splash zone	0,45
Splash zone	0,40
Zones exposed to severe frost	0,40

3.3.3 Additions

The amount of additions used in concrete mix is to respect the corresponding limits specified for the cement, as relevant.

3.3.4 Chloride

For concrete used for structural elements of the offshore structure, the total amount of chloride ions in fresh concrete is not to exceed 0,10% of the mass of cement.

3.3.5 Frost resistance

Frost resistance of concrete subjected to freezing and thawing is to be demonstrated by appropriate methods. In concrete having a slag content more than 35%, the concrete is to be carbonated before testing.

The above requirements may be waived by the Society for concrete using Portland cement with more than 80% clinker, with special consideration of air content, when entrained air is used. Additional requirements are given in ISO 19903.

3.3.6 Cement content

The minimum cement content is to comply with the requirements given in Tab 6.

Table 6 : Minimum cement content

Zone	Aggregate maximum size (mm)	Minimum cement content (Kg/m ³)
Splash zone	–	400
Reinforced or prestressed concrete outside the splash zone	< 20	360
	< 40	320

3.3.7 Minimum strength

For concrete exposed to seawater or hydrocarbon products, the characteristic cylinder strength at 28 days is not to be less than 40 MPa.

For other concrete structural elements the characteristic cylinder strength at 28 days is not to be less than 30 MPa.

3.3.8 Water absorption

For concrete hull elements, and in particular for concrete in the splash zone and below, water absorption is to be determined by testing under the same conditions to which the concrete will be exposed during operations and transit.

3.3.9 Lightweight aggregate with porous structure

For concrete where lightweight aggregate with porous structure is used, the following conditions are to be complied with:

- the mean value of the oven-dry density (105°C) for two specimens after 28 days is not to deviate by more than 50 Kg/m³ from the required value
- any individual value is not to deviate by more than 75 Kg/m³
- the mean value for the entire production are to remain between +20 Kg/m³ and -50 Kg/m³.

3.4 Mortar and grout

3.4.1 General

Constituents of grout and mortar are to comply with the same requirements given for concrete constituents given in [3.2], as relevant.

3.4.2 Grout for injection in prestressing ducts

The properties of grout for injection in prestressing ducts are to be unambiguously specified, and are to be compatible with the other prestressing materials and with the prestressing procedure.

3.4.3 Batching

All materials are to be batched by mass. Mixing water is also to be batched by volume. Batching accuracy is to be as follows:

- 2% for cement and admixtures
- 1% for water.

Water/cement ratio is not to be higher than 0,45.

3.5 Reinforcing steel

3.5.1 General

Reinforcing steel is to be delivered with a Works Certificate.

All steel materials are to be clearly identifiable.

3.5.2 Standards

Reinforcing steel is to comply with standards recognized by the Society, as defined in Sec 1, and in particular with ISO 6935.

In general, reinforcing steel is to be of hot-rolled, ribbed bars of weldable quality and high ductility.

3.5.3 Galvanized and stainless steel

Galvanized steel may be used as reinforcing steel, provided that it is proven that there will be no chemical reaction with cement having a detrimental effect on the bond to the galvanized steel.

Stainless steel may be used provided that the requirements specified for the mechanical properties of ordinary reinforcing steel are met.

3.5.4 Fatigue properties

Fatigue properties and S-N curves proven by steel documentation are to be consistent with the assumptions used for design.

3.5.5 Welding procedures

Welding procedures and the extent of testing for weld connections are to be specified for each case and approved by the Society.

Generally, welding procedures are to be in accordance with standards recognized by the Society. Case-by-case requirements may also be defined, depending on the weld type or on the specificities of weld connections.

3.5.6 Mechanical splices and end-anchorage

Mechanical splices and end-anchorage are to be delivered with a Works Certificate.

Fatigue properties are to be tested and documented for the actual combination of rebars, couplers and anchorages.

Couplers giving a permanent slip on unloaded specimen of more than 0,1 mm after 10 cycles of loading to 75% of the nominal yield strength are not to be used.

Friction welded end-anchorage on rebars are to be qualified by testing in advance and during production. Testing programme for qualification is to include a tension test and a bending test, documenting the strength and ductility of the connection. The friction weld is not to fail before the rebar.

3.6 Prestressing steel and equipment

3.6.1 General

Prestressing steel and components are to be delivered with a Works Certificate.

Prestressing steel is to comply with relevant standards recognized by the Society, as defined in Sec 1, and in particular with ISO 6934.

Prestressing equipment is to comply with the requirements of work specification and are to be approved by the Society. Previous approval by a national authority or a recognized institution may be accepted on a case-by-case basis.

3.6.2 Components

Prestressing system is generally composed by:

- tendons (wire, strands, bars)
- anchorage devices
- couplers
- ducts or sheaths.

All components are to be compatible each other and clearly identifiable.

Sheaths for post-tensioning tendons are, generally, of a semi-rigid or rigid type. They are to be watertight and with adequate stiffness to prevent damages and deformations.

4 Execution

4.1 General

4.1.1 The execution of concrete works influence directly on the quality of the structural concrete of the offshore barge. The present Article defines requirements applicable for the execution procedures and for the use of various materials and equipment during construction.

4.1.2 The compliance with the requirements of the present Article will be verified by surveyors of the Society based on the existing documentation and by attendance of execution operations.

The extent and duration of surveyors attendance is to be established on a case-by-case basis, taking into account the specificities of concrete works, the used equipment and the site of execution.

Survey reports carried out by certified parties recognized by the Society or relevant authorities may be accepted by the Society.

4.1.3 The present Article adopts the requirements given in ISO 19903.

4.2 Falsework and formwork

4.2.1 General

Falsework and formwork including their supporting elements and foundations are to be designed and constructed based on the following principles:

- to be compatible with the execution procedure specified for the intended project
- to sustain actions and loading expected during construction
- to have a stiffness compatible with the tolerances specified for the structural element under construction.

4.2.2 Falsework

A method statement for falsework is to be submitted and approved by the Society. Generally, it is to include:

- requirements specified for handling and adjusting, and chosen methods
- requirements specified for intentional precambering and methods
- requirements specified for unkeying, striking and dismantling and methods.

A particular attention is to be given to falsework deformations in order to prevent cracking of young concrete.

4.2.3 Formwork

Formwork is to keep the concrete in the shape until its hardening.

The boards of panels are to be sufficiently tight to avoid loss of water or fine materials. When materials used for formworks are expected to absorb or facilitate evaporation of water, they are to be wetted in order to minimize these effects.

Slipform systems and jumpform systems, when used, are to comply with the requirements of ISO 19903.

4.2.4 Temporary inserts

Temporary inserts and embedded components relating to formwork are to comply with the following requirements:

- to be fixed such as to ensure their position during placing and concreting
- to be of materials that are not expected to react with concrete and reinforcing steel
- to not impair placing and compaction of the fresh concrete
- to avoid unacceptable surface blemishes.

4.2.5 Recesses

Recesses used for temporary works are to be filled and finished with a material of similar quality as the surrounding concrete, unless otherwise specified.

4.2.6 Block-outs and temporary holes

Block-outs and temporary holes are generally to be cast with normal concrete. Their surfaces are to be prepared as construction joints.

4.2.7 Removal

The removal of falsework and formwork is not to be done before the concrete has gained sufficient strength:

- to resist damage to surfaces that can arise during the striking
- to undertake the actions imposed at the concrete members at the stage
- to avoid deflections not compliant with specified tolerances, taking into account the elastic behavior and creep of the concrete.

Striking is not to produce damage to concrete structure.

4.3 Reinforcing steel

4.3.1 Storage

During the execution, reinforcing steel is not to be stored on the ground. Adequate protections of the storage area are to be provided against mechanical damage and corrosion.

For concrete works, the surface of reinforcing steel is to be free from loose rust, mill scale and deleterious substances.

4.3.2 Bending

The following requirements are to be complied with:

- bending of reinforcing steel is to be done at a uniform rate
- bending using heat treatment is generally not to be used.

A particular attention is to be given to bending of reinforcing steel at a temperature below 0°C. Depending on the specificities of the concerned site, the Society may require to apply relevant national standards covering this aspect.

Bars and wires are to be tested using bending test mandrels, in order to verify if the related diameter can be bent without cracking or damage. Bending for concrete works is not to be done with mandrels having a diameter lower than 1,5 times the diameter of test mandrels.

Bending of steel in the formwork is allowed only if it can be demonstrated that the prescribed bending radius is obtained, and no mispositioning of the reinforcement occurs.

4.3.3 Coil delivered steel

Coil delivered steel is to be handled using appropriate equipment. The straightening is to be done using approved procedures, and all specified mechanical properties are to be maintained.

4.3.4 Prefabricated assemblies

When prefabricated assemblies are used, they are to comply with all requirements for positioning tolerances of reinforcing steel.

A particular attention is to be given to the overall stiffness of the assemblies, in order to ensure the requested shape during transport, storage, positioning and concreting.

4.3.5 Welding

Welding of reinforcing steel is to be used only on materials which are categorized as weldable by their requested documentation.

The requirements of recognized standards specified for the project and relating to welding are to be considered. In particular, the relevant requirements of ISO 6935 are to be considered.

Welding is not to be executed near bends, except when specifically approved by design.

When galvanized or epoxy-coated reinforcing steel is used, welding is allowed only if a procedure for repair is specified and approved.

4.3.6 Positioning of reinforcing assemblies

Reinforcing steel assemblies are to be positioned in full accordance with the design drawings. The requirements concerning related tolerances for final position and for fixing the reinforcing steel given in the present Guidance Note are also to be complied with.

Assemblies of reinforcing steel are to be done by tie wire. Spot welding or equivalent welding fixation are generally not to be used, except when the risk of fatigue failure of the main rebar of the weld is taken into account.

In zones with high density of reinforcing steel, measures are to be taken to allow a normal flow of fresh concrete and fill all voids without segregation. Measures are also to be taken to ascertain that the concrete can be adequately compacted.

The cover of the reinforcing steel, as specified on design drawings, is to be maintained by chairs and spacers. Spacers in contact with the concrete surface in a corrosive environment are to be made from concrete having at least the same quality as the structure.

4.3.7 Joints

Joints of reinforcing steel are to be made by laps or couplers. Couplers are accepted when tested and approved.

Butt welds on bars are allowed provided that prequalification testing with non-destructive examination and visual inspections of all welds during execution are carried out.

The length and position of all lapped joints are to be in accordance with design drawings and project work specifications.

4.4 Prestressing steel and systems

4.4.1 General

Generally, prestressing systems/assembly consist of elements defined in [3.6.2]. All components are to be protected from harmful influences during transport, storage, and all stages before the permanent protection in the final structure.

Any material or element found damaged or corroded is to be replaced.

4.4.2 Fabrication

Identification documents and certification of tests on materials and tendons is to be available on the site of execution. Each component is to be clearly identified and traceable.

Prestressing steel is not to be subjected to welding and oxygen cutting. Exceptions may be accepted based on the provisions of ISO 19903.

4.4.3 Positioning

Prestressing system assemblies are to be positioned in accordance with the supplier specifications and in accordance with the construction drawings.

Relevant requirements of the present Guidance Note relating to positioning tolerances are to be complied with. Tendons are not to sag or have a kink of any kind.

4.4.4 Tendons tensioning

A method statement for tendons tensioning is to be submitted and approved. The jacking force/pressure and elongation at each step of the stressing operation until full force is obtained are to be recorded in a log and compared with pre-calculated values. All problems and/or non-conformities during tensioning are also to be recorded for the approval of the Society.

The calibration of force-measuring devices is to be done on the site of execution, before the start of tensioning operations.

The prestressing forces are to be transferred to a concrete structural element only at a concrete strength fully compliant with the requirements specified by the design, and in no case less than the minimum compressive strength specified by the approval document of the prestressing system. A particular attention is to be given to the anchorage areas.

4.4.5 Post-tensioned tendons

The following parameters are to be checked for compliance with supplier specification and other relevant approval documents:

- straight entry into anchorages and couplers
- coaxiality of tendons and anchorages.

Vents and drains on the sheaths are to be provided at both ends and at all points where air or water can accumulate. For sheaths of considerable length, intermediate vents and drains are to be provided.

Alternative means of draining may be accepted on a case-by-case basis.

Vents and drains are to be marked such as to identify the cable.

The sheaths are to be checked after pouring of concrete to ensure sufficient passage for the tendons, and are to be cleared of any water immediately prior to tendon threading.

4.4.6 Pre-tensioning

The release of prestressing force is to be done such that the bond in the anchorage zone of the tendon will not be damaged.

When fresh concrete cannot be cast in due time after tensioning, appropriate protective measures are to be taken to avoid damage of the bond or detrimental effect of steel or concrete.

During stressing, the calculated elongation is to be achieved within a range of 3% for a group of tendons or 5% for a single tendon within the group for the specified tensioning force. Otherwise, relevant actions are to be taken regarding the tensioning programme or the design.

4.4.7 Post-tensioning

Tensioning is not to be carried out when air temperature is below -10°C , or in other conditions where there is a risk of grout freezing.

During stressing, the calculated elongation is to be achieved within a range of 5% for a group of tendons or 10% for a single tendon within the group for the specified tensioning force. Otherwise, relevant actions are to be taken regarding the tensioning programme or the design.

When planned performance of tensioning is not achieved, further work (including grouting of tendon cut-off) is to be postponed until the tendon is approved or corrective actions established. Additional tests may be requested by the Society to confirm friction factors or elastic modulus of tendon assembly.

The period from threading to prestressing of tendons is normally not to exceed 4 weeks. During this period, tendons are to be protected against corrosion.

Grouting/injection is to be done as soon as possible after tensioning, normally within 2 weeks.

4.4.8 Protective measures

Tendons placed in sheaths, couplers and anchoring devices are to be protected against corrosion by filling all voids with a grouting/injection material such as:

- cement grout
- grease
- wax.

These materials are to comply with the requirements of [3.4].

Anchorage areas and end caps are also to be filled and protected. Inlets and outlets are to be sealed.

4.4.9 Grouting

A method statement is to be provided for the preparation and execution of grouting/injection operations. All important data and observations relating to grouting are to be recorded in a log.

Grouting operations using cement-based grout are to be done within temperature conditions as given in Tab 7. Grouting at temperatures other than specified in Tab 7 may be accepted by the Society on a case-by-case basis, taking into account the specificities of grouting method and materials.

Grouting at temperatures lower than $+5^{\circ}\text{C}$ may be allowed only when frost resistant grout material is used.

Grouting is to be carried out at a continuous and steady rate from the lowest inlet until the emerging grout through anchor heads and outlets.

As a rule, grout pressure in ducts is not to exceed 2 MPa, unless when allowed by the design. A particular attention is to be given to vertical ducts.

Non-retarded grout and grout without an expanding admixture is to be used within 30 minutes after mixing.

In vertical or inclined ducts, or ducts with large diameter, post-injections before grout stiffening may be required in order to remove voids or water. When voids are detected after grout stiffening, post-injection by vacuum grouting is to be carried out. Vacuum grouting is also required in case of duct blockage.

Vacuum injections are to be pre-qualified by trials, particularly for vertical ducts. When vacuum injection are used, the free volume of ducts is to be measured and compared with the volume of injected grout.

After completion of grouting, the ducts are to be sealed under a pressure of at least 0,5 MPa during at least 1 minute.

When the grouting of a duct is interrupted, the fresh material inside the duct is to be washed. No duct is to be left with incomplete filling of grout.

Table 7 : Temperature ranges for cement-based grouting

	Temperature ranges (°C)	
	Minimum	Maximum
Structure temperature	+5	+35
Cement-based grout temperature	+10	+25

4.4.10 Greasing

Greasing is to be carried out at a continuous and steady rate. After completion of greasing, the ducts are to be sealed under pressure.

The volume of the injected grease is to be checked against the theoretical free volume in the duct. The change of grease volume with the change of temperature is to be taken into account.

4.5 Concreting

4.5.1 General

Reference is made to the requirements of ISO 19903.

4.5.2 Concrete testing

Concrete is to be inspected at the point of placing. In the case of ready-mixed concrete, inspections are also to be done at the point of delivery. Samples are to be taken at the point of placing.

4.5.3 Identity testing

Identity testing is to be carried out in order to verify that the concrete comes from a conforming population.

Identity testing are requested at the point of delivery for ready-mixed concrete produced according to a recognized certification scheme which certifies that all project requirements are complied with. Identity testing may replace the requirements of [4.5.2].

4.5.4 Pre-concreting operations

All preparation works are to be completed, inspected and documented, as requested by the present Guidance Note, before the casting is initiated.

When fresh concrete is pumped, an adequate back-up or emergency procedure in case of blockage of piping is to be prepared and submitted.

Construction joints are to present a roughened surface, which can be obtained by the application of a surface retarder on the fresh concrete and later cleaned by water jet. Concrete joints are to be clean and free of laitance.

A particular attention is to be given to the protection of concrete against freezing, when the temperature is forecasted to be below 0°C at the time of casting or in the curing period.

Where the ambient temperature is forecasted to be above 30°C at the time of casting or in the curing period, precautions are to be planned to protect the concrete against damaging effects of high temperatures.

4.5.5 Placing and compaction

The concrete is to be placed and compacted in order to ensure that all reinforcement and cast-in items are properly embedded in compacted concrete and that the concrete achieves its intended strength and durability.

Appropriate procedures are to be used where cross-sections are changed, in narrow locations, at box-outs, at dense reinforcement arrangements and at construction joints. Settlement cracking over reinforcement in the top surface is to be avoided by re-vibration.

The rate of placing and compaction is to be high enough to avoid cold joints and low enough to prevent excessive settlements or overloading of the formwork and falsework. The concrete is to be placed in layers of a thickness that is compatible with the capacity of the vibrators used. The concrete of the new layer is to be vibrated systematically and include re-vibration of the top of the previous layer in order to avoid weak or inhomogeneous zones in the concrete. The vibration is to be applied until the expulsion of entrapped air has practically ceased, but not so as to cause segregation or a weak surface layer.

Concrete is to be placed in such a manner as to avoid segregation. Free fall of concrete from a height of more than 2 m is not occur unless the mix is demonstrated to allow this without segregation.

Concrete is to be compacted by means of high-frequency vibrators or by alternative methods that can be demonstrated to give adequate compaction. Contact between internal vibrators and reinforcement or formwork will be avoided as much as possible. Vibrators are not be used for horizontal spreading of concrete.

Alternative methods to the use of vibrators in order to obtain an adequately compacted concrete are permitted, provided they are able to be documented for the relevant type of conditions by trial casting. During placing and compaction, the concrete is to be protected against adverse solar radiation and wind, freezing, water, rain and snow. Surface water is to be removed during concreting if the planned protection fails.

4.5.6 Curing and protection of hardened concrete

Relevant requirements given in ISO 19903 are to be complied with. Reference is also made to the requirements of ISO 1920-3 and ISO 1920-4.

Concreting procedures are to ensure adequate curing in order to obtain maximum durability, minimize plastic shrinkage, losses in strength and durability and to avoid cracking. The curing period is not to be less than two weeks. The duration of curing may be further estimated based on testing of strength or alternatively by the maturity of the concrete on the basis of the surface temperature of the concrete or the ambient temperature. The maturity calculation is to be based on an appropriate maturity function proven for the type of cement or combination of cement and addition used.

Curing compounds are not permitted on construction joints, on surfaces where bonding of other materials is required, unless they are fully removed prior to the subsequent operation, or they are proven to have no detrimental effects on bonding.

The surface is to be protected from damage due to heavy rain, flowing water or other mechanical influences.

4.5.7 Post-concreting

After removal of formwork, all surfaces are to be inspected for conformity to the requirements of the design. The surface are to be protected from damages during construction.

4.6 Embedded components

4.6.1 General reference

The requirements of ISO 19903 are to be complied with.