RCC-CW 2015 Edition

Rules for Design and Construction of PWR Nuclear Civil Works

1st Errata - July 2016

French Association for Design, Construction, and In Service Inspection Rules for Nuclear Island Components



This document proposes modifications identified through:

- the feedback of AFCEN codes users.
- the preparation of "Traduction Française de l'Edition RCC-CW 2015".

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GTABL ORGANISATION OF THE RCC-CW

GTABL 1000 GENERAL ORGANISATION

RCC-CW consists of four Parts. Nevertheless, RCC-CW shall be considered as a whole.

Figure GTABL 1000-1 gives an overview of RCC-CW organization.

PART G defines the generic provisions : structure and scope of RCC-CW, standards and texts referred to and quality management requirements.

PART D provides design requirements :

- the actions and combinations of actions to be taken into account in the design of civil works (see DGENR 3000). However, numerical values (intensity of loads) associated to these actions shall be provided by specific documents for each Nuclear Power Plant Project (such as SR, see Table 1200-1);
- GREFD the rules or criteria needed to design the structures are in chapters DCONC for concrete structures, DCLIN for containment liners (metal parts involved in the tightness of the RB containment), DPLIN for pool and tank liners, DSTLW for structural steelwork, DANCH for anchorages and DGEOT for geotechnical issues.

PART C provides requirements applicable to construction (concrete, reinforcement, prestressing system, leaktightness of metal parts, etc...).

PART M provides the main principles for containment testing and monitoring, covering the initial acceptance test and subsequent periodic tests.

PART G GENERAL GREFD STANDARDS AND DOCUMENTS REFERRED TO IN THE RCC-CW

STANDARD	DATE	TITLE
NF P 18-508	01/2012	Additions for concrete - Limestone additions - Specifications and conformity criteria
NF P 18-509	09/2012	Additions for concrete - Silicious additions - Specifications and conformity criteria.
NF P 18-545	09/2011	Aggregates – Defining elements, conformity and coding
NF P 18-576 ⁽¹⁾	02/2013	Aggregates - Measurement of the friability coefficient for fine aggregate
XP P 18-420	05/2012	Concrete - Scaling test for hardened concrete surfaces exposed to frost in the presence of a salt solution
XP P 18-594	02/2004	Aggregates – test methods on reactivity to alkalies

(1) A translation is given in APPENDIX CE.

(2) A translation is given in APPENDIX CF.

(3) A translation is given in APPENDIX CG.

(4) The procedure, extracted from NF P 18-454, to evaluate the potential reactivity of a concrete mix with regard to alkali silica reaction is given in APPENDIX Standards referred to in chapter CFNSH

СН

PART G GENERAL GREFD STANDARDS AND DOCUMENTS REFERRED TO IN THE RCC-CW

	STANDARD	DATE	TITLE
	EN ISO 15609 (parts 1 to 6)	Part 1 : 10/2004 Part 2 : 09/2001 /A1 : 12/2003 Part 3 : 08/2004 Part 4 : 05/2009 Part 5 : 10/2011 Part 6 : 03/2013	Specification and qualification of welding procedures for metallic materials - Welding procedure specification : Part 1 : arc welding Part 2 : gas welding Part 3 : electron beam welding Part 4 : Laser beam welding Part 5 : Resistance welding Part 6 : Laser-arc hybrid welding
	EN ISO 17637	03/2011	Non-destructive testing of welds. Visual testing of fusion-welded joints
	EN ISO 23277	11/2009	Non-destructive testing of welds. Penetrant testing of welds. Acceptance levels
ΕN	ISO 3452-1	06/2013	Non-destructive testing. Penetrant testing. General principles

GDEFN 4400 ACCIDENTAL ACTIONS RELATED TO DEC AND DEH

Symbol	Action		
A _{de,P}	Design extension value of actions resulting from the rupture of a double-strain rupture of the pipework of the main primary circuit (LOCA _E DEC)		
$A_{de,St}$	Design extension value of actions resulting from the break of the pipework of the main secondary system (SSPB)		
$A_{de,A}$	Design extension values enveloping the actions (including the thermal effects) caused during an accident with a core melt (DEC).		
$A_{de,E}$	Design extension value of actions caused during a DEE, including the induced vibration, and the reaction of the equipment and water for pools.		
A _{de,exp}	Design extension value of action caused by an external explosion in DED.		
A _{de,m}	Design extension value of action caused by dropped loads in DED.		
A _{de,s}	Design extension value of actions caused by snow in DED.		
A _{db,T,ext}	Design extension values of extreme environmental temperatures.		
Adb,to	Design extension values of tornado.		
A _{de,w}	Design extension values of actions caused by wind or by a tornado (wind and projectile actions) in DED.		
A _{de,wl}	Design extension value of actions caused by flooding in DED.		

MATERIALS AND DESIGN VALUES

Greek letters

Symbols	Description		
σ _c	Compressive stress in the concrete.		
$\sigma_{c,QP}$	Stress in the concrete adjacent to the tendons, due to self-weight and initial prestress and other quasi-permanent actions where relevant.		
σ _{cw}	Compressive stress in shear struts of the concrete.		
σ _n	Axial stress (at a joint).		
Δσ _P	Variation of stress in prestressing steel.		
σ _{pi}	Absolute value of the initial prestress.		
$\Delta\sigma_{\rm pr}$	Absolute value of the loss of prestress by steel relaxation.		
σ <mark></mark>	Tensile stress in the reinforcement steel.		
S Ogw	Tensile stress in the shear reinforcement steel.		
o _t	Tensile stress in the concrete.		
φ(t,t ₀)	Creep coefficient, defining creep between times t and t_0 , related to elastic deformation at 28 days.		
φ _b	Basic creep coefficient.		
φ _d	Drying creep coefficient.		
τ	Shear stress (at a joint).		

6.2 bis Human resources

People involved in the preparation of a product shall be trained to the identification of the importance of his tasks with reference to safety and to the potential impact on safety of any error in his activities.

7.3.5 bis Design and development verification

The verification of design shall be performed by individuals other than those who perform the design tasks.

7.4 bis Purchasing

Regardless of its position in the supply chain, the supplier shall take necessary provisions to ensure that any purchasing data they issue contains suitable provision for ensuring that the client's contractual requirements are taken into account by the subcontractor.

The supplier shall take necessary provisions to verify the proper implementation of its contractual requirements by its subcontractors. All tests and verifications shall be recorded.

GGENP

In case a supplier may not be able to demonstrate that his quality management system fulfills 0.3 requirements, his client shall demonstrate that the supplied products comply with their requirements related to safety.

7.5.3 bis Identification and traceability

All documents required by this code or stipulated in the purchase order (whether handed to the client or kept at his disposal) shall be clearly identified and linked with no ambiguity to the related products.

8.2.4 bis Monitoring and measurement of product

All activities required by this code or stipulated in the purchase order concerning verification, validation, inspection, control and tests on products shall be performed by individuals different from the ones involved in the preparation of the products.

8.3 bis Control of nonconforming product

Supplier arrangements regarding the processing of non-conformities shall be in accordance with the requirements of GGENP 4000.

GA RPP - MANAGEMENT SYSTEM

This chapter is a RPP.

5100

As stated in GGENP 2240, the Project may decide to make this whole appendix applicable and that it shall replace or complete GGENP 5000.

GA 1000 INTRODUCTION

GA 1100 STRUCTURE

This chapter provides the requirements to implement a Management System associated to the implementation of the RCC-CW requirements. They are based on the AIEA GS-R-3 and its guidelines. Requirements from AIEA GS-R-3 are highlighted in **bold** with the source paragraph in square brackets.

The structure of the chapter is based on the AIEA GS-R-3'structure:

0.A.2 Management system;

0.A.3 Management responsibility;

0.A.4 Resource management;

0.A.5 Process implementation;

0.A.6 Measurement, assessment and improvement.

A quality management system that meets the requirements of ISO 9001-2008 is a pre-requisite for the supply of any activity specified in this code.

Any supplier in charge of one of these activities, have to implement a management system that meets the requirements provided in this chapter.

GA 1200 DEFINITIONS

[Glossary] Management system:

A set of interrelated or interacting elements (system) for establishing policies and objectives and enabling the objectives to be achieved in an efficient and effective way.

The management system integrates all elements of an organization into one coherent system to enable all of the organization's objectives to be achieved. These elements include the structure, resources and processes. Personnel, equipment and organizational culture as well as the documented policies and processes are parts of the management system. The organization's processes have to address the totality of the requirements on the organization as established in, for example, IAEA safety standards and other international codes and standards.

- Three variable levels, associated with the variable actions Q_{k,wl,EH}, Q_{k,wl,EF} and Q_{k,wl,φEF} (see DGENR 3320), are relative variations from the permanent level;
- The design basis accidental level, associated with accidental flooding action A_{db,wl} (see DGENR 3330), is an absolute value defined by the Project and depending on site conditions;
- The design extension accidental level, associated with accidental external flooding action A_{de,wl} (see DGENR 3330), should be assessed by a specific study.



Figure DGENR 3315-1 Schema of groundwater table levels

DGENR 3316 Permanent thermal actions

The permanent thermal actions $G_{k,T}$ due to air conditions shall be derived by the following methodology:

- The temperature variation from a reference construction configuration (uniform temperature) to a reference operation configuration shall be taken into account. The reference operation configuration shall consist in general of a global temperature increase and gradients in external as well as in internal walls.
- To enable calculation of the actions described above, a number of reference temperatures in operation shall be defined, in addition to the construction reference temperature:
 - A unique external reference temperature, representative of site conditions (for instance, the mean yearly temperature);
 - A unique reference temperature for each internal room, representative of operational conditions.

The permanent pools water thermal value is $G_{k,TN}$:

- G_{k,TN} is determined with average thermal value during operating life time of the structure.
- If needed $G_{k,TN,inf}$ shall be used in case of favourable and $G_{k,TN,sup}$ in case of unfavourable (see DGENR 3310).

Design basis values

The Project defines accidental climatic conditions to be considered for DBD:

- Accidental wind: A_{db,w};
- Accidental snow: A_{db,s};
- When is relevant, accidental rain falls are taken into account as a design situation. In this case, a specific combination is added into the list of Table DGENR 3400-1 using the same combination principles that other accidental situations.
- Accidental low and high external temperature: A_{db,T,ext};
- Tornado: A_{db,to}.

Design extension values

The Project defines accidental climatic conditions to be considered for DED:

- Actions related to wind: A_{de,w},
- Actions related to snow: A_{de,s}
- Actions related to low and high external temperature: A_{de,T,ext};
- For concrete structures this load thermal case has not to be taken into account except when exceptional conditions are expected such as fatigue conditions, in the verification of stability where second order effects are of importance
- Actions related to tornado: A_{de.to}.

DGENR 3339 Internal or external fire

The Project defines the structures that shall resist to internal or external fire.

As a generic principle, fire-resistance is obtained by the layout, detailed design and construction arrangement of the structural elements, as defined in EN 1992-1-2 and EN 1993-1-2.

Nevertheless, for specific cases, the fire action may be defined on a case by case basis by the Project by a room temperature increase curve and minimum fire-resistance durations.

DGENR 3340 INTERNAL ACTIONS SPECIFIC TO THE REACTOR BUILDING

For the RB, the internal actions, among the general actions defined in DGENR 3310 to DGENR 3330, are supplemented or modified as stated hereafter. If these additional internal actions also affect structures located near the RB, the effects of these actions should be taken into account in the design of these structures.

DGENR 3341 Permanent actions

Actions due to prestressing: P_m and P_k

Values of actions due to prestressing are considered by factoring in deferred losses of tension.

However, if the prestressing actions are penalising (as in the case of construction), they shall be considered without time-dependent losses.

DGENR 3342 Variable actions

Pressures (positive or negatives ones) due to the fluids contained by the structure:

The maximum negative pressure in the RB containment shall be defined by the Project. This value corresponds to the untimely start-up of sprinkler systems.

Test pressure

Test pressure shall be taken into account.

Pressure shock

The pipes shall be designed for a pressure shock (hammering) defined by the Project.

DGENR 3353 Accidental actions related to DBC or DBH

Design Basis Earthquake:

The effect of an earthquake on buried conduits results in structural deformations, differential settlement of the ground or between the ground and the buildings connected to the conduits, and seismic movement. Variations in space shall be taken into account.

This shall be calculated in accordance with APPENDIX DA and EN 1998-4, Appendix B.

Other additional accidental actions:

Other specific accidental actions such as flooding, dropped loads, etc. shall be taken into account depending of the Project requirements.

DGENR 3354 Accidental actions related to DEC or DEH

If some buried tunnels and ducts are required in DED situation, relevant DEC and/or DEH situation shall be taken into account.

DGENR 3400 COMBINATIONS OF ACTIONS

Load combinations shall be defined in order to cover safety requirements. The load combinations shall be submitted to the Project approval.

This section gives the principles and guidelines of combinations of actions with the help of two tables respectively applied to safety classified structures for which design extension analyses are required.

and to structures

When a component is common to several safety-classified structures and structures for which design extension analyses are required (e.g. the raft), it shall be designed with the different combinations of actions associated with the different structures.

PART D DESIGN DGENR DESIGN GENERAL REQUIREMENTS

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These combinations of actions are defined:

- In Table DGENR 3400-1 for DBD: Limit states are defined in accordance with EN 1990 (see notations in GDEFN 3000). In the Table DGENR 3400-1:
 - "ULS.f" includes the verifications associated with STR and GEO;
 - "ULS.a" includes the verifications associated with all ultimate limit states (EQU, STR, GEO), except for the case of "accidental flooding" for which a specific combination is given for equilibrium issues (EQU 14a).
- In Table DGENR 3400-2 for DED where all accidental actions described in DGNER 3330 and DGENR 3344 are considered as independent (assumption to be confirmed by the Project).

In these two tables, situations considered during the design are numbered from "1" to "20" for DBD and "DE1" to "DE10" for DED. If several combinations are defined for a particular situation, the number is completed by a letter ("a", "b", etc.). Finally, in DBD, another letter may be added:

- "c" if construction variable action is the leading variable action as defined by EN 1990;
- "L" if operating variable action is the leading variable action;
- "t" if thermal variable action is the leading variable action;
- "w" if wind variable action is the leading variable action;
- "s" if snow variable action is the leading variable action;
- "wl" if groundwater level action is the leading variable action

For instance, "2bs" designates:

- "2" for "Normal operation situations";
- "b" for "ULS.f";
- "s" for "snow as leading variable action", i.e. the factor of snow action is greater than that of other actions: (1.5 × 1.0 = 1.5) for Q_{k.s}, (1.5 × 0.7 = 1.05) for Q_{k,L} (operating load), (1.5 × 0.6 = 0.9) for Q_{k,T} (thermal load) and (1.5 × 0.6 = 0.9) for Q_{k.w} (wind action).

The combinations are presented supposing that all the variable actions act unfavourably. If this is not the case, the factor shall be taken as 0 (zero).

Under justifications approved by the Project:

- Only a part of these combinations of loads may be applied for a structure or part of structure
- Additional combinations may be set.

DGEOT 2260 Variable groundwater pressure

three

the frequent value

Variations of water pressure to taken into account are defined in DGENR 3326 by two levels: $Q_{k,wl,EF}$ and $Q_{k,wl,eF}$ and $Q_{k,wl,eF}$ and $Q_{k,wl,\phi EF}$

DGEOT 2270 Accidental ground reaction

Ground reaction resulting from accidental actions, earthquake, airplane crash, and external explosion, shall be accounted for through an equivalent model representing dynamic soil-structure interaction.

DGEOT 2280 Accidental lateral earth pressure on infrastructures of building

Dynamic earth pressure resulting from earthquake is evaluated following DA 9000 If necessary, dynamic earth pressure effects may be analysed using a global analysis including soils and structures.

DGEOT 2290 Accidental water pressure

Accidental water level is the maximum flooding water level considered for the site, and shall be defined by the Project.

Water level acting simultaneously with design earthquake is QK, W, EF, the frequent value of groundwater table level (see Table DGENR 3400-2 and DGENR 3326)

DGEOT 2300 COMBINATIONS OF ACTIONS

DGEOT 2310 Ultimate limit states

Limit states UPL, STR and GEO are defined in EN 1997-1, 2.4.7.1.

UPL

See combination 2awl for EQU given in Table DGENR 3400-1

STR/GEO

The checking of STR and GEO limit states shall be based on the design approach 2 described in EN 1997-1. This approach does not require combinations other than those given in Table DGENR 3400-1.

Lateral earth pressure (permanent and variable) shall be added as an action.

The different types of ground reaction model shall be accounted for in STR combinations.

GEO ultimate limit state shall consider the following combinations, covering normal and accidental situations:

1awl, 2bL, 2bwl, 11, 12, 13, 14b, 15 and 16.

DGEOT 2320 Serviceability limit states

The relevant combination for settlement evaluation is the quasi-permanent combination where permanent loads are combined with a partial coefficient equal to 1 and variable loads are combined with their quasi-permanent value.

Combination 2eL given in Table DGENR 3400-1 is the relevant combination.

In DED:

If the safety factor is less than 1.25, the overall post-liquefaction stability (loss of bearing capacity, lateral spreading...) shall be assessed applying DGEOT 5200. When there is a risk of failure, the potential consequences shall be considered as unacceptable.

If there is no risk of instability or if reliable remediation measures are implemented, the liquefaction-induced deformations and displacements shall be assessed applying DGEOT 5300.

DGEOT 5100 ASSESSMENT OF THE LIKELIHOOD OF THE "TRIGGERING" OR INITIATION OF SOIL LIQUEFACTION

The liquefaction hazard shall be assessed when the foundation soils include loose layers or lenses of silt, sand or gravel, beneath the water table level.

The analysis is performed by comparing the Cyclic Resistance Ratio (capacity of soil) to the Cyclic Stress Ratio (demand due to earthquake).

In DBD:

Empirical methods based on SPT (Standard Penetration Test) or CPT (Cone Penetration Test) measurements shall be used. The methods based on the shear wave velocity (V_S) measurements are not recommended when used as the only means of evaluation.

Two correlations for triggering of liquefaction are recommended: NCEER (Youd et al. 2001) or Idriss & Boulanger (2006). When a method is chosen, it implies the use of all relationships that were used in its development. Any other correlation shall be submitted to the Project approval.

A probabilistic liquefaction correlation may be used in a complete probabilistic evaluation of the performance of a structure or facility and the associated risks. This requires a probabilistic representation of ground motion hazards, site characteristics, liquefaction assessment, liquefaction consequences – see DGEOT 5130.

The analysis shall be performed under free field conditions.

In DED:

The risk of liquefaction and its consequences (seismic-induced displacements) may be assessed with a nonlinear step-by-step analysis that should be able to evaluate directly the build up of pore pressure and the dynamic ground response. When using data derived from laboratory tests, a sensitivity study shall be carried out to search for a potential cliff-edge effect.

DGEOT 5110 Cyclic Stress Ratio (CSR)

To reduce uncertainties on CSR value, τ_{max} / σ'_v may be computed using linear equivalent site response studies, based on reliable shear wave velocity measurements on site. The study shall account for variability of input motions (by the use of a set of at least 3 accelerograms) and soil characteristics (V_S profile and modulus degradation curves).

DGEOT 5120 Cyclic Resistance Ratio (CRR)

The use of cyclic laboratory test results alone to assess CRR is not allowed. They may only be used in addition to one of the mandatory empirical methods.

Requirements on SPT tests are given in DGEOT 1150. CGEOT 1500

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CH2.2 DGEOT 15/20

Other specifications concerning the relaxation are given in CPTSS (relaxation at 80% $F_{m,\ a},$ relaxation at 40°C, etc.).

(2) Ductility characteristics

The characteristic value of maximum force shall not be greater than 1.15 times the specified maximum force.

EN 1992-1-1, 3.3.4 applies with $f_{pk} / f_{p0.1k} > 1.1$ (k = 1.1).

The minimum total percentage elongation at maximum force is equal or higher than 3.5%.

(3) Design assumptions

Refer to EN 1992-1-1, 3.3.6, (1) to (7).

The design "stress-strain" diagram is defined with:

- $\epsilon_{ud} = 0.02$ and;
- $f_{pk} / f_{p0.1k} = 1.125.$

The modulus of elasticity of the multi-strand tendons E_p shall be taken as 190 GPa instead of 195 GPa as given by EN 1992-1-1, 3.3.6. The modulus of elasticity is equal to 195 GPa for one strand.

(4) Prestressing tendons in sheaths or ducts

Refer to EN 1992-1-1, 3.3.7, (1) and (2).

The ducts may be made either in steel corrugated sheaths or in steel pipes.

The designer shall define where sheaths are used and where steel pipes are used. The aim is to avoid leakages.

Some concerns about the leakage are:

- Leakage from concrete to the inner part of the duct during the pouring,
- Leakage from the grout (or grease of wax) to the outer part of the duct during the filling of the tendon and the life the design working life of the containment.
 during

Leakage may be caused by:

- Mechanical effect during the pulling of the tendons (specially in case of radius curvature is less than 80 times the duct diameter),
- High pressure in the duct during the filling operation,
- Distance between ducts less than or equal to 1 diameter of duct.

Or may be located in:

- Anchorage zone, until the tendon reaches its design current radius location,
- Concrete joints zone distance less than or equal to 1 diameter of duct,
- Penetration area distance less than or equal to 1 diameter of duct.

In all cases listed above, the tube parts extend one meter beyond the specified limit.

Usually, horizontal tendons are inside steel corrugated sheaths, except close to the anchorage, close to the concrete joints or when the curvature radius is small. In these last cases, the parts of the horizontal tendons are inside steel pipes.

Usually, vertical tendons and tendons in the dome are inside steel pipes as the designer should consider higher pressure of the duct filler during the filling operation or during the life of the containment and also the distance between the tendons is reduced over the dome.

In any case, the choice has to be submitted to the Project approval.

CH2.3 DCONC 10/48

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(5) Coating – Grouting

or If the tendons are composed of strands coated by grease of wax, they are considered as unbonded tendons.

If the tendons are made of sheathed greased strands injected by cement grout, they are considered as unbonded tendons from a mechanical point of view.

If the tendons are made of strands coated by cement grout, they are considered as cement grouted tendons and as bonded tendons.

For the design, if the tendons are considered as bonded, the tendons participation can be taken into account for the reinforcement calculation. In this case, the bonding properties are used and a variable stress increasing (increasing under cracking) is considered.

(6) Prestressing systems and devices

The prestressing system shall comply with the "Guideline for European Technical Approval – ETAG 013".

In any case, the choice has to be submitted to the Project approval.

The prestressing system shall comply with the necessary certification according to country specific requirements.

The bearing concrete stress behind anchorage plates and the reinforcement to prevent bursting and spalling of concrete shall be checked according to EN 1992-2, J.104.2 "Anchorage zones of post-tensioned members".

The principle of this reinforcement according to the concrete strength shall comply with the design of the ETA.

However, some adaptations may be needed concerning the geometry of this reinforcement in order to avoid too high concentration of reinforcing bars and in order to improve the concreting.

The concrete compressive stress in the structure (except in the primary regularisation prism) resulting from the prestressing force and other loads acting at the time of tensioning or release of prestress, should be limited to 0.6 f_{ck}.

The prestressing systems shall comply with PART C requirements.

DCONC 2240 Durability and cover

(1) Environmental cover conditions

See CCONC 3200.

(2) Nominal cover, c_{nom}

The special requirement regarding the bond of circular post-tension sheaths or ducts for tendons injected into cement grout is:

 $c_{nom} = 100 \text{ mm}.$

For clarification, cracks limitation takes account of the two following criteria:

A crack width criterion for durability requirements, applied to a SLS.qp for reinforced concrete structures and to SLS.f for prestressed concrete structure;

A steel stress limitation criterion, as defined:

- In Table DCONC 4110-1;
 - amended by DCONC 6000 for the raft and buried walls.

Method is explained in APPENDIX DB.

The calculated crack width w_d is considered to be the width at the surface of the concrete. It is admitted to take into account the actual cover (from reinforcement drawings) compared to the required cover (and if possible, the diameter of reinforcing bars).

If the actual cover is larger than cover required, those practical limit values for the crack width can even be enlarged proportionally but should not exceed 0.4 mm:

Equation DCONC 4110-1

$$\begin{cases} w_{lim} = min \ (w_{lim,0} \times Q \ ; 0,4 \ mm) \\ Q = 1 + \frac{c_{prov} - c_{req}}{c_{req}} \end{cases}$$

Where:

 \geq

- w_{lim,0} is the recommended value of EN 1992-1-1;
- c_{prov} is the actual cover;
- c_{req} is the required cover.

(3) Stress limitations

- Compatibility of deformations:

ε_{Ci}

Equation DCONC 4222-6

$$\epsilon_{ci} = \epsilon_{c0} = \epsilon_{si} = \epsilon_{se}$$

The mechanical moment if any, shall be taken into account for the overall checking of stresses and strains.

Where:

- N + δN is the normal force due to pressure (thermal and mechanical loads) and overtension;
- $-\sigma_{ci}, \epsilon_{th}, c_{ci}$ are the stress and thermal strain in concrete due to the thermal gradient, on the hot face;
- σ_{c0} , ε_{th} , c_{n} are the stress and thermal strain in concrete due to the thermal gradient, on the neutral axis;
- σ_{si} , ε_{th} , σ_{si} , ε_{th} , σ_{si} are the stress and thermal strain in the intrados reinforcement due to the thermal gradient, on the hot face; ε_{si}
- $-\sigma_{se}, \varepsilon_{th}, s_{e}$ are the stress and thermal strain in the extrados reinforcement due to the thermal gradient, on the cold face; ε_{se}
- $\delta\theta_{ci}$ and $\delta\theta_{si}$ are the temperatures variations in the intrados concrete and at the intrados reinforcement level;
- A_{si} is the intrados reinforcement section;
- α_c and α_s are the thermal expansion factors of concrete and steel;
- E_{cm,th} is the modulus of elasticity of concrete according Table DCONC 2110-2;
- E_s is the modulus of elasticity of steel;
- N_{se} is the normal force in the equivalent tensile tie;

Stress are positive in compression.

Strain are positive for elongation.

Tensile force in tie is considered as positive in tension.

The stiffness K of the equivalent tensile tie is estimated in accordance with the principle of the cracking theory of EN 1992-1-1, 7.3. This theory is more precisely described in the CEB-FIP model code 1990 or in the fib model-code 2010 and detailed in APPENDIX DL. The figure hereafter shows the evolution of stress in a prestressed reinforced concrete tie and thus the decrease of stiffness. Moreover this figure highlights the tensile concrete contribution, which is essential in order to not underestimate the thermal loads.

Combinations for inner containment of the RB		Criteria		
Level	Name	N°	Specific criteria Table DCONC 53i0-1 *	General case See DCONC 4100
	Internal projectile	5		х
	Dropped load	6		х
	RHEP	8	x	
	LOCAB	9a	х	
	SSPB _B	9b	х	
	LOCA _B + DBE	1c 10		х
	DBE	11	х	
	Aircraft crash	12		х
	External explosion	13		Х
	Accidental wind	15		Х
	Accidental snow	16		Х
	Fire	17		х
	Accidental groundwater level	18		Х
	Accidental environmental temperatures	19		Х

* Table DCONC 53i0-1: refers to DCONC 5310-1 DCONC 5320-1 DCONC 5330-1 or DCONC 5340-1 depending on RB containment material or zone

Table DCONC 5100-2 Level of situations

Combinations for inner containment of the RB			Criteria	
Level	Name	N°	Specific criteria Table DCONC 53i0-1 *	Specific criteria DCONC 5350
	DEC-A/LOCA	DE1a	х	
	DEC-A/ SSPB _E	DE1b	х	
LEVEL II.1	SA DEC-B	DE1c	х	
	SA DEC-B + Earthquake	DE1d	х	
	Dropped loads	DE2		х
	Design Extension earthquake	DE3		х
	External explosion	DE4		Х
	Flooding	DE5		х
LEVEL II.2	Tornado	DE6		х
	Snow	DE7		х
	Wind	DE8		х
	Temperature	DE9		Х
	Aircraft crash	DE10	Out of code	scope

* Table DCONC 53i0-1 refers to Tables DCONC 5310-1 DCONC 5320-1 DCONC 5330-1 or DCONC 5340-1 depending on RB containment material or zone.

The RB containment is sealed by means of a metal liner. In order to limit tensile deformation in the liner, additional requirements are given in DCONC 5310-1, DCONC 5320-1 DCONC 5330-1 and DCONC 5340-1 for the different levels of situation.

The following criteria shall apply for a standard concrete characterized by a 28-day value for compressive strength (f_{ck}).

The purposes of these additional requirements are to:

- Limit the creeping effect under construction and normal operating:

Equation DCONC 5100-1

$$\sigma_{c,mean} \leq 0.45 \; f_{ck} / \gamma_c$$

- Limit the formation of cracks under uniaxial compression:

Equation DCONC 5100-2

$$\sigma_{\rm c,max} \le 0.6 \ f_{\rm ck}/\gamma_{\rm c}$$

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		Normal operating (2eL SLS.qp)	Normal operating (2gt SLS.f)	Exceptional water temperature (2h SLS.c)	Accidental water temperature (7 ULS.a)
ete	Compression stress σ _c [MPa]	$Max \ \sigma_{c} \leq 0.6 \cdot \frac{f_{ck}}{\gamma_{c}}$ $Mean \ \sigma_{c} \leq 0.45 \cdot \frac{f_{ck}}{\gamma_{c}}$	$Max \ \sigma_{c} \leq 0.6 \cdot \frac{f_{ck}}{\gamma_{c}}$ $Mean \ \sigma_{c} \leq 0.45 \cdot \frac{f_{ck}}{\gamma_{c}}$	$Max\sigma_c \le 0.6 \cdot \frac{f_{ck}}{\gamma_c}$	
Conc	Compression stress in shear strut σ _{cw} [MPa]				$Max \sigma_{e} \leq \frac{f_{ck}}{\gamma_{c}}$
einforcement	Tensile stress σ _s [MPa]	$\sigma_{s, \max} \le \min \begin{cases} \frac{2}{3} \cdot f_{ys}; \max \\ \text{with } f_{ys} = \min(f_{yk}; 500 \text{ M} \\ \text{bond reinf} \end{cases}$	$\left(0.5 \cdot f_{ys}; 110 \cdot \sqrt{\eta \cdot f_{ctm}}\right)$ Pa) and $\eta = 1.6$ for high- orcements	$Max\sigma_{s} \leq 0.8 \cdot \frac{f_{yk}}{\gamma_{s}}$	
Passive re	Ultimate strain ε _{uk} [‰]				10‰.(see DCONC 2120)

Table DCONC 9000-1 Specific material criteria for walls and slabs of pools subjected to thermal effects



Figure DCLIN 2400-1 Supporting line segment

In a geometric discontinuity, the supporting line segment is the smallest segment linking the two sides of the liner (Figure DCLIN 2400-1). In all cases we note h the supporting line segment length.

For a given supporting line segment, the Cartesian frame of reference (0123) is defined (Figure DCLIN 2400-1) such that the axis 3 contains the supporting segment of length h and its origin is taken in the middle of this segment. The abscissa of a point of the supporting line is denoted x_3 .

In a geometric singularity, the supporting line segment is not defined.

Membrane stress:

For a stress tensor σ , of components σ_{ij} (i and j = 1, 2, 3) in the Cartesian frame of reference (0123), the membrane stress tensor is the tensor whose components $(\sigma_{ij})_m$ are equal to the mean value of stresses σ_{ij} along the support line segment. These components $(\sigma_{ij})_m$ are defined by the following equation:

Equation DCLIN 2400-1

$$\left(\sigma_{ij}\right)_{m} = \frac{1}{h} \int_{-h/2}^{+h/2} \sigma_{ij} dx_{3}$$

The notations are given in Figure DCLIN 2400-1 and Figure DCLIN 2400-2.



Figure DCLIN 2400-2 Definition of stresses on a supporting line segment (through the thickness)

Bending stress:

For a stress tensor σ , of components σ_{ij} (i and j = 1, 2, 3) in the Cartesian frame of reference (0123), the bending stress tensor is the tensor whose components $(\sigma_{ij})_{b}$ are defined by the following equation:

Equation DCLIN 2400-2

$$\left(\sigma_{ij}\right)_{b} = \frac{12x_{3}}{h^{3}} \int_{-h/2}^{+h/2} \sigma_{ij} x_{3} dx_{3}$$

The notations are given in Figure DCLIN 2400-1 and Figure DCLIN 2400-2.

The bending stress (for each component of the stress tensor), at any point across the thickness, is the difference between linear stress and the membrane stress.

Thermal stresses and those due to restraints, when there is no risk of elastic follow-up, are not considered as primary stresses.

The primary stresses are subdivided into three categories:

- The general primary membrane stress, noted $(P_{ij})_m$;
- The local primary membrane stress, noted (P_{ij}) ;
- The primary bending stress, noted $(P_{ii})_{ij}$.

DCLIN

General primary membrane stress:

Outside of the geometric discontinuity or geometric singularity, the general primary membrane stress $(P_{ij})_m$ is the membrane stress (Equation, 2400-1) of primary stress.

DCLIN Local primary membrane stress:

In the geometric discontinuity that is in a small zone adjoining the discontinuity, the local primary membrane stress $(P_{ij})_{ij}$ is the membrane stress (Equation 2400-1) of primary stress.

DCLIN

NOTES

- Because of the elastic follow up, unless it can be demonstrated that they can disappear because of low deformation, all membrane stresses (primary and secondary) are classified in this category;
- In general, therefore, in a common zone and in a geometric discontinuity, it is prudent to define the local primary membrane stress as the membrane stress of total stress of geometric discontinuity.

Primary bending stress:

The primary bending stresses are the bending stresses distributed linearly in the thickness equal to the bending stresses (Equation,2400-2) of general primary or local primary stresses.

Secondary stress:

The secondary stresses are the fraction of the total stress which can disappear as a result of small scale permanent deformation, minus the peak stresses.

Peak stress:

The peak stress is the fraction of the total stress which meets the following two conditions:

- This is the additional stress due to a geometric discontinuity of the structure or to the non-linearity of the distribution of stresses in the thickness;
- This additional stress, which is generally very localized, cannot cause deformation of the whole structure should it be redistributed.

DCLIN 2700 SCALARS REPRESENTING STRESS STATE

The stress state is represented at each point by a tensor σ of Cartesian components σ_{ij} (i and j = 1,2,3) and principal components σ_1 , σ_2 et σ_3 . This is true both for the total stress as for a partial state corresponding to a stress category or combination of stress categories.

Conservative value could be used without reinforced concrete strain analysis:

- ϵ_{sm} = 0.01 for levels I.1, I.1 bis, I.2 and I.2 bis
- $\epsilon_{sm} = 0.05$ for level II.1, II.2 and Class B reinforcing bars;
- $\epsilon_{sm} = 0.075$ for level II.1, II.2 and Class C reinforcing bars.

NOTE Class B and C are defined according to EN 1992-1-1, Appendix C.

Table DCLIN 4800-1 Safety coefficient C_s – Concrete cracking

Combinations	C_{s}
Level I.1	10
Level I.1 bis (only for DPLIN) Level I.2	5
Level I.2 bis (only for DPLIN) Level II	2.5

DCLIN 4900 EQUIPMENT ANCHOR PLATE DESIGN RULES

The anchoring part of the equipment anchor plate shall be designed in accordance with the section DANCH.

DCLIN 5000 CONTAINMENT PENETRATIONS

DCLIN 5100 DESIGN PRINCIPLES

The penetrations shall be designed:

- To be adapted to all of the combinations of actions listed in DCLIN 4200 considered without loss of leaktightness or structural integrity (the effects of temperature, shrinkage and creep as well as prestressing of the concrete shall be taken into account);
- With an anchorage system capable of transferring the effects of the combinations of actions to the civil engineering structure.
- To be adapted to the following combinations of actions considered without structural integrity:
 - Level I.2 bis: Loss Of Primary Coolant Accident and Design Basis Earthquake (LOC_{AB} + DBE):

(10) $(G_{k,sup}; G_{k,inf})^* + P + Q_{k,L} + A_{db,p} + A_{db,E}$

(*): The critical case between $G_{k,sup or} G_{k,inf}$ shall be chosen.

DCLIN 5200 DESIGN RULES FOR LEVELS 0 AND I.1 COMBINATIONS OF ACTIONS

For levels 0 and I.1 combinations of action, an elastic analysis is required applying DCLIN 3310.

The design rules are those described in DCLIN 4400. Outside geometric singularities, the criteria to be respected are those in Table DCLIN 4410-1. These design rules and criteria are to be applied to situations level 0 and I.1.

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The anchors design rules are :

- For anchors that are covered by DANCH, the design rules are those of DANCH.
- For anchors that are not covered by DANCH, the anchor strength shall be justified in accordance with DPLIN 8100 and in compliance with the criteria detailed in DCLIN 4700.
- If the embedded system of detection and recovery of the leaks is fixed to the liner, this one shall be designed following requirements in DPLIN 8100.

DPLIN 8300 DESIGN RULES FOR ANCHORS AND FRAMEWORKS (PD2 AND PD3)

The loads transmitted by the metal plate to the frameworks (forces and displacements) and the reactions at the supports (anchors) shall be calculated.

These forces are noted F of components F_1 , F_2 and F_3 (Figure DPLIN 8300-1).



Figure DPLIN 8300-1Forces on the frameworks and anchors

For PD2 and PD3 design:

- The "decoupled" design rules of the anchors and frameworks are:
 - The framework including the welded joints between framework and anchors shall be designed according to an appropriate code or validated experimental method and submitted to the Project approval.
 - The anchor design rules are:
 - For anchors that are covered by the chapter DANCH, the design rules are those of chapter DANCH.
 - For anchors that are not covered by the chapter DANCH, the anchor strength shall be justified in accordance with DPLIN 8100 requirements and in compliance with the criteria detailed in DCLIN 4700.
- The "global" design rules for the anchors and frameworks are:
 - For the assembly framework/anchors the tangential and normal forces transmitted by the metal plate (Figure DCLIN 8300-1-a) are defined as follows:

DPLIN
$$F_T = \sqrt{(F_1)^2 + (F_2)^2}$$
 and $F_N = F_3$

• For the assembly frameworks/anchors the tangential and normal displacements transmitted by the metal plate are defined as follows:

$$U_T = \sqrt{(U_1)^2 + (U_2)^2}$$
 and $U_N = U_3$

The reference standards for steel structures are given in GREFD 1000.

All normative annexes of Eurocode 3 shall be applied.

The following informative annexes of EN 1993-1-1 are also applicable for steel structures covered by this Chapter unless otherwise specified by the Project:

- Annex A: Interaction factors k_{ij} for interaction formula in EN 1993-1-1, 6.3.3(4) (Method 1)
- Annex B: Interaction factors k_{ij} for interaction formula in EN 1993-1-1, 6.3.3(4) (Method 2)
- Annex AB: Additional design provisions
- Annex BB: Buckling of components of building structures.

DSTLW 2000 DESIGN WORKING LIFE

Unless otherwise defined by the Project, the design working life of steel structures shall be consistent with DGENR 1200.

DSTLW 3000 COMPLEMENTARY REQUIREMENTS ABOUT ACTIONS

The actions to be considered in the design are defined in DGENR 3000 and DGEOT and are supplemented by the following requirements.

DSTLW 3100 SELF-WEIGHT OF STRUCTURAL ELEMENTS

The self-weight considered in structural analysis shall take into account the additional weights of the connection devices and of secondary elements that are not represented in the structural model.

DSTLW 3200 SELF-WEIGHT OF FIXED EQUIPMENT

The structural analysis shall take into account the additional weights of any fixed equipment and their supports.

A minimum nominal distributed load of 150 N/m² shall be applied to any steel structure that supports a horizontal surface (floors and roofs), in addition to the identified equipment loads.

REQUIREMENTS

DSTLW 3300 PARTICULAR REUIREMENTS FOR THERMAL LOADING

Unless otherwise required by the Project, the analysis of steel structures subjected to thermal loading shall ignore any thermal gradients through the section of structural elements.

The whole thermal loading shall always be considered as a variable action in the different combinations of actions.

DSTLW 3400 EFFECTS OF DISPLACEMENTS IMPOSED ON THE STRUCTURE

Imposed displacements on steel structures, including displacements from seismic situations, shall be taken into account.

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Additional requirements for grades and qualities of main structural elements are given in DSTLW 7710.

DSTLW 4200 REQUIREMENTS FOR THE SECTION OF STRUCTURAL ELEMENTS

+ is not permitted to use structural elements comprising cold formed sections.

For all the structural elements, the minimum thicknesses are :

Table DSTLW 4200-1: Minimum thickness of sections

	Open cross sections (mm)	Hollow sections (mm)
Internal structures	4	2,5
External structures	5	4

For main structural elements in compression or bending, the section shall be minimum class 2 on the basis of EN 1993-1-1.

For secondary structural elements in compression or bending, the section shall be minimum class 3 on the basis of EN 1993-1-1.

DSTLW 4300 BOLTS

lt

The following bolt types are permitted:

- SB bolts according to EN 15048 (ordinary bolts) for connections of secondary elements only
- HR bolts according to EN 14399-3 (preloaded bolts) for all connections

For ordinary bolts, the use of bolt classes 4.8, 5.8 and 6.8 is not permitted.

The use of bolts of a higher grade than class 10.9 is not permitted.

The use of HV bolts according to EN 14399-4 or HRC bolts according to EN 14399-10 shall be submitted to the Project approval.

For anchor bolts DSTLW 7500 applies.

DSTLW 4400 PARTICULAR REQUIREMENTS FOR THE USE OF STAINLESS STEEL

The use of stainless steel structural elements shall be subject to the Project approval.

The design of the stainless steel structures shall comply with EN 1993-1-4.

The material shall be in the range of austenitic Cr-Ni-Mo or duplex steels defined in EN 10088. Basic austenitic Cr-Ni steels are not permitted unless authorized by the Project.

The final choice of the stainless steel grade in the above permitted range is made by considering the aggressiveness of the environmental conditions and shall be subject to the Project approval.

For all bolted connections of stainless steel structural elements, stainless steel bolts shall be used. All nonpreloaded bolts shall conform to the grades defined in EN 15048 and shall be compatible with the steel grade of the connected elements.

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This objective is more important for the main structural elements (see DSTLW 1100) therefore the requirements below only concern the main structural elements.

DSTLW 7710 Steel material and products

A minimum quality J0 is required for thicknesses up to 35 mm and a minimum quality J2 is required for thicknesses greater than 35 mm.

Hollow section structural elements shall comply with EN 10210 (hot finished hollow sections).

DSTLW 7720 Design of the steel structures

All main structural elements shall be of section class 1 or 2 (see DSTLW 4200), even when elastic global analysis of the structures is required.

The stability of main structures shall be ensured, either by beam and column frames, or by centred braced frames. Eccentricities and K shaped bracings are not permitted.



For the Saint-André bracings of main structures, the non-dimensional slenderness of the diagonal bars shall be more than 1.3 and less than 2. For V shaped bracings, the non-dimensional slenderness of the diagonal bars shall be less than 2.

DSTLW 7730 Design of the connections

All the connections of the main structural elements shall be designed to ensure no translational displacement.

- Shear connections of the main structural elements shall be designed as category C connections according to EN 1993-1-8 (preloaded bolts, slip-resistant connections at the ultimate limit state).
- Tension connections of main structural elements shall be designed as category E connections according to EN 1993-1-8 (preloaded bolts).
- For T welded connections of main structural elements fillet welds shall not be permitted if the thickness of the welded flange is greater than or equal to 16mm, in these cases full penetration welding is mandatory.
- For connections by end plates the end plates shall be systematically overhanging according to the figure below:



Figure DSTLW 7730-1: End plate overhanging

In general, the following assumptions are applicable:

- the external load set applied by the centre of the attached profile shall take into account the installation tolerance,
- The anchor plate is assumed rigid. Special attention shall be paid concerning the verification of this assumption,
- All anchorage connectors of a standardized anchor system shall be identical,
- The loads generated in the anchors are calculated assuming a linear distribution of displacements along the anchor plate.

The design of the anchoring system shall be consistent with these assumptions.

The anchor plate shall be designed according to EN 1993.

DANCH 2000 PARTIAL FACTORS FOR MATERIALS

The partial factors to be considered are given in the following tables:

Table DANCH 2000-1 Partial factors consistent with CEB

		ULS.f	ULS.a	SLS
	Failure mode fyk	NOC (*), Long term and transient	Accidental	
1	Steel γ _{Ms} (anchorage steel) (basis f_{y.k})	1.40	1.25	1.00
2	Steel γ _s (reinforcement bar)	1.15	1.00	1.00
3	Concrete (compression) γ _{MC}	1.50	1.20	1.00
4	Concrete (tension) γ _{MC}	1.80	1.44	1.20

Table DANCH 2000-2 Partial factors consistent with ETAG 001 and CEN/TS 1992-4

		ULS.f	ULS.a	SLS	
	Failure mode fuk	NOC (*), Long term and transient	Accidental		
1a	Steel γ _{Ms} (anchorage steel) (basis f _{u,k}) Tension	$1.2 \ /(f_{yk}/f_{uk}) \geq 1.4$	$1.2 \ /(f_{yk}/f_{uk}) \geq 1.4$	1.00	
1b	Steel γ _{Ms} (anchorage steel) (basis f _{u,k}) Shear f _{uk}	$1.0/(f_{yk}/f_{uk}) \ge 1.25$ ^A 1.50 ^B	1.0/(f _{yk} /f _{uk}) ≥ 1.25 ^A 1.50 ^B	1.00	
2	Steel γ _{Ms,h} (reinforcement bar)	1.15	1.00	1.00	
3	Concrete (compression) γ _{MC}	1.50	1.20	1.00	
4	Concrete (tension) γ _{MC}	1.50	1.50	1.30	
A: Valid for $f_{uk} \le 800 \text{ N/mm}^2$ and $f_{yk}/f_{uk} \le 0.8$ B: Valid for $f_{uk} > 800 \text{ N/mm}^2$ and $f_{yk}/f_{uk} > 0.8$ (*) NOC: Normal Operating Conditions					
Com	binations of loads are defined in DGENR 3	3000 (Table DGENR 3400)-1 and Table DGENR 34	00-2).	

SLS is used for deformation control if required.

DANCH 3000 GENERAL REQUIREMENTS FOR CHECKING THE RESISTANCE OF THE ANCHORS

The formulae used to check the resistance of the anchors (see DANCH 4000) depend on the type of anchor (connectors, studs, etc.), the depth and spacing of the anchor, the distance from the anchor or anchor group to a free edge and, where applicable, the state of stress of the medium (e.g. concrete in tension).

DANCH 5000 POST INSTALLED ANCHORS

The Project may open the use of post installed anchors. In this case this chapter shall be applied.

Post installed bonded anchor including bonded steel reinforcement are not covered by this chapter.

The use of both post-installed anchors plate and embedded anchors plate for a given equipment shall be avoided. If this option is taken, more justifications shall be provided to take into account stiffness of different type of anchors.

Post installed anchors are forbidden for vibrating equipment.

DANCH 5100 USE LIMITATION AND USE CLASSES

Displacement controlled expansion anchors are not allowed.

An estimation of cracks opening in the concrete support shall be performed according to DCONC. If cracks opening is higher than 1 mm, post installed anchors are not allowed.

In case maximum cracks opening under high speed loading (for example impact loads or RHEP) exceed 0.3 mm, post installed anchors are not allowed.

For seismic loading, use classes are defined in Table DANCH 5100-1.

Table DANCH 5100-1.

		Equipment requirements	
		1: Functional during and / or after earthquake	2: others
Maximum cracks opening under earthquake	≤ 0.8 mm	1a	2a
	0.8mm < w _k ≤ 1 mm	1b	2b
	> 1 mm	Not allowed	

DANCH 5200 PRODUCTS REQUIREMENTS

All post installed anchors shall have a European Technical Agreement delivered by a notified body with the following options:

- ETAG option 1;
- Partial safety factor $\gamma_2 = 1.0$;
- Category C2 of ETAG 001 Annex E.

For use classes 1b and 2b, anchors shall have a technical approval certificate complying with A3 Category of DIBT "Guideline for fastenings with post installed anchor plates in nuclear power plants and nuclear facilities (2010)".

DANCH 5300 POST INSTALLED ANCHORS CALCULATION

Calculation and checking of post installed anchors shall be in compliance with ETAG 001, Annex C for all failure modes, including concrete failure.

For high speed loading the material partial factor shall be increased by γ_{imp} =1.5.

For use classes 1a and 2a, seismic characteristics resistance for steel failure (including pullout and pull through failure) are indicated by ETAG 001, Annex E.

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For structures specifically sensitive to low frequencies (base isolated structures, structures mainly governed by hydrodynamic convective effects, very flexible steel frames, etc.), the spectra is extended for the very low frequencies with the basic hypothesis of a constant displacement.

The spectra representing the input motion which must be taken into account shall be given by a dedicated document such as SR (see GREFD 1100).

Table GREFD 1200-1

DA 3000 REPRESENTATION OF SOIL EFFECTS

When several NPP projects are located on different sites, a generic design study can be performed instead of site specific design studies. If so, the soil conditions range modelled in the generic study shall envelope the specific site soil conditions of the sites.

DA 3100 SOIL CONDITIONS

DA 3110 Generic design

When generic studies are performed, the Nuclear Island is assumed to be seated on a homogeneous half space. In order to cover the generic design soil range, calculations are performed for different modules within a wide range. The soil conditions recommended for the Nuclear Power Plant are those presented in EUR documents.

Where it is deemed appropriate, homogeneous half space may also be assumed depending on site specific information.

The homogeneous half space is represented for every soil condition by an elastic, homogeneous isotropic material, defined by its mechanical characteristics:

- G = shear modulus;
- v = Poisson's ratio;
- γ = specific weight;
- D = material damping.

DA 3120 Site Specific Design

When not homogeneous, the soil should be considered as constituted by successive horizontal layers, the deepest one being the bedrock. Each layer has constant short term properties.

Each soil layer shall be characterized by the preceding parameters (G, v, γ and D).

The values of the soil layer properties shall be in accordance with the values of the geotechnical parameters defined in Table DGEOT 6000-1.

The thickness of each layer and the water table level shall also be available.

As far as possible, the degradation curves for the soil properties (G and D), which are strain dependent, shall be assessed by laboratory and in situ tests, or by data obtained on similar materials.

The non-linear properties of the soil layers can be approximated by equivalent linear properties consisting of the equivalent linear shear modulus and damping ratio for the soil which are compatible with the induced strain amplitudes in the soil medium, using methodology as proposed by Seed and Idriss. Non linear models may also be used (e.g.: last version of Seed and Idriss methods).

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Table DA 3234-3	Parameter values	for rocking factors
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	f _{R1}		f _{R2}			
a0	v = 0	v ≥ 1/3	v = 0	v = 1/3	v = 0.45	v = 0.5
0.00	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000
0.25	1.0212	1.0179	0.0048	0.0037	0.0036	0.0036
0.50	1.0766	1.0663	0.0370	0.0285	0.0278	0.0280
0.75	1.1441	1.1298	0.1153	0.0898	0.0880	0.0890
1.00	1.1941	1.1870	0.2437	0.1934	0.1906	0.1932
1.25	1.1981	1.2152	0.4082	0.3326	0.3302	0.3357
1.50	1.1399	1.1973	0.5807	0.4892	0.4905	0.5008
1.75	1.0227	1.1275	0.7280	0.6387	0.6481	0.6651
2.00	0.8670	1.0128	0.8260	0.7583	0.7801	0.8055
2.50	0.5501	0.7216	0.8598	0.8652	0.9182	0.9624
3.00	0.3322	0.4619	0.7639	0.8281	0.9074	0.9674
3.50	0.2208	0.2862	0.6463	0.7352	0.8285	0.9001
4.00	0.1712	0.1772	0.5535	0.6443	0.7413	0.8207

Rocking soil transmittance coefficients have been established by Lateral and rocking vibrations of footings, Journal of the Soil Mechanics and Foundations Division, Proceedings of the American Society of Civil Engineers, September 1971, pp. 1227-1248.

The rocking stiffness is calculated as:

 $K_{R} = \frac{8}{3(1-\upsilon)} \times G \times \frac{f_{R1}}{f_{R1}^{2} + f_{R2}^{2}}$

The critical damping ratio is given by the following formula:

Equation DA 3234-7

$$\eta_R = 0.05 + 0.25 \cdot \frac{f_{R2}}{f_{R1}}$$

a ₀	f _{T1}	f _{T2}
0	1.0006	0.0000
0.25	1.0120	0.0024
0.5	1.0455	0.0174
0.75	1.0925	0.0538
1	1.1416	0.1211
1.25	1.1758	0.2143
1.5	1.1878	0.3290
1.75	1.1655	0.4510
2	1.1086	0.5718
2.5	0.9221	0.7422
3	0.6990	0.8007
3.5	0.5228	0.7769
4	0.3982	0.7181

Table DA 3234-4 Parameter values for torsion factors

The torsion stiffness is calculated as:

Note that the torsion stiffness is independent from Poisson's ratio.

The critical damping ratio is given by the following formula:

Equation DA 3234-10

$$\eta_T = 0.05 + 0.25 \cdot \frac{f_{T2}}{f_{T1}}$$

DA 3235 Fixed base analysis

A fixed base analysis can be performed for seismic response of the structure when the frequency obtained with a rigid structure supported on soil springs representing the soil supporting medium is more than twice the dominant frequency obtained from a fixed base analysis of the structure.

Unless otherwise justified, the SSI analyses shall be performed using either direct or substructure methods.

DA 3300 VALUES OF DISPLACEMENTS

Relative displacements calculated at levels of possible interaction between structures shall be provided.

Unless otherwise justified, these values shall be multiplied by a factor equal to 1.5 to take into account the non-linearity in the soil and the structures due to seismic excitation.

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$$K_T = \frac{16}{3} \times G \times \kappa_0^3 \times \frac{f_{T1}}{f_{T1}^2 + f_{T2}^2}$$

Equation DA 3234-9

DA 4220 Elastic coefficients (E, v) and others requirements

The values of modules of elasticity and Poisson's ratios to be used to determine the stiffness properties of concrete and steel members are given below. These values complement the values of material properties defined in sections DCONC and DSTLW for seismic analysis.

These values are given for materials at or near ambient temperature.

Concrete

For a normal density (2 500 Kg.m⁻³) prestressed and/or reinforced concrete with a specified compressive strength f_{ck} (the design characteristic cylinder strength, in MPa):

 The modulus of elasticity Ecm to be used in the dynamic analysis, according to EN 1992-1-1 shall be taken as:

Equation DA 4220-1

$$E_{cm} = 22 \cdot \left(\frac{f_{ck} + 8}{10}\right)^{0.3}$$
 (GPa)

- Poisson's ratio shall be taken as: v = 0.2

Steel

For steelworks, the corresponding values shall be taken as:

- E_s = 210 000 (MPa);
- -v = 0.3.

The modulus of elasticity of austenitic steel shall be confirmed by test or by data supplied by the manufacturer.

DA 4300 MODELLING OF STIFFNESS

The modelling of the stiffness of reinforced concrete members shall use the properties given in EN 1992-1-1. In the general case of linear analysis (without reduction factor) to assess the structure internal loads set reinforced concrete members are modelled as uncracked sections (Poisson's ratio is taken as 0.2) for earthquake level belonging to Design Basis Level.

This assumption is applicable under the following assumptions:

- shear wall design: for the 2 horizontal directions and for every level a minimum of 2 shear walls in 2 different plans is neeeded.
- the stiffness of the floors has to be stiff enough to avoid floors significant vibrations been assessed through a dynamic calculation and validated by the project. Project

Where these assumptions are not valid, specific calculation shall be performed. Best estimate values shall be used to model the stiffness of infill panels and non structural elements (reinforced concrete or reinforced masonry), taking into account cracking and the type of supports (see other condition for using infill panels at the beginning of DA4200).

DA 4400 MODELLING OF MASS

The inertial mass shall include all masses expected to be present at the time of the earthquake.
Table DB 3120-1 Global approach (acceptable methods)

	Generic case		Specific case of RB containment	Specific case of small buildings ^{(1), (2)}
Requirement(s)	Durability only	Durability + Leaktightness	All	All
Consideration of drying shrinkage	Strain method (see DB 3400) or possibly Force method (see DB 3310)	Force method (see DB 3310)	Force method (see DB 3310)	Shrinkage may be neglected
Consideration of crack width	Included in the strain method (see DB 3400) or in the Force method, crack width control (see DB 3320)	Crack width control (see DB 3320)	Crack width control (see DB 3320)	Crack width control (see DB 3320)
(1) Exce	pt structures with leakt	ightness requirer	ments regarding rac	lioactive fluids.

(2) Small buildings correspond to concrete independent structures with highest size lower than d_{joint} (for horizontal directions). The value of d_{joint} shall be defined by the Project according to the local climatic conditions.

DB 3200 DESIGN DATA

For all calculations defined in DB 3000, the modulus of elasticity of concrete corresponding to each of these structural elements is the long-term one defined in Table DCONC $\frac{2110-1(2)}{210}$.

2110-2

Table DB 2400-1 gives acceptable values of relative humidity.

DB 3300 FORCE METHOD AND CRACK WIDTH CONTROL

Figure DB 3300-1 describes the process related with the force method and the additional control of crack width. Particularly, the force method results in the design of the reinforcement sections for the relevant element. The reinforcement design is performed using:

- Global or local models in an elastic analysis;
- Material criteria given in DCONC depending on serviceability requirements. According to DCONC 6000, a difference is made for rafts and buried walls related to buildings which contain radioactive fluid.



Figure DB 3300-1 Force method process and crack width control

DB 3310 Force method

(1a) Calculation of the drying shrinkage strain for the relevant element: ϵ_r

The shrinkage strain ε_r is defined as follows:

Equation DB 3310-1

$$\varepsilon_r = \varepsilon_{cd}(t_f)$$

Where:

- t_f is the design working life time;
- $\epsilon_{cd}(t)$ is the value of the drying shrinkage in the relevant element at the age t (see equations given in DB 1300 and DB 2200).

(1b) Transformation of the shrinkage strain into equivalent force

The shrinkage strain ϵ_r is transformed into an equivalent and uniform thermal load ΔT_{eq} (based on linear elastic calculation), as follows:

Equation DB 3310-2

$$\Delta T_{eq} = \frac{\varepsilon_r}{\alpha_c}$$

where α_c is the thermal expansion factor of concrete and is assumed to be 10×10^{-6} K⁻¹ (see Table DCONC 2110-3).

The effects of cracking caused by shrinkage on the structure stiffness shall be taken into account by using a reduction factor according to DB 4423 in calculations.

(2) Calculation of the differential strain: $\Delta \epsilon_r$

 $\Delta \varepsilon_r$ is the difference between strains caused by shrinkage in:

- the relevant element;
- a reference element.

For walls and for slabs, the reference element can be taken to the thicker shell adjacent to the studied area.

between

 $\Delta \epsilon_r$ is calculated as follows:

Equation DB 3400-2

$$\Delta \varepsilon_r = \max_t \Delta \varepsilon_r(t) = \varepsilon_{cd}(t) - \varepsilon_{cd,ref}(t) \quad \text{with } 0 < t < t_f$$

Where:

- t is the age of the considered element,
- t_f is the design working life time,
- $\epsilon_{cd}(t)$ is the value of the drying shrinkage in the relevant element at the age t (see equations given in DB 1300 and DB 2200);
- $-\epsilon_{cd,ref}(t)$ is the value of the drying shrinkage in the reference element at the age t.

(3) Calculation of the residual crack opening: w_{res}

Residual opening, which occurs for the combinations of actions to be considered, is deduced as follows:

Equation DB 3400-3

$$W_{res} = W_{max} - W_s$$

Where:

- w_{max} is defined in EN 1992-1-1, 7.3.1 (Table 7.1N);
- w_s is the crack width consumed by shrinkage. It is calculated with EN 1992-3, Annex M:

Equation DB 3400-4

$$W_s = R_{ax} \cdot S_{r, \max} \cdot \Delta \varepsilon_r$$

Where $R_{ax} = 0.5$ (defined in EN 1992-3, 1.7).

(4) Calculation of the difference between the strain in the concrete and the strain in the reinforcement: ($\epsilon_{sm} - \epsilon_{cm}$)

The value of $(\epsilon_{sm} - \epsilon_{cm})$, where:

- ϵ_{sm} is the mean strain in the reinforcement under the relevant combination of loads, and;
- ϵ_{cm} is the mean strain in the concrete between cracks;

is calculated as follows:

Equation DB 3400-5

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$$\mathcal{E}_{sm} - \mathcal{E}_{cm} = \frac{W_{res}}{S_{r,\max}}$$

DCENGINEERING METHODS FOR MISSILE IMPACT AND DROPPED LOADS

DC 1000 SCOPE OF THE APPENDIX

This appendix describes engineering methods which may be used to prove the bearing capacity of structural members under either missile impact or dropped loads. If these methods are used, verifications shall be performed for the local area of the impact.

These methods ensure the integrity of structural elements: they do not guarantee the integrity of anchorages in the impact area. A special attention should be paid for these equipments.

The impact energy depends on the velocity of the missile or the dropped load.

Table DC 1000-1 gives the descriptions and units of relevant parameters used in formulae introduced by the APPENDIX DC. The Table DC 1000-1 also gives where the parameters are defined.

NOTE The sign convention which applies in the APPENDIX DC is:

- Shortening strain and compressive stress are negative ($\epsilon < 0$ and $\sigma < 0$);
- Elongation strain and tensile stress are positive ($\epsilon \ge 0$ and $\sigma \ge 0$).

Parameter	r Description		Defined by
	Generic parameters of mechanical behaviour of reinforced conc	crete stru	ucture
d	d Effective depth of the cross sectional area of bending reinforcement		Figure DC 4100-1
h	Thickness of the reinforced concrete element	[m]	Figure DC 2300-1
V _{fd}	Contribution of concrete to shear resistance	[MN]	Appendix DH
x	Neutral axis depth	[m]	
σ_{cp}	Compressive stress in concrete due to axial load	[Pa]	Equation DC 2200-1
	Specific parameters of methodology described in Append	dix 1.C	
	Model displacement and strain		
Uu	Displacement	[m]	
U _{ctl}	Ultimate displacement of bending reinforcement	[m]	Equation DC 4130-3
U _{cts,a}	Ultimate displacement of shear reinforcement (stirrups)	[m]	Equation DC 4120-4
U _{cys,a}	Maximum elastic displacement of shear reinforcement (stirrups)	[m]	Equation DC 4120-2
U _{cys,b}	Maximum elastic displacement of shear reinforcement (concrete)	[m]	Equation DC 4110-2
U _{dy}	Maximum elastic displacement of circular reinforced concrete slab	[m]	Equation DC 4220-4
U _{dk}	Maximum plastic displacement of circular reinforced concrete slab	[m]	Equation DC 4220-6
W	Elastic displacement of the circular slab embedded at the periphery and loaded by a unit force	[m]	Equation DC 4220-2
ε _m	Uniform strain in bending reinforcement	[-] or [‰]	Equation DC 4130-1
ε	Admissible elongation strain in reinforcing steel	[-] or	Table DC 5000-1

Table DC 1000-1 Definitions and units of parameters used in APPENDIX DC

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PART D DESIGN DC ENGINEERING METHODS FOR MISSILE IMPACT AND DROPPED LOADS

Parameter	Description	Unit	Defined by
		[‰]	
Ŷ	Ratio a / r	[-]	Equation DC 4220-2
Θ_{lim}	Admissible rotation	[-]	Equation DC 4300-1
	Model geometry		
а	Radius of the impact area	[m]	Figure DC 2100-1
Ι	Radius of the punching cone at the depth of bending reinforcement	[m]	Figure DC 4130-1
I ₁	Longer dimension of the reinforced concrete structure (length)	[m]	Figure DC 2300-1
I ₂	Shorter dimension of the reinforced concrete structure (width)	[m]	Figure DC 2300-1
r	Radius of a circular slab from the impact centre	[m]	Figure DC 2100-1
α	Angle of the punching cone	[rad] or [°]	Equation DC 2200-1
r	Radius of the punching cone	[m]	Equation DC 6200-2
L	Diameter of the punching cone at the depth of bending reinforcement	[m]	Equation DC 6300-2
I _{As}	Length on which the reinforcement is to be taken into account in direction x (or y)	[m]	Equation DC 6200-3
	Model mass		
M _c	Punching cone mass	[kg]	Equation DC 3100-1
M _d	Dynamic equivalent mass of a circular plane slab	[kg]	Equation DC 3200-2
Ms	Surrounding structure mass	[kg]	Equation DC 3200-3
	Model resistance and stress		
R _{cl}	Strength of bending reinforcement	[N]	Equation DC 4130-2
R _{ct/}	Ultimate strength of bending reinforcement	[N]	Equation DC 4130-4
R _{ct/}	Ultimate strength of bending reinforcement direction x	[N]	Equation DC 6200- 87
R _{cts,a}	Ultimate strength of shear reinforcement (stirrups)	[N]	Equation DC 4120-4
R _{cys,a}	Elastic strength of shear reinforcement (stirrups)	[N]	Equation DC 4120-1
R _{cys,b}	Punching concrete shear resistance	[N]	Equation DC 4110-1
R _{dy}	Elastic resistance of circular reinforced concrete slab	[N]	Equation DC 4220-3
R_{dk}	Plastic resistance of circular reinforced concrete slab	[N]	Equation DC 4220-6
M _{dk}	Ultimate plastic bending moment	[N.m/m]	DC 4200
M_{dy}	Elastic bending moment	[N.m/m]	DC 4200
σ_c	Dynamic strength of concrete	[Pa]	Table 1.C-2
	Model stiffness		DC 5000-1
K _c	Stiffness of an elasto-plastic spring representing the punching phenomenon	[N/m]	Figure DC 2100-1
K _{cys,a}	Elastic stiffness of shear reinforcement (stirrups)	[N/m]	Equation DC 4120-3
K _d	Stiffness of an elasto-plastic spring representing the bending of the circular slab	[N/m]	Figure DC 2100-1
Ks	Stiffness of an elastic spring representing the behaviour of the surrounding structure	[N/m]	Figure DC 2100-1

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DC 4200 ELASTO-PLASTIC SPRING OF THE CIRCULAR SLAB

DC 4210 Calculation

A bi-linear elasto-plastic diagram is assumed for the spring which represents the plasticised circular plane slab.



Figure DC 4210-1 Displacement-resistance diagram

DC 4220 Verification

The total energy of the circular slab, *E*_{circular slab}, is:

Equation DC 4220-1

$$E_{circularslab} = \frac{R_{dy} \cdot u_{dy}}{2} + \frac{R_{dk} + R_{dy}}{2} \cdot \left(u_{dk} - u_{dy}\right)$$

NOTE $E_{circular slab}$, is calculated by taking the integral of the displacement-resistance diagram presented in Figure DC 4210-1.

According to the amount of reinforcement and to the concrete cross-section, the elastic bending moment M_{dy} and the cracked rigidity D ($D = E I_{cracked}$) are evaluated by taking into account the normal force (if any) associated with the bending moment.

The ultimate plastic bending moment M_{dk} is evaluated following the design criteria concerning the allowable strains in the concrete and in the reinforcement.

The elastic displacement of the circular slab embedded at the periphery and loaded by a unit force concentrated on a circular area is given by:

Equation DC 4220-2

$$\frac{1}{K_{dy}} = w = \frac{1}{64\pi \cdot D} \cdot \left[\left(4 - 3 \cdot \gamma^2 \right) + 4 \cdot \gamma^2 \cdot \ln \gamma \right]$$

with: $\gamma = a / r$.

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The elastic resistance R_{dy} of a circular slab embedded at the periphery and loaded by a unit force concentrated on a circular area is (the Poisson' ratio v is taken as equal to 0):

Equation DC 4220-3

$$R_{dy} = \frac{16\pi \cdot M_{dy}}{\left[\gamma^2 - 4\ln\gamma\right]}$$

The maximum elastic displacement of the slab is given by:

Equation DC 4220-4

$$u_{dy} = \frac{\alpha^2}{4 \cdot D} \cdot \frac{\left[4 - 3 \cdot \gamma^2 + 4 \cdot \gamma^2 \cdot \ln \gamma\right]}{\left(\gamma^2 - 4 \cdot \ln \gamma\right)}$$

The plastic resistance R_{dk} of the circular slab embedded at its periphery and loaded by a unit force concentrated on a circular area is calculated according to the formula from the yield-line theory:

Equation DC 4220-5

$$R_{dk} = \frac{2\pi \cdot \left(M_{dk}^{+} + M_{dk}^{-}\right)}{\left(1 - \frac{2 \cdot a}{3 \cdot r}\right)}$$

With:

M_{dk}+ the ultimate bending moment which creates tension in the lower fibre;

M_{dk}- the ultimate bending moment which creates tension in the upper fibre.

The maximum plastic displacement of the slab is evaluated according to the allowed rotation θ_{lim} of the plastic hinge:

Equation DC 4220-6

 $u_{dk} = r \cdot \theta_{\lim}$

DC 4300 ELASTIC SPRING OF THE SURROUNDING STRUCTURE

The elastic spring which represents the surrounding structure is defined according to the two calculations which determine the radius of the circular slab. The displacement difference between the two calculations for a unit force gives the elastic stiffness of the surrounding structure.

DC 5000 DESIGN CRITERIA FOR THE LOCAL VERIFICATION

For the evaluation of the ultimate bending moment, the calculations shall be performed using one of the options of Table DC 5000-1, depending on the Project specification.



Figure DD 1300-1 Example of symmetrical reinforcement

The steel reinforcement density should be calculated taking into account the total mass of steel within the considered structural element (horizontal, vertical and transverse).

DD 1400 APPLICATION CONDITIONS

For reinforced concrete:

A down-rating coefficient of 12% shall be applied to the calculated velocity for all cases in which perforation of the reinforced concrete structure is unacceptable from a safety viewpoint:

Equation DD 1400-2

$V_{acceptable} = 0.88 V_{just perforation}$.

 The perforation formula shall be applied directly for all cases in which just perforation is acceptable (special case of a double-wall protection).

For prestressed concrete, the conditions defined above are also applicable :

- For a prestressed concrete structure without leaktight liner, the reinforced concrete formula is directly applied;
- For a prestressed concrete structure with leaktight liner, an up-rating coefficient is considered, taken as 10% of the just perforation velocity calculated for reinforced concrete.

DD 1500 GENERAL METHOD

The general method defined in this Appendix applies only for the validity ranges given below:

- f_{ck} ≥ 25 MPa;
- $0.5 \le \frac{D}{H} \le 1.5$

$$- 0.5 \le \frac{M}{\rho \cdot H^3} \le 5.0$$

- Symmetrical reinforcement
- 100 kg.m⁻³ ≤ "symmetrical reinforcement" ≤ 250 kg.m⁻³
- V ≥ 20 m.s⁻¹

DE 4000 EQUIPMENT ANCHORS CONNECTED TO POOL OR CONTAINMENT LINER.



Figure DE 4000-1: anchor plate or anchor ring in the same plane as the liner's one

Figure DE 4000-2: anchor plate for specific equipment

Figure DE 4000-1: the equipment anchor plate 8, its anchoring system 2b, and the welds 5a refer uppermost to chapters dealing with leaktightness or watertightness. Welds 5c refer to structural steelwork requirements.

Figure DE 4000-2: for specific equipment 13 (e.g. polar crane bracket), the equipment anchor plate 8 refers uppermost to leaktightness or watertightness. The anchoring system 14 has to be specifically designed. The design shall be subject to the Project approval.

The following table gathers the entry points for the requirements applicable to Figures DE 2000-1 to DE 4000-2.

N: No E <i>i</i> : E A <i>i</i> : A	ormal situation xceptional situations ccidental situations	Key: Characterization of the expected function of the structures after application of the permanent, variable or accidental actions. F: serviceability ; C: containment (* with ventilation) (** limitation radiological impact) L: leaktightness (* by liner) ; R: resistance (* partial) (Index B: concrete structure - Index M: metal structure)								
	Situations: categories and definitions	Bunker: Fuel Building andSafeguard Building 1 & 2Nuclear auxiliary Building / Effluent treatment building 2 & 3Nuclear auxiliary Building / Effluent treatment buildingSafeguard Building RIS [SIS] 						Nondrainable comp.		
N	Reactor states or environmental conditions	F _Β	F _B	F _B	F _B	/	1	F _Β	L	L
E1	PCC2 conditions	F _B	F _Β	F _B	/	F _Β	/	/	L	L
E2	DBSE	F _B	F _B	F _B	F _Β	F _B	F _B	F _Β	L	L
E3	Snow and wind	1	F _B	F _B	F _B	1	1	F _B	1	1
E4	Exceptional temperatures	1	F _B	F _B	F _Β	/	1	F _Β	1	1
E5	Water table	1	/	F _Β	F _B	/	/	F _B	1	1
A1	Earthquake	R _B	R _B	R _в / L*	R _B	R _B	Rв	Rв	L	L
A2	Aircraft crash	1	1	1	R _B *	R _B *	R _B *	1	1	1
A3	Explosions / fires	1	R _B	R _B	R _B	1	1	R _B	1	1
A4	RHEP / projectiles	1	/	1	1	/	1	1	1	1
A5	PCC3/4 conditions & DEC-A environment	R _B /C*	R _B / C*	L*	1	R _B / C**	1	1	1	L
A6	DEC-B environment	1	1	/	1	1	R _B / C**	1	1	1

Table DG-2 Design safety requirements applicable to the design of buildings for the Nuclear Island excluding the Reactor Building PART D DESIGN DG (INFORMATIVE) TABLES OF REQUIREMENTS A wall without predominant out of plane bending is a wall not subjected to out of plane actions.

The minimum reinforcement $\rho_{w,min}$ is defined by the following equation:

Equation DH1000-1

$$\rho_{w,\min} = \frac{0.08 \times \sqrt{f_{ck}}}{f_{yk}}$$

Whatever the thickness, DH 2000 to DH 6000 shall apply in supplement of previous criteria.

Maximum required spacing is detailed in DH 10000.

DH 2000 ELEMENTS NOT REQUIRING DESIGN SHEAR REINFORCEMENT CALCULATION

EN 1992-1-1, 6.2.2, Equations (6.2a) and (6.2b) apply with the following parameter values:

Equation DH 2000-1

$$V_{Rd,c} = \left[C_{Rd,c} \cdot k \cdot (100 \cdot \rho_l \cdot f_{ck})^{1/3} + k_1 \cdot \sigma_{cp}\right] \cdot b_w \cdot d \text{ (EN 1992-1-1, (6.2a))}$$

With a minimum value of:

Equation DH 2000-2

$$V_{Rd,c,\min} = (v_{\min} + k_1 \cdot \sigma_{cp}) \cdot b_w \cdot d$$
 (EN 1992-1-1, (6.2b))

With:

$$C_{Rd,c} = \frac{0.18}{\gamma_c}$$

$$k = 1 + \sqrt{\frac{200}{d}} \le 2$$
with d in [mm]

- Ratio of longitudinal reinforcement:

$$\rho_l = \frac{A_{sl}}{b_w.d} \le 0.02$$

$$- k_1 = 0.15$$

- The value vmin is given by:

$$v_{\min} = 0.035 \cdot k^{3/2} \cdot \sqrt{f_{ck}} \quad \text{(EN 1992-1-1, (6.3N))}$$
$$\sigma_{cp} = \frac{N_{Ed}}{A_c} < 0.2 \cdot f_{cd} \quad \text{in [MPa]}$$

 $N_{\rm Ed}$ is the axial force in the cross-section due to loading or prestressing ($N_{\rm Ed}$ >0 for compression). The influence of imposed deformations on $N_{\rm E}$ may be ignored.

 N_{Ed}

DH 10000 MAXIMUM SPACING OF SHEAR REINFORCEMENTS

Table DH 10000-1 Maximum spacing of shear reinforcement

	$V_{Ed} \leq V_{Rd,c}$	V_{Ed} > $V_{Rd,c}$
Principal slabs where transverse redistribution of loads is possible	$\max (\mathbf{s}_{\mathbf{x}}; \mathbf{s}_{\mathbf{y}}) \le 0.8 \text{ m}$ $\frac{1}{\mathbf{s}_{\mathbf{x}} \cdot \mathbf{s}_{\mathbf{y}}} \ge 4$	0.75∙d x 1.5∙d Or d x d
Secondary slabs	$\max (s_x; s_y) \le 0.8 \text{ m}$ $\frac{1}{s_x \cdot s_y} \ge 4$	0.75∙d x 1.5∙d Or d x d
Principal slabs without transverse redistribution of loads	0.75·d x 1.5·d	
Walls without predominant out of plane bending	$\max (s_x; s_y) \le 0.8 \text{ m}$ $\frac{1}{s_x \cdot s_y} \ge 4$	0.75∙d x 1.5∙d Or d x d
Walls with predominant out of plane bending	See slabs require	ements

Where:

- s_x is the maximum longitudinal spacing of shear reinforcement;
- s_y is the maximum transversal spacing of shear reinforcement.

DH 11000 ADDITIONAL SHEAR DESIGN REQUIREMENTS FOR LEVELS 0, I.1 AND I.2 COMBINATIONS

DH 1000 to DH 8000 and DH 10000 shall apply.Resistant shear shall be checked according to the following equations and using Table <u>1.H-4</u> (only for RB containment).

DH 11000-1

To determine the ratio A_{sw} /s, the following expression is used instead of EN 1992-1-1, 6.2.3, (4), Formula (6.13):

Equation DH 11000-1

$$V_{Rd} = \frac{A_{sw}}{s} \cdot z \cdot \overline{\sigma_{sw}} \cdot (\cot \theta + \cot \alpha) \cdot \sin \alpha + \tau \times V_{fd}$$

Equation DH 11000-2

$$V_{Rd} \leq V_{Rd,\max} = \alpha_{cw} \cdot b_{w} \cdot z \cdot v_{1} \cdot \overline{\sigma_{cw}} \cdot \frac{\cot \theta + \cot \alpha}{1 + \cot^{2} \theta}$$

(1) The median values of material properties proposed in this section are used for each failure mode in DJ 3000.

(2) Actually the variability in test results is randomness; however, these variabilities are relatively small and for simplicity are assumed to be uncertain.

DJ 2000 GEOMETRICAL PARAMETERS AND REINFORCEMENT SECTION VARIABILITIES

Concerning the variabilities of geometrical parameters (impacted area, reinforcement diameter, reinforcement spacing, concrete cover, height of the slab, etc.), the logarithmic standard deviation β_U shall be assessed with the following assumptions:

- The dimensions B, h, c, e_I, s_w, e_x, e_y, s_x,s_y are characterized by +/- 2 cm tolerances around the median value and the associated variability can be assessed with a 95% fractile;
- The dimension d_{ast} is characterized by +/- 10 cm tolerances around the median value and the associated variability can be assessed with a 99.9% fractile;
- he reinforcement diameters Φ_x , Φ_y , Φ_{sw} , have geometrical tolerances equal to +/- 2.2 %, and the reinforcement section AI have a mass tolerance equal to +/-4.5% (according to EN 10080). The associated variabilities can be assessed with a 99% fractile;

The dimensions, spacings and diameters are defined from EC2 and/or in the texts and figure of section DJ 3000 below.

For the following failure modes:

- diagonal shear cracking,
- in-plane flexure,
- sliding shear friction,

These variabilities concerning geometrical parameters and reinforcement section shall not be considered, in consistence with EPRI Guide. These variabilities are already taken into account in the variabilities of formulae.



DJ 3000 MEDIAN STRUCTURAL CAPACITIES OF STRUCTURE FOR FAILURE MODES

DJ 3100 DIAGONAL SHEAR CRACKING

Diagonal shear cracking is a concrete failure mode concerning low-rise shear walls.

According to EPRI TR-103959, the median capacity of low-rise shear walls V_m may be realistically represented by Equation DJ 3100-1 for the diagonal shear cracking failure mode:

Equation DJ 3100-1

$$V_m = v_u \cdot d_{DED} \cdot t_n$$

For indirect loads applied on the considered reinforced concrete element, a concrete basement or a stiffened plate may be considered to estimate the impacted area.

The design procedure for punching shear structural capacity is based on a "multi-conditions" formulation similar to the EN 1992-1-1, 6.4.5 formulation. This approach takes into account both concrete resistance and shear reinforcement resistance. The punching zone shall have at least shear reinforcement as required in APPENDIX DH.

The structural capacity for the punching failure mode P_m is defined by:

Equation DJ 3500-1

$$P_m = \min(V_C + V_S; V_{C,out}; V_{max})$$

Where:

 $-V_c$ is the concrete resistance inside the shear reinforced zone and is given by:

Equation DJ 3500-2

$$V_{C} = 0.18 \cdot u_{1} \cdot (h-c) \cdot \min\left(1 + \left(\frac{0.2}{h-c}\right)^{0.5}; 2\right) \cdot \left(100\left(\frac{A_{l}}{h-c}\right) \cdot \frac{f_{c,med}}{1.2}\right)^{\frac{1}{3}}$$

- V_s is the shear reinforcement resistance and is given by:

$$V_{S} = A_{sw} \cdot \left(4.B.1.5.(h-c) + \pi \cdot (1.5.(h-c))^{2}\right). \min\left(250 + 250 \cdot (h-c); \frac{f_{y,med}}{1.1}\right)$$
$$V_{S} = A_{sw} \cdot \min\left(250 + 250 \cdot (h-c); \frac{f_{y,med}}{1.1}\right)$$

Equation DJ 3500-3

- $V_{c,out}$ is the resistance outside the shear reinforced zone and is defined by:

Equation DJ 3500-4

$$V_{c,out} = 0.28 \cdot u_{out} \cdot (h-c) \cdot \min\left(1 + \left(\frac{0.2}{h-c}\right)^{0.5}; 2\right) \cdot \left(100\left(\frac{A_l}{h-c}\right) \cdot \frac{f_{c,med}}{1.2}\right)^{\frac{1}{3}}$$

- V_{max} is the resistance of concrete at the interface between column and slab and is defined by:

Equation DJ 3500-5

$$V_{max} = \mathbf{0.30} \cdot u_0 \cdot (h-c) \cdot \frac{f_{c,med}}{1.2} \cdot \left(1 - \frac{f_{c,med}}{1.2 \times 250}\right)$$

CH2.J DJ 8/10 Copyright AFCEN © n°157-2015. This document is the property of AFCEN. It must not be reproduced or communicated to a third party without permission signed by the President of AFCEN. The associated perimeters and reinforcement sections are represented on Figure DJ 3500-1 and defined below:



Figure DJ 3500-1 Punching cone geometry

- The perimeter u_0 of the loaded area is :

Equation DJ 3500-6

$$u_0 = 4 \cdot B$$

Where B is the width of the square loaded area. For a rectangular impact: $B = (a_0 \cdot b_0)^{\frac{1}{2}}$.

 The basic control perimeter u₁ located at 1.5.d (different value with EN 1992-1-1) from the loaded area is:

Equation DJ 3500-7

$$u_1 = 4 \cdot B + 2\pi \cdot 1.5 \cdot (h - c)$$

Where:

- o h is the height of the cross section,
- o c is the concrete cover of the reinforcement (see Figure DJ 3500-1 above).
- The outermost perimeter u_{out} located at 1.5.d from the shear reinforcement location is:

Equation DJ 3500-8

$$u_{out} = 4 \cdot B + 2\pi \cdot d_{ast} + 2\pi \cdot 1.5 \cdot (h - c)$$

Where d_{ast} is the distance between the loaded area and the end of the shear reinforcement.

The associated steel sections are defined as follows:

- A_{sw} (m²/m²) is the area of the shear reinforcement (diameter ϕ_{sw}) around the loaded area, associated with the s_x and s_y spacings: For a rectangular regular distribution around the loaded area :

Equation DJ 3500-9

$$A_{sw} = \sum \pi \cdot \frac{\Phi_{Sw}^{2}}{4 \cdot (s_{x} \cdot s_{y})}$$

DM 2300 CAPACITY OF A STRUCTURE

In order to assess A_{HCLPF} , the median value of the DESC of the structure shall be firstly calculated. This median value is defined as:

Equation DM 2300-1

$$\underline{\mathbf{A}}_{m} = \underline{\mathbf{F}} \cdot \mathbf{A}_{DBE}$$

Where:

- \underline{A}_m : The median value of the random variable describing the DESC of the structure;
- A_{DBE}: The deterministic value of the DBE capacity (expressed as **PGA** or **A**_s);
- <u>F</u>: The median value of the Scale Factor F.

Equation DM 2300-1 may be expanded in order to identify the part of margin related to both seismic response of the structure and strength (structural capacity):

Equation DM 2300-2

$$\underline{F} = \frac{\underline{A}_{m}}{A_{\text{DBE}}} = \frac{\text{Median DESC of the structure}}{\text{DBE shake acceleration}}$$

$$\underline{\mathbf{F}} = \frac{\text{Median DESC of the structure}}{\text{Design DBE response of the structure}} \times \frac{\text{Design DBE response of the structure}}{\text{DBE shake acceleration}}$$

$$\underline{\mathbf{F}} = \underline{\mathbf{F}_{c}} \times \underline{\mathbf{F}_{rs}}$$

Where:

- \underline{F}_{rs} : The median value of the response margin factor of the structure F_{rs} described in DM 2420.

- \underline{F}_{c} : The median value of the structural capacity factor of the structure F_{c} detailed in DM 2430.

AFMF: according to the EPRI Report TR-1019200, the method considers both F_{rs} and F_c may be decomposed using nine factors assumed to be independent of each other and representing various fundamental parameters of the FA:

Equation DM 2300-3

$$\mathbf{F}_{rs} = \mathbf{F}_{gm} \times \mathbf{F}_{m} \times \mathbf{F}_{d} \times \mathbf{F}_{mc} \times \mathbf{F}_{GMI} \times \mathbf{F}_{ec} \times \mathbf{F}_{SSI}$$

Equation DM 2300-4

 $F_c = F_E \times F_\mu$



F_{μ} : The inelastic energy absorption factor.

Each of the nine factors has a certain randomness (β_R) and uncertainty (β_U). These two variations usually depend on the specific structure, on the means of analysis of its response to an earthquake and on the means by which the input earthquake is specified. Given the postulated statistical independence of the factors, the variations in randomness and uncertainty factors are combined using the square-root-of-the-sum-of-squares (SRSS) in order to obtain the global randomness or the global uncertainty of the scale factor:

Equation DM 2300-5

$$\boldsymbol{\beta}_{r} = \sqrt{\sum_{i} \boldsymbol{\beta}_{r_{i}}^{2}} \text{ and } \boldsymbol{\beta}_{u} = \sqrt{\sum_{i} \boldsymbol{\beta}_{u_{i}}^{2}}$$

Where β_{ri} and β_{ui} for each input factor in the building response are defined as the change in "ln(A_s)" per standard deviation in the input factor (see APPENDIX DI).

Additional dedicated factors may be considered if necessary, especially if the seismic design calculations are based on simple modelling ignoring torsion effects or uniform input motion in all directions. This case should not occur if APPENDIX DA. is dutifully applied.

With these notations, the capacity of a structure is evaluated through the scale factor which is composed by these primary factors assessed through the basic formulae which are described in the following sections.



Figure DM 2421-1 Example horizontal ground response spectra demonstrating peak and valley randomness

If the DEE and DBE spectra have the same shape, the corresponding scale factor should be set at $\underline{F}_{gm, Spec Shape} = 1.0$.

DBE spectra are normally smoothed, taking the shape of a "plateau" of amplified structural response motion relative to the ground motion in the frequency range of about 2-10 Hz. The comparison of smoothed DBE/DEE spectra with real earthquake spectra therefore includes randomness in the peaks and valleys compared to the flat plateau of amplified motion.

Randomness in ground motion frequency content and the corresponding peaks and valleys is the only variation for spectral shape. A lot of data (more earthquake free-field spectra) would not reduce the scatter of peaks-to-valleys or the estimated value of $\beta_{R, \, Spec \, Shape}$. The peaks and valleys variability is usually already considered in the Probabilistic Seismic Hazard Analysis (PSHA) as stated in EPRI Report TR-1019200 to avoid double-counting this randomness. In this case, no separate peak and valley randomness variability is required for the spectral shape factor.

Thus, the variability of spectrum shape due to randomness can be taken as:

Equation DM 2421-2

$\boldsymbol{\beta}_{r, \text{ Spec Shape}} = 0.$

And as suggested in EPRI Report TR-103959 for variability due to uncertainty, $\beta_{U, Spec Shape}$ depends on the considered frequency.

Table DM 2421-1	Value of	βu, Spec Shape	when o	earthquake	response	spectrum	shape	anchored	to PGA
parameter	-								

f (Hz)	$oldsymbol{eta}_{U, \; Spec \; Shape}$
1	0.32
5	0.24
10	0.16
16	0.12
33	0

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When Uniform Hazard Spectrum (UHS) is used as the design extension response spectrum target, then $\beta_{u, Spec Shape}$ can be taken equal to 0.

In general case:

Equation DM 2421-3

 $0 < \beta_{u, \text{ spec shape}} < 0.32 \text{ and } \beta_{r \text{ spec shape}} = 0.$

In particular cases, values of β_r shall be assessed according to EPRI Report TR-103959, TR-1002988 and TR-1019200 and submitted to the Project approval.

The hypothesis $\beta_{r, Spec Shape} = 0$ shall be justified based on site data or generic earthquake level assessment procedure.

Horizontal Direction Peak Response:

The actual earthquake response spectrum should be different for one direction from the one of the other direction. The design horizontal input motion is supposed to be the average value of the two horizontal directions of the considered earthquake. Consequently, the scale factor is equal to 1 ($\underline{F}_{gm, Hor Dir Peak} = 1$).

For other assumption, the procedure to assess the scale factor (and the associated variability) shall be submitted to the Project approval.

This randomness variability should stay in the range $0.12 \le \beta_{r, \text{Hor Dir Peak}} \le 0.14$.

The effect of the horizontal direction peak response variability on the final fragility parameters of a structure depends on how the two horizontal earthquake components individually affect the response of the structure. The variability can be finally reduced according to EPRI Report TR-103959 and EPRI Report TR-1019200.

Equation DM 2421-4

$$\beta_{r, \text{ Hor Dir Peak}} = 0.13 \text{ and } \beta_{u, \text{ Hor Dir Peak}} = 0.$$

Vertical component response:

For most structures, the vertical earthquake does not have a major effect on capacity. This phenomenon can be assessed by a simplified manner: when the vertical earthquake is assumed to be equal to 2/3 of the horizontal component, the variabilities shall be taken as:



This value concerns the variability of the ratio between vertical and horizontal ground acceleration. This variability shall be propagated through the response calculation.

If another assumption for vertical design input motion is considered, the procedure, data and criteria to assess both scale factor and variabilities shall be submitted to the Project approval.

Table DM 2421-2 Indicative summary for F_{gm} variability

Median value	Randomness	Uncertainty
<u>F_{gm} ≥ 1.0</u>	$0. \leq \beta_{\rm r} = \sqrt{\beta_{\rm r, \ Spec \ Shape}^2 + \beta_{\rm r, \ Hor \ Dir \ Peak}^2 + \beta_{\rm r, \ Vert \ Comp}^2} \leq 0.30$	$\beta_{U} = 0$

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DM 2427 Soil Structure Interaction Factor (F_{SSI})

General findings

The interaction between the structure and the supporting foundation includes:

- the vertical spatial variation of ground motion;
- the SSI itself;

The vertical spatial variation of ground motion: depth effect

Depending on the soil properties shaking intensity decreases with depth beneath the ground surface. As a result buildings with deeply embedded foundations are not subjected to uniform input between the ground surface and the bottom of the basemat. A deconvolution analysis should be conducted and the reduced motion applied at the foundation in the SSI analysis.

standard deviations

EPRI Report TR-103959 considers response results from seismic analysis taking into account the deconvolution of the surface motion to be median-centered. Furthermore, seismic analysis ignoring the reduction of the motion with depth (deconvolution) represents a response at three standard .Codes and standards allow motion reduction at the base of the building foundation limited to 60% of the shaking intensity at the ground surface (U.S. NRC NUREG-0800). If this bias is present in the SSI analysis it shall be compensated in the fragility calculations by a deconvolution factor. The deconvolution factor clearly depends on:

- The soil properties,
- The depth of the embedment of the foundation.

Without any particular studies the values of Table DM 2427-1 can be used based on judgment and experience (these values are consistent with the elastic theory and predominant frequencies between 2Hz and 4Hz). Other values can be used if specific studies are performed in order to represent a deconvolution effect adapted to the site conditions. These studies shall be submitted to the Project approval.

V _{S30} Foundation depth	250 m/s	350 m/s	450 m/s	600 m/s	> 800 m/s
5 m	1.075	1.05	1.025	1.0	1.0
8 m	1.275	1.125	1.05	1.025	1.0
> 12 m	1.425	1.325	1.175	1.125	1.05

Table DM 2427-1 Indicative values of deconvolution scale factor

 $V_{s_{30}}$ refers to the shear waves average velocity for the first 30 m under the surface level for which the free field response spectrum is considered.

 β_R (for the depth effect part) depends on the chosen approach to assess SF_{SSI} due to the depth effect.

If SF_{SSI} due to the depth effect has to be taken from Table DM 2427-1, then β_R shall be taken from the table below.

 $\beta_{u, SSI Analysis, 2}$ is the variability due to method:

- $\beta_{u, SSI Analysis, 2} = 0.05$, if a detailed representation is considered (stratigraphy considered in up to date modelling of SSI);
- $\beta_{u, SSI Analysis, 2} = 0.1$, if a simplified representation is considered (soil considered in homogeneous and simplified method for soil spring assessment) respecting requirements of appendix DA.

Other hypotheses are out of the scope of this document.

The global variability is given by:

Equation DM 2427-3

 $\beta_{U, SSI Analysis} = \sqrt{\beta_{U, SSI Analysis, 1}^2 + \beta_{U, SSI Analysis, 2}^2}$

Table DM 2427- 3 Indicative values for F_{SSI image}

Median value	Randomness	Uncertainty
<u>F</u> _{SSI} = 1	$\mathbf{B}_{\mathbf{r}} = 0$	0.1< β _u <0.3

DM 2430 Structural Capacity Factor (Fc)

DM 2431 Special Considerations for Structural Capacity Definition

The capacity of the building structure to resist to seismic loads relies on the identification of the weakest structural elements at which a safety system may fail due to damage or deflection in the enclosing building.

The first step is to identify the weakest structural elements in the weakest structure housing a critical NPP safety system.

The govering failure mode may be failure in a shear wall at a point of stress concentration through any of three general modes, including diagonal shear cracking, failure in out-of-plane flexure or shear displacement along a horizontal crack.

The governing failure mode may be defined as cracking or spalling in a concrete wall impairing the functionality of anchor plates for critical equipment.

Alternately, the weak links may be identified as excessive displacement, typically near the roof of the structure, inducing, for example, malfunctioning of a bridge crane or loss of a crane rail.

The impact of building displacement or damage on key equipment is part in the identification of the weakest structural elements.

The FA approach for seismic design margin assessment privileges two factors for building capacity:

- The structural strength to the initiation of yield in the concrete reinforcing bar or steel frame of the building (F_E),
- The energy absorption by ductile yielding in the reinforcing bar or the frame (F_{μ}).

Equation DM 2431-1

$$F_c = F_E \times F_\mu$$

Both F_E and F_{μ} are described in the next paragraphs.

DM 2432 Strength Factor (F_E)

The spectral acceleration corresponding to initiation of yield in the weakest critical NPP structure defines the structure's elastic seismic capacity.

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The yield point shall include both the seismic forces and the non-seismic operating loads on the structure. These would include self-weight of the building structure and contents, including sloshing loads for pools, and thermal loads at anchor points for piping or pressure vessels. Identification of the yield point in the weakest critical structure would normally derive from the design calculations for the building.

Design calculations assume allowable loads in structural members which have safety margins. Nevertheless, there is dispersion in material properties and construction details.

elastic

The strength of structures and the inelastic energy absorption due to capacity beyond strength are typically dependent on the type of structures, their seismic behaviour, their expected governing mode of failure and the code used for the design of the structure.

Some general procedures can be described to address structural capacity issues.

The earthquake strength factor to be applied to the reference earthquake input to obtain the median elastic capacity can be determined as follows, provided that seismic and non-seismic demand can be distinguished.

The median value of the strength factor is given by:

Equation DM 2432-1

$$\underline{F}_{E} = \frac{\underline{C} - D_{NS}}{D_{S} + \Delta C_{S}}$$

Where:

- <u>**C**</u> is the median capacity of the structure;
- D_{NS} is the concurrent non-seismic demand. Usually, D_{NS} corresponds to the normal operating loads;
- Ds is the reference linear elastic seismic demand;
- ΔC_s is the reduction in capacity due to seismic loadings. Usually, $\Delta C_s = 0$.

The associated variability is the result of:

- Randomness (β_R) due to the typical variations in material parameters and,
- Uncertainty (β_{U}) due to limited data on construction details.

Typical values for Nuclear Island buildings are recommended in Table DM 2432-1

Assessment of F_E:

For concrete structures, $\textbf{F}_{\textbf{E}}$ shall be assessed according to methodologies and data provided in APPENDIX DJ.

For other structures, the methodologies and data used to assess \mathbf{F}_{E} shall be submitted to the Project approval.

Assessment of β_{U} :

For concrete structures, β_{U} shall be assessed according to methodologies and data provided in APPENDIX DJ.

For other structures, the methodologies and data used to assess β_{U} shall be submitted to the Project approval.

Table DM 2433-2 Indicative values for F_u

Median value	Randomness	Uncertainty
1. ≤ <u>F</u> µ ≤ 4.0	B _r = 0.4 [0.06 + 0.03 (F _µ -1)]	$B_u = C_u (F_\mu - 1) *$

*Cu : eg. Equation DM 2433-19

Effective Frequency - Effective Damping Method

The "effective frequency - effective damping" method (EPRI Report TR-103959) consists in calculating the frequency (or stiffness) and the corresponding damping of the structure for a given ductility level (μ) reached by the structure. Performing a pushover analysis of the structure, illustrated by Figure 1.M=2, the ratio of the secant frequency (f_s) to the elastic frequency (f) is given by:

Equation DM 2433-3



Figure DM 2433-1 "Effective frequency - effective damping" method

The effective frequency (f_e) is calculated as a weighted average of the secant and elastic frequencies (f):

Equation DM 2433-4

$$\frac{f_{e}}{f} = (1 - \mathbf{A}) + \mathbf{A} \cdot \left(\frac{f_{s}}{f}\right) \text{ with } \mathbf{A} = \mathbf{C}_{f} \cdot \left(1 - \frac{f_{s}}{f}\right) \le 0.85$$

The corresponding effective damping (ξ_e) is obtained to be consistent with the anticipated pinched hysteretic damping (ξ_H) depending on the studied elements and materials (reinforced concrete shear walls, steel frames, etc.). It is obtained by:

Equation DM 2433-5

$$\boldsymbol{\xi}_{\mathsf{e}} = \left(\frac{f_{\mathsf{s}}}{f_{\mathsf{e}}}\right)^2 \cdot \left(\boldsymbol{\xi} + \boldsymbol{\xi}_{\mathsf{H}}\right) \text{ with } \boldsymbol{\xi}_{\mathsf{H}} = \mathbf{C}_{\boldsymbol{\xi}} \cdot \left(1 - \frac{f_{\mathsf{s}}}{f}\right).$$

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CGEOT 1200 GEOLOGICAL, GEOTECHNICAL AND HYDRO-GEOLOGICAL MODEL DETERMINATION

The site investigations shall be performed by a company specialised in geotechnical investigations. This company and its technical experts shall provide references of comparable works to those scheduled in the Contract.

Geotechnical site investigation programs, the number of tests to be carried out, and their location and depth, shall be defined according to the geological complexity of the chosen site (stiff or soft materials, heterogeneity, discontinuities, underground cavities, anisotropy... etc.), the type and location of buildings and other works, and the type of engineering problem to be solved (required parameters).

Whatever the number of drillings necessary to obtain reliable geotechnical parameters, the minimum number of tests, and the minimum depth investigated shall be:

- **density of drilling:** as a general rule for safety-related structures, a minimum of one probe providing reliable quantitative data shall be performed within the footprint of each building.
- Under buried pipes and galleries, investigations shall be performed in such a manner to enable identification of changes in soil conditions that may involve differential settlements.
- depth: in all cases, local stratigraphy (and any qualitative data given by non-destructive geophysical testing and/or geological study) should be known to a minimum depth of twice the width of the Nuclear Island (see CGEOT 1300 and DGEOT 1300). In addition:
 - for soils and soft rock foundations, quantitative data are required on a thickness of at least once the width of the Nuclear Island. The depth shall be adapted if the thickness of the compressible ground is greater than once of the depth of the Nuclear Island. width
 - for rocky sites (when rock extends to twice the width of the Nuclear Island minimum depth), quantitative data are only required for the whole thickness of weathered strata and very fractured strata supposed to be the main cause of the settlements, in this case, the depth of investigation may be less than once the width of the Nuclear Island.
 - for safety related buildings located outside of the Nuclear Island, the depth of investigations shall be at least twice the width of the foundation, if it is reliably known that there is no geotechnical issue at a greater depth.

CGEOT 1300 GEOTECHNICAL PROPERTIES

Scope

The geotechnical investigations shall provide all the information and geotechnical data for purposes of design and construction.

The choice of characteristic values for geotechnical parameters should follow the general recommendations given in EN 1997-1, 2.4.5.2.

Methods

The geotechnical tests (laboratory and on site) shall determine, for each material affected by the plant construction, the short-term and long-term deformability and static or dynamic properties.

Different types of tests and correlations shall be performed to determine and verify the value of geotechnical parameters. Tests given in EN 1997-2 may be used, particularly in Tables 2.1 and 2.3.

Tests should not be used for soils where applicability is indicated as low in EN 1997-2, Table 2.1.

Shear tests and deformation tests shall be carried out on intact samples (i.e. quality class 1 samples according to EN ISO 22475-1 table 3.1).

The relevant standards shall be followed when undertaking the tests (see GREFD 2210).

CCONC 1200 CEMENTS

CCONC 1210 General requirements

Cements shall comply with EN 197-1 and be certified for conformity to the mark "NF – Liants hydrauliques" (hydraulic binders).

Cements shall have a certificate of conformity with the CE marking (1+system) in accordance with EN 197-1, Annex A.

In the exceptional case where non-standardised (special) cements are used, they shall be submitted to an inspection and tests equivalent to those required by a national certification.

The chloride content, sulfide content (only applicable to prestressed concrete), and alkali content of cements shall be checked during the qualification phase and shall be such that the limits for the overall concrete mix, as stated in CCONC 2400 and CCONC 2500, are not exceeded.

CCONC 1220 Cements for prestressed concrete

The cement sulfide (S^{2-}) content shall be limited:

- For post-tension prestressing $S^{2-} < 0.7$ % by mass of cement.
- For pre-tension prestressing: $S^{2-} < 0.2$ % by mass of cement.

Furthermore, cements used for the RB containment shall comply with the requirements specified in CCONC 1260.

CCONC 1230 Cements for structures in coastal areas

Cements for concrete subject to exposure classes XS1 (located at less than 1 km from the coast up to 5 km taking into account site specific conditions), XS2, and XS3 (tidal, splash and spray zones and concrete less than 500 m from the coast) according to EN 206-1 shall be certified for conformity to the mark "NF – Liants hydrauliques" and be labelled "PM" (Seawater-resisting cements). These cements shall comply with NF P 15-317.

If any additions are used, their composition (sulfate content, etc) shall be such that the binder meets the requirements of NF P 15-317.

CCONC 1240 Cements for structures exposed to water with a high sulfate content

Where exposure classes XA1, XA2 or XA3 according to EN 206-1 result from the presence of sulfates:

- cements for concrete subject to exposure class XA1 shall be labelled "PM" (seawater-resisting cements), and the composition of the binder shall be such that it meets the requirements of NF P 15-317,
- Cements for concrete subject to exposure class XA2 and XA3 shall be sulfate resisting cements (SR) according to EN 197-1. Or be equivalent to the French label "ES" (sulfate resisting cements), and the composition of the binder shall be such that it meets the requirements of NF P 15-319.

CCONC 1250 Cements for structures in contact with pure (low mineral content) water

For a structure in contact with pure water, NF EN 206 -1 /CN shall apply.

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The sulfide ion (S^{2-}) content of the mixing water shall be such that the following requirements are satisfied:

- CCONC 2400 for prestressed concrete,
- CPTSS 1410-4 for grouts for ducts and anchorages for prestressing tendons, in accordance with EN 447.

Tests stated in EN 1008 shall be carried out at the frequencies indicated therein. A conformity control shall also be carried out to ensure that the water used meets the requirements of CCONC 1600.

This conformity control shall be carried out before commencing works and at a following minimum frequency of once every three months.

In addition to the general requirements, mixing water for injection grout for ducts and anchorages of prestressing tendons shall comply with the following maximum content limits:

- Chloride content (Cl⁻): 250 mg/l,
- Sulfate content (SO₄²⁻): 250 mg/l,
- Magnesium content (Mg²⁺): 125 mg/l.

CCONC 2000 QUALIFICATION AND COMPOSITION

CCONC 2100 GENERAL REQUIREMENTS

Concrete shall comply with the requirements of NF EN 206-1/CN. Concrete shall also comply with the concrete mix requirements and properties in accordance with DCONC 3000, and with the additional requirements of CCONC 2100 to CCONC 2900

The concrete properties and exposure class shall be selected as determined from PART D. The concrete mix design shall be determined from the application of the EN 206-1, French National Annex, (NF EN 206-1/CN) also used as a reference (k-value concept for binder– effective water content). Precisions are given in appendices CB, and CD to CH.

The type of concrete (strength class, target consistence, D_{max} , grading, water content, type and content of cement) shall be adapted to the structure taking account of exposure classes of EN 206-1.

High performance concrete (HPC) is differentiated from ordinary concrete by a compressive strength class of a high strength concrete (HSC – concrete with a higher strength than C50/60), as defined in EN 206-1, and by one or more desired properties such as a higher level of compactness (for example for porosity or permeability requirements).

Qualification, information, suitability and conformity control tests are required for all concrete mixes. The variation ranges shall be in accordance with those specified in standards and requirements.

Concrete studies (qualification, sensitivity study, information and suitability tests) are only valid for a concrete mix of a given formulation with constituents of given origin and characteristics.

No change to concrete mix is permitted without the creation of a document containing the concrete studies carried out to demonstrate that the modified mix complies with the requirements.

The content of the concrete studies shall be adapted to the nature and range of the modifications. The suitability of the concrete batching plant shall be tested in the case where a too long stop in concreting occurs (i.e. several months).

CCONC 2400 AGGRESSIVE ELEMENT CONTENT

The chloride content provided by all concrete constituents shall comply with the following requirements, in accordance with EN 206-1:

- For reinforced concrete: class CI 0.40 for CEM III cement or CI 0.20 for other cements,
- For prestressed concrete: class CI 0.10.

The sulfide ion S^{2-} content provided by all the concrete constituents shall not exceed 0.5% of the cement mass for prestressed concrete.

The chloride content of concrete or mortars in contact with stainless steels (*pools liner for example*) shall be limited to prevent the risk of corrosion. In all cases, the requirement concerning the limitation of CI- content shall be submitted to the Project approval

CCONC 2500 ADDITIONAL REQUIREMENTS FOR INTERNAL EXPANSIVE REACTIONS

CCONC 2510 Prevention of Alkali-Silica Reaction

The level of prevention required shall be level C, in accordance with the "Recommendations of LCPC/IFSTTAR for the Prevention of damage by the Alkali-Aggregate Reaction" (June 1994). NQ aggregates according to CCONC 1330 shall not be used.

In the case where the concrete mix contains at least one aggregate or mixture classified PR or PRP by a specialized laboratory (according to CCONC 1330), one of the following conditions shall be respected for the nominal concrete mix:

- Where Tm (Na₂O eq.) in the concrete mix is \leq 1.4 kg/m³ : the nominal concrete mix is accepted ,
 - Where.¼ kg/m³ ≤ Tm ≤ 2.5 kg/m³, the concrete mix is accepted if the test for non-reactivity described in CCONC 2830 is successful,
- Where the concrete mix includes a cement or binder with a slag content ≥ 60%, or a fly ash content ≥ 40%, or also where a ternary cement or binder have a fly ash and slag content such that [(amount of ash / 40)+(amount of slag / 60)] ≥ 1:
 - If the active alkali content of the cement or binder is < 0.75 % Na₂O eq. and Tm is ≤ 2.5 kg/m³: no additional requirement,
 - If Tm > 2.5 kg/m³, the concrete mix is accepted if the test for non-reactivity described in CCONC 2830 is successful.

Tm is the average active alkali content of the nominal concrete mix. It equals the sum of the active alkali introduced by each constituents (aggregates, cement, admixtures, etc.) in terms of the percentage of equivalent sodium oxide ($(Na_2O \ eq. = 0.658\% K_2O \ + \ Na_2O)$ as defined in appendix E of the recommendations of LCPC/ IFSTTAR and appendix A of NF P 18 454.

The binder contributes to Tm on the basis of its alkali content averaged throughout one year.

For long lasting works, the variation of active alkali content shall be measured at least every year. It shall be checked that the alkali content lies within the range of variations assessed by the performance testing of concrete required in CCONC 2830.

CCONC 2520 Prevention of Delayed Ettringite Formation (DEF)

The prevention of the risk of DEF is based on LCPC/IFSTTAR guide "Recommendations for prevention of disorders due to Delayed Ettringite formation, (August 2007)" modified by the recommendations " Maitrise de la durabilité des ouvrages d'art en béton – Application de la démarche performantielle – control of durability of concrete structures –Table 2 March 2010".

1.4

CCONC 2880 Additional requirements for concrete subject to severe freeze-thaw attack

1- For concrete subject to exposure classes XF2, XF3 or XF4 according to EN 206-1, supplemented by a frost zone map usually included in EN 206-1 National Annexes, all the test results on the air content of the fresh concrete shall meet the minimum content specified in EN 206-1 (4%).

2- For concrete subject to exposure classes XF3 or XF4 and formulated with an air-entraining admixture, the qualification test shall include (for one mix of the nominal concrete mix) a measurement of the spacing

factor *L* according to EN 480-11.

In place of the measurement of the factor L or in case the specified maximum value of L is not respected, the concrete shall be subject to a performance test as follows:

- A performance test in accordance with NF P 18-424 (freezing in water and thawing in water), for concrete subject to severe freeze-thaw attacks with a high degree of water saturation as defined by EN 206-1,
- A performance test in accordance with NF P 18-425 (freezing in air and thawing in water), for concrete subject to moderate freeze-thaw attacks, irrespective of the degree of water saturation of the concrete, or for concrete subject to severe freeze-thaw conditions with a moderate degree of water saturation as defined by EN 206-1.

The determination of the air content of fresh concrete, in accordance with EN 12350-7, shall be carried out on two mixes derived from the nominal concrete mix (sensitivity study), as follows:

- one mix derived without an air entraining admixture,
- one mix derived with + 50% of the air entraining admixture.

3- For high performance concrete subject to exposure classes XF2, XF3 or XF4, which are formulated with little or no air entraining admixture and do not contain the minimum air content, the qualification test shall

include a performance test. (The measurement of L is not relevant in this case).

4- In addition to the previous requirements, concrete exposed to frequent or very frequent attack from deicing agents (concrete subject to exposure classes XF2 or XF4) shall be subject to a scaling test in accordance with XP P 18-420.

5- The qualification test shall be acceptable if, in addition to the specifications of CONC 2810, the following criteria are satisfied:

- For the measure of L_1 :
 - $L \le 250 \,\mu\text{m}$ for concrete subject to exposure class XF3,
 - $_{\odot}$ *L* ≤ 200 µm for concrete subject to exposure class XF4.
- For the performance tests: $\Delta I/I < 400 \mu m/m$ and $(Fn^2 / Fo^2) \times 100 \ge 75$,
- For the scaling test: the mass of the scaling particles $M \le 600 \text{ g/m}^2$.

CCONC 2900 INFORMATION TEST

The information test shall have two main objectives:

- To determine the compressive strength of the concrete at an early age in order to check that it is compatible with the methods of construction and in particular with the minimum strength necessary for the formwork removal,
- To determine the evolution of the concrete strength after 28 days.

The information test can be carried out in a laboratory at the same time as the qualification test.

The making and curing of specimens shall comply with EN 12390-2.

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CREIN REINFORCEMENT FOR REINFORCED CONCRETE

CREIN 1000 SELECTION AND ORIGIN

Steel for the reinforcement of concrete used in the form of bars, coils and welded fabric shall comply with EN 10080 and with the following specifications:

- Steel for reinforcement shall be non-alloy steel quality in accordance with EN 10020,
- Indented steels are not permitted except for prefabricated elements of structures,
- Steel shall have an European Technical Assessment and a certificate of constancy of performance of the product given respectively by an technical assessment body and a notified product certification body in accordance with the regulation (EU) N° 305/2011 of the European parliament and the council of 9 March 2011,
- The system of assessment and verification of constancy of performance shall comply with the appendix 5 of the regulation 305/2001 and EN 10080,
- Steel for reinforcement shall comply with EN 10080 and additional specifications defined by the Project in compliance with DCONC 2120 concerning:
 - o Yield strength, R_e,
 - o Ratio of tensile strength/yield strength, R_m/R_e,
 - o Percentage total elongation at maximum force Agt,
 - o Ratio of actual to specified value of yield strength R_{e,act}/R_{e,nom},
- − For welded fabrics, the nominal diameter shall be less than or equal to 16 mm and the shear force of welded connections in welded fabric (Fs) shall be higher than the minimum value: $Fs \ge 0.30$.R_e.A_n with A_n the cross sectional area,
- Suitability for bending shall be evaluated by bend and re-bend tests in accordance with EN 10080,
- Relative surface of ribbed steel and indented steel, as defined by EN ISO 15630-1, shall comply with the values given in the Table CREIN 1000-1:

Nominal diameters (mm)	f _R (Ribs)	f _P (indented)		
5 and 6	≥ 0.035	≥ 0.035		
7 to 12	≥ 0.040	≥ 0.040		
14 to 40*	≥ 0.056			
14 to 16 ≥ 0.056				
* Higher diameter may be used with justifications of the conformity				

Table CREIN 1000-1

 The assessment criteria for conformity shall comply with EN 10080 (Chapter 8) using values a1 to a4 given in Table CREIN 1000-2 and defined by the standard.

CPTSS 1100 PRESTRESSING STEEL

ETAG 013 terminology is used in the following text. It is supplemented by the appendix CC 3000.

Pre-stressing steel shall consist of uncoated strands or greased sheathed strands (named also monostrands).

Pre-stressing steel shall be certified by the Approved Body (or Notified Body) as defined by ETAG 013.

Requirements for uncoated strand or for greased sheathed strands are specified below.

Requirements for grease and for the sheaths of greased sheathed strands are specified in CPTSS 1110 and CPTSS 1120.

The number and constitution of tendons shall comply with the Project specification.

ETAG 013 certification rules shall be completed as follows:

evaluated

load

- Strands shall consist of non-alloy special steels according to EN 10020,
 - The standard Pr EN 10138 (08-2009) shall apply, modified by the following requirements:
 - The diameter of the central wires of strands shall be at least 1.02 times greater than the diameter of the outer peripheral wires of the strands,
 - The relaxation at 20°C of strands shall be evaluated with loads equal to 0.7 F_{ma} and 0.8 F_{ma} and the results shall be less than or equal to 2.5% and 4.5% respectively, at 1000 h. The relaxation test shall be performed over at least 240 h, and results may be extrapolated to 1000 h,
 - The relaxation at 40°C shall be evaluated with load equal to 0,7 $F_{m,q}$, in compliance with EN ISO 15630-3. Results shall be less than or equal to 3 % at 1000 h.
 - Corrosion strength under stress shall be evaluated in solution A (as defined in EN ISO 15630-3).
 Durations shall be greater or equal to 1.5 h and the average duration shall be greater or equal to 4 h.

CPTSS 1110 Grease for greased sheathed strands

Grease for greased sheathed strands shall comply with the requirements of ETAG 013.

CPTSS 1120 Sheaths for greased sheathed strands

Sheaths shall comply with the requirements of ETAG 013. In addition, their thickness may be increased up to the limits defined following the suitability test for threading of greased sheathed strands, as specified in CPTSS 3320.

After grouting of ducts and tensioning of tendons, sheaths for greased sheathed strands shall allow slippage of strand in the sheath without damage to the sheath or to the strand. The friction between the sheath and the strand shall comply with ETAG 013. Any exception shall be justified by the design and subject to the Project approval.

CPTSS 1200 ANCHORAGE COMPONENTS

All anchorage components shall comply with the ETA (or ETE) for the post-tensioning system (including the permanent or temporary anchorage caps).

The bearing device shall consist of a steel plate with a non-separate guide.

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In addition, on the first sampling, the following complementary tests shall be carried out on each sample:

- A relaxation test on a strand at 40 ℃ under a loa d of 0.7 F_m, according to EN ISO 15630-3. The test shall be carried out up to 240 hours and the results extrapolated to 1000 hours. The acceptance criterion shall be as specified in CPTSS 1100. The Project may specify another relaxation test at different temperature if necessary.
- A deflected tensile test in compliance with EN ISO 15630-3. The reduction coefficient of the maximum force shall be less than or equal to 28%.
- A stress corrosion resistance on 6 test pieces immersed in aqueous solution A in compliance with EN ISO 15630-3. The individual value shall not be less than 1.5h and the mean value shall be higher than or equal to 4h. The measure shall be taken after cutting the sheath and removing the grease.
- A measure of nominal diameter, cross-section area, lay length, wires diameters and strand linear mass. Tests and criteria are in conformity with ETAG 013 and the present document.

The tests shall be carried out and analyzed before the strands threading.

Grease for Greased sheathed strands

Prior to manufacture, a file justifying compliance of the grease to CPTSS 1110 shall be compiled and submitted to the Project approval.

The file shall include:

- Identification of the origin of the grease,
- Test reports on specified characteristics. Tests reports shall include the raw and interpreted test values.

The following tests shall be carried out on each manufactured batch of grease:

- Measure of dropping point according to ISO 2176 at the beginning and end of the manufacturing. In addition to the specified requirements for conformity, the variation in the value shall be less than equal to 10%.
- Measure of oil separation according to DIN 51817 at the beginning and end of the manufacturing. In addition to the specified requirements for conformity, the variation in the value shall be less than equal to 5% at 7 days and 3% at 72 hours.
- Content of Cl⁻, S²⁻, NO₃³⁻ and SO₄²⁻. The results of tests according to NF M 07-023 shall comply with the specified values.

Checks shall be written in a report to be submitted when the manufactured batches are delivered on site.

Sheath for greased sheathed strands



Prior to manufacture, a file justifying compliance of the sheath to CPTS 1120 shall be compiled and submitted to the Project approval. The file shall include:

- Identification of the origin of the sheathing base material,
- Test reports on specified characteristics. Tests reports shall include test values and analyzed values.

The following tests shall be performed on three individual samplings taken in the factory. Sampling shall be taken from the batches produced at the beginning, middle and end of the manufacturing process for the prestressing reinforcement which is installed at the beginning, middle and end of the construction of each structure.

Each sampling shall consist of 3 individual samples taken from 3 sheaths corresponding to the beginning, middle and the end of the manufacturing period for the same batch.

An analysis of the mixing water used shall be carried out every six months or before each production run of grouts. The results shall conform to the requirements of CPTSS 1410.

CPTSS 2520 Flexible products

It shall be verified that these products have a certificate of compliance with ETAG 013 requirements.

The following checks shall be carried out on each manufactured batch of wax used for injection of tendons:

- Content of aggressive elements: Cl⁻, S²⁻, NO₃³, according to NF M 07-023 standard. Values shall be less than equal to 50 ppm,
- Content of corrosive elements SO₄²⁻ according to NF M 07-023 standard. Value shall be less than equal to 100ppm.

The wax packaging shall bear the ETA (or ETE) conformity mark delivered by a Notified Body.

CPTSS 2600 DYNAMOMETER SYSTEMS

The checks and the required performances for adapter plates and dynamometers shall be similar to those carried out on anchor blocks, for which the contacting surfaces shall be parallel. The required performance level shall be supplied by the holder of the ETA (or ETE).

Dynamometer systems shall be subject to a functional test, a calibration test and a leak-tightness test before delivery.

Functional tests shall be carried out according to the following specifications:

- Mounting of adapter plates,
- Calibration of loads cells with adapter plates by an accredited organisation, under various conditions:
 - o Normal (position 0),
 - Turned through 180° horizontally (position 180),
 - Then turned through 180° vertically (turned-over p osition).

The dynamometer system shall be stored on site in a way which ensures its characteristics are not adversely altered.

The dynamometer system shall be accompanied by calibration sheets.

CPTSS 3000 INSTALLATION AND ASSOCIATED CONTROLS

Prestressing system implementation shall be carried out by PT specialist company in compliance with CWA 14646.

Prestressing system implementation includes:

- Placing of embedded anchor parts,
- Placing of anchor blocks for dynamometric systems,
- Placing and connection of ducts,
- Installation and tensioning of tendons,
- Injection of protection products.

The PT specialist company shall be certified according to CWA 14646 by a Notified Body.

Any departures from specification observed during installation and tensioning or injection shall be recorded and corrective action shall be taken.

CPTSS 3100 INSTALLATION OF EMBEDDED PARTS AND DUCTS

CPTSS 3110 Execution

The continuity of shape and leak-tightness of the duct shall be ensured throughout its entire length.

For concrete joints and construction joints, the duct length protruding from the concreted section shall be sufficiently long to enable a good connection of the continuing duct. This length shall be at least equal to a diameter of the duct.

Duct supports shall be rigid and sufficiently close to each other to avoid unintentional angular deviation (sagging) and damage of ducts during concreting. Dedicated supports shall be placed near the anchorages to reinforce the fixing of the ducts before or during concreting. Measures taken shall comply with ETA (or ETE). The minimum level required for unintentional angular deviation shall be as defined by CPTSS 5220.

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The fixing of the ducts shall take into account concreting and vibration-induced loads. The bursting reinforcement and bearing plates shall be positioned according to the construction drawings.

The upper ends of vertical tubes as well as the ends of horizontal ducts shall be sealed by a temporary stopper during the intermediate construction phases in order to reduce the risk of corrosion and to prevent foreign material or concrete from entering the duct. Stoppers shall not induce damaging condensation inside ducts.

The position, shape and diameter of vents, drains, injection and re-injection points shall comply with EN 446 and the ETA (or ETE). These aspects shall be described by a procedure and shall comply with the design requirements and with the construction drawings.

Embedded components

The unembedded faces of the components shall be painted in accordance with an ACQPA certified system which is corrosion proof in a highly corrosive atmosphere (category C5-M as per EN ISO 12944-2).

Where necessary, the positioning of ducts shall be in accordance with the tolerances relative to the steel liner.

Tubes

- The tubes shall be supplied in straight sections, then cut to the required length and bent in the workshop as indicated on the construction drawings.
- Tubes shall be suitable for bending by machine, while maintaining the minimum internal diameter.
- The adjustment of tubes shall be carried out to suit the positioning tolerances after concreting, as indicated in CTOLR.
- After adjustment, tubes shall be held by ties or welds to the nearest reinforcement. Where welds are used, the welding procedure specification and welders shall be qualified according to EN ISO 17660-1. In addition, the qualification shall demonstrate that there is no risk of perforation of tubes during welding. During welding, installed steel strip sheaths shall be protected against spillage of molten metal.

Sheaths

- Sheaths shall be provided in straight sections. They shall then be cut to the required lengths if necessary, as indicated on the construction drawings.
- Couplers shall be manufactured following the same principle and shall be cut to the desired length.
- In the absence of any surface treatment, the protection (being only temporary) shall be in the form of a soluble or emulsionized corrosion-proof oil.
- The adjustment of sheaths shall be carried out to suit the positioning tolerances after concreting, as specified in CTOLR.

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The method for adjusting the ducts shall enable the positioning tolerances to be met after concreting, as specified in CTOLR.

Ducts shall be restrained by tying them on the supports placed as indicated on the construction drawings.

Duct connection:

- Bearing device-tube assembly
 - The connection shall be made by connecting a steel tube to the metallic bearing device.
 - Leak-tightness shall be assured by gluing using a product specified in the approved operating procedure and a heat shrinkable sleeve.
- Tube-tube assembly
 - The connection shall be made by introducing a steel tube in a cold-formed bell mouth at the end of the other tube, or by means of an intermediate sleeve.
 - Leak-tightness shall be assured by gluing (using a product whose characteristics and application mentioned in the technical notice shall be approved) and placing a heat-shrinkable sleeve of a length at least equal to the duct diameter on the joint.
- Sheath sheath assembly
 - The connection shall be made by screwing on a coupler.
 - Leak-tightness shall be achieved by two heat-shrinkable sleeves, installed on each side of the coupler.
- Tube-sheath assembly
 - The connection shall be achieved by means of a standard coupler. This coupler shall be screwed on the sheath and fitted onto the tube.
 - o Leak-tightness shall be ensured by two heat-shrinkable sleeves.
- Heat-shrinkable sleeve
 - The sleeve shall be placed such that it is equally distributed over both sides of the joint.
 - Sealing shall be performed by heating the sleeve over the whole circumference of the ducts, using appropriate equipment such as a propane gas blow torch or a hot-air collar.
 - o Before sleeves are placed, the ends of the duct shall be deburred after it is cut.

CPTSS 3120 Checks

Installation of ducts

Any deformed sheath or tube elements over the allowable limits shall not be used. The allowable limits shall be such that:

- Minimum diameter defined by the procurement specification is respected in all parts of duct including parts with local deformation,
- The unintentional angular deviation complies with CPTSS 5220. DCONC 5240

The check shall cover to the absence of oxidation (uniform in colour, only slight local oxidation marks are acceptable) on the inside of ducts and tubes, where they have not received the surface treatment necessary to reduce the coefficient of friction.

The pre-stressing system, including the jacks, shall be checked in order to prove that it is suitable for the works and to limit the differential loading between strands of the same tendon. The following aspects shall be checked:

- The suitability for implementation of the system for all situations encountered during works,
- For bonded tendons only, initial simultaneous tensioning of each strand of a tendon, with individual displacements of each strand under a load between 10 and 15 kN for each strand at the anchorage, (this specification does not apply to greased sheathed strands and pure vertical tendons),
- Tensioning of the tendons in a single stroke of the jacks without further tensioning, except where the tensioning system enables a maximum standard deviation of 10kN between strands of the same tendon. The standard deviation shall be checked :
 - o based on qualification tests, or,
 - on documented reports of equivalent tests performed with the same tensioning equipment, same threading and tensioning procedures and the same Post-tensioning system. This report shall be submitted to the Project approval.
- The suitability for works of the jacks. This justification shall be based on tests carried out on tendons
 of a significant length and shall include friction loss measurements in the jacks.
- Where the pre-stressing steel consists of greased sheathed strands: the suitability of replacing strands and the re-tensioning during the construction and service life of the structure.

Unless otherwise indicated by the designer, pure vertical tendons shall be tensioned at one end. Other tendons shall be simultaneously tensioned at both ends.

For each tendon, measurements and various observations shall be recorded on the tensioning record sheet, including any incidents that may have occurred.

Surplus lengths of strand shall only be cut after acceptance of the tendon tensioning sheets and a thorough check of compliance with the requirements. In the case of greased sheathed strands, the surplus length necessary for the future tensioning shall not be cut and this shall be protected by a suitable cap.

CPTSS 3420 Checks

Determination of the duct/tendon coefficients of friction by prior measurement of the transmission coefficients.

For each structure, and for each type of prestressing steel, before the start of the first tensioning phase, the transmission coefficients for two tendons of each family shall be measured and recorded graphically in accordance with the method given in APPENDIX CC 2000.

Corrective action shall be taken if the coefficient of friction does not conform to the theoretical value defined in CCONC 5220. DCONC 5240

Force and elongation measurements

The force applied to the tendon during the tensioning operation shall be measured with a force indicator (strain gauge load cell). The force measurement of the load cell and the jack pressure shall be recorded.

The corresponding elongation, obtained during tensioning, shall be measured with an elongation indicator incorporated in the tensioning jack. The elongation measurement shall also be recorded.

The force and elongation shall be electronically displayed on the control station and recorded automatically in order to ensure that the operation is proceeding smoothly.

The tensioning procedure shall verify the force and elongation values during tensioning. They shall be in accordance with the required Project values.

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CCLIN LEAKTIGHT METAL PARTS ON CONTAINMENTS

CCLIN 1000 SCOPE

This chapter applies to the fabrication and erection of metal parts contributing to containment leaktightness. The metal parts include:

- The metallic liner (including the liner metal plate itself, the connecting parts, the equipment anchor plates and the anchoring system of all the previous components);
- The containment penetrations:
 - Sleeves with their connecting rings:
 - For fluid penetrations (standard piping, steam and water pipes...),
 - For ventilation penetrations,
 - For electrical penetrations,
 - Of the transfer tube penetration,
 - Of the personnel air-lock,
 - Reserve sleeves (including their welded caps),
 - Etc.
 - The fixed part of the equipment hatch (including the cylindrical shell with its flange and its connecting ring or similar),
 - o The construction phase access cylindrical shell with its connecting ring and its welded caps;
- The mobile part of the equipment hatch (including the hatch and its clamping components etc.);
- Generally speaking, excepted for polar crane bracket anchor plates, all anchoring systems directly welded onto metallic parts contributing to leaktightness function, the limit between the liner (chapter CCLIN) and anchor part (chapter CANCH) is defined in the APPENDIX DE;
- Other miscellaneous elements (except cases listed below) welded even temporary onto the previous components.

The following are not covered by this chapter:

- Welding of polar crane brackets onto their anchor plate,
- Welding of the equipment supports onto the liner equipment anchor plate.

This chapter does not deal with the manufacturing of stainless steel containment liners. If stainless steels are used (as allowed by DCLIN 7000) the requirements of the present chapter shall be completed to take into account the specific requirements of such manufacturing.

CCLIN 2000 GENERAL RULES

The metal parts relating to this chapter are designed according to DCLIN.

They shall be fabricated according to the standard EN 1090-2+A1 supplemented or modified as specified in the corresponding paragraphs.
CCLIN 4200 PREPARATION GRADES (EN 1090-2+A1, 4.1.3)

The preparation grade of steel surfaces to which paints and related products are to be applied shall be submitted to the Project approval.

CCLIN 4300 QUALITY PLAN (EN 1090-2+A1, 4.2.2)

A quality plan is required for all works relating to this chapter.

CCLIN 5000 CONSTITUENTS PRODUCTS (EN 1090-2+A1,5)

Clause 5 of EN 1090-2+A1 shall be applied and completed with the requirement below.

CCLIN 5100 GENERAL, IDENTIFICATION, INSPECTION DOCUMENTS AND TRACEABILITY (EN 1090-2+A1, 5.1 & 5.2)

All products shall be delivered with a "type 3.1" inspection certificate in accordance with EN 10204.

Under the Project approval, S235JR grade can be delivered with a "type 2.2" test report in accordance with EN 10204. In this case additional tests like tensile tests and chemical analysis shall be performed by sampling and comply with EN 10025-2 requirements.

Welding consumables shall be delivered with a "type 3.1" inspection certificate according to EN 10204 for chemical analysis and at least with a type 2.2 test report according to EN 10204 for mechanical properties. The class type shall be stipulated in the certificate (See CCLIN 5400 for specific requirements relating to welding consumables).

Studs, connectors and shear connectors shall be delivered according to the requirements of CCLIN 5500. Additional requirements may be required from the design.

CCLIN 5200 PLATES, TUBES, STUDS AND STRUCTURAL SECTIONS (EN 1090-2, 5.3)

CCLIN 5210 General (EN 1090-2+A1, 5.3.1)

CCLIN 5211 Specific requirements for metal parts contributing to containment leaktightness

Plates and tubes contributing to containment leaktightness shall be made of steels for pressure purpose. The following requirement shall apply:

- Plates (liner metal plate and anchor plates) contributing to containment leaktighness shall be selected from non-alloyed steels of EN 10028-2 and shall conform to its requirements.
- Tubes for penetrations contributing to containment leaktigness shall be selected from non-alloyed steel of EN 10216-2 and shall conform to its requirements. The selection from EN 10217-2 (+EN 10217-2/A1) with conformity to its requirements is permitted for tubes for penetration sleeves of more than 600 mm in diameter.

Unless specific measures have been taken by the design (e.g. suitable distance to the concrete), the grade for equipment anchor plate and tubes for penetration shall be selected in order to avoid the necessity of a detrimental (for concrete) preheating or heat treatment for welding planned after concreting.

For the corresponding products, any other material shall be submitted to the Project approval.

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+A1

For each batch, the tests to be conducted for the acceptance shall be those applying to schedule 4 as defined by EN ISO 14344. The tests shall be described in these acceptance procedures.

The criteria of the impact test for the acceptance testing of welding consumable shall cover at least the values required for the parent metals to be assembled considering the minimum following requirements : mean value of 40 J for a temperature test at-20°C (Only one value below the mean value and not less than 28 J).

For gas shielded welding processes (welding processes 13 as defined in EN ISO 4063), the acceptance test shall be performed with a shielding gas of the same sub-group (according to EN ISO 14175) as used in production.

For submerged arc welding processes (welding processes 12 as defined in EN ISO 4063), acceptance tests shall be performed for all the used combinations (lot of wire / lot of flux).

Mechanical effect of heat treatments applied to products during construction shall be taken into account in the procurement in acceptance procedure. A minimum of 2 times the holding time (4 times is recommended) shall be taken in consideration to account unexpected adaptation of manufacturing process (e.g. repeat of heat treatment because of repair, holding time overtaken etc.).

Acceptance tests shall be performed under quality control performed by the manufacturer or by the user of filler material (liner manufacturer). The results and the conformance of these tests to the acceptance procedure shall be recorded through an acceptance report established by the user of the filler material or through an inspection document established by the product manufacturer (e.g. a "type 3.1" inspection certificate according to EN 10204).

CCLIN 5420 Special requirements for welding consumables

Characteristics of electrode covering shall be "basic".

Covered electrode, fluxes for tubular cored electrodes and for submerged arc welding shall be at "very low diffusible hydrogen" (max 5 ml/100 g of hydrogen content in deposited metal (H5)).

CCLIN 5500 STUDS, CONNECTORS AND SHEAR CONNECTORS (EN 1090-2+A1, 57)

Studs, connectors and shear connectors may be subject to specific mechanical properties requirements resulting from the design.

Checks and related requirements applicable to the fabrication of studs, connectors and shear connectors are given in CANCH 3100, CANCH 3200 and CANCH 4000.

CCLIN 6000 PREPARATION AND ASSEMBLY (EN 1090-2+A1, 6)

Clause 6 of EN 1090-2+A1 shall be applied and completed with the requirements below.

CCLIN 6100 HANDLING AND STORAGE (EN 1090-2+A1, 6.3)

During storage, and in general if there is a risk of persisting contact with an aggressive atmosphere, all faces concerned shall be protected against corrosion risk.

Consumables remaining unused after 4 hours shall be dried again in accordance with the manufacturer's recommendations or with the table 16 requirements of EN 1090+A1. For electrodes, drying shall be carried out no more than twice. Remaining consumables shall be discarded. -2

Tubular cored electrodes wire coils shall be removed from the welding equipment and properly stored at the end of the welding shift.

CCLIN 7530 Weather protection (EN 1090-2+A1, 7.5.3)

Welding is not permitted if the ambient temperature is below -10°C. The part shall be kept at a temperature of at least +5°C and cooling after welding shall be slow enough not to cause any cracking.

CCLIN 7540 Preheating and post-weld heat treatment (EN 1090-2+A1, 7.5.5 and 7.5.16)

Preheating

Considering the hydrogen scale of filler metal, which shall be at least D as defined in En 1011-2 and EN 1011-2/A1 (see CCLIN 5420), minimum preheating temperatures shall be applied according to the following requirement:

- Non-alloy steels with minimum yield strength R_{eH} ≤ 275 MPa (sub-group 1.1 according to CEN ISO/TR 15608), shall be preheated in consideration of the recommendation of figure C.2.a of EN 1011-2.
- Non-alloy steels with minimum yield strength 275 < R_{eH} ≤ 360 MPa (sub-group 1.2 according to CEN ISO/TR 15608), shall be preheated in consideration of the recommendation of figure C.2.d of EN 1011-2.

Minimum heat input specified in the welding procedure specification (WPS) shall be taken into account to determine the preheating temperature.

When the coordinates (heat input, combined thickness) plotted on the figure indicate a preheating temperature between two values, the maximum value shall be considered.

For other steels, the preheating conditions shall be submitted to the Project approval.

CCLIN 7594 Production Weld data sheet

After a welding operation, a production weld data sheet per operation or group of operations which use the same welding procedure shall be prepared.

This production weld data sheet shall include at least:

- The reference plan of the equipment (or isometric drawing in the case of piping) to which the joint, the group of joints, cladding or repair belong;
- The reference of the joint, the group of joints, the repair;
- The quality level of the joint or the group of joints defined by design according to Table DCLIN 4500-3;
- The reference of the welding procedure specification (WPS);
- The reference of the filler product batches;
- Per operation, the name (the reference) of the welder(s) or operator(s) who carried out the weld;
- In the case of mechanized or automatic welding, the reference of the machine used.

For stud welding, the production weld data sheet shall be established in compliance with the paragraph 14.6 and Appendix H of EN ISO 14555.

For welding of steel reinforcement bars, the weld data sheet shall be established in compliance with EN ISO 17660-1, 15 and Annex F.

CCLIN 7600 ACCEPTANCE CRITERIA (EN 1090-2+A1, 7.6)

7.6 of EN 1090-2+A1 is not applicable. The requirements below shall apply.

CCLIN 7610 General case

In the following requirements, the geometric imperfections are classified (numbered) according to EN ISO 6520-1.

CCLIN 7611 Acceptance criteria for Visual Testing (VT)

The acceptance criteria for weld imperfections shall be the quality level B, with reference to EN ISO 5817 except for imperfections concerning an excess of weld metal (502)excessive convexity (503), excessive throat thickness (5214) and excessive penetration (504) for which quality level C shall be applied. "Incorrect toe" (505) and "Micro lack of fusion" (401) are not to be taken into account.

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Any additional requirements specified by the design for weld geometry and profile shall be taken into account.

Specific Amendment to the above requirements for welds involving the metal plates of the liner:

- When making longitudinal or circumferential welds, linear misalignment between plates (5071) shall be h ≤ 0.25t, but max. 1,5mm (where "h" is the misalignment and "t" is the smaller thickness of the assembly).
- Imperfect shape and dimensions (5011, 5012 and 5013) shall be limited to short imperfections lower than 0, 1t but maximum 0,5mm (where "t" is the smaller thickness of the assembly).

CCLIN 7612 Acceptance criteria for Penetrant Testing (PT)

The acceptance criteria for penetrant testing are those corresponding to the acceptance level 2X according to EN ISO 23277.

Groups of 5 or more indications shall not be acceptable if included in a rectangular area of 100 cm²:

- Chosen in the most unfavorable manner in terms of indication positions;
- And whose largest dimension shall not exceed 20 cm.

CCLIN 7613 Acceptance criteria for Magnetic particle testing (MT)

The acceptance criteria for magnetic particle testing are those corresponding to acceptance level 2X according to EN ISO 23278.

	-	
-	Chosen in the most unfavorable manner in terms of indication positions,	shall not be acceptable if included
_	And whose largest dimension shall not exceed 20 cm.	in a rectangular area of 100 cm ² :

CCLIN 7614 Acceptance criteria for Radiographic testing (RT)

General case:

The acceptance criteria for radiographic testing are level 1 according to EN ISO 10675-1.

Specific requirements for the welds involving the metal plates of the liner:

The acceptance criteria for radiographic testing are level 3 according to EN ISO 10675-1, except for

- Shrinkage cavities (202), crater pipes (2024), lacks of fusion (401), and incomplete penetrations (402), which shall not be permitted,
- Imperfect shape and dimensions (5011, 5012 and 5013) shall be limited to short imperfections lower than 0, 1t but maximum 0,5mm (where "t" is the smaller thickness of the assembly).

In case of use of permanent backing strips, the interpretation of the radiographic images is made difficult by the geometry (fit-up between the plates and the backing strip). To overcome this difficulty, an interpretation catalogue based on standard images shall be established in order to identify the image defects due to the "singularity". This catalogue shall be submitted for approval.

CCLIN 7615 Acceptance criteria for Ultrasonic testing (UT)

General case:

The acceptance criteria for ultrasonic testing are those corresponding to acceptance level 2 according to EN ISO 11666.

Specific requirements for the welds involving the metal plates of the liner:

The acceptance criteria for ultrasonic examination for welds involving the metal plates of the liner shall be submitted to the Project approval (see also modified clause CCLIN 12133).

CCLIN 7620 Acceptance criteria for stud welds

Acceptance criteria for stud welds are those defined in CCLIN 12200.

CCLIN 7630 Acceptance criteria for reinforcing steel bars welds

Acceptance criteria for reinforcing steel bars welds are those defined in CCLIN 12300.

CH3.7 CCLIN 16/32

- Horizontality for a given bracket: all points on the upper horizontal plate shall be between 2 horizontal planes 15 mm apart.
- Horizontality for the set of brackets: all plates shall be included between two planes ±25 mm from the theoretical plane.



FIGURE CCLIN 11800-3: polar crane brackets horizontality check

CCLIN 11900 INSPECTION OF WALL ATTACHMENT POINTS

The requirements for the position check of the polar crane brackets shall be applied except for the horizontality checks which are not applicable.

CCLIN 12000 INSPECTION, TESTING AND CORRECTION (EN 1090-2+A1, 12)

Clause 12 of EN 1090-2+A1 shall be applied for relevant part in consistency with the previous clause. It shall be applied and completed as follow.

CCLIN 12100 INSPECTION BEFORE, DURING AND AFTER WELDING

CCLIN 12110 General

Personnel performing non-destructive examinations shall be qualified to an appropriate level in accordance with EN 473 or EN ISO 9712 in the relevant NDT method industrial sector. Their qualification shall be valid.

All required documents (procedures, work instructions, etc) shall be available at the point of work where inspection is performed.

Non Destructive test report shall be established when inspection is performed. NDT report for Visual Testing before welding shall be established only in case of non conformance (a non conformance report may replace this report).

The interpretation of a non-destructive test shall be performed over a width including the deposited metal added to the two adjacent zones of the parent metal (on either side of the welded joint). The width of an adjacent zone shall be 10mm minimum for surface examination, 10 mm for radiographic or ultrasonic examination if the thickness of the weld is greater than 30 mm, and 5 mm if the thickness is less than 30 mm.

NDT and stage of manufacturing

Where, after a certain stage of manufacturing, reduced accessibility would prevent the performance of the stipulated examinations, NDT shall be performed at an earlier stage of manufacturing where accessibility is sufficient,

CCLIN 12132 Visual inspection (EN 1090-2+A1, 12.4.2.3)

Visual Inspection of the welds shall be performed in accordance with EN ISO 17637.

CCLIN 12133 Additional NDT methods (EN 1090-2+A1, 12.4.2.4)

12.4.2.4 of EN 1090-2+A1 is not applicable. The requirements below shall apply:

Acceptance levels for each method are defined in CCLIN 7610.

NDT methods shall be carried out in accordance with the following requirements:

Penetrant Testing (PT)

Penetrant testing shall be performed according to EN ISO 3452-1.

Magnetic particle Testing (MT)

Magnetic particle inspection (MT) shall be performed according to EN ISO 17638.

Radiographic Testing (RT)

Radiographic testing (RT) shall be performed according to class B techniques according EN ISO 17636-1.

Only X ray equipment or Se 75, Ir 192 or Co 60 sources are permitted.

In order to enable identification of the radiographically examined joints, an identification number shall be assigned to each joint, in halogen-free ink. The identification numbers shall remain legible until the inspected joint is considered to be satisfactory and it has been marked on a drawing.

A drawing shall identify the position of the joint numbers, their origin and their orientation. This identifying data shall allow classification of the films, prove good coverage, and avoid any confusion between films.

The radiographic testing should be performed with X-ray equipment for the inspection of twelds involving the metal plates of the liner. The use of another type of source (e.g. Se 75) shall be submitted to Project approval.

Ultrasonic Testing (UT)

Ultrasonic testing shall be performed according to technique 1 and testing level C according EN ISO 17640. Indications shall be characterized according to EN ISO 23279.

For welds involving the metal plates of the liner, ultrasonic Testing (UT) may be used under reserve that supporting documentation specifying the arrangement for its acceptance is submitted to the Project approval.

CCLIN 12134 Correction of welds (EN 1090-2+A1, 12.4.2.5)

Only two welding repairs may be performed at the same point. Further repairs shall not be performed before a report analyzing the cause of these successive repairs has been prepared and submitted to the Project approval. The same applies to the repairs which occur too regularly or to the detection of defects which might invalidate the conditions of application of the procedure, or the qualification itself of the welding procedure.

For corrections of non conforming studs, see CCLIN 12230.

CPLIN 3000 TERMS AND DEFINITIONS

Clause 3 of EN 1090-2+A1 shall be applied and completed with the requirements below.

Liner

The liner is the metallic surface that covers the concrete surfaces of the pools and tanks so as to form a watertight continuous surface. It includes the following elements: liner plates, equipment anchor plates or others elements depending of the design (e.g. frame of the doors and slot gates). It also includes the watertight metallic surface of the doors and the slot gates.

Liner anchorage system

The liner anchorage system of the pools and tanks is constituted of the metallic parts directly welded to the liner which shall ensure the transmission of forces to the concrete structure without affecting the tightness of the liner.

4000

For the pool design type PD1 (see DPLIN 6400), the liner anchorage system is constituted by continuous or punctual anchorages. For the other pool design types (PD2 and PD3, see DPLIN 4000), the liner anchorage system is constituted by steel frameworks and anchors.

Leak detection system

The leak detection system is a system that detects potential leaks from the liner.

CPLIN 4000 SPECIFICATIONS AND DOCUMENTATION

CPLIN 4100 EXECUTION SPECIFICATIONS

At least the execution class EXC3 shall be applied to all components concerned by this chapter.

EN 1090-2+A1, 4.1.2: Execution classes

The preparation grade of steel surfaces to which paints and related products are to be applied shall be specified under the Project approval.

CPLIN 4200 CONSTRUCTOR'S DOCUMENTATION

Clause 4.2 of EN 1090-2+A1 shall be applied and completed with the requirements below.

EN 1090+A1,4.2.2: Quality plan

A quality plan is required for all works relating to this chapter.

CPLIN 5000 CONSTITUENTS PRODUCTS

Clause 5 of EN 1090-2+A1 shall be applied and completed with the requirements below.

CPLIN 5100 GENERAL

Clause 5.1 of EN 1090-2+A1 shall be applied

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PART C CONSTRUCTION CPLIN POOLS AND TANKS

Acceptance tests shall be performed under quality control performed by the Manufacturer or by the user of filler material (pool or tank Manufacturer). The results and the conformance of these tests to the acceptance procedure shall be recorded through an acceptance report established by the user of the filler material or through an inspection document established by the product Manufacturer (e.g. a "type 3.1" inspection certificate according to EN 10204).

For carbon steels, the welding consumables shall be also subject to the following special requirements:

- Characteristics of electrode covering shall be "basic".
- The covered electrodes, fluxes for tubular cored electrodes and for submerged arc welding shall be at "very low diffusible hydrogen" (max 5 ml/100 g of hydrogen content in deposited metal (H5)).

CPLIN 5600 MECHANICAL FASTENERS

Clause 5.6 of EN 1090-2+A1 is not relevant.

CPLIN 5700 STUDS AND SHEAR CONNECTORS

Clause 5.7 of EN 1090-2+A1 shall be applied and completed with the requirements below.

EN 1090-2+A1, 5.7: Studs and shear connectors

Studs, connectors and shear connectors may be subject to specific mechanical properties requirements resulting from the design.

Checks and related requirements applicable to the fabrication of studs, connectors and shear connectors are given in 2.8.3.1, 2.8.3.2 and 2.8.4.

CANCH 3100 CANCH 4000

CANCH 3200

CPLIN 6000 PREPARATION AND ASSEMBLY

Clause 6 of EN 1090-2+A1 shall be applied and completed with the requirements below.

CPLIN 6100 GENERAL

Clause 6.1 of EN 1090-2+A1 shall be applied

CPLIN 6200 IDENTIFICATION

Clause 6.2 of EN 1090-2+A1 shall be applied

CPLIN 6300 HANDLING AND STORAGE

Clause 6.3 of EN 1090-2+A1 shall be applied and completed with the requirements below.

EN 1090-2+A1, 6.3: Handling and storage

During storage, and in general if there is a risk of persisting contact with an aggressive atmosphere, all faces concerned shall be protected again corrosion risk.

CH3.8 CPLIN 6/26

CPLIN 7500 PREPARATION AND EXECUTIONS OF WELDING

Clause 7.5 of EN 1090-2+A1 shall be applied and completed with the requirements below.

EN 1090-2+A1, 7.5: Preparation and execution of welding

Clause 7.5 is completed with the additional following requirements:

Qualification of workshop and construction site

The workshop and/or the site shall have suitable installations for executing satisfactory welding work.

The purpose of the technical qualification of a workshop and/or a construction site is to evaluate the capacity and the technical facilities of this workshop and/or site to carry out welding operations. In the case of a worksite, the capacity of the Manufacturer to work on a site shall be evaluated.

Before beginning the welding operations, a qualification report shall be prepared and submitted to the Project approval. The qualification report shall include:

- The name of the workshop, and the name of the person in charge of the qualification of the workshop and/or site,
- A list of relevant references justifying experience in the welding field, and the management of the workshop and/or site,
- A list of the welding equipment by welding process and demonstration of good working condition (maintenance policy for the welding generator, frequency of maintenance, special case of a work site (mobile welding generator), etc.),
- Equipment at the place of work, describing the equipment proposed for the work envisaged:
 - o Need for handling equipment,
 - o Cleanliness management,
 - Suitable means for storage of the base metals and for good protection, conservation, and drying of the filler products,
 - Protections necessary for welding work (no traces of water, no draughts, etc.),
 - Heat treatment installations in good condition and with sufficient capacity for the work to be carried out,
 - o Suitable installations for the destructive and non-destructive testing to be performed,
 - Means for checking compliance with the geometrical tolerances (joint preparation, welds dimensions etc.),
 - Means for checking compliance with the tolerances of the electrical welding parameters.

The qualification of a workshop and/or worksite remains valid as long as no significant modification of the previous arrangements has occurred.

If a serious defect is revealed on production welds, the workshop or worksite qualification shall be reviewed.

Documents at workstation

All required welding documents (procedures, welding data package, work instructions, etc) shall be available at the work station where welding is performed.

CPLIN 9000 ERECTION

Clause 9 of EN 1090-2+A1 shall be applied and completed if necessary under the Project approval to take into account specificity of the design.

CPLIN 10000 SURFACE TREATMENT

Clause 10 of EN 1090-2+A1 shall be applied and completed if necessary under the Project approval.

The surface treatment shall be in accordance with the requirements for the corrosion protection systems.

Any surface treatment shall be submitted to the Project approval.

CPLIN 11000 GEOMETRICAL TOLERANCES

Clause 10 of EN 1090-2+A1 shall be applied and completed if necessary under the Project approval.

The surface treatment shall be in accordance with the requirements for the corrosion protection systems.

Any surface treatment shall be submitted to the Project approval.

Clause 11 of EN 1090-2+A1 is not applicable. The following requirements shall be applied.

Final geometrical tolerances of the liner

The final geometrical tolerances should be set taking into account the constraints of the liner design, the layout, the system and the equipments supported by embedded parts (e.g.: equipment anchor plates, openings frame and sleeves).

The final geometrical tolerances should be constituted by tolerances of the levelness, the flatness, the local sagging or the positioning.

For each pool and tank, the final geometrical tolerances shall be specified and submitted to the Project approval.

The Manufacturer shall establish a detailed analysis describing the methods and the measures taken during all stages of manufacturing to conform to the final geometrical tolerances of the liner. The means used to check the geometrical tolerances shall be described. This analysis shall be submitted to the Project approval.

The results of the demonstration of the welding plan efficiency in workshop and on site as required in CPLIN 12000 (see modified clause 12.4.4) may be used by the Manufacturer for its detailed analysis of geometrical tolerances.

CPLIN 12000 INSPECTION, TESTING AND CORRECTION

Clause 12 of EN 1090-2+A1 shall be applied and completed with the following requirements below.

CPLIN 12100 GENERAL

Clause 12.1 of EN 1090-2+A1 shall be applied.

TYPE OF WELDED JOINT	METHOD OF INSPECTION	SCOPE			
	VT ⁽¹⁾	100%			
Butt joint or T joint with full penetration weld	PT or MT ⁽¹⁾	100%			
	RT or UT ⁽²⁾	(3)			
Butt joint or T joint	VT ⁽¹⁾	100%			
and Fillet weld	PT or MT ⁽¹⁾	100%			
Stud weld	See Clause 12.4.3 in CPLIN 12400				
Temporary attachment	See Clause 7.5.6 in CPLIN 7500				
	VT	100%			
Build-up weld	PT or MT	100%			
	RT or UT ⁽²⁾	(4)			
(1): VT and PT or MT shall be performed on the weld side and, if accessible, on the back side.					

Table CPLIN 12400-2 – Scope and methods of inspections for other welds

- (2): When RT or UT is not technically possible, compensatory measures shall be proposed and submitted to the Project approval.
- (3): RT or UT scope may be defined under the Project approval taking into account the specificity and the function of the anchoring.
- (4): RT or UT scope shall be defined under the Project approval considering the requirements of the code and of manufacturing considerations (thicknesses of the deposited metal and of the base metal, etc).

EN 1090-2+A1, 12.4.2.3 : Visual inspection of welds

Visual Inspection of the welds shall be performed in accordance with EN ISO 17637.

EN 1090-2+A1, 12.4.2.4: Additional NDT methods

Clause 12.4.2.4 of EN 1090-2+A1 is not applicable. The following requirement shall be applied.

Acceptance levels for each method are defined in CPLIN 7000 (see modified clause 7.6).

Penetrant testing (PT)

Penetrant testing shall be performed according to EN ISO 3452-1.

Magnetic particle testing (MT)

Magnetic particle inspection (MT) shall be performed according to EN ISO 17638.

Radiographic testing (RT)

Radiographic testing (RT) shall be performed according to class B techniques of EN 17636-1.

requirements

Document to be established before water testing

Before testing, the Manufacturer shall draw up a water test specification defining the conditions under which the pool or the tank test is to be run and describing the procedure adopted. This document shall contain at least the following:

- The level of the water in the pool or the tank,
- The measurements during test (level of water, temperature, characteristics of the test water, etc),
- The location, the type and characteristics of the measurement apparatus,
- The nature of the water used for the testing and any cleaning conditions after testing,
- The general requirements linked to the test and the instructions to be observed to ensure the safety of personnel during the test (reference to instruction existing elsewhere may be made here),
- The water test procedure,
- This specification is supplemented by a water test drawing that precise:
- The position of the pool or the tank during testing,
- The location of filler connections, air bleeds and drainage openings,
- The location and identification of the measuring devices.

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Execution of the test
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the pool or the tank

The characteristics of the water test and requirements concerning cleanliness before and after test shall be defined under the Project approval.

The filling rate shall be determined according to the dimensions of the tank and the seating installation conditions, and shall be stated in the water testing specification. Continuous inspection shall be performed throughout the filling period (in particular at the leak detection system).

The water test shall be performed by completely filling the pool and the tank up to the overflow level. Unless specified differently under the Project approval, pools and tanks shall be filled with water for a minimum period of one week. Periodic measurements shall be carried out during this period to check the leak detection system and the water test parameters defined in the water test specification.

The drainage shall ensure that the design underpressure limit is not exceeded. The operational drainage limit rate shall not be exceeded.

The tests shall be suspended as many times as defect repairs require and shall be repeated until the required leaktightness of the pool or the tank is obtained.

Acceptance criteria

The pool or tank shall be considered leaktight if no leaks are noted through the leak-collecting system.

In case of flow in the leak detection system, the duration of the test may be increased up to four weeks, in order to distinguish leakage from effects such as condensation. In all cases, a one week period with no recorded leaks shall be the minimum requirement.

CSTLW 4200 EXECUTION CLASSES (EN 1090-2+A1, 4.1.2)

The execution classes of structural steel elements are defined during the design according to the requirements of DSTLW 6000 and are indicated on the design drawings.

The execution classes shall be indicated on all specific drawings applicable to fabrication and erection.

CSTLW 4300 PREPARATION GRADES (EN 1090-2+A1, 4.1.3)

The preparation grade of steel surfaces to which coatings and related products are to be applied shall be specified under the Project approval.

4.2.2 CSTLW 4400 QUALITY PLAN (EN 1090-2+A1, 4.2)

A quality plan is required for all works relating to this chapter.

CSTLW 5000 CONSTITUENT PRODUCTS (EN 1090-2+A1,5)

CSTLW 5100 GENERAL (EN 1090-2+A1, 5.1)

Constituent products that are not covered by the standards listed in EN 1090-2+A1, 5 shall be subject to the Project approval.

CSTLW 5200 IDENTIFICATION, INSPECTION DOCUMENTS AND TRACEABILITY (EN 1090-2+A1, 5.2)

All products shall be covered by a type 3.1 inspection certificate as defined in EN 10204. High strength steels, as defined in DSTLW 4100 shall be covered by a type 3.2 inspection certificate as defined in EN 10204.

S235JR grade can be delivered with a "type 2.2" inspection certificate in accordance with EN 10204 if approved by the Project. In this case, if required by the Project, additional tests like tensile tests and chemical analysis shall be performed in compliance with EN 10025-2.

The traceability method of each constituent product throughout its manufacture, fabrication, delivery and eventually incorporation into the works shall be defined and subject to the Project approval.

CSTLW 5300 STRUCTURAL STEEL PRODUCTS (EN 1090-2+A1, 5.3)

CSTLW 5310 GENERAL (EN 1090-2+A1, 5.3.1)

The requirements of DSTLW 4100 concerning steel grades and qualities apply. Additional requirements for stainless steel products that are given in DSTLW 4400 apply.

All the elements of a metallic structure shall be obtained from hot-rolled sections or welded plate girders. The use of cold-formed profiles is not permitted (EN 1090-2+A1, Table 3 is not applicable).

Structural steel products shall be those listed in EN 1090-2+A1, Tables 2 and 4. The use of other materials shall be subject to the Project approval.

CH3.9 CSTLW 2/14

CSTLW 5400 STEEL CASTINGS (EN 1090-2+A1, 5.5)

The use of steel castings is not covered by this code.

CSTLW 5500 WELDING CONSUMABLES (EN 1090-2+A1, 5.5)

The filler metal shall be selected according to the base metal to be welded (matching of chemical composition and mechanical characteristics including tenacity...) regarding also the concerned WPS. Excessive overmatching of the mechanical characteristics of welding consumables should be avoided.

5.4

Welding consumable shall be procured in accordance with the lot classification requirements of EN ISO 14344. The required classes shall be at least:

- Class C3: for covered electrodes,
- Class T3: for flux-cored wires,
- Class S3: for bare solid wires, rods and strips,
- Class F2: for powdered fluxes.

Class type shall be stipulated in the certificate issued by the supplier.

For EXC3 and EXC4 the properties of welding materials shall be documented and justified for each lot through a "type 3.1" inspection document according to EN 10204.

Any potential degradation of mechanical properties following heat treatments shall be evaluated and taken into account in the material specifications

The characteristics of electrode covering shall be "basic". Rusty electrodes are not permitted.

Covered electrodes, fluxes for tubular cored electrodes and for submerged arc welding shall be at "very low diffusible hydrogen" (max 5 ml/100 g of hydrogen content in deposited metal (H5)).

CSTLW 5600 MECHANICAL FASTENERS (EN 1090-2+A1, 5.6)

CSTLW 5610 General (EN 1090-2+A1, 5.6.1)

The requirements of DSTLW 4300 concerning bolts and bolt classes apply. Additional requirements for stainless steel bolts given in DSTLW 4400 apply.

If corrosion protection is needed, bolts shall be subject to the following treatments:

- For ordinary bolts: a hot galvanization (in accordance with EN ISO 10684) or an electrolytically placed zinc deposition (in accordance with EN ISO 4042),
- For controlled-torque bolts: a hot galvanization (in accordance with EN ISO 10684).

In case of electrolytically placed zinc deposition, the minimum thickness of zinc shall be 10 microns.

In case of hot galvanization the minimum thickness of zinc shall be 50 microns on average and at least 45 microns locally.

CSTLW 5620 Structural bolting assemblies for non-preloaded applications (EN 1090-2+A1, 5.6.3)

Bolts of a diameter greater than any of those specified in the Standards listed in EN 1090-2+A1, 5.6.3 a), b) or c) shall be subject to the Project approval.

CH3.9 CSTLW 4/14

As stated in DSTLW 4400 an insulation system is required at junctions between stainless steel and other metals. The insulation system must create a barrier between the two types of steel to ensure there is no direct contact and to eliminate potential bimetallic (galvanic) corrosion if in contact with water.

The insulation system (including the washer material) shall be subject to the Project approval.

CSTLW 5630 Structural bolting assemblies for preloading (EN 1090-2+A1, 5.6.4)

All components of controlled-torque assemblies shall be:

of k-class K2 (as defined in EN 14399);

Completely traceable: each component marked with assembly lot number and the manufacturer's identification.

Stainless steel bolts are not permitted for preloaded applications without authorization from the Project.

CSTLW 5640 Additional requirements for mechanical fasteners

The use of tension indicating washers is not permitted.

The nuts of ordinary bolts shall be systematically locked. The placing of a counter nut or a second normal nut is deemed a satisfactory locking method.

Spring washers, prevailing torque type nuts and welding as locking device are not permitted.

NOTE: Welding of nuts is accepted as a positioning device in specific cases, such as embedded plates where access is limited.

Hot rivets are not covered by this code.

Self-drilling screws, self-taping screws, blind rivets, cartridge fired pins and air driven pins are not permitted for the assembly of structural elements.

Hexagon injected bolts are not permitted.

Any fastener not covered by CEN or ISO standards shall be subject to the Project approval. Associated testing may be required.

CSTLW 6000 PREPARATION AND ASSEMBLY (EN 1090-2+A1, 6)

CSTLW 6100 GENERAL (EN 1090-2+A1, 6.1)

All necessary provisions shall be taken to ensure that the steel structural elements respect the fabrication tolerances defined in CSTLW 11000

CSTLW 6200 IDENTIFICATION (EN 1090-2+A1, 6.2)

For all structural elements that have been listed to be sensitive to fatigue (see DSTLW 5600), only soft marking is allowed. In this case the use of soft or low stress stamps is permitted.

For steel grades above S355 and for stainless steels the use of soft or low stress stamps is permitted.

CSTLW 6300 HANDLING AND STORAGE (EN 1090-2+A1, 6.3)

The requirements concerning the storage, shipment and handling of the constituent products defined in EN 1090-2+A1 are applicable.

During storage, and in general if there is a risk of contact with an aggressive atmosphere, all faces concerned shall be protected against corrosion risk.

CSTLW 6400 CUTTING (EN 1090-2+A1, 6.4)

All scories or surface irregularities on the cut surface shall be eliminated by grinding.

Straight blade shear cutting is not accepted for structural elements thicker than 10 mm.

For the thermal cutting processes, the periodicity of the capability check shall be defined in the manufacturer provided component specification (MPCS) to be applied in the workshop.

The results of the measurements performed on the samples to validate the thermal cutting processes shall be available in the workshop.

For carbon steels the hardness of free edge surfaces shall comply with EN 1090-2+A1, Table 10.

The periodicity of the check for the free edge surfaces hardness shall be defined in the manufacturer provided component specification (MPCS) to be applied in the workshop.

The results of the measurements performed on the samples to validate the free edge surfaces hardness shall be available in the workshop.

CSTLW 6500 SHAPING (EN 1090-2+A1, 6.5)

CSTLW 6510 General

Cold formed profiles that constitute structural elements are not permitted as indicated in DSTLW 4200. Nonstructural plate elements may be cold formed if the following conditions are met:

- Minimum bending radius shall be greater than 10 times the thickness;
- 100 % visual inspection to check there is no crack, and no lamellar tearing.

Unless otherwise authorized by the Project the forming shall be performed before any protective coating is applied.

CSTLW 6520 Flame straightening (EN 1090-2+A1, 6.5.3)

For the use and extent of flame straightening a suitable procedure shall be developed whatever is the execution class and shall be subject to the Project approval.

6.6 CSTLW 6600 HOLING (EN 1090-2+A1, 6.2)

The periodicity of the check for the holing processes shall be defined in the manufacturer provided component specification (MPCS) to be applied in the workshop.

The results of the measurements performed on the samples to validate the holing processes shall be available in the workshop.

CH3.9 CSTLW 6/14

CSTLW 8000 MECHANICAL FASTENING (EN 1090-20+A1, 8)

CSTLW 8100 GENERAL REQUIREMENTS (EN 1090-2+A1, 8.1)

Packing plates shall be welded in all cases.

Separate components forming part of a common ply shall have the same theoretical thickness in case of connection with preloaded bolts so that packing plates shall not be used in this case.

CSTLW 8200 USE OF BOLTING ASSEMBLIES (EN 1090-2+A1, 8.2)

CSTLW 8210 General (EN 1090-2+A1, 8.2.1)

Requirements concerning locking devices for ordinary bolts are defined in CSTLW 5640.

Preloaded assemblies do not require an additional locking device.

The welding of bolts and nuts is not permitted unless otherwise authorized by the Project. As indicated in CSTLW 5640 welding of nuts is accepted in specific cases, such as embedded plates where access is limited, but never as a locking device.

CSTLW 8220 Bolts (EN 1090-2+A1, 8.2.2)

The nominal fastener diameter used for structural elements connections shall be at least M12. The use of diameter smaller than M12 for structural elements shall be subject to the Project approval.

No minimum diameter of fasteners is required for thin gauge components and sheeting as they shall be used only as non-structural elements.

Attention shall be given to the length of the unthreaded part of the bolt in case a connection is designed to use the shear capacity of the unthreaded part of the bolt.

8.2.4 CSTLW 8230 Washers (EN 1090-2+A1, 8.2.3)

In cases where plate washers are used, their grade shall be the same as the one of the assembled components, and their dimensions shall be justified during the design of the connections and subject to the Project approval.

In cases where taper washers are used, their grade shall be the same as the one of the assembled components, and their dimensions shall be justified during the design of the connections and subject to the Project approval.

CSTLW 8240 Tightening of non-preloaded bolts (EN 1090-2+A1, 8.2.4)

Nuts shall be tightened thoroughly except for the bolts of oblong-shaped holes which shall allow for the displacement of the assembled elements.

CSTLW 8250 PREPARATION OF CONTACT SURFACES IN SLIP RESISTANT CONNECTIONS (EN 1090-2+A1, 8.2.5) [8,4]

Slip resistant connections for stainless steel are not permitted.

Area of contact surfaces in preloaded joints are those defined during design.

The contact surfaces shall be prepared to produce the required slip factor defined in DSTLW 7400 e.g. 0.5. The friction surface corresponding in EN 1090-2+A1, Table 18, is class A.

If the surface treatment is not covered in EN 1090-2+A1, Table 18, friction tests of the assembly's strength shall be performed. These tests determine the roughness which the surfaces shall exhibit after treatment and the means to control this roughness (see EN 1090-2+A1, Annex G).

The nature of the surface treatment, the working conditions and the tightening of the preloaded bolts shall be specified and listed in the working documents.

CSTLW 8260 TIGHTENING OF PRELOADED BOLTS (EN 1090-2+A1, 8.2.6)

The torque method shall be used for tightening of preloaded bolts. The use of the combined method and the direct tension indicator (DTI) method, defined in EN 1090-2+A1, Table 20, are not permitted.

When different than those defined in EN 1090-2+A1, nominal minimum preloading force values shall be subject to the Project approval together with the relevant bolts assemblies, tightening method, tightening parameters and inspection requirements.

Torque wrenches shall be calibrated at least once a year according to EN ISO 6789, and the results of these calibrations shall be recorded.

CSTLW 9000 ERECTION (EN 1090-20+A1, 9)

CSTLW 9100 GENERAL (EN 1090-2+A1, 9.1)

Clause 9 of EN 1090-2+A1 should be applied and completed if necessary by the Project to take into account specificity of the design.

CSTLW 9200 ERECTION METHOD (EN 1090-2+A1, 9.3)

The assembly and setting operations detailed in the erection method shall fit the framework imposed by the design conditions and the jobsite constraints (temporary sheet pilings, assembly phases).

CSTLW 9300 SURVEY (EN 1090-2+A1, 9.4)

The reference system for setting out and measuring as well as the reference temperature shall be submitted to the Project approval.

CSTLW 9400 SUPPORTS, ANCHORS AND BEARINGS (EN 1090-2+A1, 9.5)

The final selection of grouting materials shall be subject to the Project approval.

Anchoring devices in concrete parts shall be set in accordance with the requirements of CANCH.

CSTLW 9500 ERECTION AND WORK AT SITE (EN 1090-2+A1, 9.6)

The necessary provisions shall be made to respect the storage and handling conditions allowed for in the design.

Structural steelwork elements shall be stored and handled so as to avoid contact with the ground, permanent deformations and damage to the elements or their coatings.

If an element is damaged during the erection phase it shall be returned and repaired in the workshop.

No repairing is accepted on site without the authorization of the Project.

Concerning fit-up and alignment:

- Modifications on site for adjusting two elements shall be submitted to the Project approval,
- Otherwise the elements concerned have to be returned to the workshop,
- Modifications on site for the bolts' holes shall be submitted to the Project approval,
- Otherwise the elements concerned have to be returned to the workshop.

CSTLW 10000 SURFACE TREATMENT (EN 1090-2+A1, 10)

Clause 10 of EN 1090-2+A1 shall be applied and completed if necessary by the Project.

The surface treatment shall be in accordance with the requirements for the corrosion protection systems defined by the Project, taking into account the corrosivity category referenced in EN ISO 12944.

CSTLW 11000 GEOMETRICAL TOLERANCES (EN 1090-2+A1, 11)

Fabrication tolerances shall be in accordance with essential manufacturing tolerances and functional manufacturing tolerance class 2 of EN 1090-2+A1. For metal frames and hardware it may be acceptable to use functional manufacturing tolerance class 1.

CSTLW 12000 INSEPCTION, TESTING AND CORRECTION (EN 1090-2+A1, 12)

12.4

CSTLW 12100 WELDING (EN 1090-2+A1, 12.4.1)

CSTLW 12110 Inspection before, during and after welding

Welding inspections shall be conducted according to the requirements of EN 1090-2+A1, 12.4.

For site welding, the value of inspection percentages as defined in table 24 of EN 1090-2+A1 shall be increased as follows : double all values and use a minimum value of 10%.

The inspection program shall comply with the design and shall be subject to the Project approval. The Project may require an expansion to or precision of this inspection program.

CH3.9 CSTLW 12/14

Personnel performing non-destructive examination shall be qualified to an appropriate level in accordance with EN 473 or ISO 9712 + AC1.

All required documents (procedures, work instructions, etc.) shall be available at the point of work where inspection is performed.

The interpretation of a non-destructive test shall be performed over a width including the deposited metal added to the two adjacent zones of the parent metal (on either side of the welded joint). The width of an adjacent zone shall be 10mm minimum for surface examination, 10 mm for radiographic or ultrasonic examination if the thickness of the weld is greater than 30 mm, and 5 mm if the thickness is less than 30 mm.

NDT shall be carried out after all the operations which can affect the quality of the weld (final heat treatment, flame straightening). In case of impossibility, inspections of the welds should be done at the most advanced stage of production to allow them to be performed under the best conditions.

CSTLW 12111 Inspection before and during welding (EN 1090-2+A1, 12.4.1)

Before welding all chamfers shall be visually inspected throughout their entire length.

CSTLW 12112 Inspection after welding (EN 1090-2+A1, 12.4.2)

Scope and method of inspection (EN 1090-2+A1, 12.4.2.2)

The scope of NDT is in the inspection program and shall be subject to the Project approval.

Visual inspection (EN 1090-2+A1, 12.4.2.3)

Visual Inspection of the welds shall be performed in accordance with EN ISO 17637.

Additional NDT methods (EN 1090-2+A1, 12.4.2.4)

NDT methods shall be carried out in accordance with the following requirements:

Penetrant testing (PT)

Penetrant testing shall be performed according to EN ISO 3452-1.

Magnetic particle testing (MT)

Magnetic particle inspection (MT) shall be performed according to EN ISO 17638.

Ultrasonic testing (UT)

Ultrasonic testing shall be performed according to technique 1 and testing level C according EN ISO 17640. Indications shall be characterized according to EN ISO 23279.

Radiographic testing (RT)

Radiographic testing (RT) shall be performed according to EN 17636-1.

The radiographic testing shall be performed with the X-ray technique for the inspection of thicknesses less than or equal to 20 mm. The system film class shall be C3 at least. Gamma radiography (Ir 192, Co 60) shall be used for thicknesses greater than 20 mm.

The use of selenium sources shall be submitted to the Project approval.

Acceptance levels for each method are defined in CCLIN 7600 (acceptance criteria).

Correction of welds (EN 1090-2+A1, 12.4.2.5)

Only two welding repairs may be performed at the same point. Further repairs shall not be performed before a report analyzing the cause of these successive repairs has been prepared and submitted to the Project for approval.

CSTLW 12200 CORRECTION OF WELDING DISTORTIONS (EN 1090-2+A1)

According to a special procedure which shall be established, local distortions may be corrected so as to obtain a distortion-free finished element:

- Either at room temperature, when the radius of curvature exceeds a hundred times the dimension affected by the curvature, or,
 flame straightening
- At elevated temperatures, for parts other than beams, by use of shrinkage heating according to the requirements of EN 1090-2+A1, 6.5.3. In this case, the operation shall be conducted by an experienced operator, and metal temperatures shall not exceed 600 °C, with cooling carried out in still air (CSTLW 6520 flame straightening is applicable).

CANCH 6000 SLEEVES

Sleeves may be used for different functions:

- Sleeves that act as permanent formwork,
- Sleeves that transfer load to the concrete.

The grade and quality of steels shall be marked on the execution drawings.

All the material related to the sleeve shall be delivered with material certificate 3.1 (according to EN 10204) with information about the chemical analysis of the melt and the mechanical property values.

In addition, sleeves which participate in load transfer shall be in accordance with CANCH 2000 and CANCH 7000.

The products are defined in standards EN 10025 and EN 10210. They are classified by grade and, within each grade, by quality.

The accepted steel grades of sleeves for component anchoring and shear connectors are S235JR, S235JRH, S235G2T and S355J2.

The use of rimmed steel is not permitted.

Stainless steel elements consist of materials 1.4301, 1.4541, 1.4404 and 1.4571 as defined by EN 10088.

Sleeves shall be fixed on formwork or reinforcement to avoid displacement during concrete works. The attachment mode shall ensure compliance with the tolerances given in CTOLR.

CANCH 7000 WELDING

CANCH 7100 QUALIFICATION

This section applies for:

ΕN

- Headed studs.
- Hot rolled steel (connectors and shear connectors).
- Steel reinforcing bars.

The welding process shall be defined in documents complying with EN ISO 15614-1 A1, EN ISO 14555 and EN 17660-1. The qualification method shall comply with EN ISO 15614-1, EN ISO 15613, EN ISO 14555 and ISO 17660-1.

The qualifications of the welders and operators shall be established in the following manner:

- For headed studs: EN ISO 14555 shall apply;
- For hot rolled steel and shear connectors: welders shall be qualified according to EN ISO 9606-1 and welding operators according to EN ISO 14732. In case of mechanized welding, the operator gualification shall cover the position and the design of the joint.
- For steel reinforcing bars: ISO 17660-1 shall apply.

ΕN

The criteria applied for all qualifications (welding process, welders, operators) within the indicated relevant standard are modified as follows: a tensile test is required and failure shall occur outside the joints. The frequencies of tensile tests are given in the relevant standard.

CH3.10 CANCH 6/12

CANCH 7200 PRODUCTION

The weld joint of the headed fasteners shall not affect the plate flatness.

The headed studs shall be welded by means of drawn arc with ceramic ferrules or shielding gas in accordance with EN ISO 14555.

The welding of the end plate of the connector shall be performed according to the execution drawings.

The requirement about the type of welding for shear connectors and sleeves which transfer loads to the concrete shall be in compliance with CSTLW 7300.

CANCH 7300 INSPECTION OF WELDS

The inspection of welds shall be carried out in compliance with EN 1090-2+A1 according to the relevant execution class of the concerned element.

Non-destructive testing of welds shall be carried out in accordance with the requirements of EN ISO 17635.

Visual inspections include the connectors (number, section, length, type of weld) with respect to the execution drawings.

CANCH 7400 NON DESTRUCTIVE TESTING

Visual testing

The welds shall be 100 % visually inspected and the acceptance criteria shall be as follows:

- For headed studs: visual testing shall be carried out in compliance with ISO 14555 and related criteria;
- For connectors, shear connectors and steel reinforcing bars: the required level of quality shall be class B as defined by EN ISO 5817 except for imperfections concerning excess of weld metal, excessive convexity, excessive throat thickness or excessive penetration for which class C shall apply.

The visual testing of welds shall be performed in accordance with EN ISO 17637. Welding record shall be filled out in accordance with EN ISO 17637, 5.

Penetrant testing

For dye penetrant inspections conducted in accordance with EN ISO 17635, the acceptance criteria shall be of quality class 2X (according to EN 1090-2+A1).

Controls shall be performed on 10 % of the plates. These controls shall be applied for all welds of the selected plates. Welding record shall be filled out in accordance with EN ISO 17635, 8.2.

If penetrant testing is not a relevant control according to EN ISO 17635, other testing may be used in accordance with CCLIN 7600. The frequencies that apply for this testing shall be the same as for penetrant testing.

(*)These tolerances for the positioning $(\Delta x; \Delta y; \Delta z)$ are different from the allowed shift of the anchor plates and sleeves taken into account during the design to allow their implementation into the formwork ($\Delta Y; \Delta Z$).

Specific rules shall be defined under the Project approval for the erection of the anchor plates and sleeves including this allowed shift which shall consider the anchoring system's type and associated specific constraints.

The verification of the positioning of the anchor plate and sleeves shall also consider simultaneously tolerances for the positioning (Δx ; Δy ; Δz given in table 2.8.10-1) and allowed shift considered in the design (ΔY and ΔZ given by the Project).

Without specific requirements under the Project approval, the recommended value corresponding to the sum of tolerances for the positioning and allowed shift considered in the design is 50mm :

Δy+ΔY≤50mm

Δz+ΔZ≤50mm

(**) This value may be decreased under the Project approval due to the consideration of anchor plate's dimensions and to the impact of this tolerance on the anchor plate's conception.



Figure CANCH 10000-1

CBURP 7110 Execution class applicable to welding

The execution class shall be defined by the Project and shall as a minimum be EXC2 in accordance with EN 1090-2+A1.

CBURP 7120 Welding plan

A welding plan shall be established in accordance with the requirements of section 7.2 of EN 1090-2+A1. In addition to the welding plan, the main welding data, giving a precise description of the welding and inspection operations shall be collected in a welding data package. This document shall include at least:

- an overall plan or diagram of the equipment, with the location of all the welded joints,
- for all joints:
 - the Welding Procedure Specification (WPS), compliant with EN ISO 15609, including a sketch with dimensions and tolerances of the joint design,
 - the Welding Procedure Qualification Record,
 - the Non Destructive Testing to be performed before, during and after welding,
- the list of the weld test coupons.

CBURP 7130 Welders and welding operators

Welders shall be qualified according to EN ISO 9606-1 and welding operators according to EN ISO 14732.

In addition to the qualification, welders or welding operators shall be trained and authorized by the Manufacturer before welding in workshop or on site. The authorization shall guarantee their capacities to reach the required level of quality.

The activity of the authorized welder and welding operator shall be recorded and monitored.

The modalities of training, authorization and monitoring of the welders and welding operators shall be described in a procedure submitted to the Project approval.

CBURP 7140 Butt-welds

Run-on/run-off pieces shall be used to ensure full throat thickness at the edge.

CBURP 7200 WELDS INSPECTION

Section 12.4 of EN 1090-2+A1 shall apply, completed or modified as follows:

Welds made in the factory and on site shall be subject to a 100% visual testing and a 100% penetrant testing.

-Where a weld becomes inaccessible due to other subsequent works, it shall be inspected prior to the execution of such works.

In the factory, each steel cylinder with its joint rings shall undergo a hydraulic test carried out in accordance with section 6.4.7 of EN 639 (100% inspection).

EN

CBURP 7210 Visual testing

Visual testing shall be carried out in accordance with ISO 17637.

CH3.11 CBURP 10/12

Examinations shall be performed over the entire length of welds, before, during and after welding (100% inspections).

The acceptance criteria shall be those of quality level C as defined in EN ISO 5817.

CBURP 7220 Penetrant testing

Penetrant testing shall be performed in accordance with ISO 3452-1.

Penetrant testing shall be carried out along the entire length of welds on the external face of the welded assembly and on its internal face if accessible.

The indication recording threshold shall be 2 mm which is in accordance with acceptance level 1 of standard EN ISO 23277.

Any adjacent indications separated by less than the major dimension of the smaller shall be assessed as a single, continuous indication.

The following indications are unacceptable:

- linear indications,
- non-linear indications with a dimension > 4 mm,
- three or more aligned indications with a distance between them of less than 3 mm edge to edge,
- eight or more grouped indications over a rectangular surface of 100 cm2 selected in the most unfavourable manner in relation to the indications, without its largest dimension exceeding 20 cm.

CBURP 7300 WELDS REPAIR

Welds repair shall be carried out in accordance with qualified welding procedure.

Repaired welds shall satisfy the same requirements as the initial welds, including inspections, and including the hydraulic test when repairs are made in the factory.

A procedure shall be established for repairs and submitted to the Project approval.

EN

CJOIN JOINT SEALING

CJOIN 1000 FIELD OF APPLICATION

The current section applies to linear joints. In the present text, the joint is a free space between two civil structural elements.

These joints aim to:

- Limit cracking in concrete structures (dividing joint or similar),
- Avoid disorders following either a temperature variation or a differential movement between two structures, or following vibrations, seismic tremors, shocks, etc. (expansion joint)

The joint sealing shall enable the movements of the joint defined by the Project, ensure leaktightness and sometimes a protection (with respect to propagation of fire or radiations) in accordance with safety-related functions of civil structures. The characteristics of the sealing system take into account the fluids with which it has to be in contact, the environment and the geometry of the structure concerned.

The joint sealing is usually ensured by using a system composed by a sealant and a back-up material and/or a sealing strip.

Definitions are given in EN ISO 6927 (joint sealing, sealing system, sealant, back-up material, sealing strip,...).

The followings are not taken into account:

- Joints for penetrations (equipment hatches, personnel hatches, piping, cable raceways, etc) of structures,
- Joints of doors, windows, air locks,
- Joints of tunnels, precast segments and underground piping.

CJOIN 2000 ROLE OF SEALINGS SYTEMS

The role of joint sealing systems is to provide different protections at joint level :

- In case of internal flooding :
 - By avoiding the routing of all effluents deriving from the nuclear buildings (which may contain toxic, radioactive, inflammable, corrosive or explosive components, towards the natural subsoil) and thus reducing the risk of dispersion of radionuclides in the natural ground and groundwater;
 - By avoiding the transfer of effluents from one level to another level and thus reducing the risk of aggression of safety-related equipments,
- In case of external flooding : by avoiding the penetration of external water (groundwater, rainwater, floodwater, accidental flooding linked to the rupture of hydraulic structures, etc) into the civil engineering structure, which may lead to the failure of equipment,



By avoiding fire propagation and limiting the transmission of radiations.

The sealing system shall be suitable for the dimensional variations of the joint, taking into account its working conditions (geometry, thermal expansion and differential movement of the edges, settlement, and environment).



Figure CJOIN 3200-1Sealing system comprising an embedded sealing strip



Figure CJOIN 3200-2Sealing system comprising a post-applied sealing strip

CJOIN 3300 OTHER TYPES OF PRODUCTS

Especially for joints with small movement, other types of products without neither elasticity nor plasticity may be used such as :

- Injection resins (according to the width and the movement of the joint);
- Mortars (mark NF "Liants hydrauliques" (hydraulic binders));
- Polymer sheeting (mostly used between two sections of a screed).

These products are not addressed in the following parts of CJOIN. The requirements applicable to these sealing systems and their characteristics shall be submitted to the Project approval.

CJOIN 4000 IDENTIFICATION OF THE REQUIREMENT APPLICABLE TO A JOINT

The requirements applicable to joints shall be identified.

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n°157-2015.This docum ated to a third party witho	Platforms – Ro - Earth platform - Roadways
ent is the property of ut permission signed	Piles, cast wa - Structural fou - Watertight wa
AFCEN. It must not be re by the President of AFCE	Concrete struct - 1 st phase penetrations concreting (4) - 2 nd phase penetrations by (1) At top of str
CH3.A CA 5/8 reproduced CEN.	(2) For the structure(3) The acceptation(4) Tolerances(5) This tolerance

		ABSC	DLUTE		RELATIVE			
	Independent structures		Connected structures		Internal structures			
TYPE OF WORKS	planimetry uncertainty radius	altimetry tolerance range + or -	planimetry uncertainty radius	altimetry tolerance range + or -	planimetry uncertainty radius	Vertical measurements Tolerance range + or -	BASIC	
atforms – Roadways							The deflections measured with the 3 m ruler shal not exceed:	
arth platforms	10 cm	5 cm					Foundation layer: 2 cm	
loadways	5 cm	3 cm					Base layer: 1 cm	
							Surface layer: 1 cm	
pring in the earth	20 cm	10 cm			5 cm	3 cm	The deviation of the boreholes shall not exceed 3 % of their length.	
es, cast walls, sheet piling tructural foundations Vatertight walls	5 cm 10 cm	3 cm (1) 5 cm (1)			3 cm	2 cm	For structural foundations, the deviation of the vertical elements such as piles, cast walls, shee piling, etc, shall not exceed 1 % of their length. This tolerance is raised to 4.5% for inclined piles or shee piling. For watertight walls, the continuity of the wal shall be guaranteed.	
ncrete structures (2) 1 st phase concrete (3), netrations performed during ncreting (4) 2 nd phase concrete (3), netrations by boring	5 cm	3 cm	3 cm	2 cm	2 cm (5) 1 cm (5)	1 cm (5) 0.5 cm (5)	For tunnel, shaft or other excavation linings, the tolerance on the distance of the profile performed (o line R) to the profile set up after earthwork is ± 2 cm. For sleeves , the verticality or horizontality tolerance is 1%, with a maximum off-centre of 1 cm.	
At top of structure.							·	

CFNSH 1000

uctures made up of prefabricated elements, the facing tolerances and definitions shall apply as if construction was performed on site.

tance criteria of the facings (flatness and shape defects, texture) are defined in 2.3.4.

s on the position of centre and the ends of the sleeves.

nce may be increased for penetrations which do not require very precise positioning (electrical penetrations for example).

Table CA-2

		ABSO	LUTE		RELATIVE			
	Independen	nt structures	Connected structures		Internal structures			
TYPE OF WORKS	planimetry uncertainty radius	altimetry tolerance range + or -	planimetry uncertainty radius	altimetry tolerance range + or -	planimetry uncertainty radius	Vertical measurements Tolerance range + or -	BASIC	
Large-diameter conduits	5 cm	3 cm			1 cm	0.5 cm (1)		
Revolving crane brackets (2)	5 cm	3 cm			2 cm	1 cm	All points on the upper horizontal anchor plate shall lay between two horizontal planes 1.5 cm apart.	
Structures and equipment - grouted parts - large steelwork (4) - small steelwork, metalwork	3 cm	2 cm	3 cm	2 cm	1 cm (3) 2 cm 1 cm	0.5 cm (3) 1 cm 0.5 cm	The basic tolerances applicable to the steelwork and beams of the tracks are given in 2.10 . CSTLW	

(1) Axis with connections to other supplies.

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(2) Tolerances on the position of the horizontal anchor plate to which the rail will be fixed.

(3) Upper value of the tolerances of the grouted parts.

(4) Positioning tolerance of a given element with respect to the reference unit.

Table CA-3

Test standards Admixtures EN 934-2+61	N° of reference concrete EN 480-1+A1	Concrete Compressive Strength	Air content of fresh concrete EN 12350-7	Air content of fresh concrete EN 12350-7	Setting time (on mortar)	Water reduction	Increase in consistence	Retention of consistence	Air void characteristics in hardened concrete
LN 334-2TAT	EN 12350-5	EN 12390-3	EN12390-7	EN 480-2	E	EN 12350-2 or EN 123	50-5	EN 480-11	
Water reducing / Plasticizing Admixtures	l 400± 20	At 7 & 28 days, AC ≥ 110% of CC	≤ 2% by vol. above that of CC*		For AC ≥ 5% relative to CC				
Table 2 Superplastic. admixtures Table 3.2	IV 350± 20	At 28 d, AC ≥ 90% of CC	$\leq 2\%$ by vol. above that of CC*			Slump: ∆> 120mm Flow : ∆> 160 mm	After 30min ≥ Initial value of CC		
High range water reducing Table 3.1 •	l 400± 20	At 1 d, AC ≥ 140% of CC At 28 d, AC ≥ 115% of CC	≤ 2% by vol. above that of CC*		For AC ≥ 12% relative to CC				
Air entraining admixtures Table 5 ●	III 350± 10	At 28 d, AC ≥ 75% of CC	- AC≥2.5% by vol. above BT CC - Total air content : 4 to 6% by vol.					Spacing factor ≤ 0.200 mm	
Set accelerating admixtures Table 6 •	ا 400± 20	At 28 d, AC ≥ 80% of CC At 90 d, AC ≥ AC at 28d	≤ 2% by vol. above that of CC*	At 20°, AM ≥ 30min At 5°, AM ≤ 60%CM					
Hardening accelerating admixtures Table 7 •	ا 400± 20	At 20°,24h:AC ≥120% of CC At 20°, 28d: AC≥ 90% of CC At 5°,48h: AC ≥ 130% of CC	≤ 2% by vol. above that of CC*						
Set retarding admixtures Table 8 •	I 400± 20	At 7 d, AC ≥ 80% of CC At 28 d, AC ≥ 90% of CC	≤ 2% by vol. above that of CC*	<u>Start of set:</u> AM ≥ CM+90min <u>End of set:</u> AM≤ CM+360 min					
Set retarding/ Water reducing / Plasticiz. Adm Table 10 •	ا 400± 20	At 28 d, AC ≥ 100% of CC	≤ 2% by vol. above that of CC*	<u>Start of set:</u> AM ≥ CM+90min <u>End of set:</u> AM≤ CM+360 min	For AC ≥ 5% relative to CC				
Superplasticizing / Table 11.2 +	IV 350± 20	At 28 d, AC ≥ 90% of CC	≤ 2% by vol. above that of CC*				After 60min ≥ Initial value of CC		
Set retarding/ HR water reducing admixtures Table 11.1 •	ا 400± 20	At 7 d, AC ≥ 100% of CC At 28 d, AC ≥ 115% of CC	≤ 2% by vol. above that of CC*	<u>Start of set:</u> AM ≥ CM+90min <u>End of set:</u> AM≤ CM+360 min	For AC ≥ 12% relative to CC				
Set accelerating/ water reducing/ plasticizing ad. Table 12 •	I 400± 20	At 28 d, AC ≥ 100% of CC	≤ 2% by vol. above that of CC*	At 20°, AM ≥ 30min At 5°, AM ≤ 60%CM	For AC \ge 5% relative to CC				
Curing compounds NF P 18-370	Coefficient -At 6 h, ≥	of protection for concrete: 290% - At 24h, ≥ 85%							
(*) : unless indicated otherw	ise by the Produc	er • : At equal consistence	+ : at an equal water/ce	ement ratio CC: control (Concrete AC: Adm	ixture Concrete CM	Control Mortar AM :	Admixture Mortar	

CH3.D CD 8/12

CD 2200 REFERENCE MATERIALS FOR TESTS

The checks and tests for the reference materials used for physical tests, and their frequency, shall be performed according to the following table:

Table CD 2200-1 – Cheks and tests on materials	for	physical tests
--	-----	----------------

Reference materials	Checks / tests	Minimum frequency
Aggregates in accordance with	Visual check	Each delivery
EN 12620+A1 and EN 480- 1+A1 (3.2)	Grading analysis given by the supplier	Each delivery
Fine aggregate for mortar (CEN Standard sand in accordance with EN 196-1)	Conformity with the delivery ticket and with the order form	Each delivery
Cement in accordance with EN	Conformity with the delivery ticket and with the order form	Each delivery
197-1+A1 and EN 480-1+A1 (3.1)	False setting test in accordance with NF P 18-363	Each delivery

Aggregates

Aggregates shall be rolled aggregates, of the same origin for all types of admixtures and curing compounds to be tested.

The aggregates supplier shall be proposed by the Producer and submitted to the Project approval.

Standard sand for mortar

Sand shall have the same origin for all types of admixtures to be tested.

The sand supplier shall be proposed by the Producer and submitted to the Project approval.

Cements

For factory production control, the reference cement required by EN 480-1+A1 may be replaced by an alternative cement provided that, during the Initial Type Testing, the alternative cement has been tested with the EN 480-1+A1 reference concrete in parallel with the reference cement to EN 480-1+A1, with the same admixture type.

The use of CEM II/A as a reference cement is allowed. It is restricted to CEM II/A-LL or CEM II/A-S.

The Producer may propose several cements for a range of products; however, only one cement shall be used per admixture.

Departing from EN 480-1+A1, the cement may have a specific surface between 3200 cm²/g and 4600 cm²/g, in accordance with EN 196-6. The C3A content shall be between 7% and 11% in mass of cement, in accordance with the chemical analysis of EN 196-2.

Supplies:

The following information and requirements shall be stated with the order for the reference cement:

- The cement is to be used for admixture conformity tests,
- The cement shall not present any risk of false setting,
- A record of tests relative to the characterisation of the product shall be sent with the cement.

CD 2312 Curing compounds

Note: Details about tests methods for infrared spectrum of solvent, conventional dry material content and viscosity measurement are given in appendix 2 of the NF mark.

- Products applying for the admission or extension of use for the NF Mark : The requirements of NF P 18-370, 4.1 (identification criteria) shall apply, as well as the aspect and colour of the product. Factory production control
- Factory production control : Tests and checks shall be performed according to the following table :

Table CD 2312-1 – Frequency of production control tests

Test	Frequency of test
Aspect and colour	1 per batch
Dry material content	1 per batch
Ash content	1 per batch
Viscosity	1 per batch
Infrared spectra	1 every 250t with a minimum of 2 per year on 2 different batches

CD 2320 PHYSICAL TESTS

CD 2321 Admixtures

Note: Details on the implementation of standards for the compliance dosage, high range water reducing/ superplasticizer admixtures, air content of fresh concrete, tests on mortars are given in appendix 3 of the NF mark.

- Products applying for the admission or extension of use for the NF Mark :
 - For each type of admixture concerned, the requirements of tables 2 to 12 of EN 934-2+A1 shall apply.
 - Tests shall be performed with the compliance dosage determined by the Producer with the reference cement chosen by the Producer.
- Factory production control :
 - Tests shall be performed by the Producer in accordance with the frequency defined in table B.1 (lines 8 to 16) of EN 934-2+A1.

CD 2322 Curing compounds

The coefficient of protection with the compliance dosage given by the Producer shall be measured in accordance with NF P 18-371.

CG 5400 WATER RETENTION OF FILLER OR FLY ASH

curve

Read on the cruve the value for Bo that gives a fluidity of 20 s. This value is expressed without decimals. It expresses the needed water for the filler or of the fly ash measured by the Marsh cone method.

CG 5500 TEST RECORD

The record of the test shall include:

- The identification of the sample material;
- The water content of the sample material (in its state at reception)
- The values obtained for each measurement: fluidity in seconds and water retention Bx, mix density;
- The fluidity water retention curve;
- The value on the curve of the water retention Bo leading to a fluidity equal to 20 s;
- Unanticipated operating details and incidents that may have influenced the results.

- Metallic reaction chamber equipped with heating resistors immersed in water, providing a temperature of (60 ± 2) ° C inside the container (Figure CH 9000-4).
- Non-absorbent plates, inert with reference to concrete, with a sealing gasket for the moulds (Figure CH 9000-5).

CH 3300 PRODUCTS USED

Sodium hydroxide solutions of known concentration or sodium pellets.

CH 4000 MATERIALS TO BE TESTED

The materials to be tested are identical to those that will be used on site except for the mixing water (Towns water is permitted provided it meets the requirements of EN 1008) and, where appropriate, the grading of aggregates.

Given the size of the specimens, the largest size of the aggregates is fixed at D = 22.4 mm, in accordance with EN 12620+A1. The coarse aggregate/fine aggregate (C/F) ratio of the initial concrete mix shall be retained.

For cement, special attention shall be paid to the representativeness and variability of the batch in particular with regards to its alkaline oxide content: the alkaline oxide content is increased by adding NaOH to the mixing water to account for this variability.

The calculation of the amount of alkali, $\boldsymbol{\delta},$ to be added is made as follows:

 When the statistical data of alkali content of cement are available, the amount of alkali δ added to concrete samples is equal to:

$$\delta = \frac{C}{100} \cdot \left[A_m(1+2V_c) - A_{ech}\right]$$

 $\delta = \frac{C}{100[A_m(1+2V_c) - A_{ech}]}$ expressed in kg/m³

with:

- o C cement content in kg/m3;
- A_m Na₂O_{eq} content of cement as % of mass (see CH 8000);
- \circ V_c coefficient of variation of Na₂O_{eq} content of cement;
- A_{ech} Na₂O_{eq} content of the sample of cement used for making test specimens, as % of 0.658

(With Na₂Oe_a = 0.658 Na₂O + K₂O), determined in accordance with CH 8000.

If δ is negative, no alkali is added.

In the absence of data on the dispersion of alkali content, the amount of Na2O to be added in the form of sodium hydroxide NaOH in concrete samples is equal to:

Equation CH 4000-2

Equation CH 4000-1

$$\delta = 0.0025 . C . A_{ech}$$

δ
CH 10500 EXAMPLE OF TEST REPORT

Reactiv	ity of a c	oncrete m	nix with regards	s to alkali-silica ı	reaction - I	Performance test
Test identification		Characteristic of mix				
Test Number :					Test result	s
			Fine aggregate	: 1		
Name of study:			Fine aggregate 2			
			Coarse aggreg	ate 1		
Date of mixing:			Coarse aggregate 2			
Type of test:						
		Addition 1:		W/C:		Concrete density:
Supervisor :		Addition 2:		Water:		Slump:
Operator :		Cement:		Na ₂ O equiv Cem	nent:	Vibration time
		Admixtur	es:			
Measurements				Expansion change		
Time Week 0	Expansi %	ion M char	ass nge %).0	0.1000 T		
Week 1	0.000		0.0	6)280 -		
Week 3	0.000	0 0	0.0	0.1000		
Week 4	0.000	0 ().0	5 0.000 -		
Week 5	0.000	0 0).0	0.0420 -		
Week 6	0.000	0 0).0	C.0200		
Week 9	0.000	0 0).0	6,5000 0 0 0		o o o Déanes (senares)
Week 12	0.000	0 0).0	-0.0200		
Information on te	st conditio	ins:				
 Mean of 28cm 	three sp	pecimens	7cm x 7cm x			
Tempera	ture: 60°C	;				
Relative humidity: 100 %						

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MCONT 1130 In-Service Inspection

In-Service Inspection (ISI): measure for assurance of equipment integrity and avoidance of failure for the duration of operation.

MCONT 1200 NOTATIONS

Pressure (defined as absolute pressure, unit: Pa)

Po P₀: atmospheric pressure;

P_{ILRT}: maximum pressure in the containment ILRT;

P_{ISIT}: maximum pressure in containment ISIT;

Leakage rate (in per cent of dry mass per day, %/day)

Lra^{acc}: maximum containment leakage rate acceptable under actual accident conditions;

Lrap^{acc}: maximum leakage rate acceptable for penetrations under actual accident conditions;

Lrt: containment leakage rate under leakage rate test conditions;

Lrt^{acc}: maximum acceptable containment leakage rate under leakage rate test conditions;

Lrtp^{acc}: maximum leakage rate acceptable for penetrations under the test conditions;

Lrm: overall containment leakage rate obtained from the average value measured during the P_{ILRT} pressure plateau.

MCONT 2000 GENERAL PROVISIONS

The prestressed and reinforced concrete cylindrical wall and dome of the containment withstand internal pressure, while leak tightness is ensured by the metallic liner, door and airlock seals and isolation devices. Some designs may include a secondary concrete structure that may have a leak tightness function for the overall containment.

At containment penetrations, structural strength and leak tightness are ensured by various components such as connecting parts between sleeves and penetrations, the equipment hatch and its seals, the personnel airlocks (fixed parts, doors and seals), isolation valves for fluid penetrations (valve body, covers and stems), electrical penetrations, blind flanges, etc.

The containment undergoes a test known as the "acceptance test" or "pre-operational test", comprising:

- an ILRT (Type A test) of the prestressed concrete containment preceded by LLRT (Types B and C tests);
- an ISIT;
- if required for double wall containments, an evaluation of the external containment leakage rate.

If the Pre Operational ILRT and ISIT are to be implemented jointly, the test programme shall be submitted to Project approval. Leak rate measurement shall take into account the possible effects of gas entrapped in the concrete members during pressurisation.

These tests shall be conducted by suitably qualified professionals and supervised by experienced and capable engineers.

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After completion of the ISIT, a second overall examination shall be carried out, with the same criteria to apply as before the ISIT.

Measuring devices used to measure cracks width shall be capable of measuring a minimum opening of 0.1 mm. The reported cracks shall be mapped to within +/- 10 cm of the real position.

MCONT 3400 ISIT PROCEDURE

For the resistance test, the RB containment wall shall be subjected to a pressure of P_{ISIT}, under normal temperature conditions.

The containment pressure shall be gradually increased up to the maximum pressure, followed by a gradual return to atmospheric pressure.

The rate of pressurization shall not exceed 15 kPa per hour. The depressurization rate shall also be limited to 15 kPa per hour to prevent any damage of containment (coatings and paint coverings) due to gas release from concrete members.

Readings from all instruments shall be recorded:

- at atmospheric pressure prior to starting pressurisation,
- when pressure P_{ISIT} is reached, at the end of the constant pressure stage at P_{ISIT},
- upon completion of depressurisation.

In addition, at least 4 intermediate sets of readings shall be taken during pressurisation and at least 4 intermediate ones during depressurisation to allow a more accurate assessment of the mechanical behaviour of the RB containment to be made. The plot of the acquired data against test pressure shall be used to assess the linearity of the mechanical response of the RB.

During the constant pressure stage, measurements shall be taken at least at the beginning and end of the stage.

A remote acquisition system would allow continuous monitoring and facilitate data collection which would allow a reduction in the measurement duration.

MCONT 3500 INSTRUMENTATION

The containment structure shall be instrumented in order to:

- assess the validity of the assumptions and methods used for design (e.g. overall stiffness, modulus of elasticity, etc);
- check the structural integrity of the structure;
- if required for ISI considerations, to determine the long term behaviour of the containment.

The containment instrumentation devices shall be designed so that they can be functional with the appropriate level of performance within the expected time of their use. The sustainability of a system shall be assessed, in particular through operational experience analyses.

MCONT 3510 Calibration and specifications

The measuring instruments shall have an effective range consistent with the values of the physical phenomena to be measured over the operating lifetime of the containment.

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PART M MAINTENANCE AND MONITORING MCONT LEAK RESISTANCE TEST AND CONTAINMENT MONITORING

The accuracy and precision of the instrumentation shall be specified in order to limit scatter in the collected data to within the necessary bounds to allow a meaningful comparison with design calculations. These requirements shall take into account the expected behaviour of the structure, the ambient conditions of the sensors, the criteria to apply and the accuracy of the results provided by the numerical calculation with which the records would be compared. The guidance of the European Methodology FD CEN/TR 14748 may be used to provide evidence of the performance of the instrumentation.

The measuring devices shall be calibrated against devices that are traceable to the standards of a National Metrological Institute. Resolution and repeatability shall be obtained from vendor specifications or by direct measurement.

Section 2.13 provides requirements concerning the measuring devices mounting and installation.

MCONT 3520 Requirements for instrumentation

The absolute and relative settlements of the containment basemat shall be assessed prior to and just after the pressure test, in order to check that the test did not induce any unexpected additional deformation of the foundation.

The following parameters shall be monitored:

- pressure;
- strain;
- displacement;
- temperature.

The main purpose of monitoring the temperature is to determine the thermal expansion of the structure and then to separate the thermal strain from the total strain measured by the strain sensors. This process is called "strain correction" hereafter. The procedure for undertaking strain correction shall be specified prior to the ISIT.

The parameters to be monitored during the ISIT and the related minimum specifications for the instrumentation are presented in Table MCONT 3520-1.

Vertical displacements

Relative vertical displacement of the top of the cylinder wall relative to the base shall be measured, at the same location as horizontal displacements devices.

Tilt or bending rotations

In specific areas, where significant tilt or rotations are expected such as at the gusset-cylinder or cylinderdome junctions, tilt or bending shall be assessed by measurement. At least 3 measuring points for each type of area, at different azimuth and away from large penetrations or buttresses shall be considered.

Concrete strains

For concrete strain monitoring, sensors shall be placed:

- on the inner and outer faces of the cylinder and the dome;

- on the upper and lower faces of the basemat raft.

A measuring point consists of a couple of sensors, placed in 2 orthogonal directions (horizontal tangent and vertical for the cylinder, 2 meridional orthogonal directions for the dome).

At least 3 axes of the containment wall (dome, gusset and cylinder), shall be instrumented in accordance with the following minimum requirements:

- the 3 axes shall be located away from structural discontinuities;

- In the dome, 1 measuring point at the centre and 2 other measuring points along each axis;

In the cylinder, 3 measuring points along each axis, at the same locations as the devices for horizontal displacement monitoring;

- In the gusset, 2 measuring points along each axis, at the same elevation, to determine vertical bending strain.

In addition to the 3 axes considered above, 1 prestressing buttress shall be instrumented with 3 measuring points at different elevations.

2 axes of the basemat raft shall be instrumented at two different elevations in order to determine bending strains. In plan, 1 measuring point shall be placed at the centre of the raft and 2 others along the 2 axes. This pattern is applied to both levels of instrumentation in the raft.

The wall around the equipment hatch shall be instrumented in 3 concentric circles, each with 3 equally spaced measuring points to determine strains at each point on 2 orthogonal axes. The diameter of the outer circle shall be approximately twice the diameter of the hatch.

See also Appendix MA for simplified sketches.

MCONT 3530 Recommendations for some measurement devices

Based on international operational experience, the following sections provide some information and recommendations on devices or techniques that have been used successfully. Other systems can be considered, as long as they are based on well proven technologies, tested at industrial scale and have consistent and relevant feedback concerning performance, reliability and robustness.