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| **2E2U9X** |
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**Rules or Handbooks or Guidelines**

# ITER Structural Design Code for Buildings (I-SDCB) - Part 2: Construction

The purpose of these technical specifications is to describe the varied technical requirements of the materials that are to be supplied throughout the buildings construction phase of the ITER project. This will include specified material properties, certification, testing regimes etc. that are required to satisfy this specification.These technical specifications apply to all the SIC and SR civil works, buildings and site infrastructure that are to be constructed on and around the platform of ...

| *Approval Process* | | | |
|---|---|---|---|
| | *Name* | *Action* | *Affiliation* |
| *Author* | **Patisson L.** | **22 Jul 2013:signed** | **IO/DG/CP/BSM/CEI** |
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| *Read Access* | **GG: MAC Members and Experts, GG: STAC Members & Experts, AD: ITER, AD: External Collaborators, AD: IO_Director-General, AD: External Management Advisory Board, AD: EUROfusion-DEMO, AD: IDM_Controller, AD: members-DA, AD: Auditors, AD: ITER Management Assessor, project administrator, RO, LG: [CCS] CC...** | | |

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| *Change Log* | | | |
|---|---|---|---|
| **ITER Structural Design Code for Buildings (I-SDCB) - Part 2: Construction (2E2U9X)** | | | |
| ***Version*** | ***Latest Status*** | ***Issue Date*** | ***Description of Change*** |
| v1.0 | In Work | 21 Apr 2008 | |
| v1.1 | Approved | 07 Oct 2008 | |
| v2.0 | Approved | 22 Jul 2013 | This update aims to align the document with new Codes and Standards that have been introduced/updated since the previous issue of the ITER Structural Design Code for Buildings Part II (2008).<br>These updates are supported via the following approved F4E – Supplier Deviation Requests :<br><br>Supplier Deviation Request #45 – AE PA 6.2.P2.EU.02 – PBS 62 and 63 – Proposal to Deviate from the ITER Code Part 2 for TB03 Technical Annexes B.04 (Concrete) and B.20 (Codes and Standards) (GFSVZQ)<br><br>Supplier Deviation Request #46 – AE PA 6.2.P2.EU.02 – PBS 62 and 63 – Proposal to Deviate for the TB03 Tender Documents – ITER Code Part 2 by Annex B.02 (Earthworks) and B.05 (Structural Steelwork) (GFWZ8V)<br><br>Supplier Deviation Request #47 – AE PA 6.2.P2.EU.02 – PBS 61, 62 and 63 – Proposal to Change Concrete Sliding Standard Deviation 3rd Criterion (GNSF7X)<br><br>There are two additional Supplier deviation requests currently being drafted by EU-DA covering updates to the specifications for stainless steel room liners (specifically Annex B.17 and B.18 of the TB03 Contract Documentation). These updates are to be included in the I-SDCB Part II update. This update is actually covered by the PCR 548 (PCR 548- Updates required for ITER Structural Design Code for Buildlings Part II (2E2U9X) https://user.iter.org/?uid=A7A2ZW). |

# Table of Contents

# 1 Purpose

The purpose of these technical specifications is to describe the varied technical requirements of the materials that are to be supplied throughout the construction phase of the ITER project. This will include specified material properties, certification, testing regimes etc. that are required to satisfy this specification.

# 2 Scope

This technical specification applies to all the SIC and SR civil works, buildings and site infrastructure that are to be constructed on and around the platform of the ITER Worksite. It may also be applied wholly or partially to non-SIC civil works, buildings and site infrastructure at the discretion of the PA RO. Generally, non-SIC civil works, buildings and site infrastructure shall comply with Eurocodes and supporting Euro-Norms (or French Codes as applicable).

# 3 Definitions

For a complete list of ITER abbreviations see: ITER_D_2MU6W5 - ITER Abbreviations

SIC Safety Importance Class

SR Safety Related

PA Procurement Arrangement

RO Responsible Officer

# 4 GENERAL PRINCIPLES

Modifications or adaptations to these rules (particularly regarding the characteristics of the materials or processes and the associated inspections) may prove necessary in response to changes in the industrial technology or to the technical constraints of the project.

## 4.1 Standards

These technical specifications refer to existing European standards. If these European standards are not available, technical specifications are defined with reference to national standards.

The construction of structures covered by the present rules must fulfil the standards to which reference is made in this document. The standards to observe are those in force on the issuing date of the present rules. The use of standards other than those referenced in the present document (other standard or revised standard) must be justified by a document attesting to their equivalence. Only the requirements which are not contrary to those of the present rules can be met.

## 4.2 National marks, certification, qualifications and approvals

The use of national marks, certifications, qualifications and approvals, other than those mentioned in the present document, is possible on the condition that the quality guarantees are proved to be at least equivalent (controls).

When a compliance certificate is required by the present regulations, it must be possible to prove, before the start of the works, that the materials, products or processes benefit there from or, failing this, from a compliance certificate approved as equivalent.

## 4.3 Laboratories and organisations

Where laboratories or organisations are mentioned in the present document, other laboratories or organisations may be used, on condition that proof is furnished that they provide quality guarantees that are at least equivalent.

## 4.4 Working tolerances

The relevant tolerances are collected in section 5.5.

## 4.5 Non-conformities - Deviations

If, during the controls, the requirements of the present rules are not met, a non-conformity is declared. The materials or components concerned remain under control until processing of the non-conformity.

Restoration of conformity is sought after the detection of non-conformities with respect to these rules. They are only declared as deviations when this restoration of conformity cannot be effected.

Deviations are declared as significant or brought to the attention of the Safety Authorities when the final condition of the structure does not conform to the design and construction rules described in the present document or in rules shown to be equivalent.

## 4.6 Applicable documents

Documents applicable to the construction are listed Section per Section in this specification.

Abbreviated notations used in the text are the following:

### 4.6.1 *Ministerial documentation*

They are designated in the text by an abbreviated tide that allows them to be identified.

Example: Documentation n° 4 Title II".

#### *4.6.1.1 Standards*

The standards are coded according to their origin and status. They are designated in the text by their alphanumeric code.

Meaning of the coding:

ISO: international standards

EN: european standards, adopted by the CEN

DIN: german standards

NF: standards approved by AFNOR

XP or no coding: experimental AFNOR standards

FD: AFNOR documentation

The order of the coding is shown by the following example: international standard (ISO) adopted by the CEN (EN), and then approved in France (NF): NF EN ISO 14713.

#### *4.6.1.2 Other documents*

They are designated in the text by an abbreviated title that allows them to be identified.

# 5 TOPOGRAPHY LAYOUT AND CIVIL WORKS CONSTRUCTION TOLERANCES

## 5.1 Scope

This specification relates to the topographical works, it also defines the construction tolerances of the civil works.

## 5.2 Topographical reference system

The topographical works and coordinate systems are described in the note ITER COORDINATE SYSTEMS ITER_D_2A9PXZ v3.7.

## 5.3 Working tolerances

"Working tolerance" is understood to mean the tolerances which take into account the deviations inherent in the layout topographical operations and deviations attributable to the work itself.

The tolerances relate to the permissible deviation in the specified value of a dimension, position or surface condition. Three types of working tolerance are to be considered:

Absolute tolerance: tolerance on the absolute position (X,Y,Z) of a structure axis or any part of a structure with respect to a "topographical reference unit".

For independent structures, namely: isolated structures without mandatory dimensional link with other structures or installations, the topographical reference unit is part of a known " primary" survey grid in the LAMBERT III projection system, for planimetry, and the NGF altimetric system, for altimetry.

For connected structures, i.e. those requiring a mandatory dimensional link with one or more other structures or installations, the topographical reference unit is part of a " secondary " survey grid determined in a local coordinate system and attached to the primary survey grid.

Relative tolerance: tolerance on the relative position (X,Y,Z) of any part of a structure with respect to a "topographical reference unit" linked to this structure. This «topographical reference unit" is part of a «micro survey grid» set up on the structure itself and defined with respect to the primary or secondary survey grid.

Basic tolerance: it is a tolerance on:

a dimension, orientation, inclination or surface condition requiring accuracy greater than the one given by the absolute or relative tolerances.

the relative positions of equipment items or parts of structures.

The basic tolerance is one-dimensional: it does not refer to any topographical reference unit.

Table below summarizes above definitions:

| Types of structure | Type of tolerance to be considered | Origin of the topographical reference unit |
|---|---|---|
| *Independent structures* | absolute | Primary survey grid |
| | basic | No topographical reference |
| *Connected structures* | absolute | Primary or secondary survey |
| | basic | No topographical reference |
| *Structure internaIs* | relative | Microsurvey grid |
| | basic | No topographical reference |

Maximum allowable working tolerances under normal working conditions are given in the tables provided on Section 5.5.

## 5.4 Altimetric sounding

Each structure is equipped with a set of landmarks left in place during operation and enabling the changes in basemat displacements and distortions to be measured.

The measuring frequency is generally quarterly during construction and annual during operation. However, the frequency is adapted to match the foreseeable or observed movements.

This set of landmarks is supplemented by measurements of the differential displacements between buildings and of the basemat tipping.

## 5.5 Tolerances

Reference Documents:

SFS-ISO 3443-8 Tolerances for Building, Dimensional Inspection and Control for Construction Work

SFS-ISO 7077 : Measuring Methods for Building - General Principles and Procedures for the Verification of Dimensional Compliance

Tolerances for normal working conditions are the most stringent of the tolerances specified in Chapter 7 of NF P18-201 and the tolerances specified in the following tables:

| TYPE OF WORKS | ABSOLUTE | | | | RELATIVE | | BASIC |
|---|---|---|---|---|---|---|---|
| | Independent structures | | Connected structures | | Internal structures | | |
| | levelness or indecision | altimetry tolerance range + or - | levelness or indecision | altimetry tolerance range + or - | levelness or indecision | vertical measurements tolerance range +or - | |
| **Survey works** | | | | | | | |
| • piezometers | 20 cm | 2 cm | | | | | |
| • test boring | 20 cm | 10cm | | | | | |
| • seismic profiles | 20 cm | 20 cm | | | | | |
| • gravimetric measurements | 20 cm | 2 cm | | | | | |
| • limnigraphic scales | 1 m | 5 cm | | | | | |
| **Open-air earthworks** | | | | | | | |
| • rocky soils (line A) | | | | | | | |
| - without pre-splitting (1 ) | 20 cm | 15 cm | | | 15 cm | 10 cm | |
| - with pre-splitting | 15 cm | 10 cm | | | 10 cm | 5 cm | For lined excavations, a line A basic tolerance with respect to the adopted structure profile may be required depending on the tolerance set for the lining thickness |
| • rocky backfills (profile performed) | 15 cm | 10 cm | | | | | |
| • loose earth spoils and backfills (line A or profile performed) | 10 cm | 5 cm | | | | | |
| **Underground earthworks** | | | | | | | |
| • rocky soils (line A) | | | | | | | |
| - without pre-splitting (1 ) | 20 cm (2) | 15 cm | | | 15 cm (3) | 10 cm(3) | Tolerances on the distance of the profile performed (or line A) to the axis set up after earthwork: ± 3 cm. |
| - with pre-splitting | 15 cm (2) | 10 cm | | | 10 cm (3) | 5 cm (3) | |
| - with full-sized boring machine | 12 cm (2) | 10 cm | | | | | |

(1) With surface adjustment or use of the careful splitting technique

(2) lf the length of the tunnel (L in km) is > 5 km; the applicable tolerance in normal working conditions is increased by the value in cm given by the expression: $(L-5)^{1/2}$

(3) Applies to major excavation (underground factory).

| TYPE OF WORKS | ABSOLUTE | | | | BASIC |
|---|---|---|---|---|---|
| | Independent structures | | Connected structures | | |
| | levelness or indecision | altimetry tolerance range + or - | levelness or indecision | altimetry tolerance range + or - | |
| • **Platforms - Roadways**<br>- Earth platforms<br>- Roadways | <br>10 cm<br>5 cm | <br>5 cm<br>3 cm | | | The deflections measured with the 3m ruler shall not exceed :<br>- Foundation layer : 2 cm<br>- Base layer : 1 cm<br>- Surface layer : 1 cm |
| • **Boring in the earth** | 20 cm | 10 cm | | | The deviation of the boreholes shall not exceed 3% of their length. |
| • **Piles, cast walls, sheet pilling**<br>- Structural foundations<br>- Watertight walls | <br>5 cm<br>10 cm | <br>3 cm (1)<br>5 cm (1) | | | For structural foundations, the deviation of the vertical elements such as piles, cast walls, sheet piling, etc. shall not exceed 1% of their length. This tolerance is raised to 4.5% for inclined piles or sheet piling. For watertight walls, the continuity of the wall shall be guaranteed |
| • **Concrete structures (2)**<br>- 1st phase concrete (3), embedded parts, penetrations performed during concreting (4)<br>- 2nd phase concrete (3), penetrations by boring | 5 cm | 3 cm | 3 cm | 2 cm | For tunnel, shaft or other excavation linings, the tolerance on the distance of the profile performed (or line R) to the profile set up after earthworks is ± 2 cm<br>For anchor plates and shells (sleeves and shells) the verticality or horizontality tolerance is 1% with a maximum off-centre of 1cm |

(1) At top of the structure

(2) For the structures made up of prefabricated elements, the tolerances and facing definitions shall apply as if the construction was performed on site by cast in situ concrete.

(3) The acceptance criteria of the facings (flatness and shape defects, texture) are defined in section 8.2

(4) Tolerances on the position of centre and the ends of the sleeves and shells.

(5) This tolerance may be increased for penetrations which do not require very precise positioning (electrical penetrations for example)

| TYPE OF WORKS | ABSOLUTE | | | | RELATIVE | | BASIC |
|---|---|---|---|---|---|---|---|
| | Independent structures | | Connected structures | | SIC buildings | | |
| | levelness | altimetry tolerance range + or - | levelness or indecision | altimetry tolerance range + or - | levelness or indecision | vertical measurements tolerance range +or - | |
| • **Large diameters conduits** | 5 cm | 3cm | | | 1 cm | 0,5 cm (1) | |
| • **Steel brackets for main cranes (2)** | 5 cm | 3 cm | | | 2 cm | 1 cm | All points on the upper horizontal anchor plate shall be between two horizontal planes 1,5 cm apart. |
| • **Structures and equipment**<br>- Grouted parts<br>- Large steel works (4)<br>- Small steel works, metalworks | 3 cm | 2 cm | 3 cm | 2 cm | 1 cm (3)<br>2 cm<br>1 cm | 0,5 cm (3)<br>1 cm<br>0,5 cm | The basic tolerances applicable to the steelwork and beams of the crane runways are given in chapter 15. |

(1) Axis with connections to other supplies.

(2) Tolerances on the position of the horizontal anchor plate to which the rail will be fixed.

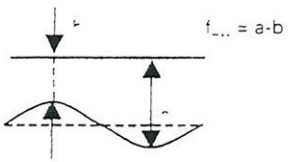
(3) Upper value of the tolerances of the grouted parts.

(4) Positioning tolerance of a given element with respect to the reference unit.

| TYPE OF WORKS | EXECUTION TOLERANCES |
|---|---|
| **Walls, beams and columns**<br><br>(1) retain the severest value of the two values. | Main linear dimension : $e_0 \leq 0{,}25\ \sqrt[3]{db}$ with :<br>db = theoretical dimension expressed in centimeters<br>$e_0$ is never less than 0.5 cm nor greater than 3 cm<br>This also applies to the dimensions of the cross section of walls, slab, columns and beams<br><br>Maximum off-centre : between two walls or two columns which must be superimposed<br><br>(1) $\begin{cases} e_1\ (\text{cm}) \leq & (1/15)\text{x}\ e_{min} \quad \text{where } e_{min} = \text{smallest thickness of the two elements} \\ e_1 \leq 3\ \text{cm} \end{cases}$<br><br>Verticality: cumulation of the tolerance over the height of a wall or column.<br><br>(1) $\begin{cases} e_2\ (\text{cm}) \leq & (1/15)\text{x}\ e \quad \text{where e = thickness of the elements} \\ e_2 \leq 0{,}5\ \text{cm} & \text{per meter height between floors or ends} \end{cases}$<br><br>Where $e_2$ = deviation between the axis of the theoretical wall and any point on the axial plane executed |
| **Offset between a beam and another beam or a column at support** | = maximum of b/30 or 3 cm<br>With b width of the beam in cm |

| TYPE OF WORKS | EXECUTION TOLERANCES |
|---|---|
| **Prefabricated slabs or pre-slabs**<br><br>**Prefabricated beams** | Straightness of the edges with respect to the straight line joining their ends : ± 0,5 cm<br><br>Maximum counter-camber = (L/100+2.5) cm, where L is the span expressed in metres<br><br>Maximum counter-camber after installation = 1 cm<br><br>Maximum vertical or horizontal deflexion measured anywhere along the non-loaded member = (L/200+1.5) cm<br><br>Maximum deflection under loads = 1.5 cm |

EXECUTION TOLERANCES (in normal execution conditions)

<table>
<tr><th>TYPE OF WORKS</th><th>STANDARD</th></tr>
<tr><td>Facing of walls and slabs</td><td>
Flatness, edges straightness and formwork panels flushing


f max = a - b
<table>
<tr><th></th><th>Flatness under 2 m straight rule</th><th>Flatness under 0.20 m rule</th><th>Straightness of edges and internal angles</th><th>Projection of formwork panels (Panels misalignment)</th></tr>
<tr><td></td><td>f max</td><td>f max</td><td>f max</td><td></td></tr>
<tr><td>Ordinary facing</td><td>1.5 cm</td><td>0.6 cm</td><td>1.5 cm</td><td>0.3 cm</td></tr>
<tr><td>Fine facing</td><td>0.8 cm</td><td>0.3 cm</td><td>0.8 cm</td><td>0.1 cm*</td></tr>
</table>
* with a length of misalignment of panels less than 1m per square meter of facing.
</td></tr>
<tr><td>Embedded plates</td><td>
Tolerance in the plane of installation = 50 mm in all directions, but limited to 30 mm for plates embedded at bottom of slabs<br>
Tolerance perpendicular to the plane of installation :outwards from the surface =0 mm<br>
: inwards from the surface = -5 mm<br>
Flatness of embedded plates (rotation from installation plane) after concreting: maximal dip is 1 mm under the 0.20m rule.
</td></tr>
<tr><td>Anchor rails</td><td>
Tolerance in length direction : + or - 50 mm<br>
Tolerance in cross direction :+ or - 20 mm<br>
Tolerance perpendicular to plane of installation: outwards from the surface = 0 mm ,<br>
: inwards from the surface = 10 mm
</td></tr>
<tr><td>Steel waterproofing liners (tanks, sumps)</td><td>
<u>Flatness of steel waterproofing liners after concreting:</u><br>
Under the 2 m-rule and the 0.20 m rule, maximum dips are :<br>
2 m rule = 0.5 cm<br>
0.20 m rule = 0.2 cm
</td></tr>
</table>

EXECUTION TOLERANCES

<table>
<tr><td rowspan="2">Type of Works</td><td colspan="2">Relative Tolerances Specifically to SIC structures</td><td rowspan="2">STANDARD</td></tr>
<tr><td>Flatness tolerance</td><td>Vertical measurements / tolerance ±</td></tr>
<tr><td>Screed, renderings</td><td>1 cm</td><td>0.5 cm</td><td>Flatness tolerance :<br>Under a 2 m rule and a 0.20 m rule, maximum dips are :<br><br><table><tr><td></td><td>2m rule</td><td>0.20m rule</td></tr><tr><td>Thrown renderings</td><td>1 cm</td><td>-</td></tr><tr><td>Renderings and second stage screeds</td><td>0.5 cm</td><td>0.2 cm</td></tr><tr><td>Incorporated screeds</td><td>0.7 cm</td><td>0.2 cm</td></tr></table></td></tr>
<tr><td>Reinforcement bars 1</td><td colspan="3">Tolerance in less on minimal cover (2) is nil<br><br>Tolerance on nominal cover is ± 1.0 cm. This tolerance is reduced to ± - 0.5 cm for pre-fabricated elements<br><br>For parallel reinforcement bars having a spacing not exceeding 10cm, tolerance on this spacing is ± 1 cm<br>In other cases, tolerance is ±2 cm in every direction.</td></tr>
</table>

(1) Use of coupling systems needs a precise positioning of the reinforcement bars. Arrangements made by the Civil Contractor to ensure this positioning (use of a templates, specific topographic organization…) as well as associated tolerances are defined in a procedure submitted to THE PURCHASER.

(2) Minimum cover and nominal cover are defined on the construction drawings.

# 6 EARTHWORKS

## 6.1 Foreword – applicable codes and standards

The works covered by the present specification must fulfil the standards cited in section 7 "Concrete Works" and 0 "Reinforcement" and the below standards.

Modifications or adaptations to these specifications may prove necessary in response to changes to the technical constraints of the project.

| Standard | Date | Title |
|---|---|---|
| NF DTU 12 | 08/95 | Earthworks for buildings |
| NF EN 1610 | 09/97 | Construction and testing of drains and sewers |
| NF P 94-093 | 10/99 | Sols. Reconnaissance et essais. Détermination des références de compactage d'un matériau. Essai Proctor normal. Essai Proctor modifié. |
| NF P 94-100 | 08/99 | Sols. Reconnaissance et essais. Matériaux traités à la chaux et/ou aux liants hydrauliques. Essai d'évaluation de l'aptitude d'un sol au traitement. |
| NF P 94-102-1 | 01/12 | Sols. Reconnaissance et essais. Sol traité au liant hydraulique, éventuellement associé à la chaux, pour utilisation en couche de forme. Partie 1 : définition – composition – classification. |
| NF P 94-102-2 | 01/12 | Sols. Reconnaissance et essais. Sol traité au liant hydraulique, éventuellement associé à la chaux, pour utilisation en couche de forme. Partie 2 : méthodologie des études de formulation en laboratoire. |
| NF P 94-103 | 04/12 | Sols. Reconnaissance et essais. Essai d'évaluation de l'aptitude d'un produit de traitement minéral sec à émettre de la poussière. |
| NF P 94-117-1 | 04/00 | Sols. Reconnaissance et essais. Portance des plates-formes. Partie 1 : module sous chargement statique à la plaque (EV2). |
| NF P 94-117-2 | 04/12 | Sols. Reconnaissance et essais. Portance des plates-formes. Partie 2 : module sous chargement dynamique à la plaque. |
| NF P 94-117-3 | 07/12 | Sols. Reconnaissance et essais. Portance des plates-formes. Partie 3 : coefficient de réaction de WESTERGAARD sous chargement statique d'une plaque. |
| NF ISO 6750 | 12/05 | Engins de terrassements. Manuel de l'opérateur. Présentation et contenu. |
| NF P 98-701 | 05/93 | Matériels pour la construction et l'entretien des routes. Centrales de traitement de matériaux. Terminologie et performances. |
| NF P 98-705 | 07/92 | Matériels de construction et d'entretien des routes : compacteurs – Terminologie et spécifications commerciales. |
| NF P 98-711 | 08/93 | Matériels pour la construction et l'entretien des routes. Traitement en place ou retraitement : matériels de préparation des sols et de stockage des liants pulvérulents. Terminologie. |
| NF P 98-712 | 08/93 | Matériels pour la construction et l'entretien des routes. Traitement en place ou retraitement : épandeurs de liants pulvérulents et |

| Standard | Date | Title |
|---|---|---|
| | | malaxeurs de sols en place. Terminologie. |
| NF P 98-713 | 08/93 | Matériels pour la construction et l'entretien des routes. Traitement en place ou retraitement. Fraiseuses. Terminologie. |
| NF P 98-736 | 09/92 | Matériel de construction et d'entretien des routes. Compacteurs. Classification. |
| NF P 98-760 | 12/91 | Matériel de construction et d'entretien des routes. Compacteurs à pneumatiques. Evaluation de la pression de contact au sol. |
| NF P 98-761 | 12/91 | Matériels de construction et d'entretien des routes. Compacteurs. Evaluation du moment d'excentrique. |
| NF P 98-771 | 12/94 | Matériels de construction et d'entretien des routes. Matériels d'aide à la conduite et de contrôle embarqués sur les compacteurs. Terminologie. Classification. |
| NOR: ENVP9430348A | 09/94 | Arrêté du 22 septembre 1994 relatif aux exploitations des carrières et aux installations de premier traitement des matériaux. |
| NOR: ENVP9650231C | 07/96 | Circulaire n°96-52 du 2 juillet 1996 relative à l'application de l'arrêté du 22 septembre 1994 relatif aux exploitations de carrières et aux installations de premier traitement des matériaux de carrières. |
| NOR: ATEP0100044A | 01/01 | Arrêté du 24 janvier 2001 modifiant l'arrêté du 22 septembre 1944 relatif aux exploitations des carrières et aux installations de premier traitement des matériaux et l'arrêté du 23 janvier 1997 relatif à la limitation des bruits émis dans l'environnement par les installations classées pour la protection de l'environnement. |

## 6.2 Excavation

### 6.2.1 *General*

Preliminary earthworks: excavation works and backfill in some areas have been first carried out in order to create a general platform set elevation 315 NGF.

This specification applies to the additional excavation works to be performed from this general platform for the buildings which are classified as SIC.

It will be therefore necessary to perform the work in a very careful and safe way, so that a full warranty may be given concerning the condition of the rock quality under the buildings.

It is recalled that all the blasting works must be completed before the first structural concrete pouring.

The excavation shall be dewatered permanently as specified in section 6.4.

The rock quality, including the treatment if necessary, will be submitted to a quality control and quality assurance program. Each step of the work has to be done according to:

The present technical specification,

Work procedures issued by the Contractor,

Quality plan prepared by the Contractor.

Each step of the work is performed under the responsibility of a qualified and experienced Contractor and controlled by a qualified representative of THE PURCHASER.

An official document will be issued for each instruction, each completion of a work.

All the documents issued during a work are reviewed, then stored in the "As built" document package in the jobsites offices, as soon as the task is completed.

A particular attention must be paid to this way of working, to the documentation to be implemented and consequently to the required degree of site organization at this stage.

The site organization should have the following features:

Permanent office and staff of THE PURCHASER for the guidance and control of the works,

Permanent office and staff of the Contractor for the execution works.

### 6.2.2 *Scope*

These specifications describe the earthworks to be performed in order to reach the foundation level from the level of the platform. It is considered that earthworks to obtain a platform at 315 NGF have already been done.

The earthworks will mainly stand in rock.

Excavation in the rock can be made using hydraulic rock-breaker, explosives or other technical means submitted to THE PURCHASER. Blasting will probably mainly be used for the excavation in rock.

These specifications do not apply to underwater blasting.

This specification does not give blasting detailed patterns and loadings, which are to be proposed by and under the responsibility of the Contractor.

### 6.2.3 *Prerequisite*

Engineering documents:

Prior the beginning of the excavation works, the following documents must be available on site:

Technical specifications

Technical specification for general earthworks,

Technical note concerning the engineering in situ properties of the foundation rock,

The rock parameters for the design of the structure (design criteria),

Technical specifications for blinding and substitution concrete,

Technical specification for the geological review and treatment under the buildings,

Technical note about the site topographic grid.

Work procedures:

Taking into account the requirements of the above documents, the Contractor will have to describe how he will meet them, with which technical means (equipment, staff, and local conditions on the site). The Contractor must prepare work procedures and working drawings and submit them to THE PURCHASER for review.

Work procedure for structural excavation, including blasting procedure,

Work procedure for the treatment of the rock faces of the cavity for Tokamak, Diagnostic and Tritium buildings,

Work procedure for blinding concrete,

Work procedure for substitution concrete,

Work procedure for rock-foundation cleaning and review,

Work procedure for rock treatment,

Work procedure for the bolts,

Work procedure for the shotcrete,

Work procedure for the drains drilled in the rock face.

Work drawings:

Excavation drawings, with the definition of the access and the phases of the works,

Excavation temporary drainage drawings,

Drawings of the rock faces with the definition and location of the nails, the drains, the weep holes and the shotcrete,

Excavation planning and scheduling.

Contractor's document submittal:

The work procedures and work drawings must be submitted to THE PURCHASER's site office at least 2 months before the beginning of the work. THE PURCHASER will review them during one month and may ask any improvements to the Contractor during this period.

The work cannot start if the review of the work procedure is not finalised.

### 6.2.4 *Site preparation*

The site has been rough graded and cleared prior the beginning of excavation.

### 6.2.5 *Realisation of earthworks*

The height of the passes will have to take into account the local stability in the face. The maximum height and the surface will be determined by the Contractor, depending on the nature of the rock encountered, but it shall not exceed 10 metres.

In all cases, the next pass will be done when the previous one is completed (earthwork, and if necessary grouting and reinforcement by bolts and shotcrete).

In case of the need of reinforcement of the rock, the following points will have to be complied with:

The earthworks in contact with shotcrete already done must be done carefully to avoid rock slide located behind the shotcrete done. If such a rock slide occurs, it must be stopped up with concrete before completion of the shotcrete below.

The earthworks will not be started unless all the structure (bolts and concrete reinforcement) can be performed during the day.

It will not be allowed to stop working, and the maximum duration between the earthwork and realisation of shotcrete will still be less than 12h.

A site survey will be done every pass and forwarded to THE PURCHASER in order to check if geology suits with the results of the geotechnical investigation (that will have to be done prior to earthwork).

In case of any difference between the findings and assumptions taken into account in preparing the project, it is necessary to proceed to corrections as soon as possible.

### 6.2.6 *Common excavation*

Common excavation consists in removing and ripping, without drilling or blasting, soil, soft rock and other material within the limits of the excavation.

The excavation shall conform to the elevations and grades, with allowable tolerance as defined in Section 5.

The Contractor may, at his expense, extend the sides of the excavation beyond the limit lines to suit his method (and approved work procedure) of excavation.

The finishing of the project level will be done by hand and mechanical tools as described in section 6.2.10.

## 6.2.7 *Rock excavation*

Excavation in rock can be made using hydraulic rock-breaker, explosives or other technical submitted to THE PURCHASER.

The possible use of rock-breaker will be regulated in the following manner:

If the power of rock-breaker is less than or equal to 250 joules, its use will not undertake any constraint.

If the power of rock-breaker exceeds 250 joules, its use will be accompanied by measures of vibrations. The vibration velocities should not exceed the limits allowed for the firing of explosives.

## 6.2.8 *Blasting*

### *6.2.8.1 General*

Below the main platform level, blasting will generally be needed to perform the excavation works.

It is recalled that employment must be specifically authorized by THE PURCHASER for the excavation phase, and that the rules will have to be respected. The use of explosives will be entrusted only to specialized people having a "Certificat de Préposé au Tir" (CPT) instituted by the interministerial order of 26, March 1997, or an equivalent foreign qualification certificate. A copy of this CPT or of the equivalent certificate shall be provided to THE PURCHASER two months before the beginning the works.

All the precautions must be taken in order not to damage the surrounding rock and the rock face treatment already done by a too powerful blasting which could fissure or crumble the rock.

The surveying of shot firing and signal measurement has to be done by the Contractor.

The program in the use of explosives, subject to approval of THE PURCHASER will include:

The nature of explosives,

The height or the length of shot firing,

The plans and procedures of shooting (drilling, loading, firing, followed by the shooting, marinating),

Security measures against projections and shocks,

Detonators for work in the open air.

Kind of blasting cap.

### *6.2.8.2 Security*

The Contractor will plan blasting taking into account:

Geology,

Rock fracturing,

Existing building or structure close to blasting area,

Paying attention to the rock surrounding the excavation.

The excavation will be performed by bench blasting, using single-multiples rows of blast-holes and short delays.

For the final grades slopes and embankment, pre-splitting, smooth blasting, as well as hand mechanical finishing will be used.

Pre-splitting and smooth blasted rocky faces will be cleared from spare blocks and secured. Appropriate treatment of rock faces under the main buildings will be decided by the Engineer-geologist in charge of the site geological review.

#### *6.2.8.3 Blasting plan*

For each shot firing, the Contractor will fill in a form on which will be given the below information:

Before firing:

Blasting pattern must be placed on a plan,

Difficulties encountered during drilling and placing explosives (locating faults or clay lenses for example),

Difference between predicted blasting and occurred blasting.

After firing:

The results of vibration recordings,

The statement from the front of slope,

The granularity of materials.

The forms will be signed by the foreman or the miner responsible for the shooting and brought to THE PURCHASER's site office. These forms and the plans will be available permanently on site.

This record does not relieve the Contractor of his responsibilities towards results to be achieved.

#### *6.2.8.4 Vibration control*

Whatever the technique adopted, there will be restrictions about the vibrations induced in the existing structures and buildings nearby.

As a general rule, the threshold values expressed in term of vibration peak particle velocity depending on the frequency of vibration shall be those defined by the "Arrêté du 22 septembre 1994 relatif aux exploitations des carrières et aux installations de premier traitement des matériaux » and the « Circulaire n°96-52 du 2 juillet 1996 relative à l'application de l'arrêté du 22 septembre 1994 relatif aux exploitations de carrières et aux installations de premier traitement des matériaux de carrières »

The peak particle velocity is limited to 10 mm/s. The ponderation function of the particle velocity is represented by three lengths of straight lines in a bi-logarithmic scale diagram defined by the below points:

| Frequency (abscissa) | Ponderation factor (ordinate) |
|---|---|
| 1 | 5 |
| 5 | 1 |
| 30 | 1 |
| 80 | 3/8 |

The above values may be reduced by THE PURCHASER for some buildings which houses equipment sensitive to vibrations.

For the reinforced concrete structures without any sensitive equipment, the threshold values are those of the "Arrêté du 22 septembre 1994" multiplied by a factor 1.5.

Additional requirements about vibration control are specified in paragraphs 6.2.8.8 and 6.2.8.9.

The monitoring of fire and the measuring of the signal are in charge of the Contractor (external control at the expense of the Contractor).

#### *6.2.8.5 Trial blast*

The Contractor will test and adjust the drilling and loading pattern for:

Ordinary bench 2 to 4 metres high,

Low bench less than 2 metres high,

Pre-splitting row and smooth blasting row for ordinary bench heights,

Single hole loading less than 1 metre depth.

The equipment will be adapted to this specification and it will be used for the final works. It will be fully described in the work procedure. This pattern will be adapted to the equipment (and described in a relevant work procedure).

The maximum overbreakage of a round is 0.4 metre at the bottom; it is reduced to 0.15 metre in case of pre-splitting.

The tests will be performed with the first rounds to be blasted. The detailed arrangement of the tests will be discussed between THE PURCHASER and the Contractor prior to the drilling of the holes.

Fully detailed reports for each test will be written by the Contractor and submitted to THE PURCHASER review at least one day after each test completion.

For each round, the test report will contain:

The date,

The location,

The name of the responsible engineer and his qualification,

The staff organization,

The drill hole diameter,

The drill hole pattern (scheme),

The detailed loading of the holes (scheme),

The type of equipment: drilling machine, charge type, fuse, detonators, ignition equipment,

The ignition plan: delay, sequence,

The throw,

The topographical checking of the final grade, the overbreakages and stumps compared to the intended level,

The ground vibration record at 30 metres from the round,

The safety measures: mats, flags, warnings, staff involved and name of the engineer responsible for the safety.

It is strongly recommended to the Contractor to involve a specialist's assistance during the trial tests and the work procedure finalization.

The final typical loading patterns successfully tested will be used without change for the whole job. They will be described in the structural rock excavation work procedure.

### *6.2.8.6 Pre-splitting and smooth blasting*

The choice of pre-splitting or smooth blasting will be justified by the Contractor to get the best possible cut in this rock.

The following provisions will be implemented and validated by trial blasting:

In the case of drilling with an out-the-hole drill, the maximum height of cut slope shall be 5 m, in order to limit the drilling deviations.

Pre-splitting in closed site should be avoided.

A pre-splitting will be carried out whenever possible on the final slope.

The diameter drilling of pre-splitting will be adapted to the type of explosive used, the below diameters are recommended:

For the pre-splitting with detonating cord, the diameter boreholes will be from 64 to 76 mm;

For the pre-splitting with boots gel (Cisalite, Sigmalite, etc..) the diameters of drilling will be from 102 to 105 mm;

The spacing of boreholes will normally be around ten times the diameter drilling, but this spacing may be changed depending on the nature of the rock and the results of trial blasting;

The tolerance of deviation drilling is ± 1 cm per linear meter of drilling;

Charges will be uniformly distributed along the drilling of pre-splitting;

The trial blasting will determine the charges that are best suited to the substratum and in particular to choose between technology pre-splitting by explosive high energy shock (explosive cord) or technical pre-splitting by high energy explosive gas (flange gels).

It may be reviewed pre-splitting and blasting of the contiguous bench during the same shooting, provided that the dates for the various detonation charges adhere to the principle of the priority of pre-splitting in relation to the shot firing.

Smooth blasting, in order to get acceptable and stabilized excavation faces, is to be performed for the external faces of the main excavations, when and where pre-splitting is not required.

Smooth blasting will be carried out for the subvertical slopes height of less than 3.50 m.

The spacing of the holes will be 10 times the drilling diameter and the bench (thickness of the slice to mine) will not exceed 1.20 m.

Blasting of the bench in front slope: mesh drilling will not exceed 2.50 square meters in the two rows of drilling on the front of cutting slope and the height of mining shall not exceed 6 m.

In front of a pre-splitted slope, earthwork of the bench will be operated by passes of maximum height of 5 m, in order to permit the realisation of anchors and shotcrete intended to ensure the stability of the rock mass, if needed.

A new earthwork cutting run will not be undertaken until slope reinforcements will not be completed on the last cutting run.

### *6.2.8.7 Blasting authorization-explosives storage*

The Contractor will get the necessary permits, authorization for purchasing, transporting and storing the explosives at his own expense and with the respect to the safety regulations.

Prior the blasting of a round, the Contractor must submit to THE PURCHASER’s review:

A blasting authorization request,

The time schedule of the blasting,

All detailed technical information concerning the round itself (hole diameter, pattern, load...),

Safety requirements.

This submittal is done at least 24 hours before blasting.

THE PURCHASER may give his comments, as well as a "stop" order at any time before the scheduled blasting time.

THE PURCHASER engineering staff will provide one Engineer responsible for the follow up of all these works.

The blasting shall be done only by skilled operators and under the authority of a qualified and experienced foreman.

#### *6.2.8.8 Blasting close to a structure*

The secondary excavation works, will have to be completed prior to the pouring of the first structural concrete. The following section applies only to quite exceptional and limited cases.

No blasting will be permitted within 30 metres of concrete or grout in place aged less than 5 days.

Blasting may be authorized, upon written request by the Contractor, at distance in excess of 30 metres from concrete or grout in place less than 5 days and more than 24 hours. In this case, a peak particle velocity measurement must be performed (see next section).

Blasting performed close to concrete or grout (without distance limitation) in place more than 5 days will be authorized only in exceptional case, after written request by the Contractor; pre-splitting will be request prior the blasting; the peak particle velocity will be controlled.

More usually, barring and digging by mechanical means only will be allowed.

THE PURCHASER may require the Contractor to stop any method of blasting than can be dangerous or destructive.

THE PURCHASER may require the Contractor to restore at its own expense any building, structure, masonry and equipment damaged by blasting direct or indirect effects.

#### *6.2.8.9 Control of the peak particle velocity*

The Contractor will provide at least one ground motion recorder in working order at any time, in order to record the peak particle velocity. The equipment will be calibrated and certified so that the results are reliable and of good accuracy. The record will be maintained in good condition. The recorder will be used for blasting trial test.

Every blasting in the vicinity of a concrete structure will be controlled with the recorder.

A maximum peak particle velocity corresponding to that of the "Arrêté du 22 septembre 1994" multiplied by 1.5 is allowed for a concrete or a grout in place for more than 24 hours.

If a maximum particle velocity higher than twice the values of the "Arrêté du 22 septembre 1994" is registered for a given structure, this structure will be considered as being possibly damaged and will have to be investigated so that possible repairs are proposed by the Contractor, including possible rebuilding of part of the structure. A "non conformance report" will be prepared for that.

## 6.2.9 *Rock face treatment of the cavity for Tokamak, Tritium and Diagnostic Buildings*

In order to guaranty the stability of the rock face and the excavation slope for a design life time of 70 years, either the rock faces will be treated; either reinforced concrete retaining walls will be constructed.

Rock face treatment includes:

Drilling holes and sealing bolts,

Placing shotcrete on the rock face,

Drilling and placing drains to collect and drain the water from the rock,

Drilling and placing weep holes to drain the water at the interface between the rock face and the shotcrete.

### *6.2.9.1 Bolts*

The aim of the nails is to improve the overall stability of the excavation slope.

The nails shall be protected from corrosion in the aim of ensuring a design life time of 70 years.

The Contractor shall provide in his offer a detailed description of the type of protection of the nails that he proposes to reach this design life time.

In complement of this protection, a decrease of the nail diameter due to corrosion will be taken into account for computing the allowable tension force resisted by the nail.

The spacing, inclination from the horizontal and length of the bolts will be determined by the Contractor in a technical note, submitted to the approval of THE PURCHASER, providing, by detailed calculations, the proof of the stability of the rock face. A uniform grid will be adopted whatever be the results of the calculations.

The spacing of the nails will be reduced in the areas where discontinuities are encountered during the excavation works.

### *6.2.9.2 Shotcrete*

The aim of the shotcrete is to protect the rock face from weathering and to prevent any local detachment of a rock block from the rock face.

Shotcrete will be placed on the rock face by the dry method, the minimum thickness of the shotcrete skin will be 250 mm, it shall be reinforced by welded wire mesh on both faces.

The Contractor shall draw up and submit to the approval of THE PURCHASER a work procedure fully describing the equipment used, the composition of the concrete, the way of placing, the trial tests and the controls on the placed concrete.

A test panel shall be shot, cured, cored and sawn, examined and tested prior to commencement of the works. The sample panel shall be representative of the project and simulate job conditions as closely as possible. The panel thickness and the reinforcing shall be the same as the panels of the project. It shall be shot at the same angle, by the same operator, with the same equipment and with the same concrete mix that will be used on the project.

All the requirements stipulated in the specifications for concrete and reinforcement in sections 7 and 0 apply to shotcrete, except those related to concrete placing.

#### *6.2.9.3 Drilled drains*

The aim of these drains is to intercept the discontinuities in the rock behind the rock face of the excavation which conduct the water and so to decrease the hydrostatic pressure exerted onto the rock and to improve the overall stability of the excavation slope, enabling to decrease the density of the nails. The drains also prevent the detachment of the shotcrete from the rock under the effect of the water pressure when the water table is high after heavy rains.

In order to detect the discontinuities in the rock, the parameters of the drillings shall be recorded.

The standard length of the drilled drains will be about 12 m, their standard spacing 4*4 meters and their slope 5° upwards from the horizontal. The final spacing and length of the drains will be determined by the Contractor in a technical note submitted to the approval of THE PURCHASER. The length of the drains shall be greater than the length of the bolts.

One or several rows of sub-horizontal drains may be placed at the bottom of the rock face in order to intercept the water below the excavation level. These drains act as discharge pits and contribute to reduce the water pressure exerted onto the underneath face of the raft of the buildings. Their characteristics are the same as the other drains, they are described below.

As guidance and as a minimum, if larger dimensions are not required to drain a higher flow, the characteristics of the drain will be as follows: the diameter of the hole will be 115 mm, the outside diameter of the PCV drain will be 90 mm; they are pierced by slots of width 1 to 2 mm, perpendicular to the drain axis, the percentage of openings is above 5%. The space between the PCV drain and the drilled hole is left void.

#### *6.2.9.4 Weep holes*

In complement of the above drilled drains, weep holes will be provided to drain the water at the interface between the rock and the shotcrete.

The spacing of the weep holes shall be about 2*2 meters and their embedment in the rock about 0.5 m. The characteristics of the weep holes shall be the same as the ones of the long drains.

A geomembrane of an area of about 1 square meter has been previously placed between the rock and the shotcrete at the location of the weep hole, in order to improve the efficiency of the drain. This geomembrane consists in two layers: a draining layer placed against the rock and a waterproof layer to be in contact with the shotcrete.

### 6.2.10 *Hand mechanical finishing*

This covers all hand equipment and tools used for excavating, wedging and finishing works in rock:

Steel rods, stone pick, drill-hammer,

Hammer, shovel.

This equipment needs usually to be completed by some mechanical devices such as:

Hydraulic backhoe,

Hydraulic or pneumatic rock break-hammer.

For the final cleaning of excavations, prior to topographical and geological checking, it is necessary to keep on site:

An air-jetting equipment (remove of dust, small particles, spare stones),

Scratching and brushing tools.

All finishing works will be done by hand mechanical means. This includes the over excavations which will be done in order to remove the unsuitable-weak rock, if any.

### 6.2.11 *Work procedures*

The Contractor shall submit to THE PURCHASER, for review, a procedure for structural rock excavation that shall include, but will not be limited to the following:

Site preparation,

Dewatering,

Access,

Planning,

Common excavation,

Blasting :

Safety: warnings, protection mats, responsible safety teams…

Time-schedule for blasting so as to interfere the least with normal project works,

Technical information.

After blasting: removal of blasted rock,

Control of rock soundness; removal of spare blocks,

Rock face securing: anchoring, wire mesh, dowel pins…

Hand-mechanical finishing works: staff, means…

Cleaning: air jetting, hand brushing,

Topographic checking, marking, mapping.

The works procedure first issue must be submitted to THE PURCHASER's review at least 2 months before the beginning of the said work.

### 6.2.12 *Acceptance of the final grade*

The final grades must be dry and cleared. They must be sound, without noticeable cracks due to blasting.

The temporary dewatering system must be ready.

A final cleaning will be performed. It includes:

Shovelling of dust, mud, stones particles deposited in hollow parts and their transportation to waste areas,

Air jetting of the entire area and shovelling of the dust due to it, then transportation to waste areas.

The quality plan forms must be completed.

## 6.3 Geological Review and Treatment under SIC Buildings

### 6.3.1 *Scope*

The acceptance of the rock-foundation is performed under the authority of a qualified and experienced engineer geologist.

The target of this acceptance is:

To check that the actual overall rock quality is in accordance with the hypothesis and criteria taken into account for the design of the structure,

To identify the geological defects, if any, for which a correction action will be necessary. This kind of action is called a "rock treatment". Its target is to restore the foundation rock so that it will be acceptable with respect to the design of the structure,

To record all the documents related to the acceptance and treatment, especially for the rock underlying the SIC buildings of Tokamak complex; all these documents will be joined in the as-built package.

## 6.3.2 *Prerequisite*

Prior to the beginning of the foundation acceptance process, for a given structure, several conditions will have to be fulfilled:

Among engineering documents,

Among drawings,

Among related work procedures,

Among the progress of site works.

For the three first points, see 6.2.3.

### *6.3.2.1 Site works*

For the best convenience the size of a basic area which will have to be reviewed for acceptance should not be smaller than 1/6 of the total foundation surface of the SIC buildings and 1/3 for each main building.The detailed arrangement and extent of the areas will be fixed on site according to local conditions.

The first area to be reviewed will be the one where the first structural concrete will have to be poured. The geological acceptance review and treatment sequence will then anticipate the raft bottom level concreting sequence.

The geological acceptance work will begin right after the end of the excavation works.

As soon as (within 12 hours delay) the acceptance of an area will be delivered, the rock will have to be protected by a layer of concrete. A cleanliness control is done just before pouring.

## 6.3.3 *End of the excavation works*

All the spare blocks, weakened layers, areas noticeably damaged by blasting effects must be fully removed by mechanical means until project level is reached.

An efficient temporary drainage-ditch network has been excavated and equipped with dewatering pumps, so as to maintain the project level in dry condition.

Enough access ramps allow an easy starting of the next activities and allow acceptable handling facilities on site.

An accurate cleaning of the excavated area is performed by shovelling, then air-jetting finishing. Hand brush finishing is necessary in order to get a perfectly clean rock bottom.

A topographical checking using some basic benchmarks related to the site secondary grid will control that the excavation is achieved within the specified margins with respect to the drawings.

A topographic map (recommended scale 1/100) will be drawn by the Contractor, showing the "as excavated" rock; it will bear some reference grid axis and the structure basic outlines and main boundaries (internal and external) which will be shown on site with some paint marks.

## 6.3.4 *Geological acceptance*

### *6.3.4.1 Main steps*

The main steps are:

Review of the site,

Mapping,

Rock treatment prior to pouring, when necessary,

Rock faces colour photography,

Final acceptance,

Concreting (substitution, blinding).

### *6.3.4.2 The geological review and mapping*

The topographical map prepared is given to the geologist who will perform on site the geological review of the area.

The geologist may ask for some additional cleaning if necessary, as well as additional spare blocks removing.

Topographic marks or other points will be added on site by the geologist along geological structures (cracks, faults, folds, change of rock nature and quality…) in order to plot them accurately during the review. The Contractor will provide necessary help and equipment (paint, topographical team…).

These points will be surveyed and added onto the topographical map described here above by the Contractor topographical team, right after the review.

The completed map is given to the geologist who will use it to finalise the geological mapping.

The geologist will issue a geological map of the structure foundation level (recommended scale 1/100).

### *6.3.4.3 Criteria for the rock quality acceptance*

Using the geological map, the geologist will give:

- The outlines of the area of acceptable rock,
- The outlines of the area where some rock treatment is necessary,
- The detailed treatment to be done in these areas.

The criteria of rock quality will take into account:

- The type of rock,
- The degree of weathering (grades derived from AFTES classification),
- The density of cracks, joints, faults,
- The length, depth and width of the defective areas (too strong weathering, too strong faulting, unexpected rock conditions…).

N.B: doubtful case may be raised when an unexpected rock condition is met, which cannot be treated according to the usual criteria and specification. It is then mandatory to solve this point on a case by case basis, with the technical agreement of all the design parties involved.

### *6.3.4.4 Type of treatment*

The method used for the treatment of usual defects is called “dental work”.

Other methods may be used for special cases which are not covered by this specification.

#### *6.3.4.5 Acceptance of treated area*

When the treatment work is completed, the Contractor gives to THE PURCHASER all the relevant documents including a full photographic cover of the rock bottom before any blinding, and before any substitution concreting in the over-excavated areas.

The geologist in charge of supervising the treatment prepares an official acceptance form (for each sub-area if necessary) if the final result is satisfactory. This form will be approved and dispatched by THE PURCHASER.

In cases of treatment with the dental work method, the geologist will check the rock quality and then issue the acceptance after the over-excavation and before the concreting.

#### *6.3.4.6 As built package*

The entire here above documents are stored in an "as built package".

#### *6.3.4.7 Final levelling*

When the acceptance for an area is given, the Contractor will place concrete on the top of the rock in order to restore the project foundation level. This placing has to be done at least 12 hours after the geological acceptance is issued.

This layer will be made with blinding concrete and substitution concrete which are laid onto the rock.

### 6.3.5 *Quality plan*

Each step of the work is controlled through a quality plan managed by the Contractor.

The Contractor gives a copy of the quality plan to THE PURCHASER, after completion of the work.

### 6.3.6 *Treatment with dental work method*

#### *6.3.6.1 Scope*

This specification describes the removal of weak rock or soil areas, then the filling of such areas with substitution concrete.

#### *6.3.6.2 Rock weathering classification*

The geology of the site consists in a calcareous substratum.

A classification in 5 grades is given below with correspondence with AFTES Classification:

- RS (residual soil): final weathering product of rock material which is completely converted into soil. It corresponds to class AM 5 of the AFTES Classification.
- HW (highly weathered): the rock is discoloured and more than half of the rock material is decomposed as a soil. It corresponds to class AM 5 and AM 4 of the AFTES classification.
- MW (moderately weathered): the rock is discoloured and noticeably weakened. Less than half of the rock material is decomposed to a soil. It corresponds to class AM 3 of the AFTES classification.
- SW (slightly weathered): the rock is slightly discoloured but not noticeably lower in strength than the fresh rock. All the discontinuities are stained. It corresponds to class AM 2 of the AFTES classification.

- F (fresh rock): no discoloration or slight discoloration along discontinuities, loss of strength or any other effect of weathering. It corresponds to class AM 1 of the AFTES classification.

#### *6.3.6.3 Criteria*

Under SIC buildings of Tokamak complex, fresh rock and slightly weathered rock will be considered as acceptable rock quality.

Moderately weathered rock may not be acceptable, depending on the actual extend and shape of such rock occurrence sensitivity to external meteorological condition (moisture…) and noticeable secondary effects of blasting work. Engineering judgment will be done under the authority of a qualified geologist and on a case by case basis.

Highly weathered (HW) rock and residual soil (RS) are considered as not acceptable rock.

Fault, shear zones, fractured zone when surrounded and-or filled with HW, RS, fault clay, breccias… are considered as not acceptable.

Rock showing noticeable effects due to blasting because of excavation works will be considered as not acceptable.

#### *6.3.6.4 The dental work method*

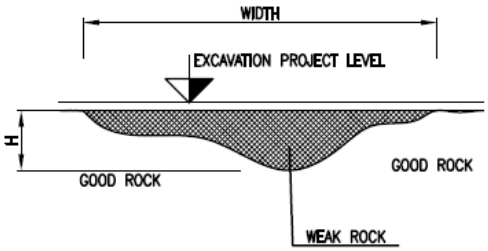
Basically, the "not acceptable" areas according to the here above criteria will be removed by mechanical means (without blasting), then carefully cleaned, and filled with substitution concrete (grade of substitution concrete is defined in paragraph 7.8.3.2). Then the excavation project level is restored by adding, where it is necessary, a layer of blinding concrete (grade of blinding concrete is defined in paragraph 7.8.3.2).

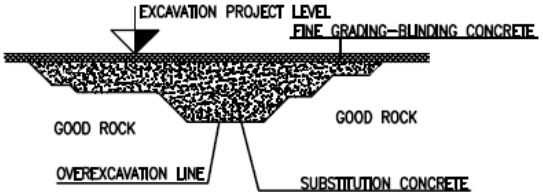
#### *6.3.6.5 Shape of substitution*

The three below cases are considered with the recommended shape of the substitution concrete, they shall be considered as typical cases and adapted on a case by case basis.

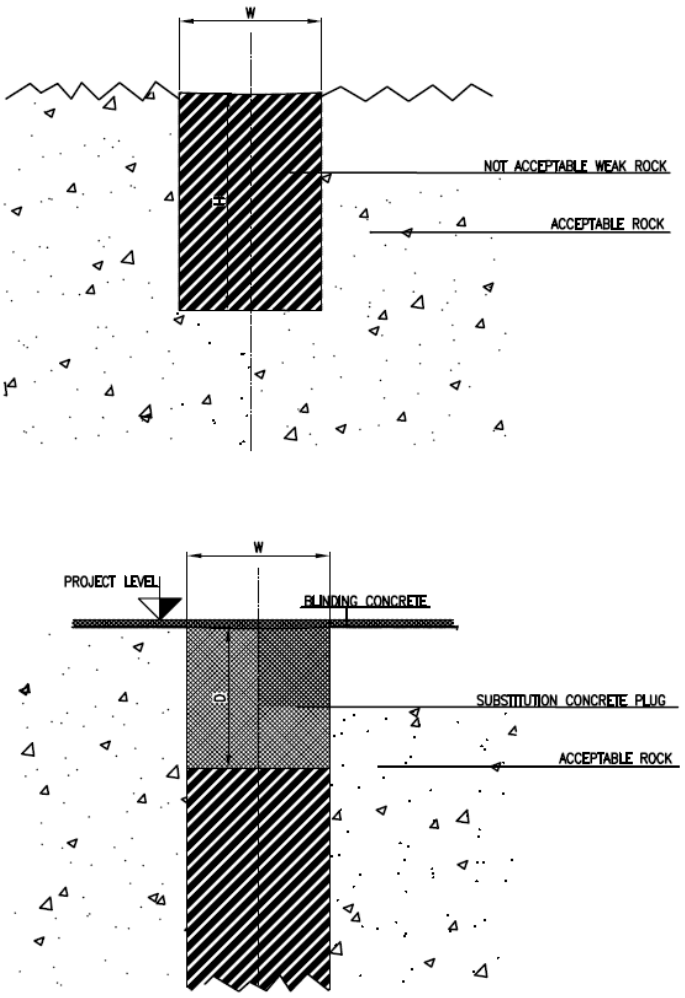
The grade of the substitution concrete is defined in paragraph 7.8.3.2.

- The not acceptable area is shallow (criteria : WIDTH > H),



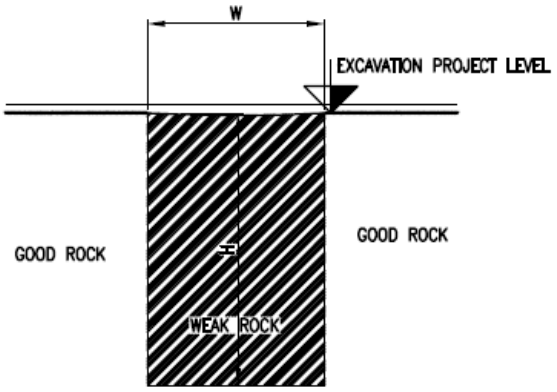



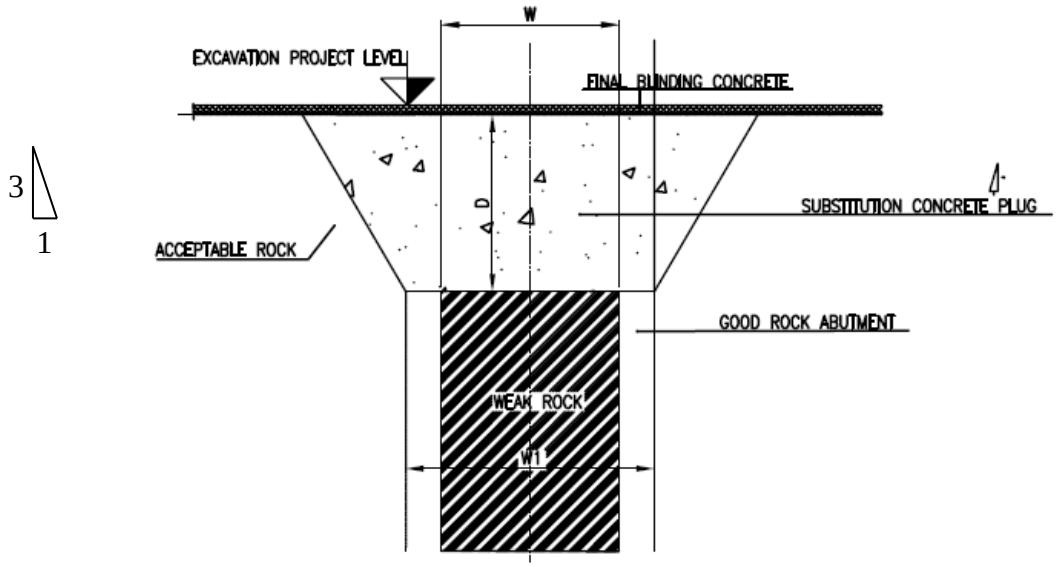
- The not acceptable area is subvertical, deep and narrow (criteria: width < 2 m, Height >> width),




Depth D = Width W

- The not acceptable area is sub-vertical, deep and wide
  (Criteria: 5 m > W > 2 m and H >> W),
  Sub-vertical means usually a flexible angle of deviation of ± 15° maximum from vertical reference.




$W_1 = W+2A$,

Where A is the width of the substitution concrete extending on each side of the weak rock, A = 0.2 W

D = W

The slope of the sides of the substitution concrete plug shall be about 1 in horizontal for 3 in vertical.

### *6.3.6.6 Other shape*

Where the not acceptable area has another shape, this will be studied on a case by case basis.

The advice of a rock-soil mechanics consultant will be required.

The rock-soil mechanics consultant will be designated by THE PURCHASER with the agreement of the civil works designer of the SIC buildings.

He will make a proposal in order to solve the case. This proposal will be agreed by both parties to its issuance toward site management with a CFC status.

## 6.4 Dewatering

The Contractor shall provide and run a dewatering network: trenches, pits, pumps so as to maintain in dry condition the area of excavation works.

Electrical pumps with floating switches are recommended so that the system operates automatically on a 24 hours/24 hours basis, when connected to the site electrical network.

If manual start of pump is preferred, the Contractor will have to place a special dewatering team operating day and night.

There will be a safety diesel generator on the site, connected to the pumps and ready to start, in order to face any electrical network breakdown.

The design of temporary dewatering system will be submitted to THE PURCHASER. It will be design for a strong rainfall rate. In addition, it will have to pump out all the underground ingresses.

The water flowing have to be divert in order to prevent flooding of the platform.

All the drainage outflows will be collected by trenches and culverts in order to keep the accesses free of flooding.

The drained water will be rejected into the storm basins already constructed: either the south storm basin or the ITER area storm basin

This system will run as long as required, until the construction of the buildings has reached a specified degree of completion.

## 6.5 Topographic surveying

### 6.5.1 *Tolerance*

The final grades must be completed with the following tolerance:

- Presplitting: no more than 15 centimetres beyond the project line,
- Smooth blasted slopes bottom, only at raft elevations: no more than 15 centimetres beyond the project line,
- Other: more than 10 centimetres and less than 40 centimetres beyond the excavation project line.

All the excavations in excess will be filled with substitution concrete by and at the Contractor’s expense, after the geological acceptance of the area.

### 6.5.2 *Final grade*

A topographical checking must be performed by the Contractor in order to establish the final grade elevation and draw the as-built excavation line. This checking is clearly related to the site topographic secondary grid monuments so that there can be absolutely no doubt concerning the coordinates and the elevation of the final grade compared to the project level (accuracy of the mapping shall be 2 centimetres).

When the excavation is clean, the topographical team will place paint-marks showing the major buildings raft outlines, so that the boundaries of the structures are clearly shown.

## 6.6 Backfilling

### 6.6.1 *Scope*

This specification covers the general backfilling.

### 6.6.2 *Type of backfilling*

If possible, materials coming from the preliminary site work and from the structural excavation will be used for backfilling. It can be light material or coarse material.

The location of backfilling of each type of material will be given on execution documents or drawings.

Fill material can be crushed, sorted, mixed in order to obtain different kind of material.

Unsuitable materials are forbidden in the backfill, especially:

Peat, timber and organic materials,

Material susceptible to spontaneous combustion,

Clay with a liquid limit > 80 and a plasticity index > 55,

Material with unsuitable moisture content.

### 6.6.3 *Execution of backfilling*

#### *6.6.3.1 Common conditions*

The backfill shall not contain unsuitable materials.

If unsuitable materials are found, they will have to be cleared.

#### *6.6.3.2 Procedure*

Backfill has to be spread correctly.

The meteorological conditions have to be good (not too dry, not too rainy).

The water content of each layer has to be checked.

The layer has to be removed if not acceptable.

Run-off water system if necessary to keep platform out of water (temporary drains or trenches have to be removed at completion of backfilling).

Light and rocky materials have to be spread layer after layer, according to compaction tests.

For rocky materials, no block shall have a dimension exceeding 2/3 of the layer thickness.

If necessary, some water can be added to wet the backfill.

#### *6.6.3.3 Execution tolerances – outside profiles*

The Contractor shall execute profiles as specified in the working drawings.

Final platform adjustment is obtained by levelling the peaks and filling the hollows, possibly with the addition of material, until the following requirements are met:

No point shall be above or below than 10 cm from the project altitude,

The surface obtained must be suitable for the circulation of light vehicles.

### 6.6.4 *Compacting*

#### *6.6.4.1 Test boards*

For each type of material, defined by its grading and water content, before the beginning of the works, the Contractor shall execute test boards to determine, as a function of the required compactness, the equipment to use and the utilisation conditions of the various compactors.

For the materials which present a high sensitivity to the water content and for which the compaction index decreases very much when the water content of the optimum Proctor is exceeded, their specified water content before compaction shall be –1% to –2% below the water content determined for the optimum Proctor.

#### *6.6.4.2 Inspection*

For light material, the requirements are:

Proctor's optimum water content: ± 3%, No value lower than 95% normal Proctor's optimum,

An average value of 98% normal Proctor's optimum.

Checking of these values have to be done by the Contractor every 2 000 $m^3$ for the general backfilling work.

For rocky material, plate loading tests have to be carried out. The criteria are:

EV2 > 80 MPa,

EV2/EV1 < 2.

#### *6.6.4.3 Submission of documents*

The Contractor will provide:

A technical note about the processes for the site excavated materials: excavating, stockpiling…

Backfilling trial-tests report,

A work procedure including at least:

Transportation,

Identification,

Measurement of the quantities,

Method for dewatering,

Methods for cleaning-clearing the subgrade,

Methods for backfilling, placing, compacting, checking,

Backfilling team organisation,

Reporting to THE PURCHASER: forms, frequency.

## 6.7 Excavation and backfilling of galleries and trenches

### 6.7.1 *Scope*

This section describes the excavation, the placing and control of compacted backfills around and under structures and buried structures.

### 6.7.2 *Type of material*

See section **6.6.2**.

## 6.7.3 *Compaction*

Light materials will be controlled trough Proctor tests.

Rocky materials will be controlled trough plate loading tests.

## 6.7.4 *Excavation and backfilling*

### *6.7.4.1 Excavation*

When digging trenches and excavations, the suitable excavated materials will be stored and kept in order to be re-used for the backfilling after completion of the structure. They will be re-used in accordance with the general criteria and specifications related to these structures.

Unsuitable and excess materials will be removed to dump areas as approved by THE PURCHASER.

The Contractor will provide and maintain all necessary temporary access roads and temporary drainage.

The Contractor will keep the excavation in dry condition with appropriate temporary means that will be removed-filled at completion of the work.

When and where blasting is required, specifications of section 6.2.8 will be fully followed.

When and where blasting is not required, specifications of sections 6.2.6 and 6.2.7 will be followed.

The tolerance of the final grade will be adjusted as following: 40 centimetres maximum beyond the excavation project line, and 10 centimetres minimum under the excavation project line. These 10 centimetres are used for the placing of a blinding concrete layer.

The excavation in excess will be filled by compacted backfill or substitution concrete at the Contractor's expense.

The Contractor will maintain the excavations slopes at a stable and safe status.

### *6.7.4.2 Backfilling*

See section 6.6.3.

When materials are laid within a 5 metre distance from a structure, the thickness of layer is limited to 50 centimetres.

When filling is to be placed against structures, it will have no elements with a diameter more than 100 mm within 1 metre of the structure.

## 6.7.5 *Backfill supporting a structure*

See section 6.6.4.

## 6.7.6 *Subgrade of a structure*

See recommendation of light material in section 6.6.4.

It is assumed that unsuitable material will be removed and substituted with compacted fill or substitution concrete.

The excavation has to be kept in dry conditions (temporary trenches and pumping pits if necessary, that will have to be removed at the end of the work).

## 6.7.7 *Backfill surrounding a structure*

For compacting light and rocky material see section 6.6.4.

The below particular measures shall be observed:

When rocky materials are laid within a 5 metre distance beside a structure, the elements greater than 350 mm must be carried away. No elements with a diameter more than 100 mm will be placed within 1 meter of the structure.

Where backfill is to be drained, provide pervious coarse grained materials separated with filters (non woven polyester material chosen to be compatible with the materials being separated) from other backfills to prevent clogging of drains and washout of fines particles.

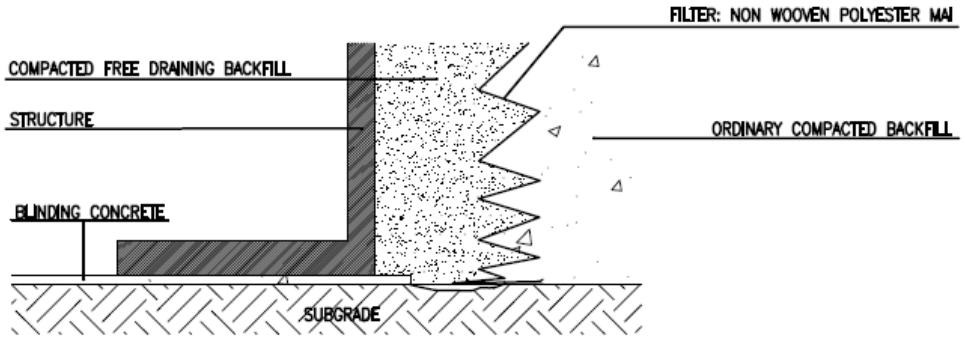
Close to low walls (height less than 2 meters), heavy compaction equipments are not allowed to operate closer than a distance equal to 2/3 the unbalanced height of fill at any time.

The structure will be equally covered on all sides. Its stability must be preserved.

In narrow areas, or in areas without access for trucks, plate loading test could be replaced by density test.

The criteria to be met will be the average value of densities corresponding to satisfactory plate loading tests performed during trial tests.

Moreover, the accordance of compaction execution with the relevant work procedure will be strictly controlled.




## 6.7.8 *Backfilling trenches for pipes*

For compacting of light and rocky material see section 6.6.4.

When rocky materials are laid within a 5 metre distance beside a structure, the elements greater than 350 mm must be carried away. No elements with a diameter more than 100 mm will be placed within 1 meter of the structure.

Other recommendations

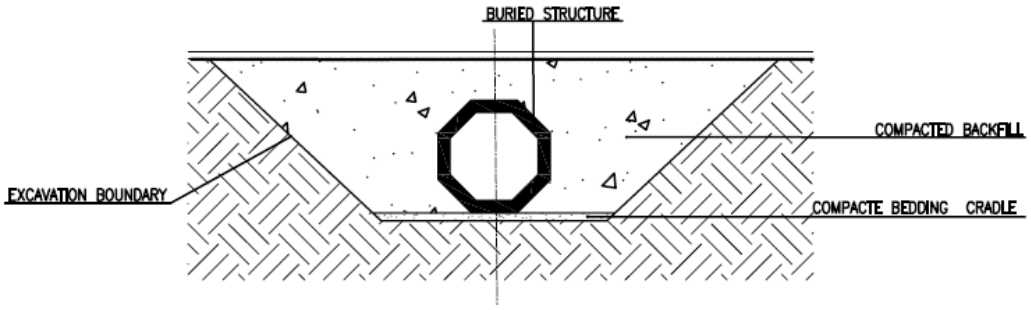
A cradle is formed in natural soil and backfill, placed by tamping in order to provide the proper bedding layer. The bedding layer is compacted as indicated in section 6.6.4.

Backfill placed within 2 metres against pipes and buried structures will not have elements larger than 100 mm.

The structures will be equally covered on all sides.

Any precautions must be taken when compacting above pipes in order not to damage them: the use of heavy compactors will be strictly limited in such area and will take into account the pipes-structures loading capacity and safe thickness of backfill cover over the said systems.

The backfilling will be performed in such a way that the stability of the structure is preserved.




### 6.7.9 *Backfill made of substitution concrete*

Buried utilities may need to be maintained with concrete block support or to be laid onto concrete bedding.

Besides, where and when soil fills cannot be compacted in compliance with the requirements: narrow spaces, fills between circular pipes laid close to each other, it will be necessary to use substitution concrete fill.

### 6.7.10 *Tests*

The following data are to be collected (using standards in application):

Current identification test:

Sieve analysis,

Atterberg limits,

Soil classification.

Compaction – moisture – density field test:

Dry density,

Moisture content,

Plate loading test.

Laboratory compaction test (Proctor test).

Frequency of these tests will be determined with quantities of backfill to be placed.

### 6.7.11 *Work procedure*

The Contractor will submit a work procedure where the following items will be described:

Backfill team organisation,

Backfill equipment,

Equipment for watering,

Laboratory equipment and internal testing procedures,

Control of fill material,

Backfilling method,

Fulfilling control forms,

Reporting to THE PURCHASER.

### 6.7.12 *Trial tests for the work procedure*

Trial tests must be carried out before beginning the work.

Trial tests will determine:

Thickness of layer for each type of soil,

Compacting intensity,

Kind of roller used,

Number of passes.

Controls will have to be done during compacting.

## 6.8 Underground earthing circuit

The underground earthing circuit is in the scope of the Civil Contractor and shall be constructed in compliance with the following technical specifications:

The Civil Contractor shall refer to EDH Part 4: Electromagnetic Compatibility (EMC) (ITER_D_4B523E) and EDH Part 5: Earthing and Lightning Protection (ITER_D_4B7ZDG) for all technical requirements relating to the underground earthing circuit.

# 7 CONCRETE WORKS

## 7.1 References

Civil Works - List of Applicable Codes and Standards.

Reference documents are indicated Section per Section in this specification.

## 7.2 Aggregates

### 7.2.1 *SCOPE*

This section applies to aggregates for concrete and hydraulic mortar in structures covered by the contract. All materials must be subjected to acceptance tests before use and to check tests during their utilization.

The materials used and the services provided shall meet the requirements of this specification and the below reference documents.

### 7.2.2 *DOCUMENTS QUOTED IN REFERENCE IN THIS SECTION*

#### *7.2.2.1 Standards*

NF EN 196-2 (04/06): Methods of testing cement – Part 2 – chemical analysis of cement

NF EN 206-1 (04/04) and Addenda A1 of April 2005 and A2 of October 2005: Concrete – Part 1: Specification, performance, production and conformity

NF EN 933-1 (05/12) Tests for geometrical properties of aggregates - Part 1: Determination of particle size distribution - Sieving method.

NF EN 933-2 (05/96) Test for geometrical properties of aggregates - Part 2: Determination of particle size distribution - Test sieves, nominal size of apertures.

NF EN 933-3 (03/12) Tests for geometrical properties of aggregates - Part 3: Determination of particle shape - Flakiness index.

NF EN 933-4 (06/08) Tests for geometrical properties of aggregates - Part 4: Determination of particle shape - Shape index.

NF EN 933-5 (06/98) + Addendum A1(07/05) Tests for geometrical properties of aggregates - Part 5: Determination of percentage of crushed and broken surfaces in coarse aggregate particles.

NF EN 933-6 (09/02) Test for geometrical properties of aggregates - Determination of surface characteristics - Part 6: Flow coefficient of aggregates

NF EN 933-7 (08/98) Tests for geometrical properties of aggregates - Part 7: Determination of shell content - Percentage of shells in coarse aggregates.

NF EN 933-8 (03/12) Tests for geometrical properties of aggregates - Part 8: Assessment of fines - Sand equivalent test.

NF EN 933-9 (12/09): Tests for geometrical properties of aggregates – Part 9: Assessment of fines. Methylene blue test.

NF EN 1744-1 (10/10): Tests to determine the chemical properties of aggregates – Part 1 – chemical analysis.

NF EN 12620 + A1 (06/08) (08/03): Aggregates for concrete.

NF EN 13055-1 (12/02) Lightweight aggregates - Part 1 : lightweight aggregates for concrete, mortar, and grout

EN ISO 14001 Environmental management

NF EN 1097-1 (08/11) Tests for mechanical and physical properties of aggregates - Part 1: Determination of the resistance to wear (micro-Deval)

NF EN 1097-2 (06/10) Tests for mechanical and physical properties of aggregates - Part 2: Methods for the determination of resistance to fragmentation

NF EN 1097-5 (10/08): Test for mechanical and physical properties of aggregates – Part 5 – Determination of the water content by drying in a ventilated oven.

NF EN 1097-6 (06/01): Test for mechanical and physical properties of aggregates – Part 6 – Determination of particle density and water absorption.

P 18-576 (12/90): Aggregates – Measurement of the friability coefficient for fine aggregate

NF P18 545 (09/11): Aggregates – Defining information, compliance, codification and related test standards. Only french version

FD P 18-542 (02/04): Aggregates – Classification criteria governing natural aggregates for hydraulic concrete with respect to the alkali-reaction. Only french version

P 18-556 (09/90): Aggregates - Determination of the continuity index. Only french version

P 18-557 (09/90): Aggregates - Elements for identification of aggregates. Only french version;

#### *7.2.2.2 Other documents*

Recommendations for the prevention of damage caused by the alkali-reaction, LCPC, June 1994.

Recommandations pour la prévention des désordres dus à la réaction sulfatique interne of the LPC (Laboratoires des Ponts et Chaussées) August 2007.

Guide to drawing up the quarry file, LCPC, June 1994.

### 7.2.3 *REQUIREMENTS AND RELATED CHECKS*

#### *7.2.3.1 General stipulations*

The aggregates used are natural and common in accordance with standard EN 12620 and NF P 18-545 item 10.

The aggregates used for C30/37 concrete shall, at minimum, comply with the category B specifications in standard NF P 18-545.

The aggregates used for C40/50 concrete shall comply with the category A (one or two specifications could be B after studies or reference in accordance with Fascicule 65) specifications in standard NF P 18-545.

Lightweight aggregates shall conform to the requirements of NF EN 13055-1.

The aggregates shall be subject to a certificate of compliance by obtaining the CE marking, where applicable.

#### *7.2.3.2 Classification with respect to the alkali-reaction*

The prevention level adopted vis-à-vis the alkali-reaction is level C.

Each type of aggregate forming part of the composition of the concrete shall be classified as either non-reactive (NR) or potentially reactive (PR), or potentially reactive to the effect of pessimum (PRP). This classification must be carried out by a specialist laboratory, subject to the approval of THE PURCHASER, according to document bundle P 18-542. The classification of a production shall be carried out in accordance with the "Recommendations for the prevention of damage caused by the alkali-reaction" (LCPC, June 1994).

**In principle, NR aggregates will be used**. However, bearing in mind local deposits, the use of PR or PRP aggregates is possible subject to compliance with the stipulations of Section 7.7.

Alkaline content levels in cement and aggregate shall be controlled and the non-reactivity of the alkaline-boosted formula shall be ensured, whilst evaluating safety margin available vis-à-vis the reaction activation threshold.

#### *7.2.3.3 Chloride, sulphate and sulphur content*

The chloride and sulphur content of the aggregates shall comply with the overall criteria of the concrete described in Section 7.8. To this end, marine aggregates, if used, shall be washed in fresh water in order to observe the maximum level of chlorine ions (determined by the Civil Contractor and submitted for the approval of THE PURCHASER) which may be contributed by the aggregates.

The maximum size of the pyrite grains and other oxidizable metal compounds shall be limited to 2 mm.

#### *7.2.3.4 Information to be submitted by the Civil Contractor*

For each type of aggregate (including aggregates which fall within the composition of the mix), the origin and level of active alkaline content (test method LPC n°37) expressed in equivalent $Na_2O$ (in the case of PR and PRP aggregates), and the origin and level of sulphates and chlorides shall be submitted to THE PURCHASER at the same time as the technical datasheet for the product.

When the aggregates come from a quarry, a deposit characterisation and identification file (quarry file) shall be drawn up via core boring on the geological entities to be exploited during the construction operations.

This file, drawn up during the design study of the concrete (for example, according to the principles of the "Guide to drawing up the quarry file" of the LCPC, June 1994), shall show the core boring plan and the results of the following tests for the various geological entities:

- identification of aggregates via petrographic analysis in accordance with standard P 18-557,
- determination of the continuity index of the rock for crushed stone materials, in accordance with standard P 18-556,
- intrinsic and manufacturing characteristics: the tests shall be carried out in accordance with the standards referenced in standard NF P18-545 and/or NF EN 12-620,
- friability coefficient of sands in accordance with standard P 18-576,
- micro-Deval coefficient in the presence of water, in accordance with standard NF EN 1097-1 + Addendum A1,
- classification with respect to the alkali-reaction as specified in LCPC, June 1994 document "Recommendations for the prevention of damage by alkali-aggregate reaction",
- the quarry exploitation plan with:

  overview of the quarry installations (hoppers, breakers, crushers, screens, storage, etc.)

  the projected mode and programme for quarry exploitation operations.

#### *7.2.3.5 Further requirements for aggregates for prestressed concrete*

The aggregates used for prestressed concrete shall comply with the category A specifications in standard NF P18-545.

In addition to the stipulations of this standard, the sand friability coefficient, in accordance with standard P 18-576, shall be equal to or lower than 30 (FS $\leq$ 30) and the sands used shall have regularity ranges comprised within the specification range as follows:

| Sieve in mm | Screened material PERCENTAGE OF TOTAL MASS OF SAND | |
|---|---|---|
| | at minimum | at maximum |
| 5 | 98 | - |
| 2.5 | 85 | 95 |
| 1.25 | 65 | 85 |
| 0.63 | 40 | 60 |
| 0.315 | 20 | 38 |
| 0.16 | 10 | 20 |
| 0.08 alluvial | 2 | 6 |
| 0.08 crushed | 2 | 10 |

**Table 1**

If the grain size of the sand extracted or manufactured does not fall within the range, it shall be treated or mixed with several other sands. If necessary, elementary sands will be proportioned separately at the concrete mixing plant.

#### *7.2.3.6 Further requirements for aggregates for concrete subject to action from water flow*

Fine gravel used for concrete subject to the action of water flow (for example, pumping station casings) have a micro-Deval coefficient in the presence of water, in accordance with standard NF EN 1097-1 + Addendum A1, of less than or equal to 25 (MDE $\leq$ 25).

#### *7.2.3.7 Further requirements for high density aggregates for Heavy concrete*

The aggregate shall conform to the requirements of NF EN 12620. The clay, silt and dust values shall be limited to 2% maximum by mass for coarse and fine aggregate. With prior written permission of THE PURCHASER, alternate grading may be used if the Civil Contractor can demonstrate their use satisfies all other requirements of the specification.

The relative density of aggregate on an oven dry basis for both coarse and fine material shall be not less than 4.15. The Civil Contractor shall not mix different sources of heavy aggregates throughout the duration of the Contract, without the prior written permission of THE PURCHASER.

A chemical analysis of the proposed aggregate shall be submitted to THE PURCHASER for acceptance at the start of the Contract and prior to any proposed change in source. This shall include lead content together with any other heavy metals present. The Civil Contractor shall note that these may have a derogatory effect on the hydration process of the concrete. A maximum combined lead and zinc content of 1.5% by weight of total dry aggregate is permitted, unless prior written agreement is given by THE PURCHASER.

The Civil Contractor shall guarantee THE PURCHASER that the supplier of heavy aggregates operates adequate quality systems during all stages of the production of the aggregates in order to meet the requirements of this specification.

The Civil Contractor shall ensure that all deliveries of aggregates are accompanied by a Certificate of Compliance from the supplier in relation to grading and relative density.

The Civil Contractor shall submit a report of the physical properties of the proposed materials to THE PURCHASER at the start of the contract. This shall include grading's, relative densities and water absorption, ten per cent fines, flakiness and elongation (coarse aggregate only).

Heavy aggregates shall be suitable to allow the same thermal expansion coefficient than the one used for normal concrete (10x10-6/°C) therefore barite aggregates are not allowed.

#### *7.2.3.8 Further requirements for lightweight aggregates for concrete, mortar and grout*

Lightweight aggregates shall conform to the requirements of NF EN 13055-1.

The mastery of the production will be in accordance with the normative appendix F of the standard NF EN 13055-1.

#### *7.2.3.9 Study, suitability and control tests*

The Civil Contractor shall carry out study, suitability and control tests on the aggregates. The aggregates must satisfy:

- study and suitability tests, prior to the supply thereof on the site,
- control tests, prior to the use thereof in the concretes.

However, if the Civil Contractor can submit reports for tests carried out by a COFRAC-certified laboratory proving that the aggregates have some of the required characteristics, the corresponding tests do not need to be repeated within the framework of the study test.

The table below summarises the study, suitability and control tests currently in progress, duly stating the frequency of the control tests:

| | TESTS | STANDARD | STUDY | SUITABILITY | CONTROL |
|---|---|---|---|---|---|
| FILLERS 0/D (D<2mm) and fine sand 0/D (D≤1mm) | Particle size distribution by sieving | NF EN 933-1 | X | X | 1 per delivery day |
| | Cleanliness: methylene blue value | NF EN 933-9 | X | X | 1 per delivery day |
| | Alkali-reaction | P 18-542 | X | | |
| SAND 0/D 1<D≤6.3mm | Friability of sands | P 18-576 | X | | |
| | Cleanliness of sands:Sand equivalent at 10% fines | NF EN 933-8 | X | X | 1 per delivery day |
| | Organic matter: colorimetric test | NF EN 1744-1 | X | X | 1 per month for alluvial materials |
| GRAVEL d/D d≥1mm D≤125mm | Continuity index (of rock for crushed materials) | P 18-556 | X | | |
| | Micro-Deval in the presence of water (for concrete particularly subject to the action of water) | NF EN 1097-1 | X | | |
| | Los Angeles | NF EN 1097-2 | X | X | |
| | Surface cleanliness | P 18-591 | X | X | 1 per delivery day |
| | Flakiness | NF EN 933-3 | X | X | 1 per week |
| SAND and FINE GRAVEL | Identification of aggregates | P 18-557 | X | | |
| | Particle size distribution by sieving | P 18-560 | X | X | 1 per delivery day |
| | Density, porosity, absorption coefficient, water content | P 18-554<br>P 18-555 | X | X | water content: 1 per concreting day |
| | Alkali-reaction | P 18-542 | X | | |
| | Determination of the total sulphur content | NF EN 1744-1 | X | | |
| | Gravimetric proportioning of sulphate | NF EN 196-2 | X | | |
| | Chloride content | NF EN 1744-1 | X | | |
| | Chloride content of marine aggregates | NF EN 1744-1 | X | X | 1 per delivery day |

**Table 2**

For the lightweight aggregates the frequency of controls will be in compliance with the picture (board) F1 of the standard NF EN 13055-1.

With the agreement of THE PURCHASER, the chloride content of marine aggregates may be checked via a resistivity test.

The procedure for carrying out this test shall be drawn up by the Civil Contractor on the basis of a resistivity calibration/chloride content study determined in accordance with the Volhard

method (NF EN 1744-1). This procedure, subject to the approval of THE PURCHASER, shall specify, in particular, the quantity of aggregates to be introduced, the amount of demineralised water to be added, the waiting time, and the uncertainty of the measurement.

This test is conducted after washing the marine aggregates. The limit criterion, established by the Civil Contractor and submitted for the approval of THE PURCHASER, must enable the possibility, taking into account the uncertainty of the measurement, of ensuring, with regard to reinforced concrete or concrete containing embedded metallic parts, that the chloride content of the aggregates is low enough to observe the overall criterion in the concrete.

#### *7.2.3.10 Storage*

The supplier has to take precautions to protect the quality of aggregates.

Aggregates of different categories or different grain classes are stored in separate batches in order to avoid mixtures.

Aggregates shall not be delivered directly to the batching plant; instead it should be delivered first to a buffer stock pile.

The storage capacities on or near the site for the various categories of aggregates correspond to two weeks consumption at the highest concreting rate.

The storage areas and traffic systems around the storage areas shall be drained and coated with a layer of concrete, or treated to ensure equivalent conditions of cleanliness. All the stocks, on the ground or in hoppers, will have to be the object of identification by registrations or by signs.

All precautions shall be adopted to avoid the segregation of the aggregates during storage or reworking and to avoid any mud which may accumulate in storage areas and the bases of the silos being mixed in the concrete and mortar. These storage areas and silo bases shall be periodically cleaned and washed.

#### *7.2.3.11 Further requirements for storage of High density aggregates*

To avoid possible contamination of High density aggregates with aggregates for different purposes, different sources shall be stored separately from other aggregates.

High density aggregates shall be stored under cover on an impervious hard standing with suitable drainage measures.

The Civil Contractor shall employ handling methods that prevent degradation of High density aggregates.

High density aggregates are prone to degradation by attrition. The mixing time shall be controlled to prevent degradation of the aggregates by over-mixing.

## 7.3 Cement

### 7.3.1 *SCOPE*

This technical specification applies to the cement used in the construction of concrete structures covered by the contract. It defines the following:

- the criteria governing the choice of cements,
- the conditions of delivery and storage,
- the related inspections and checks.

- Any material must be subjected to manufacture tests before delivery and check tests before use. Cement products shall be produced by certified suppliers operating EN ISO 14001 systems.

## 7.3.2 *DOCUMENTS QUOTED IN REFERENCE IN THIS SECTION*

### *7.3.2.1 Standards*

NF EN 196-1 (04/06): Methods of testing cement – Part 1: Determination of strength

NF EN 196-3 (04/06): Methods of testing cement – Part 3: Determination of setting time and soundness

NF EN 196-6 (04/12) Methods of testing cement – Part 6: Determination of fineness. Only French version

NF EN 196-9 (09/04): Methods of testing cement – Part 9: Heat of hydration – Semi-adiabatic method

NF EN 197-1 (04/12): Cement – Part 1: Composition, specifications and conformity criteria for common cements

NF EN 206-1 (04/04) and Addenda A1 of April 2005 and A2 of October 2005 °: Concrete – Part 1: Specification, performance, production and conformity

P 15-466 (08/83): Binders – Rapid recognition of cement at the time of delivery by comparison with a reference sample

P 18-363 (12/86): Admixtures for concrete, mortar and grout – Ordinary injection grouts for prestressed concrete – Determination of false setting (Tusschenbroeck test)

NF EN 196-6 (04/12): Methods of testing cement – Part 6: Determination of fineness. Only french version

NF EN 196-7 (07/08): Methods of testing cement – Part 7: Methods of taking and preparing samples of cement. Only french version, english version expected in 2008

NF P 15-318 (09/06): Hydraulic binders – Cements with a limited sulphur content for prestressed concrete. (Only french version)

NF P15-433 (02/94) Methods of testing cement. Determination of shrinkage and swelling.

NF P15-466 (08/83) Binders – rapid recognition of cement at the time of delivery by comparison with a reference sample

NF P18-363 (12/86) Admixtures for concrete, mortar and grout – Ordinary injection grouts for prestressed concrete – Determination of false setting (Tusschenbroeck test)

## 7.3.3 *REQUIREMENTS AND RELATED CHECKS*

### *7.3.3.1 Criteria governing choice of cements*

7.3.3.1.1 General characteristics

Cements shall comply with standard NF EN 197-1 and shall be subject to a certificate of compliance via admission under the marking "NF – Hydraulic Binders".

If, under exceptional circumstances, special, non-standardised cements are used, these shall be subject to an equivalent check in accordance with the marking "NF – Hydraulic Binders" via a COFRAC-certified laboratory.

The additional characteristics required for the cement used are defined below and in Section 7.8.

7.3.3.1.2 Cement for prestressed concrete

The cements used form part of the list of the marking "NF – Hydraulic Binders" with the inclusion of CP1 for prestressing via post-tension and CP2 for prestressing via pre-tension. These cements shall comply with standard NF P 15-318.

The cements used for prestressed structures shall not contain either fly ash or blast furnace slag and must, moreover, observe the stipulations of paragraph "Cement for mass concrete".

7.3.3.1.3 Cement for concretes exposed to sea salt or in contact with seawater

Cements used for concrete subjected to exposure classes XS1, XS2 and XS3, in accordance with standard NF EN 206-1, form part of the list of the marking "NF – Hydraulic Binders" with the inclusion of "PM" (for marine construction).

7.3.3.1.4 Cements for structures in contact with highly-sulphated water

When the aggressively class XA1, XA2 or XA3 as per standard NF EN 206-1 results from the presence of sulphates, the following prescriptions shall be complied with:

- The cement used for concrete subjected to exposure class XA1 are included in the list of the mark "NF-Liants hydrauliques" and be labelled "PM" ( Prise Mer) and the composition of the binder must be such that it meets the requirements of standard XP P 15-317.
- The cement used for concrete subjected to exposure class XA2 and XA3 are included in the list of the mark "NF-Liants hydrauliques" and be labelled ES (concrete works in highly sulphated water) and the composition of the binder must be such that it meets the requirements of standard XP P 15-319.

7.3.3.1.5 Cements for structures in contact with pure (slightly mineralized water)

Cements used for structures in contact with waters the total hardness of which TH is less than 6 french degrees are either cements with a high slag content (CEM III/B, CEM III/C in the context of standard NF EN 197-1or CEM II/B, CEM IV or CEM V containing at least 30% of pozzolanic secondary constituents, in the context of NF EN 197-1).

The use of other cements meeting the standard NF EN 197-1 is possible, in combination with additives, provided that the slag content of the binder is greater than 60% or that the pozzolanic secondary constituent content in the context of NF 197- is greater than 30%.

7.3.3.1.6 Cement for large volume of concrete and confinement areas

This clause is particularly important for cement used in concrete for slab and wall elements designed for gas pressure confinement, i.e. where permissible cracking is governed by the associated leakage.

The limitation of the heat of hydration of the cements used for concrete poured in large volume concrete (thickness $\geq$ 1.20 m) is used to minimise cracking, depending on the formulation of the concrete and, in particular, the proportioning of the cement. The Civil Contractor shall submit his proposals for limiting the temperature to THE PURCHASER.

Cement used for concretes in large volumes for the thick parts of the SIC buildings shall either:

- conform with class LH of standard NF EN 197-1, or

- the heat of hydration of the cement used for the concrete, measured in accordance with standard NF EN 196-9, shall be less than or equal to 270 J/g at 41h.

However, if the specifications of Section 7.8 on the increase of the temperature of the concrete during setting can be observed, cement "PM ES" with a greater heat of hydration may be used.

The maximal limit value of the cement shrinkage, measured according to the NF standard P15-433 shall be in the most equal to 700 μm/m on average lower than 650 μm/m.

7.3.3.1.7 Cements for Heavy concrete

The cements used for heavy concrete

- shall conform with class LH of standard NF EN 197-1
- Or the heat of hydration of the cement used for the concrete, measured in accordance with standard NF EN 196-9, shall be less than or equal to 270 J/g at 41h.

However, if the specifications on the increase of the temperature of the concrete during setting can be observed, cement CEM 1 "PM ES" or CEM 2 "PM ES" with a greater heat of hydration may be used.

7.3.3.1.8 Cement for injection grouts

The cements used for injection grouts on prestressed concrete pipes for cables and prestressed tension rods shall be CEM 1, or CEM II/A-L, or CEM II/A-D limited to 8 % of silica fume.

The cements, in accordance with standard NF EN 197-1 and admitted under marking "NF – Hydraulic Binders", shall, moreover, comply with the following specifications:

- $Cl^- < 0.05\%$
- $S^{2-} < 0.01\%$
- do not contain any element which may entail steel corrosion
- secondary constituents < 3%
- additives < 0.1%. Only grinding agent additive shall be tolerated
- the cement must not have any false setting, measured by the Tusschenbroeck test, in accordance with standard NF P18-363.

### *7.3.3.2 Conditions of delivery and storage*

The cements shall be delivered:

either directly by the manufacturing plant, or by a distribution centre approved by the specific committee under the marking "NF – Hydraulic Binders" as being a terminal of the plant.

All the transportation and storage operations for the binders shall be designed to avoid:

- mixing between different cements,
- contamination of the cements, in particular during the transportation thereof,
- any identification errors,
- their exposure to bad weather.

Cement delivered in bulk shall be stored in silos, depending on the grade thereof, with, in accordance with each grade of cement, at least two silos, thus ensuring there is always one silo subject to filling and one subject to emptying. With the exception of cements intended for the injections which will be delivered in bags.

Each silo shall be fitted with the following:

- an independent riser fitted with devices to avoid any risk of unwanted filling of the silo,
- stock or flow control devices (level detector, anti-arching system, etc.)
- Every silo must be provided with two thermometers placed respectively; the one on the base of the cone of draining, to allow measuring the temperature of the cement in the use, the other one on the vertical sleeve (round) of filling of the silo, to allow measuring the temperature during the supply.

The vertical sleeve will contain a sign with the name of the type of cement, a fool proof device to avoid any error of filling and allowing taking sample of cement.

The storage capacity of the cement on site (in silos, in trucks or in wagons) shall correspond to the quantity of cement of the biggest concrete elements to be concreted in a continuous way. Furthermore the storage capacity of cement shall correspond to one week's consumption at the highest concreting rate.

To limit the risks of false set, cements must be delivered at a temperature lower than 70°C.

At the time of use, the temperature of the cement shall be under $50^{o}$C and the Civil Contractor shall adopt all measures to ensure that this maximum temperature is complied with, whatever be the temperature of the cement at the time of delivery.

Storage of the cement in bags for the injections: the bags of cement will be stored under cover in a dry premise and shall be used in the delivery order.

#### *7.3.3.3 Inspections and checks*

The Civil Contractor shall:

For Test study and Trial mix testing check the following characteristics:

- Determination of the setting time and stability, in accordance with standards NF EN 196-3
- Determination of fineness french version NF EN 196-6
- Determination of the density, in accordance with standards NF EN 196-6
- Measurement of the heat of hydration, at 12 h and 41 h in accordance with standard NF EN 196-9
- Determination of the shrinkage
- A compression strength test after 2 days
- A compression strength test after 28 days,

<u>For each delivery truck or container and according to the grade of the cement:</u>

- inspect the packaging, markings and delivery dockets,
- carry out a rapid identification test on the cement in order to detect any errors in the delivery. This test shall be conducted on site on the arrival of the cement and prior to the transfer thereof to the silo, in accordance with standard P15-466.
- Sample-taking for tests shall be carried out in accordance with NF EN 196-7 on the arrival of the cement at the site. Ten kilograms of cement taken shall be reserved for sampling as a precautionary measure. The conservative samples shall be placed in waterproof containers and deposited in a dry area. They shall be destroyed (unless stipulated otherwise by THE PURCHASER) at the end of six months.

<u>Per delivery day and for each grade of the cement, check the following characteristics:</u>

- Determination of the setting time and stability, in accordance with standards NF EN 196-3

- Determination of the density, in accordance with standards NF EN 196-6

The results of these tests must comply with the specifications of standard NF EN 197-1 according to the class of cement concerned, and the cement must not be subject to false setting. When the manufacturing plant is ISO 9001 certified and deliveries of the quality of cement are on a daily basis, the frequency of the checks may be reduced to two days.

Once a month and according to the quality of cement:

- a compression strength test after 28 days,
- a compression strength test after 2 days for cement with high short-term strength.

These tests shall be carried out in accordance with NF EN 196-1. They shall be conducted for the purposes of checking the characteristics of the cements used in relation to the characteristics of the concrete. The sampling operations shall be carried out at the concrete mixing plant and correspond to the cement used in the batch subject to a concrete inspection test. The results must comply with the specifications of NF EN 197-1 for the class of cement concerned.

With regard to the cements used for large volume of concrete

- Before the first large volume concrete pours, measurement of the heat of hydration, in accordance with standard NF EN 196-9 shall be carried.
- a measurement of the heat of hydration, in accordance with standard NF EN 196-9, for every 500 $m^3$ of concrete used. The results must comply with the stipulations of paragraph 7.3.3.1.6 “Cements for large volume of concrete”.
- Determination of the shrinkage shall be carried out for every 500 $m^3$ of concrete produced and once a month of delivery.

## 7.4 Additions

### 7.4.1 *SCOPE*

This technical specification applies to the standardised additions used in concrete for the structures covered by the contract. The additions concerned are as follows:

- coal fly ash,
- limestone additions,
- siliceous additions,
- silica fume,
- ground granulated blast furnace slag.

This technical specification does not concern constituents directly added to the clinker (added constituents) in compound cements.

### 7.4.2 *DOCUMENTS QUOTED IN REFERENCE IN THIS SECTION*

#### *7.4.2.1 Standards*

NF EN 206-1 (04/04) and Addenda A1 of April 2005 and A2 of October 2005 °: Concrete – Part 1: Specification, performance, production and conformity.

NF EN 450-1 + A1 (12/07): Fly ash for concrete – Part 1 - Definitions, specifications and conformity criteria.

NF EN 450-1 IN1 (12/07): Fly ash for concrete – Part 1 - Definitions, specifications and conformity criteria- Instruction sheet.

NF EN 450-2 + A1 (12/07): Fly ash for concrete – Part 2 - Conformity evaluation.

NF EN 13263-1+A1 (05/09): Silica fume for concrete – Part 1 - Definitions, specifications and conformity criteria.

NF EN 13263-2+A1 (05/09): Silica fume for concrete – Part 2 - Conformity evaluation.

NF EN 15167-1 (09/06): Ground granulated blast furnace slag for use in concrete, mortar and grout – Part 1 - Definitions, specifications and conformity criteria.

NF EN 15167-2 (09/06): Ground granulated blast furnace slag for use in concrete, mortar and grout – Part 2 - Conformity evaluation.

NF EN 451-2 (12/94): Method of testing fly ash – Part 2: determination of fineness by wet sieving. Only french version.

NF P15-317 (09/06): Hydraulic binders – Cement for operations at sea. Only french version.

NF P18-507 (11/92): Additions for hydraulic cement – Water requirements, regularity checking – Method for measuring fluidity by flow with “Marsh cone”. Only french version.

NF P18-508 (01/12): Additions for hydraulic concrete – Limestone additions – Specifications and conformity criteria. Only french version.

NF P18-509 (12/98): Additions for hydraulic concrete – Siliceous additions – Specifications and conformity criteria. Only french version.

NF P18-512-1 (09/06) Ground granulated blast furnace slag for use in concrete, mortar and grout - Part 1: definitions, specifications and conformity criteria.

NF P18-512-2 (09/06) Ground granulated blast furnace slag for use in concrete, mortar and grout - Part 2: conformity evaluation.

## 7.4.3 *REQUIREMENTS AND RELATED CHECKS*

### *7.4.3.1 General stipulations*

An addition is a finely divided mineral material used in concrete to enhance certain properties or provide it with specific properties.

The additions for concrete used shall be subject to a certificate of compliance by obtaining an EC marking, where applicable.

The additions can be added, in the concrete or in the mortar, only in quantities and with characteristics such as they are harmful neither to the durability (porosity, heat of hydration, resistance in the frost, the alkali-reaction, the corrosion of the reinforcement), nor in the quality of aspect of facings.

The Civil Contractor shall take into account the influences, possibly negative, on certain parameters (water requirement, setting time, resistance at the youngest age) and particular conditions given below.

The additions used in partial substitution of cement will be admitted in the strict respect for the table NA.F.1 of the NF standard EN 206-1.

The chloride content of the additions shall be compliant with the overall criteria for the concrete, as specified in Section 7.9.

During inspections and checks on receipt of the additions, rapid identification tests shall be carried out prior to transfer to the silo.

#### *7.4.3.2 Delivery and storage on site*

All the transportation and storage operations for additions shall be designed to avoid:

- mixing between the different additions,
- contamination of the additions, in particular during the transportation thereof,
- any identification error,
- their exposure to bad weather.

In the case of bulk transportation via sealed road tanker, a certificate of cleanliness for each tanker shall be attached to the delivery docket.

A 5 kg sample of additions shall be taken from each mix at the time of delivery to the site. The precautionary samples shall be placed in waterproof packaging and deposited in a dry area. They shall be destroyed (unless otherwise stipulated by THE PURCHASER) at the end of a period of six months.

The additions shall be stored in silos. The storage capacity on the site corresponds to three weeks' consumption at the highest concreting rate.

Each silo shall be fitted with the following:

- an independent riser fitted with devices to avoid any risk of unwanted filling of the silo,
- stock or flow control devices (level detector, anti-arching system, etc.).

#### *7.4.3.3 Coal fly ash*

The fly ash used shall comply with standards NF EN 450. The use of fly ash is prohibited for the concrete of prestressed structures.

Physical and chemical characteristics

In addition to standard NF EN 450, water requirements shall be subject to a determination in accordance with standard NF P 18-507. A variation range for the value thereof shall be adopted from the average values measured during the concrete study test.

The fly ash used shall, at minimum, observe the class B specifications of standard NF EN 450. The specification of class A of standard NF EN 450 shall be met if they are used in a concrete subjected to exposures classes XF3 or XF4 as per standard NF EN 206-1.

Inspections and checks on receipt

The inspections and checks on the receipt shall be carried out on each batch of fly ash delivered to the site.

Receipt shall cover the following:

- checking the delivery docket,
- checking the water requirements in accordance with NF P 18-507, adopted as a rapid identification test. The result must fall within the variation range established by the formulation studies,
- checking the fineness, measured in accordance with the method described in standard NF EN 451-2. The result must comply with the specifications of standard NF EN 450.

#### *7.4.3.4 Limestone additions*

The limestone additions for concrete used must comply with standard NF P 18-508.

Physical and chemical characteristics

In addition to standard NF P 18-508, the water requirements shall be subject to a determination according to standard NF P 18-507. A variation range governing the value thereof shall be created from the average values measured during the concrete study test.

Inspections and checks on receipt

Inspections and checks on receipt shall be carried out on each batch of limestone additions delivered to the site.

Receipt shall cover the following operations:

- checking the delivery docket,
- checking the water requirements in accordance with NF P18-507, adopted as a rapid identification test. The result must fall within the variation range established by the formulation studies,
- checking the grain size distribution and fineness (Blaine mass surface), according to the standards referenced in standard NF P18-508. The result must comply with the specifications of standard NF P18-508.

#### *7.4.3.5 Siliceous additions*

The siliceous additions for concrete used must comply with standard NF P18-509.

Physical and chemical characteristics

In addition to standard NF P18-509, the water requirements shall be subject to a determination according to standard NF P18-507. A variation range governing the value thereof shall be created from the average values measured during the concrete study test.

If siliceous additions are used in prestressed concrete, they must observe the type A specifications of standard NF P18-509.

Inspections and checks on receipt

Inspections and checks on receipt shall be carried out on each batch of siliceous additions delivered to the site.

Receipt shall cover the following operations:

- checking the delivery docket,
- checking the water requirements in accordance with NF P18-507, adopted as a rapid identification test. The result must fall within the variation range established by the formulation studies,
- checking the grain size distribution and fineness (Blaine mass surface), according to the standards referenced in standard NF P18-509. The result must comply with the specifications of standard NF P18-509 for the type of siliceous addition and fineness concerned.

#### *7.4.3.6 Silica fumes*

The silica fumes for concrete used shall comply with standard NF EN 13263.

Physical and chemical characteristics

The silica fumes used shall observe the class A specifications of standard NF EN 13263.

Additional characteristics shall be subject to a determination in accordance with standard NF EN 13263:

- water requirements,
- bulk density.

Variation ranges governing the values thereof shall be created from the average values measured during the concrete study tests.

Silica fume production plant and treatment units

The choice of production plant and treatment units shall be made by the Civil Contractor, and subject to the approval of THE PURCHASER. No change to these items shall be permitted during operations without the consent of THE PURCHASER and renewed justification.

Delivery and storage on site

In addition to the specifications of paragraph 7.4.3.2, a buffer stock shall be created, corresponding to a minimum of six weeks' consumption of silica fumes at the highest concreting rate.

The stock volume must be managed in accordance with the production requirements at the plant and the treatment units. In particular, it must be increased prior to a silica fume production shutdown (where scheduled), thus ensuring that the six-week minimum stock rule is observed until the end of this shutdown.

In the case of densified powders, the transportation and storage modes shall ensure permanent water content for the silica fumes of less than 1% at any time.

Inspections and checks on receipt

Inspections and checks on receipt shall be carried out on each batch of silica fumes delivered to the site.

Receipt shall cover the following operations:

- checking the delivery docket,
- checking the water requirements, adopted as a rapid identification test. The result must fall within the variation range established by the formulation studies,
- checking the bulk density. The result must fall within the variation range created by the formulation studies.

#### *7.4.3.7 Ground granulated blast furnace slag*

The ground granulated blast furnace for concrete used shall comply with standards NF EN 15167-1 (NF P18-512-1) and NF EN 15167-2 (NF P18-512-2). The use of slag is forbidden for concrete of prestressed structures.

The inspections and checks shall be carried out on each batch of ground granulated blast furnace slag delivered to the site.

Receipt shall cover the following:

- checking the delivery docket,
- checking the grain size distribution and Blaine mass surface according to the standards referenced in standards NF EN 15167-1 (NF P18-512-1) and NF EN 15167-2 (NF P18-512-2). The result must comply with the specifications of standards NF EN 15167-1 (NF P18-512-1) and NF EN 15167-2 (NF P18-512-2) for the category concerned.

## 7.5 Admixtures and Curing Products

### 7.5.1 *SCOPE*

This technical specification shall apply to admixtures and curing products for concrete in the structures covered by the contract.

Any admixture shall be subjected to acceptance tests before use, these tests shall be carried out with the aggregates and cement used for the construction works and under the current conditions of concrete fabrication.

## 7.5.2 *DOCUMENTS QUOTED IN REFERENCE IN THIS SECTION*

### *7.5.2.1 Standards*

NF EN 934-1 (04/08): Admixtures for concrete, mortar and grout - Part 1: Common requirements.

NF EN 934-2 (08/09): Admixtures for concrete, mortar and grouts – Part 2: Admixtures for concrete – Definitions, requirements, compliance, marking and labelling

NF P 18-370 (10/95): Admixtures – Curing products for concrete and mortar – Definition, specifications and marking. Only french version

## 7.5.3 *REQUIREMENTS AND RELATED CHECKS*

### *7.5.3.1 General stipulations*

The admixtures and curing products used shall be subject to a certificate of compliance in accordance with the marking "NF – Admixtures for concrete, mortar and grouts, curing products".

The conditions of use for admixtures and curing products shall comply with the conditions issued by the manufacturer in its technical instructions. When the expiry date shown on the manufacturer's certificate is reached, the products must no longer be used.

The storage of admixtures and curing products must be carried out in a shelter which protects them from bad weather and, in particular, frost, duly observing the storage conditions stipulated by the manufacturer in its technical instructions.

### *7.5.3.2 Admixtures*

The admixtures used shall comply with standard NF EN 934-2. Moreover, the chloride content of the admixtures must observe the overall criteria for the concrete shown in Section 7.8.

The storage capacity for admixtures on the site shall correspond to three weeks' consumption at the highest concreting rate.

The delivery docket shall be checked with each batch delivered to the site.

For every 1500 litres delivered to the site, the following shall be carried for each admixture:

- checking of the relative density,
- checking of the conventional dry material content.

The results of these checks must comply with the specifications of standard NF EN 934-2.

The Civil Contractor shall take into consideration that the use of helicopter trowelling on the top surface of reinforced concrete ground slab in conjunction with the use of concrete additive such as "Air entrained concrete " is not allowed.

### *7.5.3.3 Curing products*

The curing products used shall comply with standard NF P 18-370.

The storage capacity on the site shall be adapted to the curing operations to be carried out.

The delivery dockets shall be inspected with the delivery of each batch to the site.

For every 200 litres of curing product delivered to the site, the following shall be carried out:

- checking of the relative density; the result must fall within the variation range in the manufacturer's technical datasheet.
- checking of the dry material content, which must comply with standard NF P 18-370.

The Civil Contractor must ensure curing products are compatible with any applied finishes, un-moulding agents and any paint system that might need to be applied to the concrete.

## 7.6 Mixing water

### 7.6.1 *SCOPE*

This technical specification shall apply to mixing water for grouts, mortar and concrete in the structures covered by the contract.

### 7.6.2 *DOCUMENTS QUOTED IN REFERENCE IN THIS SECTION*

#### *7.6.2.1 Standards*

NF EN 1008 (07/03): Mixing water for concrete

### 7.6.3 *REQUIREMENTS AND RELATED CHECKS*

#### *7.6.3.1 Requirements*

Mixing water shall comply with standard NF EN 1008. If water is not classified in 3.1 standards (water), the Civil Contractor shall provide monthly a certificate of physical and chemical analysis. If requirements (section 4) of the standard are not met, the Civil Contractor will seek an alternative source of supply, which will be analysed again. Without proper study, water recovery of the concrete industry cannot be used.

The chloride content of the mixing water must observe the overall criteria for the concrete stipulated in the Section 7.8.

Seawater for mixing shall be prohibited for reinforced or prestressed concrete, or concrete containing embedded metal parts.

Checks

The Civil Contractor shall carry out an analysis of the mixing water on the opening of the site and, at minimum, once a quarter. The frequency of these checks, subject to the agreement of THE PURCHASER, shall be adapted to the origin of the mixing water, if it is not potable.

#### *7.6.3.2 Further requirements for Mixing water used for injection grouts*

As a supplement to the prescriptions of the NF EN 1008 for the class 3.1 (drinking water), the following maximal contents must not be exceeded:

- chlorides (as Cl-) <250 mg / l
- Sulphate (as SO42-) <250 mg / l
- Magnesium (as Mg + +) <125 mg / l
- Absence of detergent

## 7.7 Concrete manufacturing plant on site

### 7.7.1 *SCOPE*

This technical specification shall apply to concrete manufacturing plants. These include ready-mixed concrete manufacturing plants which shall be the subject of a certificate of compliance in accordance with the marking "NF – Ready-mixed concrete" (NF-BPE).

Ready-mixed concrete can only be used after the approval of mix designs and tests. Manufacturing at the ready mixed concrete plant does not exclude the concrete study, information, suitability and control tests.

This concrete, ordered by the Civil Contractor, shall be concrete with specified properties in accordance with standard NF EN 206-1.

For each delivery, the manufacturer shall draw up a delivery certificate stating the production plant, the destination site, the nature and proportioning of the constituents, strength, values of other characteristics required, the mass of materials and matter used in each mix, the precise fill time for the concrete in the mixing tank (truck mixer) and the maximum utilisation time.

All the constituents of the concrete, including the water, shall be proportioned and fully mixed at the plant before the mixing tanks leave the premises.

### 7.7.2 *DOCUMENTS QUOTED IN REFERENCE IN THIS SECTION*

#### *7.7.2.1 Standards*

NF EN 206-1 (04/04) and Addenda A1 of April 2005 and A2 of October 2005 : Concrete – Part 1: Specification, performance, production and conformity.

### 7.7.3 *REQUIREMENTS AND RELATED CHECKS*

The equipment, maintenance and repair mode relating thereto and the manufacturing conditions shall be the subject of procedures drawn up by the Civil Contractor, and submitted for the approval of THE PURCHASER. In the event of plant failure the Civil Contractor shall submit contingency plans for ensuring a continued supply of concrete during large pours.

The quality of the equipment and the use thereof shall observe the following tolerance limits for proportioning constituents, as a percentage of the required quantity; mixing water, admixtures and added constituents in liquid form may be proportioned in mass or volume and the other constituents must be proportioned in mass.

These tolerance limits (+ or -) shall be agreed for 100% of proportioning measurements:

- cement: 2%,
- water: 3%,
- each class of aggregates: 3%
- aggregates as a whole: 3%
- additions used in quantities of > 5% of the cement mass: +2%.
- additions used in quantities of < or = 5% of the cement mass: +5%.
- Admixtures: 5%

The scales shall have weighing capacities appropriate to the nominal capacity C (expressed in $m^3$) of the mixer. The range (in tonnes) shall be less than:

- 3 C for aggregates weighed together,
- 1.5 C for aggregates weighed separately,
- 0.6 C for cement,

- 0.3 C for water.

It must be possible to seal or lock the scale adjustment systems.

Provision shall be made for an alarm indicating the non-reset of the scales.

The measuring equipment for admixtures shall ensure that each admixture is measured individually.

The concrete mixing plant shall be fitted with equipment for measuring the water content of sand (sensors) installed in the storage area. Measurements shall be taken immediately before weighing. The accuracy of the sensor and the precision of the measuring method shall be the subject of an inspection procedure drawn up by the Civil Contractor, duly submitted for the approval of THE PURCHASER. With regard to high-strength concretes (compression strength class in excess of C50/60) and self-placing concrete, the accuracy of the sensor must be checked at least once every production day. The concrete mixing plant shall be fitted with an indicator providing a direct reading of the measurement taken. The water content of the fine gravel shall be measured at least once every concreting day. The plant shall comprise equipment enabling the automatic correction of the quantities of water in the aggregates to be introduced.

A recording wattmeter shall be used to monitor any changes in the energy expended in mixing operations and to detect the time when this mixing operation has been completed satisfactorily. The mixing time shall not be shorter than the time required to obtain the stabilisation of the power absorbed by the mixer motors. However, the mixing time shall not be shorter than 55 seconds.

The plant's operations shall be controlled by a programmer which will enable an automatic operating mode.

The plant shall also be fitted with systems enabling an automatic print-out, for each batch, of the concrete code, the quantities measured of all the constituents, and the duration and power level of the mixing operation, prior to emptying.

When the distance required to transport the concrete is greater than 300 m, the Civil Contractor shall create a radio link between the concreting site and the concrete mixing plant.

Via checks conducted at the outlets of the weigh trucks at least once a month, the Civil Contractor shall ensure that the compositions actually used comply satisfactorily with the compositions stipulated with regard to the aforementioned tolerance limits. If this is not the case, the Civil Contractor shall immediately make the necessary corrections and carry out an inspection on the equipment.

The weighing equipment must be checked at least once a year by the Service Instruments and Measures (SIM).

## 7.8 Studies, composition and manufacture of concrete

### 7.8.1 *SCOPE*

This technical specification applies to the study, composition and manufacture of concrete for the structures covered by the contract.

### 7.8.2 *DOCUMENTS QUOTED IN REFERENCE IN THIS SECTION*

#### *7.8.2.1 Standards*

ISO 1920-10 (09/10): Concrete – Testing Concrete.

NF EN 196-1 (04/06): Methods of testing cement – Part 1: Determination of mechanical strength.

NF EN 206-1 (04/04) and Addenda A1 of April 2005 and A2 of October 2005 °: Concrete – Part 1: Specification, performance, production and conformity.

NF EN 206-9 (06/10) Concrete. Part 9: Additional rules for self-compacting concrete (SCC)

NF EN 12350-2 (04/12): Testing fresh concrete – Part 2: Slump test.

NF EN 12350-5 (06/09): Testing fresh concrete – Part 5: Flow table test.

NF EN 12350-7 (04/12): Testing fresh concrete – Part 7: Air content – Pressure method.

NF EN 12350-8 (11/10): Testing fresh concrete – Part 8: Self compacting concrete – Slump flow test.

NF EN 12350-9 (11/10): Testing fresh concrete – Part 9: Self compacting concrete – V-funnel test.

NF EN 12350-10 (11/10): Testing fresh concrete – Part 10: Self compacting concrete – L-box test.

NF EN 12350-11 (11/10): Testing fresh concrete – Part 11: Self compacting concrete – Sieve segregation test.

NF EN 12350-12 (11/10): Testing fresh concrete – Part 12: Self compacting concrete – J-ring test.

NF EN 12390-3 (04/12): Testing hardened concrete – Part 3: Compressive strength of test specimens.

NF EN 12390-6 (04/12): Testing hardened concrete – Part 6: Tensile splitting strength of test specimens.

NF EN 12390-7 (04/12): Testing hardened concrete – Part 7: Density of hardened concrete.

NF P18-404 (12/81): Concrete – Development, feasibility and control tests – Preparation and storage of test specimens.

NF EN 13670 (06/09): Execution of concrete structures.

NF P15-319 (09/06): Hydraulic binders – Sulphate-resisting cements. Only french version.

NF P15-433 (02/94) Methods of testing cement. Determination of shrinkage and swelling.

NF P18-427 (12/96) Concrete - Determination of dimensional variations between two faces opposing hardened concrete specimens. Only french version.

NF P18-454 (12/04): Reactivity of a concrete formula with regard to the alkali-reaction. Only french version.

FD P18-326 (11/04) Concrete - Areas of frost in France.

FD P18-542 (02/04): Aggregates – Criteria for the classification of natural aggregates with respect to the alkali-aggregate reaction. Only french version.

#### *7.8.2.2 Other documents*

Draft test method No. 59 of the LPC (Laboratoires des Ponts et Chaussées) [French Public Works Research Laboratory]: Reactivity of a concrete formula with regard to an internal sulphate reaction – Performance test. Only french version.

Recommandations pour la prévention des désordres dus à la réaction sulfatique interne of the LPC (Laboratoires des Ponts et Chaussées) August 2007.

Recommendations of the national self-placing concrete project, published by the AFGC (Association Française de Génie Civil) [French Civil Engineering Association]. Only french version.

## 7.8.3 *REQUIREMENTS AND RELATED CHECKS*

### *7.8.3.1 Supply of materials.*

Supplies shall observe the stipulations of the Technical Specifications for concrete works, Sections 7.1 to 7.4.

The choice of supplies shall be made by the Civil Contractor, subject to the approval of THE PURCHASER. No changes shall be permitted during the operations unless the Civil Contractor can submit justification that the new supplies comply with the stipulations of the contract. The change shall then be submitted for the approval of THE PURCHASER.

With regard to each delivery, the supplier shall draw up a delivery docket specifying the recipient site and, for each supply delivered, the production plant, its standardised name and the packaging thereof.

The supplies shall be identified on arrival on site thereby ensuring the traceability thereof, and avoiding any risk of inversion with other types of materials.

With regard to each type of supply, the conditions governing transportation, handling, identification, storage and control operations on receipt (including the provisions to be adopted in the case of refusal) shall be recorded under a procedure drawn up by the Civil Contractor, and submitted for the approval of THE PURCHASER.

During checks on receipt, any difference in relation to the specifications shall be noted. The supplies concerned shall be isolated until a definitive decision has been issued by THE PURCHASER.

The delivery docket, technical datasheets for the products, certificates of compliance and self-checking by suppliers of their products shall be made available to THE PURCHASER.

### *7.8.3.2 Study and composition of the concrete*

7.8.3.2.1 Concrete Grades

The following concrete grades shall be provided for structural concrete of the SIC buildings:

- C30/37
- C40/50
- C60/75

The exposures classes are as below:

- For external walls and slabs above ground : XC4
- For external walls below ground level, in contact with humid soil : XC4
- For internal structures: XC1
- For internal structures in permanent contact with humid air : XC3

Structural class shall be determined accordingly, in taking into account a design life time of 70 years for the concrete structure; Structural class shall not be lower than S5.

The characteristics of the concrete used are defined in the following table, the list shown being in no way exhaustive:

| | Superstructure | | Infrastructure | |
|---|---|---|---|---|
| Type of structure | Internal | External | Internal | External |
| Prestressed or highly stressed concrete structure | C60/75-XC1 (1) | | C60/75-XC1 (1) | |
| Heavily stressed structures | C40/50-XC1 | C40/50-XC4 | C40/50-XC1 | C40/50-XC4 |
| Heavily stressed structures in permanent contact with humid air | C40/50-XC3 | C40/50-XC4 | C40/50-XC3 | C40/50-XC4 |
| Moderately stressed structures | C30/37-XC1 | C30/37-XC4 | C30/37-XC1 | C30/37-XC4 |
| Moderately stressed structures in permanent contact with humid air | C30/37-XC3 | C30/37-XC4 | C30/37-XC3 | C30/37-XC4 |

(1) With a silica fume content >5% for equivalent binder (the quantity of equivalent binder shall be defined by standard NF EN 206-1; the maximum silica fume content is also defined by this standard: $A/(A+C) \leq 0.10$ where A represents the quantity of silica fume and C the quantity of cement), without fly ash and without blast furnace slag and excluding self-placing concrete.

For mass concrete, substitution concrete and blinding concrete, the exposure class is XC4. The concrete characteristics grade shall be determined according NF EN 206-1 :2000, the concrete grade shall be C30/37 for SIC buildings, unless otherwise noted in the drawings.

7.8.3.2.2 Conditions Of Durability

According to LCPC « Maîtrise de la durabilité des ouvrages en béton - Application de l'approche performantielle - recommandations provisoires » and « Conception des bétons pour une durée de vie donnée des ouvrages – Indicateurs de durabilité» AFGC 2004 ; the following criteria shall be respected.

Pwater = Peau, d = days (jours)

| | Study test | Trial mix testing | Control tests /500 $m^3$ |
|---|---|---|---|
| XC1 | Pwater 90d ≤15 %<br>And Pwater 28d | Pwater 28d<br>Pwater 28d (Trial mix) ≤ 1.1 Pwater 28d (study) | Pwater 28d<br>Pwater 28d ≤ 1.1 Pwater 28d (study)<br>Pwater 90d ≤15 % |
| XC3 XC4 | Pwater 90d ≤13 %<br>And Pwater 28d<br>Kgas90d ≤ 150 10-18 m² (CEMBUREAU) | Pwater 28d<br>Pwater 28d (Trial mix) ≤ 1.1 Pwater 28d (study) | Pwater 28d<br>Pwater 28d ≤ 1.1 Pwater 28d (study)<br>Pwater 90d ≤13 % |

7.8.3.2.3 Shrinkage maximum value

| Concrete | maximum value |
|---|---|
| Confinement | target ≤ 450 μm/m – maximum 500 μm/m |
| Heavy Concrete | 500 μm/m |
| Other | 600 μm/m |

7.8.3.2.4 Gas permeability maximum value (CEMBUREAU)

| Concrete | maximum value |
|---|---|
| Confinement/Heavy Concrete | $7.7 \times 10^{-17}$ m² |
| Other | $15 \times 10^{-17}$ m² |

7.8.3.2.5 General stipulations

The concretes have specific properties. They shall observe the specifications of standard NF EN 206-1 as well as the additional requirements of the below paragraphs.

The composition of the concrete shall:

- satisfy the requirements of the contract and, in particular, the stipulated strengths,
- obtain a grain size distribution and consistency adapted to the provisions of the structure and the construction conditions,
- ensure the durability thereof in respect of the exposure classes for the structural sections.

The study, information and suitability tests are only valid for original constituents and specific characteristics and for a given formulation.

No change shall be authorised during operations without the creation of a file adapted to the new study and suitability tests proving the observance of the same stipulations.

7.8.3.2.6 Grain size distribution

The upper nominal dimension of the aggregates (D) shall be chosen by the Civil Contractor in relation to the dimensions of the structure and the mesh of the reinforcement. This upper dimension D shall be submitted for the approval of THE PURCHASER.

7.8.3.2.7 Consistency of concrete

A target consistency value shall be specified by the Civil Contractor during the concrete studies in relation to the density of the reinforcement of the structure to be concreted and the implementation resources provided for on site. This target consistency shall be submitted for the approval of THE PURCHASER.

To this end, use may be made, except for the prestressed structures, of self-placing concrete, subject to the agreement of THE PURCHASER.

7.8.3.2.8 Nominal formula

The composition of each type of concrete shall be specified by the Civil Contractor and subject to the approval of THE PURCHASER. It shall be defined via a nominal formula stating, per cubic metre of concrete:

- the type and mass (dry material) of the various categories of aggregates and any additions,
- the type and mass of the binder,
- the type, percentage of dry material and the mass of any admixtures,
- the total volume of water: the volume of mixing water plus the volume of water contributed by the various constituents of the concrete:
- aggregates,
- any additions,
- admixtures.

7.8.3.2.9 Content of aggressive elements

The content of chlorides contributed by all the constituents of the concrete shall observe:

- the class CI 0.20 specifications of standard NF EN 206-1 for reinforced concrete,
- the class CI 0.10 specifications of standard NF EN 206-1 for prestressed concrete.

The content of $S^{2-}$ sulphur ions contributed by all the constituents of the concrete shall be limited to 0.5% of the mass of the cement for prestressed concrete.

7.8.3.2.10 Density for heavy concrete

Oven Dry Density of heavy weight concrete (Heavy Concrete) = From 3200 to 3600 kg/m3 (see drawings for localisation).

Heavy weight concrete is used for shielding purposes.

7.8.3.2.11 Special stipulations for the use of potentially reactive aggregates

When the aggregates used are classed as PR or PRP by a specialised laboratory according to document bundle number P 18-542, the following stipulations must be observed:

average alkaline content of the cement < 0.6% in equivalent $N_{a2}O$,

average active alkaline content of the concrete, expressed as equivalent $N_{a2}O$, < 2.6 kg/$m^3$, except for prestressed concrete for which the limit is 2.2 kg/$m^3$

The test governing the non-reactivity of the concrete formula in paragraph 7.8.3.3.4 “Additional stipulation for the use of potentially reactive aggregates” must be conclusive.

7.8.3.2.12 Special stipulations for self-placing concrete

Self-placing concrete shall be formulated according to the recommendations of the national self-placing concrete project, published by the AFGC (Association Française de Génie Civil) *[French Civil Engineering Association]*, and NF EN 206-9.

The specifications of self-compacting concrete (SCC) evidence of their composition, test studies, trial mix design, trial mix testing, tests of propriety and control shall respect the requirements of the Fascicule 65 article 87.

7.8.3.2.13 Special stipulations for concrete of large volume (thickness ≥ 1.2m)

In addition to the specifications of Section 7.3.3.1.6, regarding limits to the heat of hydration in cement, the formulation of the concrete and, in particular, the proportioning of cement shall ensure that cracking is limited.

To reduce the increase in temperature in concrete during setting, a concrete cooling system (in particular for the thick rafts, especially when concreted in hot weather) via water circulation in pipes may be adopted, subject to the approval of THE PURCHASER. Where necessary, this system shall be subsequently injected with a cement grout. Insulation of the curing concrete to limit the thermal gradients may also be necessary to control cracking. The Civil Contractor shall submit his proposals to THE PURCHASER stating what methods are to be adopted with calculations showing the expected maximum core temperature and temperature gradients. Temperature measuring devices shall be used to confirm the predicted values.

7.8.3.2.14 Special requirements for concrete subjected to severe frost

According to FD P18-326 of November 2004 which defines the frost zones in France, the site of Cadarache is not in a zone of severe frost, so no specific requirements shall be prescribed.

### *7.8.3.3 Study test*

The study of the composition of a concrete shall comprise the determination of a nominal formula for the concrete and the performance of the study test. The Civil Contractor shall carry out this study sufficiently early in order to conduct the suitability test before any concreting. The study test shall be the subject of a compliance justification file.

The manufacture and storage of the specimens for this test shall comply with standard NF P 18-404.

At the request of THE PURCHASER, additional test specimens may be manufactured and supplied to THE PURCHASER for the purposes of carrying out additional tests.

7.8.3.3.1 Study of validity of the formula

This concerns the following mixes:

- 3 mixes made according to the nominal formula,
- 1 mix deriving from the nominal formula, duly increasing the quantities of the solid constituents by +2%, and reducing the quantities of the liquid constituents by -2%.
- 1 mix deriving from the nominal formula, duly reducing the quantities of the solid constituents by -2% and increasing the quantities of the liquid constituents by +2%.

Each mix shall give rise to a sample from which the following shall be carried out:

- a consistency test adapted to the workability of the concrete (slump test according to standard NF EN 12350-2 or flow table test according to standard NF EN 12350-5),
- a test to determine the air content of the fresh concrete according to standard NF EN 12350-7,
- the determination of the practical duration of usage of concrete at a temperature representative of the foreseeable conditions, by regular measurements of the consistency with respect to time in accordance with the test suited for the workability of the concrete,

- density measurement of the fresh concrete
- a test to determine the compressive strength after 28 days measured on three cylindrical test specimens according to NF EN 12390-3; the result adopted shall be taken as equal to the arithmetic average of the measurements taken on the test specimens,
- a test to determine the tensile strength after 28 days, measured by splitting three cylindrical test specimens, according to standard NF EN 12390-6; the result adopted shall be taken as equal to the arithmetic average of the measurements taken on the test specimens,
- a test to determine the density according to standard NF EN 12390-7; the result adopted shall be taken as equal to the arithmetic average of the measurements taken on the three test specimens for determining the compressive strength after 28 days,
- a test to determine the porosity according to an operating mode subject to the approval of THE PURCHASER: process EDF-TEGG CE 02-33 or equivalent.
- a test for the shrinkage on three prismatic concrete samples 10x10x40 using NF P 15-433 for sampling and curing; NF P18-427 for the measure. These tests shall be realised in a laboratory.
- tests to determine porosity and gas permeability according to AFPC-AFREM process (Conditions Of Durability (in according with LCPC mars 2010 and AFGC 2004) (see section Specified Properties)

The cement used for the study test shall be the subject of a compressive strength test according to standard NF EN 196-1 and a precautionary sample shall be taken, it may be destroyed (unless otherwise stipulated by THE PURCHASER) after a period of six months.

The study test shall be considered as probative if the following conditions are satisfied:

- all the consistency results fall within the tolerance range relating to the target consistency value; the tolerance limits are given in standard NF EN 206-1,
- 0.975 < fresh concrete theoretical density / fresh concrete true density <1.025
- the concrete working time of each mix observes the minimum duration required, where applicable,
- all the 28-day tensile strength results observe the required characteristic value, where applicable,
- the arithmetic average ($f_{cE}$) of the results adopted for the 28-day compressive strength test, carried out over three mixes, in accordance with the nominal formula, shall satisfy the following three conditions:

$$f_{cE} \geq f_{c28} + C_E - (C_{moy} - 3Sc) + 3$$

$$f_{cE} \geq 1.2\ f_{c28} \text{ for } f_{c28} < 50 \text{ MPa}$$

$$f_{cE} \geq 1.15\ f_{c28} \text{ for } f_{c28} \geq 50 \text{ MPa}$$

The results adopted for the 28-day compressive strength test, carried out over three derived mixes, shall satisfy the following two conditions:

$$f_c \geq f_{c28} + C_E - (C_{moy} - 3Sc)$$

$$f_c \geq 1.1\ f_{c28}$$

With regard to these inequalities (the values being expressed in MPa):

- $f_{cE}$ is the arithmetic average of the result adopted for compressive strength at 28 days calculated from the three nominal mixes,
- $f_c$ is the result adopted for compressive strength at 28 days calculated from the derived mix,
- fc28 is the characteristic value required for compressive strength at 28 days,
- $C_E$ is the compressive strength at 28 days of the cement used for the study test,

- $C_{moy}$ is the average value for the compressive strength at 28 days, observed by the supplier during the six months preceding the study test,
- Sc is the standard deviation for the values used to determine $C_{moy}$.

7.8.3.3.2 Checking Tensile strength at 28 days (NF EN 12390-6)

The results for tensile strength at 28 days must observe the characteristic value required.

$f_{ctm28} \geq 2.9$ MPa for C30/37

$f_{ctm28} \geq 3.5$ MPa for C40/50

$f_{ctm28} \geq 4.4$ MPa for C60/75

7.8.3.3.3 Formula sensitivity study

This concerns the following mixes:

- 2 mixes derived from the nominal formula by modifying the quantity of cement by +7.5% for one and -7.5% for the other,
- 2 mixes derived from the nominal formula by modifying the quantity of mixing water by +7.5% for one and -7.5% for the other,
- 2 mixes derived from the nominal formula by modifying the quantity of admixture (not including air-entraining agent) by +7.5% for one and -7.5% for the other,
- for each type of addition, including silica fume, 2 mixes derived from the nominal formula by modifying the quantity of addition by +7.5% for one and -7.5% for the other.

Each mix shall give rise to a sample from which the following shall be carried out:

- a consistency test adapted to the workability of the concrete (slump test according to standard NF EN 12350-2 or flow table test according to standard NF EN 12350-5),
- a test to determine the compressive strength after 28 days measured on three cylindrical test specimens according to NF EN 12390-3; the result adopted shall be taken as equal to the arithmetic average of the measurements taken on the three test specimens,
- a test to determine the tensile strength after 28 days, measured by splitting three cylindrical test specimens, according to standard NF EN 12390-6; the result adopted shall be taken as equal to the arithmetic average of the measurements taken on the test specimens,

An analysis of this study shall be carried out by the Civil Contractor. Depending on the conclusions of this study, specific manufacturing checks may be imposed by THE PURCHASER.

7.8.3.3.4 Additional stipulations for the use of potentially reactive aggregates

The study test shall, moreover, comprises a nominal formula non-reactivity test. This test shall be conducted according to standard NF P18-454, plus the following:

- proportioning of alkaline at 150% of the initial quantity determined according to NF P18-454 for prestressed concrete and at 125% in the other cases,
- measurement of dimensional variations according to the deadlines defined in the standard up to 9 months.

The acceptance criterion is an expansion of the test specimens at 9 months under 0.02%.

The Civil Contractor shall, moreover, carry out a test parameterised in relation to the proportioning of alkaline in order to determine the reaction trigger threshold. This study shall be submitted for the opinion of THE PURCHASER.

7.8.3.3.5 Additional stipulations for the concrete in the prestressed structures

The study test shall, moreover, comprises, in respect of the nominal formula a test to determine the static modulus of elasticity under compression after 28 days, according to standard ISO 1920-10 (secant modulus $E_{cm}$ according to NF EN 1992-1-1).

In addition, the modulus shall be determined by measuring the deformation under a stress equal to 0.4 times the characteristic strength of the concrete after 28 days, corresponding to a stress of 24 MPa. The result must be greater than or equal to 39 GPa.

In addition to the study file, the Civil Contractor shall supply THE PURCHASER with the constituents of the concrete, in order to carry out additional tests (creep, in particular).

7.8.3.3.6 Additional stipulations for concrete for large volume

The study test shall comprise, moreover, a calculation of the increase in temperature in the nominal formula of the concrete during setting, in accordance with one of the following processes:

- digital simulation, via a software subject to the approval of THE PURCHASER,
- concreting of a model or a portion of the construction representing the dimensions of the structure (thickness, in particular).

The prevention Level Ds of the LCPC's « Recommandations pour la prévention des désordres dus à la réaction sulfatique interne of the LPC (Laboratoires des Ponts et Chaussées) August 2007 » must be followed.

The following conditions must be satisfied:

$\Delta T_{max} < 40°C$

$T_{c\,max} < 65°C$

In respect of these inequalities:

- $\Delta T_{max}$ represents the maximum increase in temperature linked to the hydration of the binder in relation to the temperature of the fresh concrete.
- $T_{c\,max}$ represents the maximum temperature in the core of the concrete.

With regard to the results of this study, the Civil Contractor shall draw up a procedure, submitted to THE PURCHASER for approval, specifying the provisions to be adopted to limit the thermal gradient between the core and the skin of the moulded concrete and to avoid thermal shocks during demoulding.

With regard to massive constructions in a wet environment (exposure classes XS2 and XS3 according to standard NF EN 206-1, such as rafts, tanks, pumping station), the limitation of the temperature of the concrete to $65^{o}C$ must be used to avoid the internal sulphate reaction. Under circumstances where this temperature level cannot be observed, the LCPC's recommendations for the prevention of an internal sulphate reaction must be observed, for a prevention level C: the maximum temperature in the core of the concrete shall be under $75^{o}C$ and one or other of the following conditions must be satisfied:

- the cement used shall be included in the list in the marking "NF – Hydraulic binder" with the letters "ES" (concrete exposed to water with high sulphate content). The composition of the binder shall observe the requirements of standard XP P 15-319 and

the average alkaline content of the concrete, expressed in equivalent $Na_2O$, shall be under 3 kg/m3,

- the performance test with regard to the internal sulphate reaction according to draft test method No. 59 of the LPC (Laboratoires des Ponts et Chaussées) [French Public Works Research Laboratory] shall be carried out and shall be conclusive.

The final accepted limits should be agreed with THE PURCHASER following the numerical simulation or analysis of the results from the test slab.

With regard to the results of this study, the Civil Contractor shall draw up a procedure, submitted to THE PURCHASER for acceptance, specifying the provisions to be adopted to limit the thermal gradient between the core and the surface of the concrete to avoid thermal shocks.

7.8.3.3.7 Additional requirement for Conditions of Durability

| | Study test |
|---|---|
| XC1 | Pwater 90d ≤15 %<br>And Pwater 28d |
| XC3 XC4 | Pwater 90d ≤13 %<br>And Pwater 28d<br>Kgas90d ≤150 $10^{-18}$ m²<br>(CEMBUREAU) |

7.8.3.3.8 Additional stipulations for concrete to be placed by pumping

With regard to concrete to be placed by pumping, the study tests shall, moreover, comprise a pumping test with a length of piping forming an outline comparable to that of the pipe to be used during operations under the most difficult conditions.

With regard to “traditional” concretes, that is to say, where we have formal feedback, this test can be carried out at the time of the suitability test. With regard to innovative concretes (in particular, self-placing concretes), this test must be carried out at the time of the study test.

7.8.3.3.9 Additional stipulations for self-placing concrete

With regard to self-placing concretes, the study test shall, moreover, comprise tests to characterise the following:

- mobility in a non-confined environment (described by the flow test),
- mobility in a confined environment (described by the L box),
- stability (resistance to segregation and bleeding).

These tests shall be carried out according to the recommendations of the national self-placing concrete project, published by the AFGC (Association Française de Génie Civil) *[French Civil Engineering Association]* and NF EN 12350 parts 8 to 12.

The results must satisfy the functional stipulations for these concretes.

The producer defines a range spreading to manufacturing that considers the travel time between any site and production site. This information is filled in the technical file known SCC.

The producer pays particular attention to the consistency of manufacture including the regularity of the water content. A specific procedure for this type of concrete shall be prepared and used by the producer. It must mention in particular the frequency control of the spread to manufacturing.

7.8.3.3.10 Special stipulations for special concrete

Special concretes like fibre concretes, heavy and neutron absorbing concretes, light concrete, shotcrete, refractory concretes, concrete poured under water, shotcrete placed against ground..., undergo a qualification test suited to their function.

### *7.8.3.4 Information test*

This test may be carried out by the Civil Contractor at a laboratory at the same time as the study test or at the concrete mixing plant stipulated for the site at the same time as the suitability test.

The manufacture and storage of the specimens for this test shall comply with standard NF EN 12390.

To carry out this test, one of the following procedures shall be adopted:

- measurement of compressive strength at 3 days on three test specimens,
- measurement of compressive strength at 24 hours on thermo-matured concrete according to the operating mode, subject to the approval of THE PURCHASER.

Prior to the commencement of the works, in order to determine a minimum value for the strength of the green concrete below which there is a significant risk of not attaining the required compressive strength at 28 days, the following mixes shall be performed:

- 3 mixes according to the nominal formula (mixes from the study test or suitability test),
- 2 mixes derived from the nominal formula by modifying the quantity of cement by -10% for one and -20% for the other,
- 2 mixes derived from the nominal formula by modifying the quantity of mixing water by +10% for one and +20% for the other,
- 1 mix derived from the nominal formula by modifying the quantity of cement by -10% and the quantity of mixing water by +10%,
- 1 mix derived from the nominal formula by modifying the quantity of cement by -20% and the quantity of mixing water by +20%.

Each mix shall be the subject of:

- a test to determine the air content of the fresh concrete according to standard NF EN 12350-7,
- a measurement of the compressive strength at 3 days on three specimens or a measurement of the compressive strength at 24 hours on thermo-matured concrete on three specimens,
- a measurement of the compressive strength at 28 days on three specimens,
- a measurement of the compressive strength at 90 days on three specimens.

The tests to determine the compressive strength are carried out on cylinders and shall comply with standard NF EN 12390-3.

The compressive strength value adopted for comparison purposes shall be the arithmetic average of the measurements taken on each series of mixes of the same composition.

At the end of this test, the Civil Contractor shall draw up a procedure, submitted for the approval of THE PURCHASER, enabling an interpretation of the compressive strength results for green concretes and the consequences of any non-controlled malfunctioning of the concrete production plant.

### *7.8.3.5 Manufacture of concrete*

The concrete shall be manufactured either on site or in the ready-mixed concrete manufacturing installation, accepted under the marking "NF – Ready-mixed concrete" (NF-BPE), the choice of which shall be justified by the Civil Contractor.

The mixing time and introduction mode for admixtures shall be defined during the suitability tests.

7.8.3.5.1 Manufacture of concrete on site

The concrete manufacturing plant shall observe the requirements of Section 7.7.

7.8.3.5.2 Concrete manufactured at a ready-mixed concrete plant

The ready-mixed concrete manufacturing installation shall be the subject of a certificate of compliance in accordance with the marking "NF – Ready-mixed concrete" (NF-BPE).

Ready-mixed concrete can only be used after the characteristics thereof have been justified in accordance with the stipulations.

This concrete, ordered by the Civil Contractor, shall be concrete with specified properties (BPS) in accordance with standard NF EN 206-1, supplemented by the additional requirements of paragraphs 7.8.3.2.5 to 7.8.3.2.13.

For each delivery, the manufacturer shall draw up a delivery docket stating the production plant, the destination site, the nature and proportioning of the constituents, strength, values of other characteristics required, the mass of materials and matter used in each mix, the precise fill time for the concrete in the mixing tank (truck mixer) and the maximum utilisation time.

All the constituents of the concrete, including the water, shall be proportioned and fully mixed at the plant before the mixing tanks leave the premises.

Manufacturing at the ready mixed concrete plant does not exclude the concrete study, information, suitability and control tests.

### *7.8.3.6 Suitability test*

7.8.3.6.1 General stipulations

The information test described in paragraph 7.8.3.4 may be carried out at the time of the suitability test. The same applies to the pumping test for the "traditional" concretes described in paragraph 7.8.3.3.8.

No concrete with a given formula shall be used if it has not undergone a suitability test in advance.

The following shall be defined during this test:

- admixture introduction mode,
- concrete mixing time,
- practical duration of use.

The manufacture and storage of the specimens for this test shall comply with standard NF P18-404.

At the request of THE PURCHASER, additional specimens may be manufactured and supplied to THE PURCHASER in order to carry out supplementary tests.

The suitability test shall be the subject of a compliance justification file.

Three mixes of concrete corresponding to the nominal formula shall give rise to samples and tests which are identical to those defined for the study test. The results of these tests shall be deemed satisfactory if the following two inequalities are observed:

$$f_{cE} > fc_{28} + CE - (C_{moy} - 3Sc) + 3$$

$$f_{cE} > 1.1\ fc_{28}$$

With regard to these inequalities (the values being expressed in MPa):

- $f_{cE}$ is the arithmetic average of the results adopted for the compressive strength at 28 days over the three mixes,
- $fc_{28}$ is the characteristic value required for the compressive strength at 28 days,
- CE is the compressive strength at 28 days of the cement used for the suitability test,
- $C_{moy}$ is the average value for the compressive strength at 28 days, observed by the supplier during the six months preceding the suitability test,
- Sc is the standard deviation for the values used to determine $C_{moy}$.

The suitability test shall, moreover, comprise a performance measurement to ensure that the concrete formula under study, and used with the resources of the site, will satisfactorily lead to the manufacture of one cubic metre of concrete at approximately 2%. The mixer shall be loaded to its nominal capacity. This test shall be carried out in cylindrical, cubic or parallelepipedal containers submitted for the approval of THE PURCHASER, the smallest dimension of which shall be at least equal to ten times the size of the largest aggregate. The concrete in these containers shall be vibrated in the same way as in the structure.

Using the materials taken at the batching plant, a test for the shrinkage on three prismatic concrete samples 10x10x40 using NF P15-433 for sampling and curing; NF P18-427 for the measure will be carried out. This test shall be realised in a laboratory.

7.8.3.6.2 Additional requirement for Conditions of Durability

| | Trial mix testing |
|---|---|
| XC1 | Pwater 28d<br>Pwater 28d (Trial mix) ≤ 1.1 Pwater 28d (study) |
| XC3 XC4 | Pwater 28d<br>Pwater 28d (Trial mix) ≤ 1.1 Pwater 28d (study) |

7.8.3.6.3 Further stipulations for concrete subjected to severe frost

Not applicable to the site of Cadarache.

7.8.3.6.4 Further stipulations for high-strength concrete and self- placing concrete

With regard to high-strength concretes (compressive strength class in excess of C50/60) and self-placing concretes (BAP), the suitability test shall, moreover, comprise specific tests in order to adjust the procedure, drawn up by the Civil Contractor and submitted for the approval of THE PURCHASER, stipulating the precautions to be adopted during the manufacture, transportation, use (vibration, recovery time, treatment of the construction joints, free fall height etc.) and curing of these concretes.

To this end, the concreting of a model or portion of a construction representing the dimensions of the structure (thickness, in particular) may be envisaged.

### *7.8.3.7 Special concretes*

The composition of special concretes and the characteristics thereof must satisfy the functional requirements.

To this end, the Civil Contractor shall carry out study, suitability and control tests adapted to their function, in accordance with the procedures drawn up in that respect, and submitted for the approval of THE PURCHASER.

The suitability test shall, moreover, comprise specific tests in order to adapt the procedure, drawn up by the Civil Contractor and submitted for the approval of THE PURCHASER, stipulating the precautions to be adopted during the manufacture, transportation, use (maximum free fall height, vibration, overlap time limit between two successive layers, treatment of construction joints, etc.) and curing of these concretes.

#### 7.8.3.7.1 High Density concrete

High density concrete refers to concrete with specific properties according to standard NF EN 206-1.

It shall be manufactured in vertical axis mixers.

During tests, the following shall be checked on three mixes:

- density, in accordance with standard NF EN 12390-7,
- compressive strength at 28 days, in accordance with standard NF EN 12390-3,
- absence of any segregation.

The tests shall be considered as probative if the results satisfy the functional stipulations, and if the concrete does not show any evidence of segregation.

#### 7.8.3.7.2 Neutron absorbing concrete

This concerns concrete with neutron absorbing properties created via the incorporation of colemanite and/or limonite. The standard proportioning operations are as follows:

- colemanite concrete: approximately 75 kg/$m^3$ of colemanite,
- limonite concrete: approximately 830 kg/$m^3$ of limonite,
- limonite and colemanite concrete: approximately 830 kg/$m^3$ of limonite plus 10 kg/$m^3$ of colemanite.

With regard to the limonite and colemanite, the Civil Contractor shall notify THE PURCHASER of the following:

- grain size distribution,
- density,
- chemical composition, boron content, for colemanite, in particular.
- chemically-fixed water content (hydrates), measured according to an operating mode submitted for the approval of THE PURCHASER.

The constituents and composition of the neutron absorbing concretes shall be submitted for the approval of THE PURCHASER.

During tests, the following shall be checked over three mixes:

- compressive strength at 28 days, in accordance with standard NF EN 12390-3,

- tensile strength at 28 days, in accordance with standard NF EN 12390-6.

The tests shall be considered as probative if the results satisfy the functional stipulations.

## 7.9 Transportation and Placing of Concrete

### 7.9.1 *SCOPE*

This Section applies to the transportation and placing of concrete for the structures covered by the contract.

### 7.9.2 *DOCUMENTS QUOTED IN REFERENCE IN THIS SECTION*

#### *7.9.2.1 Standards*

ISO 1920-10 (09/10): Concrete – Testing Concrete

NF EN 206-1 (04/04) and Addenda A1 of April 2005 and A2 of October 2005 °: Concrete – Part 1: Specification, performance, production and conformity.

NF EN 1992 (varies) Eurocode 2 – Design of concrete structures – All parts

NF EN 12350-2 (04/12): Test for fresh concrete – Part 2: Slump test

NF EN 12350-5 (06/09): Test for fresh concrete – Part 5: Flow table test

NF EN 12350-8 (11/10): Test for fresh concrete – Part 8: Self compacting concrete – Slump flow test

NF EN 12390-3 (04/12): Test for hardened concrete – Part 3: Compressive strength of test specimens

NF EN 12390-6 (04/12): Test for hardened concrete – Part 6: Tensile splitting strength of test specimens

NF EN 12390-7 (04/12): Test for hardened concrete – Part 7: Density of concrete

NF EN 13670 (06/09): Execution of Concrete Structures

NF P 18-404 (12/81): Concrete – Study, suitability and control tests – Manufacture and storage of test specimens

NF P18-427 (12/96) Concrete - Determination of dimensional variations between two faces opposing hardened concrete specimens. Only French version

NF P15-433 (02/94) Methods of testing cement. Determination of shrinkage and swelling.

### 7.9.3 *REQUIREMENTS AND RELATED CHECKS*

#### *7.9.3.1 Transportation of concrete*

The time lapse separating the manufacture of the concrete from the use thereof shall be compatible with the practical duration of use measured during the suitability tests.

No transportation process shall be used which is liable to give rise to any segregation of elements, commencement of setting prior to use, or any alteration to the qualities of the concrete as a result of the atmospheric conditions (in particular, excessive evaporation).

When the transportation of the concrete is carried out in mixing tanks (truck mixers) over a distance of more than one kilometre, they shall be fitted with a two-speed drum, one for the agitating operation to be maintained during transportation and the other for the mixing.

With the exception of fluidifiers (to be confirmed during the suitability study), there shall be no addition of any admixture or water during transportation or on site.

The concrete may be transported via conveyor belts in the case of large-scale concreting operations.

Prior to concreting, the Civil Contractor shall define the following:

- the equipment used and the sketch of the installation,
- the concreting operating rates,
- the circulation zones planned for personnel,
- the precautions adopted to avoid overfilling the conveyor belt,
- the maximum gradients for the belts,
- the adaptation of the reinforcement, if needed,
- the adaptations stipulated to avoid segregation at the commencement and end of the concreting sequence.

#### *7.9.3.2 Placing concrete*

7.9.3.2.1 Measurement of temperature and wind speed

The Civil Contractor shall install the following on site:

- recording thermometers protected by shelters,
- recording anemometers.

7.9.3.2.2 Concreting programme

The Civil Contractor shall submit for the approval of THE PURCHASER, fifteen days prior to the commencement of the construction of each structure, the provisions it proposes to adopt regarding the placing of the concrete. These provisions, accompanied by the required drawings, shall constitute the concreting programme and define the following:

- the concreting phases,
- the position and configuration of the specific joints,
- the amount of concrete used per unit of time and per formula,
- the overlap time limits between successive layers,
- the nature of the forms,
- the equipment required for placing,
- the means of supply, including reserves,
- the number of personnel, duly specifying their professional qualifications,
- any back-up electrical emergency supply,
- the provisions adopted in the case of any stoppage in concrete supply.

7.9.3.2.3 General instructions for concreting

Any addition of water to the concrete shall be prohibited after exiting the mixer.

In the case of pacing with pumps, the concrete shall be mixed in the transportation vehicle (truck mixer) prior to tipping into the pump hopper. The pipe systems exposed to the sun shall be suitably protected. Prior to concreting, if a mortar is used to favour the movement of the concrete in the pipes, it shall be fully discharged before concreting.

At the time of use, the concrete shall be free of any segregation. It shall be laid before the commencement of any setting or drying.

The temperature of the fresh concrete used shall be between 5 and 30$^{o}$C.

The placing and vibration of the concrete must not cause the displacement of any reinforcements or prestressing ducts.

Reinforcements exiting a lift shall be firmly maintained to ensure that the minimum concrete cover thereof is always guaranteed in the following lift.

The concrete shall be in perfect contact with the faces or forms and shall cover the reinforcement throughout the surface thereof.

The concrete must not fall freely from a height in excess of 1.50 m. The fall shall be guided via flexible chutes and concreting chimneys may be specified in the reinforcement layout.

Power and water supply and concrete placing equipment shall be equipped with back up measures to avoid severe consequences on the pours entailed by on interruption.

#### 7.9.3.2.4 Cold weather concreting

When the temperature on the concreting site falls below $0^{o}$C (from $+5^{o}$C, if slag cement is used, if the concrete is to be prestressed or if this concerns the use of high-strength and/or self-placing concrete), any concreting operation shall be prohibited unless special provisions are implemented, duly stipulated in a procedure drawn up by the Civil Contractor, and submitted for the approval of THE PURCHASER, such as:

- heating of aggregates via steam injection ensuring the suitable homogeneity of the water content and temperature of the aggregates,
- heating of the mixing water up to the maximum temperature of 70°C,
- use of formwork with thick timber or heat insulation of metal formwork,
- use of an accelerator admixture in setting and hardening after classification of the formula in accordance with Section 7.8,
- increase in proportioning of cement and use of a cement with a higher heat of hydration if this method does not run contrary to a minimal cracking objective.

Irrespective of these provisions, when frost is anticipated, freshly concrete surfaces shall, on the termination of operations, be covered to ensure they are effectively protected against frost, in particular with polyane or polyethylene sheeting, canvas, heat covers, and panels fitted on boards. These devices shall be designed so as not to be displaced by the wind.

All these systems shall ensure that the temperature level, at all points in the concrete, remains at least equal to $+10^{o}$C during at least 72 hours after concrete placing. The Civil Contractor shall draw up a specific procedure to determine when form removal can only take place, in function of the strength of the concrete, in relation to the external temperature. This procedure shall be submitted to the approval of THE PURCHASER.

When the protective systems are removed, the Civil Contractor shall ensure that the rate at which the temperature on the surface of the concrete falls does not exceed $1^{o}$C per hour.

Concreting cannot normally be resumed after the cold period until any damaged parts have been demolished by the Civil Contractor and the surface of the construction joints has been accepted by THE PURCHASER.

#### 7.9.3.2.5 Concreting in hot weather

In periods when the temperature is high (exceeds $30^{o}$C), above all when accompanied by dry air, all provisions shall be adopted to avoid any problematic consequences with regard to the fresh concrete (high acceleration in setting, rapid evaporation of water, rapid reduction in plasticity, cracking after setting) or with regard to the hardened concrete (increase in

temperature of the concrete entailing a reduction in the ultimate strength and cracking). The temperature of the fresh concrete must not exceed 30°C, at the time of its placement.

The Civil Contractor shall draw up procedures, submitted for the approval of THE PURCHASER, listing the precautions to be adopted in order to eliminate the noxiousness of these specific atmospheric conditions. The following provisions may be adopted:

- use of a set-retarding admixture subsequent to classification of the formula according to Section 7.8,
- refrigeration of water and aggregates,
- use of ice flakes in the mixer,
- protection of concrete surfaces immediately after the placing of the concrete via wet mats or canvas,
- use of a cement with a low heat of hydration,
- concreting early in the morning, late in the evening or during the night.

7.9.3.2.6 Large concrete volume pour

To confirm validity of the increase in temperature in the nominal formula of the concrete (see Additional requirements of the study test for large volume concrete pours) the first four large volume concrete plots poured will be instrumented with probe temperature (centre and corner on surface and core) then the 50% of the remaining plots will be instrumented with probe temperature.

The Civil Contractor could submit a justification and proposal for the acceptance of THE PURCHASER to decrease this frequency after the four first pours.

7.9.3.2.7 Concrete chutes and chimneys

It shall be included in the Civil Contractor work procedures and Execution drawings, measures ensuring the correct placing of concrete inside formworks. For instance, must be specified for highly reinforced structures the position of required concrete hoppers and chimneys in order either to place the concrete or to vibrate it.

Where deemed necessary, THE PURCHASER may request the implementation of formwork panels including transparent zones or any other method, to attest the absence of air pockets.

7.9.3.2.8 Vibration

A vibration procedure, in relation to the concrete used, shall be drawn up by the Civil Contractor, and submitted for the approval of THE PURCHASER.

The concrete shall be compacted via internal vibration (internal vibrator) with the exception of specific cases where it is supplemented or replaced by external vibration (vibration of formwork, surface vibration, vibrating table).

Under these circumstances, the effectiveness of this method shall be demonstrated by the Civil Contractor via tests on a model.

Internal vibration shall be implemented by taking care to avoid any excess vibration entailing segregation, in particular in the case of self-placing concrete, dense concrete and fluidised concrete.

The dimensions of the vibrating needles shall ensure that they can easily penetrate the reinforcements and, where required, between reinforcements and formwork in the stipulated areas, thus ensuring they can act on the concrete in its entirety. They shall never be used to push or spread the concrete.

In the case of concreting on a slope, the Civil Contractor shall demonstrate, via tests on a model, that internal vibration can successfully been carried out.

The vibrating needles shall be held vertically and displaced in accordance with its axis. Concrete shall only be removed slowly to ensure that any indentation closes up when the needle is raised. The thickness of the layers subject to internal vibration shall not exceed 50 cm.

All precautions shall be adopted to ensure that vibrating needles do not enter into contact with the prestressing cable pipes and reinforcement bars.

The superimposition of a layer of fresh concrete on a layer already applied shall not be considered as a construction joint if the last layer can be re-vibrated (the same applies when a vibrating needle easily penetrates this layer and the indentation closes up when the needle rises). In vibrating the new layer, it is therefore advisable to ensure the penetration of the vibrating needle into the layer below. If the layer already applied is not liable to be re-vibrated, the superimposition of a layer of fresh concrete on to the first layer shall be treated in accordance with the stipulations defined in below paragraph "Construction Joints".

The thickness of the layers compacted by surface vibration via vibrating floats or rammers shall be limited to 20 cm, unless tests can demonstrate the possibility of adopting greater thicknesses. Vibration shall continue on each device position until the flow-back of the mortar to the edges and via any apertures in the surface of the device panel. The successive positions of the device shall overlap.

#### 7.9.3.2.9 Construction joints

The mode for treating construction joints shall be defined in a procedure drawn up by the Civil Contractor and submitted for the approval of THE PURCHASER.

At the time of setting, the surface of the concrete shall be entirely purged of grout using a pressurised water and air jet to stir up the surface and clear it of any friable or fatty elements, taking care not to loosen the aggregates. If the result is not attained, prior to any concreting, the surface shall be stirred up, either using high-pressure water jet (in excess of 10 MPa) or via slight rescraping followed by re-cleaning and re-washing.

Construction joint shall conform to NF EN 1992-1-1 (smooth, rough or indented) as specified on the drawings or in calculations notes.

The use of joint treatment techniques other than those described above must be submitted for the approval of THE PURCHASER.

Openings and a discharge network for collecting water and materials from cleaning operations, without dirtying the neighbouring concrete, shall be arranged by the Civil Contractor in the formwork thereof.

With each operation on hardened concrete, the surface to be concreted shall be fully cleaned and subsequently moistened until the old concrete is saturated. Prior to concreting, the excess water shall be eliminated via oil-free compressed air.

At the end of the concreting operation or the time of treatment of the joint, the starter bars and the reinforcement shall be cleared of any slag and mortar pours which may cover them.

The vertical joints shall be limited as much as possible. Where they are inevitable, a procedure shall specify their forming mode relating thereto. The concreting of the adjacent plot shall only be undertaken when the concrete has done sufficient shrinkage. The location of day joints between formed construction joints shall be agreed with the Civil Contractor.

All joints in reinforced concrete confinement zones have to resist gas pressure and shall have a proprietary reinjectable waterbar grout tube system installed such as Sika's Injectoflex System

or other equal approved system that can be injected with grout or resin throughout the life of the structure to minimise gas leakage across joints. The Civil Contractor shall submit full details of his proposed re-injectable waterbar grout tube system for the acceptance of the THE PURCHASER prior to procurement. Such details shall include the proposed locations of permanent grout injection points. The system used shall be of a complete and single proprietary design. Adaptations and substitution of components shall not be permitted.

The system shall be installed and tested strictly in accordance with the manufacturer's recommendations. The Civil Contractor can propose an alternative system that shall be suitable for the requirements. This proposal shall be fully documented and, if necessary, qualified with mock-up.

All joints in reinforced concrete non-confinement zones below ground level and subject to water inflow shall have a proprietary flexible preformed PVC waterstop to prevent the ingress of ground water.

See also section 18.

The grid concreting stops shall be submitted for the approval of THE PURCHASER. Where applicable, the grid shall be removed when the concrete so allows (green concrete).

7.9.3.2.10 Additional stipulation for self-placing concrete

The maximum length of horizontal progression for self-placing concrete in formwork shall be limited to 10 m. Similarly, the free fall height is 2 m.

Upon delivery, sampling and testing of the fresh concrete is performed before unloading starts. A visual inspection is performed at each load delivered and spread measurement (slump flow test in accordance with NF EN 12350-8).

The requirements of treatment are identical to the requirements for other concretes (for curing, surface finish, protection from environmental conditions, etc.).

7.9.3.2.11 Additional stipulation for high density concrete

Bearing in mind the significant risk of segregation in these concretes, the following precautions shall be adopted:

- minimum fall height,
- effective vibration without excess,
- applying via layers of 25 cm (maximum).

These provisions shall be recorded in the implementation procedure for these concretes.

7.9.3.2.12 Additional requirements for minimisation of early thermal cracking.

The Civil Contractor shall employ best industry practice in the planning, placing and curing of concrete to minimise the effects of early thermal cracking with particular regard to confinement structures. Such measures shall include:

- control of placing temperatures;
- control of exposure to solar gain and evaporation;
- careful consideration of spacing and position of construction joints;
- control of cement content and use of cement replacements where appropriate;
- measures to deal with plastic cracking in deep sections;
- control of temperature gradients in large sections;
- avoidance or mitigation of stress concentrations due to holes or corners; and

- careful consideration of restraint to shrinkage due to pour sequencing (particularly in walls).

7.9.3.2.13 Concrete curing

The curing of the concrete is mandatory.

A procedure, drawn up by the Civil Contractor and submitted for the approval of THE PURCHASER, shall determine the curing period in order to satisfy the stipulations of standard NF EN 13670. This procedure shall, in particular, take into account the temperature, wind (high wind increases the water evaporation and if the curing is realized by the humidification process, special care shall be observed in order that the concrete surface be continuously wet) and relative hygrometry of the site, the composition of the concretes (presence of slag, fly ash or silica fume, in particular), the surface/volume ratio of the elements (slabs, terraces, shells, etc.) and the purpose of the surfaces (in particular, the surfaces to be covered).

Minimum curing period

Under no circumstances shall the curing period be less than three days. Curing shall be stopped simultaneously throughout the area concerned. The curing period in days shall not be less than the period stipulated under standard NF EN 13670 Table F.2 using a curing class of 3.

Temperatures under $+5^{o}C$: if there is no isothermal protection, curing shall be continued insofar as the temperature remains under $+5^{o}C$ (for subsequent scenarios, refer to the corresponding cases in the table).

The temperature normally to be taken into account is the average level on two days for the noon temperature in shade, and the hygrometric degree is the lowest of these figures corresponding to these two times. For cases within the limits, the longest curing period shall be adopted.

For very slow concrete strength (i.e r <0,15), curing period of slow strength will be applied.

Processes for curing concrete

Curing shall be carried out using one of the following processes:

- permanent humidification of the surfaces,
- temporary impermeable protection of the surfaces (sealed sheets, curing products, formwork, etc.)

The nature of the curing process and the application conditions thereof shall be defined in a process drawn up by the Civil Contractor and submitted for the approval of THE PURCHASER on the basis of a study to check that the processes used are compatible with the end use of the surface.

During periods of strong winds, the use of a curing product is preferable to humidification.

Implementation of curing

For surfaces not subject to formwork, curing shall be applied once the condition of the surface permits the implementation thereof, that is to say:

- in the humidification process: when, after the concrete has set, its surface does not run the risk of being altered by surface water,
- in the process involving protection via a curing product: when setting commences (surface becoming matt).

For surfaces form-stripped prior to the end of the normal curing period, curing shall be completed from the time of form removal onwards.

The humidification and impermeable film created using a curing product shall be regular and apply to the surface in its entirety. Humidification shall be maintained on a continuous basis; intermittent runoff or sprinkling shall, in particular, be prohibited.

Specific stipulations for high-strength concrete

The curing of high-strength concrete (compressive strength class in excess of C50/60) shall require particular care, as a result of slight to non-existent bleeding and the risk of plastic shrinkage prior to setting.

The curing of concreting joints shall be systematic. It must, in particular, prevent the drying of the concrete prior to setting, and any micro-cracking during setting.

The curing method shall be justified by experiments conducted beforehand.

Irrespective of the geometry of the concrete structure concerned, all provisions required shall be adopted to ensure normal hydration conditions for the cement, and the correct maturing of the concrete.

These measures shall also apply to form-stripped surfaces (from form removal onwards).

#### *7.9.3.3 Concrete pours supervision by Civil Contractor*

During pours, all parts of the structure being cast shall remain visible for work and control teams. For example, in the case of night pours or cramped elements, sufficient lighting must be available on site.

The Civil Contractor shall monitor the respect of the practical workability of the concrete during the pours. A concrete which production time is incompatible with the workability time established during mix validation must not be used.

As part of the working procedure, the Civil Contractor shall focus on the concrete layers bonding so that to adapt its phasing with the concrete characteristics. Dedicated labour will be in charge of the fresh-to-fresh link between successive layers. To that purpose, vibrating pokers number and types must be adapted to the works carried out. No damage can be accepted neither on formwork nor reinforcement.

#### *7.9.3.4 Control test*

The control tests check the compliance of the concrete with the specifications. They shall be recorded in one or several technical reports updated and sent to THE PURCHASER for information each month.

7.9.3.4.1 Sampling

Sampling for the concrete producer

Samples of fresh concrete shall be taken at the time the concrete is used, at the nearest possible point to the implementation thereof in the structure - for example, when tipping the concrete from the truck mixer. The sampling rate shall be as specified in NF EN 206-1.

The manufacture and storage of specimens for this test shall comply with standard NF P 18-404.

The specimens will be used for the compressive strength at 28 days.

At the request of THE PURCHASER, additional test specimens shall be manufactured and supplied to THE PURCHASER as precautionary test specimens and/or for carrying out additional tests.

Sampling for the Civil Contractor

Samples of fresh concrete shall be taken at the time the concrete is used, at the nearest possible point to the implementation thereof in the structure - for example, when tipping the concrete from the truck mixer. The sampling rate shall be per formula and following tables below:

| Test | Sample / Frequency |
|---|---|
| Consistency | Each delivery truck mixer |
| Temperature of fresh concrete | Each delivery truck mixer |
| Compressive strength 28 days | Per building and per level<br>1 sample of 3 test cylinders per 200 $m^3$ of concrete and minimum 1 sample per construction part (foundation, wall, slab, column beam…) plus for Nuclear Buildings (11, 14, 21, 23) minimum 1 sample for confinement walls plus for Building 11 minimum one sample for the bioshield wall |
| Compressive strength at 90 days | Per building<br>1 sample of 3 test cylinders per 500 $m^3$ of concrete and minimum 1 sample per month |
| Tensile strength at 28 days (NF EN 12390-6) | Per building<br>1 sample of 3 test cylinders per 500 $m^3$ of concrete and minimum 1 sample per construction part (foundation, wall, slab, column beam…) plus for Nuclear Buildings (11, 14, 21, 23) minimum one sample for confinement wall plus for Building 11 minimum 1 sample for the bioshield wall |
| Static Modulus of Elasticity | Nuclear Buildings (11, 14, 21, 23 & 74)<br>1 sample of 3 test cylinders per 1000 $m^3$ of concrete and minimum 1 sample per month |

| Porosity control | Control tests /500 $m^3$ |
|---|---|
| XC1 | Pwater 28d<br>Pwater 28d ≤ 1.1<br>Pwater 28d (study)<br>Pwater 90d ≤15 % |
| XC3 XC4 | Pwater 28d<br>Pwater 28d ≤ 1.1<br>Pwater 28d (study)<br>Pwater 90d ≤13 % |

The manufacture and storage of specimens for this test shall comply with standard NF P 18-404.

At the request of THE PURCHASER, additional test specimens shall be manufactured and supplied to THE PURCHASER as precautionary test specimens and/or for carrying out additional tests.

For each concrete sample, a cement sample is also taken. The cement sample is taken at the concrete mixing plant, as near as possible to the mixer, at the time of mixing the batch which produces the concrete sample. This sample, which is used to verify the characteristics of the cement in the case of the non-compliance of the concrete checked, shall be destroyed once the concrete checked is deemed to be compliant.

7.9.3.4.2 Gas permeability maximum value (CEMBUREAU)

The gas permeability will be tested once per year on three specimens.

7.9.3.4.3 Shrinkage

Using the materials taken at the batching plant, test for the shrinkage on three prismatic concrete samples 10x10x40 using NF P 15-433 for sampling and curing; NF P 18-427 for the measure will be carried out each year. This test shall be realised in a laboratory.

7.9.3.4.4 Consistency check

A consistency check adapted to the workability of the concrete (slump test according to standard NF EN 12350-2 or spreading test on a vibrating table according to standard NF EN 12350-5) shall be carried out using the sample.

The concrete is deemed to be compliant if the result of the consistency test falls within the tolerance range relating to the target value stipulated during the concrete studies. The tolerance limits are specified in standard NF EN 206-1.

If the result does not fall within the tolerance range, the corresponding mix shall be removed and the following mix shall be the subject of a sampling operation for a new test.

If the result still fails to fall within the tolerance range, concreting shall be stopped until the reasons for non-compliance have been determined and adjustments have been made.

7.9.3.4.5 Checking of temperature of fresh concrete

A measurement of the temperature of the fresh placed concrete shall be carried out using the sample.

The concrete is deemed to be compliant if the concreting temperature thereof lies between 5 and 30°C.

7.9.3.4.6 Checking of compressive strength of green concrete

For Nuclear Buildings (Tokamak Complex, Hot Cell, Radwaste) every 500 $m^3$ of concrete placed, three test specimens shall be produced to test the green concrete by measuring the compressive strength in accordance with the process adopted during the information test:

- either at 3 days,
- or at 24 hours on thermo-matured concrete.

If a result is lower than the minimum value predetermined during the information test, all the elements of the concrete mixing plant liable to be incorrectly adjusted shall be checked, as well as the materials used.

If the results on the green concrete do not improve, concreting shall be stopped and the Civil Contractor shall organise more detailed checks to determine the origin of the cause and the foreseeable consequences concerning the part of the structure in question.

7.9.3.4.7 Checking strength at 28 days

Following the table of the Civil Contractor's Technical Annex that defines Sampling for the Civil Contractor, the Civil Contractor shall carry out the following:

- a test to determine the compressive strength at 28 days measured on the cylinder in accordance with standard NF EN 12390-3. The result adopted shall be taken as equal to the arithmetic average of the measurements taken on three test specimens,
- a test to determine the tensile strength at 28 days measured by splitting on three cylindrical test specimens, in accordance with standard NF EN 12390-6. The result adopted shall be taken as equal to the arithmetic average of the measurements taken on the test specimens.

The 28-day compressive strength shall comply with the requirements of EN 206-1, 8.2.1.3 and the Civil Contractor shall propose, with justification their preferred method for determining the standard deviation, $S_b$, from the two methods described therein.

The results for tensile strength at 28 days must observe the characteristic value required.

Two periods shall be considered for checking strength;

- initial production covering the first 35 samples
- continuous production thereafter.

During initial production, fc and $S_b$ shall be formally calculated only when the first 35 results are available (during the initial period and before 35 results are available, $S_b$ shall be monitored and kept as close as possible to condition 1, below). Also during initial production, fc and $S_b$ shall be calculated from the previous 15 test results where possible, otherwise they shall be calculated using the available data set.

During continuous production, fc and $S_b$ shall be calculated from the previous 15 test results (as noted below).

The Sb criteria shall be checked individually for the winter and summer formulae.

For a given structure, in terms of each compressive strength test at 28 days relating to a concrete with a given composition and for each individual concrete batching plant, three conditions must be simultaneously satisfied:

Condition 1:

$S_b < 3.5$ for class below C35/45 (measured on cylinders) or 4.5 (measured on cubes) or

$S_b < 0.1 * fc_{28}$ for a concrete with a compressive strength class $fc_{28}$ greater than or equal to C35/45

Condition 2:

$fc > fc_{28} + 1.3\ Sb$

Condition 3:

$fci > fc_{28} - 3$

With regard to these inequalities (the values being expressed in MPa):

- fc is the sliding arithmetic average of the last fifteen results of the compressive strength test at 28 days relating to the concrete for the concrete under consideration,
- $fc_{28}$ is the characteristic compressive strength at 28 days,
- fci is the value of the compressive strength at 28 days given by the test in question,
- $S_b$ is the standard deviation for the aforementioned fifteen results (even if there is a short or long downtime period of the batching plant).

If one of the three conditions is not satisfied, the concrete used relating to the fifteen results shall be declared non-compliant with the specifications and the Civil Contractor shall submit to THE PURCHASER the provisions it proposes to adopt for the purposes of remedying the non-compliance.

7.9.3.4.8 Monitoring of correct operation of the concrete mixing plant

To ensure the correct operation of the concrete mixing plant, the Civil Contractor shall monitor the results of checks on the compressive strength of the concrete formula(e) most used.

To this end, the Civil Contractor shall draw up a procedure, submitted for the approval of THE PURCHASER, specifying the monitoring mode and the provisions to be adopted in the case of any difference in relation to the standard deviation, in particular.

7.9.3.4.9 Checking of instantaneous static modulus of elasticity

The Civil Contractor shall carry out the following tests:

every 3000 $m^3$ of concrete intended for the Nuclear Buildings (Tokamak Complex, Hot Cell, Radwaste), The following tests shall be carried out:

- A test to determine the instantaneous static modulus of elasticity in compression at 28 days and one test at 1 year, in accordance with standard ISO 1920-10. The modulus shall be determined by measuring the deformation under a stress equal to 0.4 times the characteristic strength of the concrete at 28 days, corresponding to a stress of 24 MPa applied to the concrete of grade C60/75. The results must be greater than 39 GPa for concrete with a minimum strength class of C60/75.

7.9.3.4.10 Additional stipulations for high density concrete

For high density concrete, a sample shall be taken at minimum for every 50 $m^3$ of concrete used in order to check the strength levels at 28 days. The control test comprises, moreover, a calculation of the density in accordance with standard NF EN 12390-7.

The concrete is deemed to be compliant if the density observes the functional stipulations.

7.9.3.4.11 Additional stipulation for neutron absorbing concrete

With regard to neutron absorbing concrete, a minimum of two samples shall be taken per concreting day for checking strength levels at 28 days.

Moreover, a sample shall be taken to check strength levels at 1 year, for every 150 $m^3$ of concrete used.

The concrete is deemed compliant if the results satisfy the functional stipulations.

# 7.10 Injections of additional sealant for concrete

## 7.10.1 *SCOPE*

This technical specification shall apply to injections of additional sealant for concrete. It shall cover the following two types of operations:

- Injection for which a specific injection network is positioned in advance,
- Injection of cracks observed after the concreting phases and for which the injection system is adapted to each case.

## 7.10.2 *List of documents quoted in reference in the specification*

- NF P 18-800 (12/89) Special products intended for repair work, bonding, injecting, wedging, embedding, applicable to hydraulic concrete constructions. Definitions, classification, packaging, marking, acceptance conditions.
- P 18-802 (10/92): Special repair, bonding, injection, levelling and sealing products for hydraulic concrete constructions. Control on building site. (Only french version)
- NF P 95-103 (10/92) Repair and strengthening of concrete works and masonry. Injection of cracks and protection of concrete.

## 7.10.3 *REQUIREMENTS AND RELATED CHECKS*

In addition to the enhancement of the sealing, the injections shall have a restructuring capacity by contributing new mechanical bonds in the area concerned.

### *7.10.3.1 Choice of products*

The Civil Contractor shall choose the injection products in relation to the operation to be carried out and submit them for the approval of THE PURCHASER after carrying out an injectability study to adjust the practical period of use and establish the viscosity required in relation to the geometry to be injected, duly ensuring the non-aggressiveness of the products vis-à-vis the reinforcement bars.

In complement, a study of the behaviour after polymerisation at a temperature equivalent to that of the reference accident shall be undertaken to check the behaviour of the product in hot temperature conditions.

7.10.3.1.1 Hydraulic binders

Hydraulic binders are chosen for their homogeneity with the surrounding concrete environment.

7.10.3.1.2 Resins

Resins shall be chosen according to their criteria to penetrate cracks with very small openings and their effectiveness after polymerisation (% of dry material content).

### *7.10.3.2 Acceptance of products*

The Civil Contractor shall:

- check the identity of the references of the products delivered with the references specified in the technical datasheet, on each delivery,
- for each manufacturing mix, it shall provide THE PURCHASER with rapid identification checks.

### *7.10.3.3 Installation of equipment and preliminary tests*

7.10.3.3.1 Choice of equipment

This shall comprise a proportioning unit and manufacturing unit, as well as an injection unit. The installation and design of the equipment must enable the quality of the product to be checked as near as possible to the injection point.

7.10.3.3.2 Injection of networks

The injection system, submitted for the approval of THE PURCHASER, shall be positioned according to the progress of the work and in accordance with the construction drawings. The injections shall be carried out from this system, located in accordance with a procedure submitted for the approval of THE PURCHASER.

7.10.3.3.3 Injection of cracks observed after the concreting phases

Overall sealing

The Civil Contractor shall submit the injection procedure for the approval of THE PURCHASER, as well as the basic plan of the injection system, describing the type, number and position of the injectors.

The maximum pressure at the injection head shall be specified by the Civil Contractor and submitted for the approval of THE PURCHASER, duly ensuring the penetration of the injection product into the crack network, taking care not to enlarge this network or create other unfavourable effects for the structure.

The manometer monitoring the injection pressure shall be positioned as near as possible to the injectors.

Surface sealing

The cracks shall be sealed via the implementation of adhesive strips or resin, which can also be used to secure the flat injectors.

Tests

Prior to injection treatment, air tests for resin-based products or water tests for hydraulic binder-based products shall be carried out to assess any communications within the crack network.

### *7.10.3.4 Preparation of products to be injected*

The products shall be prepared according to the information in the manufacturer’s technical datasheet.

Cement grout

Prior to injection, the grout shall be filtered with a 80 µm sieve in order to remove any elements liable to disrupt the correct implementation of the injection.

Checks

The Civil Contractor, in accordance with standard NF P 18-802, shall submit the product control procedure for the approval of THE PURCHASER.

The temperature and fluidity shall be measured on each mix manufacture, prior to injection.

#### *7.10.3.5 Monitoring of the injection operation*

The Civil Contractor shall submit for the approval of THE PURCHASER the procedure for monitoring the injection settings (pressure at injection head, temperature of product at the end of injection, monitoring of quantities injected, total injection period, ambient temperature, etc.).

#### *7.10.3.6 Checking injection of cracks*

At the request of THE PURCHASER, the Civil Contractor shall carry out core drilling operations perpendicular to the crack injected for visual checking purposes and physical and mechanical tests.

Where applicable, the core drilling holes shall be plugged with a sealing product or shrinkage compensated mortar, accepted under mark "NF – Special products for hydraulic concrete structures authorised for use".

#### *7.10.3.7 Cleaning*

The Civil Contractor shall carry out the removal of injectors and sealings, and clean the surfaces.

#### *7.10.3.8 Documentation*

The Civil Contractor shall create and update the following documents:

- the schedule governing the state of progress of the operations,
- the injection report for each area, stating, in particular:
- the reference identification for the area,
- the start and end dates and times of the operation,
- the results of the tests prior to injection, where applicable,
- the injection pressure levels and the quantities injected,
- the climatic conditions,
- any observations and incidents during injection operations, such as leakage, grout spoils, etc.

In the month following the completion of the injection operations, the Civil Contractor shall submit the end of operations report to THE PURCHASER.

## 7.11 Self-smoothing mortar screed for the finishing of slabs supporting air-cushion convoys.

Some surfaces will have to support the traffic of air-cushions convoys.

The surface must be non porous, smooth and perfectly plane, the required flatness tolerances are:

| | | | | | |
|---|---|---|---|---|---|
| Tolerances in mm | 1 | 3 | 9 | 12 | 15 |
| Distance between measure in m | 0.1 | 1 | 4 | 10 | 15 |

To comply with the above requirements a self-smoothing hydraulic mortar will be poured on the concrete floor, the minimum nominal thickness of the mortar screed will be 8 mm.

The mortar shall be packaged in pre-dosed kits of two components: the emulsified resin and the cement including special fillers. The required characteristics are as below:

- Compression strength at 28 days ≥40 Mpa,
- Bending strength at 28 days ≥ 10 MPa
- Adhesion on concrete ≥ 2 MPa
- Maximum particle size = 2 mm

The substrate shall be clean and sound (any loose particles will be removed), without traces of oil, grease, laitance and curing product likely to be prejudicial to the adhesion of the mortar screed on the concrete slab.

The substrate must be wetted abundantly on the day before the application and wetted again immediately before the application, without puddle of water on its surface.

If the site makes the wetting of the substrate impossible apply a primer and pour the mortar when the primer is still sticky.

The primer shall be a solvent free resin packaged in pre-dosed kit of two components : the resin and the hardening agent, with the following general characteristics: rapid hardening, very good adhesion on the concrete and very high mechanical strength: bending tensile strength = 70 MPa after 7 days at 23°C.

The application of the mortar shall conform to the manufacturer’s specifications. A curing agent must be applied on the fresh mortar to protect it from drying.

# 8 FORMWORK

## 8.1 References

Documents quoted in reference are indicated Section per Section in this specification

## 8.2 Facings and forms

### 8.2.1 *SCOPE*

This technical specification applies to the facings and formworks of the structures covered by the contract.

The materials used and the services provided shall meet the requirements of this specification and the below reference documents.

### 8.2.2 *DOCUMENTS QUOTED IN REFERENCE IN THIS SECTION*

#### *8.2.2.1 Standards*

NF EN 1504 (varies): Products and systems for the protection and repair of concrete structures. Definitions, requirements, quality control and evaluation of conformity (all parts)

NF EN 13670 (06/09): Execution of concrete structures

P 18-503 (11/89): Concrete surfaces and facing – Identification elements. Only french version

NF P 93-350 (06/95): Building site equipment – Wallforms for concrete structures. Only french version

### 8.2.3 *REQUIREMENTS AND RELATED CHECKS*

#### *8.2.3.1 Facing*

The facings of the concrete structures subject to this documentation are defined in relation to their texture and by their acceptable flatness and shape defects (refer Table F.4 NF EN 13670, Appendix F). In NF EN 13670 Tolerance Class 2 shall apply where there is a choice between Class 1 and Class 2.

They are classified into four categories:

- Basic,
- Ordinary,
- Plain,
- Special

The basic finish generally applies where there is no particular requirement. Ordinary finish does not require special formwork, concrete should be free from blemishes and honeycombing. Plain finish requires careful selection of concrete, release agent and good quality formwork. Special finish requires the same items as plain but more importance given to appearance. Only facing which meets the requirements of Plain/Special facing can be coated via a sealing or decontaminable system.

The construction drawings specify the categories of facing for the various sections of the structure. In the absence of any information, facing shall be Plain facing and a power float finish for slabs.

Where facing comprises false joints, the concrete construction joints shall obligatorily be made in line with these false joints.

The acceptance criteria for flatness defects in facing do not provide for the observance of concrete cover thicknesses. The tolerance limit on the minimum covering of reinforcements shall be zero.

#### 8.2.3.1.1 Basic surface finish

This finish shall be a closed uniform surface produced by levelling, no further work is required and may receive a screeded finish or other applied finish.

#### 8.2.3.1.2 Ordinary finish

Ordinary finish shall be a level uniform surface produced by floating or similar processes and be free of cavities and have a uniform colouring. The acceptance criteria for ordinary facing shall be as follows:

- flatness: observance of criterion P(1) of documentation P 18-503, that is to say:
  - maximum dip under straight edge of 2.00 m: 15 mm,
  - maximum dip under rule of 0.20 m: 6 mm,
- straightness of edges and internal angles: maximum dip under straight edge of 2.00 m: 15 mm,
- projection of formwork panels (form panel misalignment) at most equal to 3 mm,
- height of burrs : less than 3 mm,
- texture: observance of criterion E(1-2-0) of documentation P 18-503, that is to say:
  - average bubbling characterised at maximum by scale No. 7 (identical to plate No. 7 in report No. 24 of the International Building Council),
  - maximum area per bubble :3 $cm^2$,
  - maximum depth of a bubble: 5 mm,
  - area of surface bubbles (average): 10% of the total area,
  - maximum area of concentrated surface bubble zones (scatter of bubbles): 10% of the surface of the elementary panel under consideration,
- non-evolving cracking,
- no cracking in prestressed anchoring zones.

#### 8.2.3.1.3 Plain finish

Plain facing shall be free of pebble cavities and shall be finished by troweling or similar processes and have uniform colouring. It shall not have any burrs, or tears in the skin of the concrete, no damage to angles or edges, no spalling, no run of laitance, no stratification, no marbling, no rust stains, and no marked construction joints. It shall not require further work to be carried out.

The acceptance criteria for Plain facing shall be as follows:

- flatness: observance of criterion P(2) of documentation P 18-503, that is to say:
  - maximum dip under straight edge of 2.00 m: 8 mm,
  - maximum dip under rule of 0.20 m: 3 mm,
- straightness of edges and internal angles: maximum dip under straight edge of 2.00 m: 8 mm,
- projection of formwork panels at most equal to 1 mm, with a length of less than 1 m per $m^2$ of facing,
- texture: observance of criterion E(2-3-0) of documentation P 18-503, that is to say:

  - average bubbling characterised at maximum by scale No. 5 (identical to plate No. 24 of the IBC),
  - maximum area per surface bubble : 1.5 $cm^2$,
  - maximum depth of a surface bubble : 3 mm,
  - area of surface bubbles (average): 3% of the total surface,
  - maximum area of concentrated surface bubbles zones (scatter of bubbles): 5% of the surface of the elementary panel under consideration,
- non-evolving cracking,
- no cracking in prestressed anchoring zones.

Prior to implementation, the Civil Contractor shall carry out a suitability test on a model or section of structure (reference element). The work may only commence subsequent to THE PURCHASER's approval of the results of the suitability test. This work shall be carried out in accordance with a procedure drawn up by the Civil Contractor and submitted for the approval of THE PURCHASER.

With regard to Plain finished faces to be coated, the facing shall be accepted by THE PURCHASER in the presence of the Painting Contractor. In the case of non-compliant surface bubbles, any additional consumption of coating shall be the responsibility of the Civil Contractor.

8.2.3.1.4 Special finish

Refer to the drawings for any requirements for special finish class.

Prior to construction the Civil Contractor shall prepare a test panel of a section of structure (reference element). The work may only commence subsequent to THE PURCHASER's acceptance of the results of the panel. This work shall be carried out in accordance with a procedure drawn up by the Civil Contractor and submitted for the acceptance of THE PURCHASER.

With regard to plain finished faces to be coated, the finishing shall be approved by THE PURCHASER in the presence of the Painting Contractor. In the case of non-compliant surface bubbles, any additional consumption of coating shall be the responsibility of the Civil Contractor.

### *8.2.3.2 Repair of any defects*

Any repairs to defects shall only be carried out subsequent to the approval of THE PURCHASER.

The defects shall be the subject of a precise record prior to repair operations.

Any defects relating to flatness, straightness, burrs and misalignment in forms, surface bubbles and cracking which fail to observe the specifications of the facing under consideration shall be repaired in accordance with a procedure drawn up by the Civil Contractor and submitted for the approval of THE PURCHASER.

Spalling, pebble cavities and anchor cavities in formwork shall be repaired with a surface repair product in accordance with the NF EN 1504 Parts 1 to 10. This procedure states that thorough surface preparation is required prior to product application.

Where the facing concerned is intended to be visible, the repair product used shall be of the same colour/shade as the neighbouring concrete.

### *8.2.3.3 Formwork*

8.2.3.3.1 General stipulations

The methods of calculation and tests to determine the strength of the sheeting for concrete structures, and the dimensional characteristics thereof for the relevant operations shall comply with standard NF P 93-350.

The forms and props shall observe the specifications of standard NF EN 13670, as well as the requirements defined in the following paragraphs.

Formwork, scaffolding and supporting props must be able to withstand the various loads, excess loads and actions they may be required to support during the execution of the operations up until and including their removal. They must not cause any damage to the structures which have already been constructed or are in the process of construction.

The forms shall contribute to the creation of facing which meets the requirements defined in paragraphs 8.2.3.1.1 to 8.2.3.1.4. The forms shall be sealed to avoid any loss of mortar or binder during the placing of the concrete, in particular in the case of fluid or self-placing concretes. Their implementation and their deformation shall ensure that the stipulated tolerance limits are observed.

The propping system (e.g. to support formwork for casting slabs etc.) shall be provided on a grid with maximum spacing of 1.2 m x 1.2 m (on plan). The propping system shall be designed to be able to support weight of the concrete element being cast and any additional load as appropriate, to the floor level immediately below element being cast (i.e. the propping should span one level only). Exceptions shall be considered on a case by case basis.

Formwork methodology shall not damage existing elements. Where vertical propping is needed, the implantation of the props must be clearly localized and are submitted for acceptance. The density of propping shall allow access for the inspection of the formwork during concrete pour.

In the absence of any information in the construction drawings, the edges of beams, columns and wall ends shall be chamfered (2 x 2 cm) to avoid spalling of the edge.

The forms shall be constructed to ensure the placing and correct compacting of the concrete throughout all the operating phases. If necessary, to that end, it shall comprise moveable wall elements.

The forms shall enable correct form striking without damage to the structure.

The use of left in place formwork shall be subject to the approval of THE PURCHASER. A removal system for left in place formwork shall be proposed by the Civil Contractor, duly enabling the removal of formwork where the design so requires (in particular for joints).

8.2.3.3.2 Securing of formwork within the concrete

Where formwork comprises a securing system within the concrete, this system shall be designed to ensure that, after form removal, none of its elements are located at a distance from the facing which is lower than that of the minimum concrete cover stipulated for reinforcements.

When the structure plays the role of a biological protection or a leak-tightness role (retention and confinement structures), the use of securing systems via cross-holes is prohibited. Such elements will be clearly indicated in the drawings.

Where authorised, the cross-holes shall be sealed in accordance with a procedure drawn up by the Civil Contractor and submitted for the approval of THE PURCHASER. Cone holes shall be plugged with a surface repair product accepted in accordance with the marking “NF – Special

products for hydraulic concrete constructions) (of the same colour/shade as the neighbouring concrete when the facing is intended to be seen). The surface preparation mode, means of implementation and related checks shall be defined in the procedure.

The use of ties comprising twisted wires or grouped parallel wires penetrating the concrete shall be forbidden other than for Basic facing not in contact with water.

#### 8.2.3.3.3 Maintaining of formwork outside concrete

The maintaining of the formwork shall comply with the current safety rules.

Cables tightened by winches between the formwork panels and temporary anchoring points are forbidden.

#### 8.2.3.3.4 Alignment of embedded plates in relation to facing

Plates embedded in concrete shall be positioned in accordance with the information in the construction drawings and shall observe the specified tolerance limits.

The provisions adopted by the Civil Contractor to observe this alignment shall be recorded in a procedure submitted for the approval of THE PURCHASER.

The tolerances on the positioning of the embedded plates, as installed after concreting, are stipulated in Section 5.5.

The calculation of the bearing capacity of the embedded plates takes into account the offset effect induced by these tolerances.

The positioning of the embedded plates is described in the Draft Manual 12 – Plant Design Layout Guidelines (282BPW_v2_1).

#### 8.2.3.3.5 Cleaning

Prior to placing the concrete, the formwork shall be carefully cleaned to ensure that it is free of dust and debris of any nature. Cleaning shall be finished, if necessary, using compressed air. Windows with a mobile blanking system shall be reserved where necessary in order to facilitate the cleaning and inspection of parts subject to difficult access, such as bottoms and corners of formwork.

If the same formwork is used several times, it shall be perfectly cleaned and restored. Holes and other pockets shall be plugged to ensure that no trace appears on the new facing.

Storage shall be carried out with care (vertically, if possible) to avoid any deterioration.

#### 8.2.3.3.6 Form release products

All formwork shall be coated with form release products. These products shall be applied carefully avoiding any contact with the reinforcements, in order to form an even and homogenous layer. Moreover, they must not colour the concrete. These products shall be the subject of suitability tests carried out by the Civil Contractor.

The work may only commence subsequent to THE PURCHASER’s approval of the results of the suitability tests. This work shall be carried out in accordance with a procedure drawn up by the Civil Contractor at the end of this test and submitted for the approval of THE PURCHASER.

The form release products must not be incompatible with the coating products. Under all circumstances, the Civil Contractor shall provide THE PURCHASER with an identification of the facing subject to form release products.

#### 8.2.3.3.7 Form removal

The Civil Contractor shall be responsible for determining the safe time for removal of formwork and propping. The Civil Contractor shall submit a comprehensive method statement covering proposed curing, formwork striking times and de-propping for each generic type of reinforced element to be cast.

No form removal or props removal shall be carried out until the concrete has attained sufficient strength to ensure there will be no resultant damage for the structures. These operations are carried out without shocks.

The method statement shall address the following issues and provide sufficient calculations or quantitative justification to support the Civil Contractor's proposals where appropriate:

- The required characteristic structural strength of the concrete when the formwork or propping is removed, taking into consideration all loading to be placed on the immature structure prior to its attaining its full design characteristic strength.
- The prevention of shock loading on removal of formwork or propping.
- The method of verifying that the required minimum strength has been attained, taking into consideration appropriate factors of safety.
- The role of the formwork in acting as a curing membrane.
- The role of the formwork in acting to control the thermal gradient through the concrete section.
- The timing of removal of propping as compared to the removal of formwork moulds.
- The requirement to control deflection of slabs and beams in their immature state.
- The expected rate of gain in strength of the particular concrete mix to be used, including demonstration of this using data from compressive tests prepared using trial mixes.
- Requirements for temporary protection of the concrete surface from impact, abrasion or frost damage.

The use of empirical in-situ test methods to determine the in-situ strength of the immature concrete shall be supported by calibration tests conducted on concrete cube samples prepared with the same mix as that intended to be used in the permanent works. The use of such empirical in-situ tests to determining formwork and propping removal times shall be subject to the acceptance of THE PURCHASER.

#### 8.2.3.3.8 Formwork for beddings

Holes and cavities to be prepared for the sealing of parts shall be reserved via the installation of the formwork in accordance with the geometry of the pocket and arranged to ensure that all the elements thereof can be easily withdrawn when the forms are removed.

The material used must enable observance of the dimensional characteristics of the pocket and ensure satisfactory adherence between the bedding and the first phase concrete.

The use of reconsolidated wood is prohibited. The use of expanded polystyrene for pockets is forbidden. Coffered holes are wider at the hole base than at the facing level.

8.2.3.3.9 Void formers and cast-in items

Set out and fix cast-in items shown or referenced on the drawings. Any clashes between holes, cast-in items and reinforcement shall be resolved to the agreement of THE PURCHASER before any concrete is placed. Void formers shall be cleaned out after concreting.

8.2.3.3.10 Lift Shaft tolerances

Lift shafts are required to be built to a level of verticality and alignment between the landing openings which must meet with the requirements of the lift supplier. In addition to meeting the tolerance requirements of NF EN 13670 the Civil Contractor shall ensure that the construction tolerances of all lift shafts are compatible with his chosen lift supplier.

## 8.3 Securing of embedded parts in concrete

### 8.3.1 *SCOPE*

This Section applies to securing systems for equipment supports, to anchor plates, to the sleeves cast into the concrete and metal edgings used at the interface of two different civil engineering elements in concrete or steelwork incorporated into the concrete of the structures covered by the contract.

This section excludes metal parts contributing to containment leak tightness and watertight metal liners lining inner faces of specified volumes.

The securing devices covered are as follows:

- embedded plates,
- sealed rods,
- metal anchors
- anchoring rails,
- cross-rods,
- anchoring sockets

Civil Contractor shall take into consideration that before pouring whatever concrete element, the Civil Contractor shall provide a survey of all embedded parts that are already placed in the associated concrete element. This survey represents a Hold Point before concreting.

If the survey identifies some out of tolerances, Civil Contractor shall make necessary adjustment and proceed to a replacing the related one and submit a revised survey.

The supporting document for the survey shall be an elevation drawing or a top view or bottom view drawings to scale with all relevant information.

### 8.3.2 *LIST OF DOCUMENTS QUOTED IN REFERENCE IN THE SPECIFICATION*

Draft Manual 12 – Plant Design Layout Guidelines (282BPW_v2_1).

### 8.3.3 *REQUIREMENTS AND RELATED CHECKS*

The implementation of securing systems shall be carried out in accordance with a procedure drawn up by the Civil Contractor and submitted for the approval of THE PURCHASER.

The securing of the plates by tack welding the anchoring points on the concrete reinforcements shall be subject to the prior approval of THE PURCHASER. The direct anchoring of the plates on to the reinforcements is forbidden.

In other respects, the Civil Contractor shall take into account, in its organisation, the surface preparation and the minimum application of the primary coat of the coating system on the sides not embedded in concrete (i.e. sides exposed to atmospheric corrosion after form removal), prior to the installation of the securing systems in the forms. All precautions shall be taken to avoid the deterioration of the coating system during transportation, storage and installation operations.

The construction drawings shall specify the embedded plates which must be subject to a peripheral joint, to avoid the degradation of the concrete during welding.

The tolerances on the positioning of the embedded plates, as installed after concreting, are stipulated in Section 5.5 and the positioning is described in the Draft Manual 12 – Plant Design Layout Guidelines (282BPW_v2_1).

## 8.4 Securing of sleeves and metal edging

### 8.4.1 *SCOPE*

This Section shall apply to the sleeves incorporated into the concrete, and the metal edgings used at the interface of two different civil engineering elements in concrete or steelwork (used, in particular, in the construction of gutters, hoppers, decking and joints).

### 8.4.2 *LIST OF DOCUMENTS QUOTED IN REFERENCE IN THE SPECIFICATION*

No referenced document

### 8.4.3 *REQUIREMENTS AND RELATED CHECKS*

#### *8.4.3.1 General stipulation*

The Civil Contractor shall take into account, in its organisation, the surface preparation and the minimum application of the primary coat of the coating system on the sides not embedded in concrete (i.e. sides exposed to atmospheric corrosion after form removal), prior to the installation of the sleeves and metal edging. All precautions shall be taken to avoid the deterioration of the coating system during transportation, storage and installation operations.

#### *8.4.3.2 Sleeves*

The choice of materials shall be submitted for the approval of THE PURCHASER.

Metal sleeves shall be installed on support pieces linked to the formwork or on templates separate from the formwork which may be kept in the concrete. The securing mode shall be determined in relation to the tolerance limits.

#### *8.4.3.3 Metal edging*

The construction drawings shall specify the design of the metal edging to be used.

## 8.5 Grids and floor drains

### 8.5.1 *SCOPE*

This Section applies to grids and floor drains incorporated into the concrete in the structures covered by the contract.

### 8.5.2 *DOCUMENTS QUOTED IN REFERENCE IN THE SECTION*

NF EN 1253-1 (03/11): Gullies for buildings – Part 1: Requirements

NF EN 1253-2 (07/04): Gullies for buildings – Part 2: Testing

NF EN 1253-3 (06/99): Gullies for buildings – Part 3 : Quality Control

NF P98-321 (11/86) Inspection devices for yards and buildings. Gully tops with a clear opening less than 200 mm. Floor drains, requirements, dimensions and tests.

### 8.5.3 *REQUIREMENTS AND RELATED CHECKS*

The construction drawings specify the dimensions of the grids and floor drains, as well as the diameter of the pipes to which the floor drains must be connected. In the absence of any information, the dimensions of standard NF P 98-321 shall be observed in relation to the nominal diameter (ND) of the pipes.

Grids and floor drains covered by the contract (including all networks) shall be constructed from:

- stainless steel in the SIC Buildings
- ordinary steel in the other zones.

The connection of floor drains to the discharge pipes is provided for by welding.

The depth of water in the siphon must be a minimum of 50 mm, in accordance with standard NF EN 1253-1.

In areas subject to chemical hazards, each drain shall comprise a screw-in plug, which can resist a 22% dilute sulphuric acid solution which may attain 100$^{o}$C in contact with the wash water.

The grids and plugs must be capable of withstanding a load of 15 kN according to standard NF P 98-321.

The choice of grids, plugs and floor drains shall be submitted for the approval of THE PURCHASER.

The use thereof shall be implemented according to the supplier’s stipulations, in compliance with a procedure drawn up by the Civil Contractor and submitted for the approval of THE PURCHASER.

# 9 REINFORCEMENT

## 9.1 References

Documents quoted in reference are indicated Section per Section in this specification

## 9.2 Reinforcement for reinforced concretes

### 9.2.1 *SCOPE*

This technical specification applies to reinforcement for reinforced concretes in structures covered by the contract.

### 9.2.2 *DOCUMENTS QUOTED IN REFERENCE IN THIS SECTION*

#### *9.2.2.1 Standards*

NF EN ISO 6892-1 (10/09): Metallic materials – Tensile testing – Part 1: Method of test at room temperature

NF EN 10080 (09/05) Steel for the reinforcement of concrete

NF EN 1992 (varies) Eurocode 2 – Design of concrete structures – All parts

NF EN 10204 (01/05): Metallic products – Types of inspection documents

NF EN 10020 (09/00): Definition and classification of grades of steel.

NF A 35-015 (11/09): Reinforcing steels – Weldable smooth steel – Bars and coils. Only french version

NF A35-080-1 (10/10): Reinforcing steels - Weldable ribbed steel - Part 1: Bars and coils. Only french version

NF A35-080-2 (10/10): Reinforcing steels - Weldable ribbed steel - Part 2: Welded fabric. Only french version

NF A35-024 (12/07): Steel for concrete reinforcement - Surface welded fabric composed of wires with a diameter less than 5 mm. Only french version

ISO 14654 :1999 Epoxy-coated steel for the reinforcement of concrete.

NF EN 1504-7 Products and systems for the protection and repair of concrete structures. Definitions, requirements, quality control and evaluation of conformity. Part 7: Reinforcement corrosion protection.

XP A 35-031 (98) Concrete reinforcing steels. Weldable ribbed bars of diameter over 40 mm

NF EN 13670 (02/13) Execution of concrete structures

### 9.2.3 *REQUIREMENTS AND RELATED CHECKS*

#### *9.2.3.1 Choice of steels for reinforced concrete*

All steel reinforcement shall conform to EN 10080 and EN 1992-1-1 Table C1 Class B. Only ribbed bars shall be used with characteristic yield strength of 500 MPa and be certified and marked as conforming to a AFCAB certification scheme.

The steels used are classed as non-alloyed quality steels in accordance with standard NF EN 10020.

High-bond steel (HA) bars, coils and welded meshes shall comply with standard NF A35-080 Parts 1 and 2 "Reinforcing steel - Weldable steel". These shall be only category B (description: B500B) and must benefit from marking "NF – Concrete reinforcing steels.

Bars with a diameter of over 40 mm shall comply with experimental standard XP A 35-031. They are controlled via specific product checks in accordance with standard NF EN 10204 and shall be the subject of a "3.1.B"-type acceptance certificate.

"Welded wire fabric" shall comply with standard NF A 35-024. It must have the marking "NF – Concrete reinforcing steels".

#### *9.2.3.2 Packaging*

Concrete reinforcement may be delivered to the site either as straight bars or coils, or in the form of panels or rolls, or in the form of prefab elements (cut, fabricated and assembled) in an industrial reinforcing bar workshop.

The re-straightening of high-adherence reinforcing parts (HA) accidentally bent during manufacture, transportation or handling is forbidden. After removing the bent sections, the re-use of straight waste shall be authorised insofar as the length thereof so permits.

The supply of steels in coil form with a diameter over 6 mm shall only be authorised if the site or workshop has straightening tools whose effectiveness has been demonstrated by the suitability tests listed in Section 9.3.

#### *9.2.3.3 Transportation, handling and storage*

In accordance with NF EN 13670, transportation and handling shall be organised and carried out duly ensuring that the reinforcement bars and industrial reinforcements do not undergo any alterations (permanent deformation, staining, scoring, smudges or fractures).

Reinforcements and steels shall be stored in a special area either on the site or at the manufacturing workshop for assembled elements, if different from the site. The storage areas shall be clean and tidy, duly ensuring that the reinforcements do not come into contact with the ground and do not undergo any alteration.

Concrete reinforcing steels shall be classed and identified according to type, grade, category and diameter.

#### *9.2.3.4 Inspections and checks on delivery*

High-adherence reinforcing parts accidentally bent during manufacture, handling or transportation shall be scrapped.

Prior to using high-adherence steels (HA), the relevant mechanical characteristics thereof shall be identified and checked.

Identification shall consist of checking the production plant, the denomination of the reinforcements, the marking according to the identification sheet, grade, category, the batch or casting number of the product and the number of the certificate "NF – Concrete reinforcing steels".

Checking the mechanical characteristics shall comprise the following:

- a tensile test to determine the yield stress, the tensile strength and the total percentage elongation under maximum load (elongation in accordance with standard NF EN ISO 6892-1),
- a non-brittleness test,

- a control of the mass per unit length.

The tests shall be carried out in accordance with the current standards and any additional stipulations in the marking "NF – Concrete reinforcing steels". They shall be conducted by a sampling appraisal for every 1000 tonnes of steel of the same commercial name and same diameter, delivered by the manufacturer, or every three months, if the quantity delivered over three months is less than 1000 tonnes.

The use of plain bar reinforcement in accordance with standard NF A 35-015 shall be subject to the identification thereof, which consists of ensuring that the delivery docket specifies their origin, grade and mechanical characteristics (3.1.B-type certificate of acceptance shall be provided).

In the case of reinforcements manufactured in a workshop external to the site, the identification and mechanical characteristics of the steels shall be checked within the framework of the acceptance of the workshop supplies. The acceptance of industrial reinforcements on the site consists of checking the compliance of the reinforcements with the delivery docket and a dimensional check by sampling, concerning at least one element per delivery.

## 9.3 STRAIGHTENING AND SHAPING OF REINFORCEMENT

### 9.3.1 *SCOPE*

This section defines the requirements relating to the straightening and fabrication of the reinforcement used as concrete reinforcing steels in the structures covered by the contract.

### 9.3.2 *DOCUMENTS QUOTED IN REFERENCE IN THIS SECTION*

#### *9.3.2.1 Standards*

NF A35-020-1 (06/11): Steel products – End coupling and anchoring steel devices for high-adherence steel for concrete reinforcement – Part 1: Requirements for mechanical performances. Only french version

NF A35-020-2 (06/11): Steel products – End coupling and anchoring devices for high-adherence steel for concrete reinforcement – Part 2: Test methods. Only French version

NF A 35-027 (11/09): Steel products for reinforced concrete– Reinforcements. Only french version

FD A 35-029 (09/99): Steel for concrete reinforcement. Welded connections. Approval of a welding procedure. Approval of welders. Only french version.

ISO 15835-1 (04/09) Couplers of reinforcing bars intended for the mechanical connection of bars

### 9.3.3 *REQUIREMENTS AND RELATED CHECKS*

#### *9.3.3.1 General stipulations*

The construction arrangements must be compatible with the placing of the reinforcements and the placing of the concrete.

Reinforcements for concrete may be straightened, cut, fabricated and assembled, via ties or welds, in cages or panels, on the site or in a workshop external to the site.

In the case of the latter, the workshop must hold a certificate "NF – Industrial reinforcements for concrete" covering all the operations used by the workshop for the manufacture of reinforcements. The certificate shall be issued by the AFCAB. It shall certify the quality of

manufacture of reinforcements for concrete in accordance with the specific regulations of the marking.

If reinforcements are straightened and/or shaped on site, they must satisfy the provisions of standard NF A 35-027 and the requirements and checks in this document.

The operating modes for welding and welders must be qualified according to the recommendations of documentation FD A 35-029 and the stipulations of the present document.

#### *9.3.3.2 Straightening*

9.3.3.2.1 General stipulations

The effectiveness of the coil steel straightening tools shall be checked and inspected in accordance with the following stipulations.

9.3.3.2.2 Suitability tests

The suitability tests shall be carried out for the minimum and maximum diameters liable to be used and for the diameter closest to the average diameter corresponding to the routine production of the tools concerned. The intermediate diameters shall be covered by these suitability tests.

For each of these diameters, three samples shall be taken of sufficient length, bearing the full identification marking of the reinforcement, in order to carry out the following checks:

- a geometrical check after straightening: the height of the impressions remaining on the re-straightened reinforcements shall be greater than or equal to 90% of the height observed on a sample of the same coil prior to straightening. The measurements shall be carried out using measuring systems with a precision level of 0.01 mm,
- weighing to check the mass per unit length. The mass per unit length measured shall fall within the tolerance limit stipulated in the reference standard for the reinforcement,
- a tensile test (yield stress, rupture, elongation). The values measured must comply with the stipulations of the reference standard for the reinforcement.

9.3.3.2.3 Manufacturing checks

The straightened bars shall be the subject of an inspection of their geometrical characteristics and their mass per unit length, according to machine and manufacturing unit, for a maximum period of 9 hours. These checks shall be carried out at the beginning of the work unit and continue during manufacture on each change of diameter or category of steel, or after a production of 30 tonnes of straightened reinforcements of the same diameter and origin.

The acceptance criteria shall be the same as for the suitability tests.

The results of the manufacturing control tests shall be recorded in a test register.

If one of the aforementioned conditions is not observed, the reinforcements manufactured under non-satisfactory conditions shall be subject to specific treatment. The specific treatment is defined and submitted as a non-compliance subject to the approval of THE PURCHASER. The manufacturing conditions shall be amended and a further control test shall be carried out after the adjustment of the tools concerned.

### *9.3.3.3 Fabrication*

9.3.3.3.1 General stipulations

The shaping of reinforcements in the formwork is not permitted, with the sole exception of the closing of frames and stirrups with a diameter not exceeding 12 mm.

The cutting of reinforcements shall only be carried out using a shearing machine or abrasive disc.

Bending shall be carried out mechanically and smoothly, at a constant speed appropriate to the ambient and sufficiently moderated temperature, using a mandrel to ensure a constant radius of curvature on the bent section.

9.3.3.3.2 Grade FeE235 plain bar reinforcements

The minimum diameters (in millimetres) of the fabrication mandrels are stipulated in standard NF A 35-027.

9.3.3.3.3 Deformed reinforcements

The minimum diameters (in millimetres) of the shaping mandrels are stipulated in standard NF A 35-027.

If the ambient temperature falls below +5 °C, precautions must be taken with regard to shaping process, either by reducing the shaping speed or by increasing the diameters of the mandrels if this is compatible with the structural provisions.

It is forbidden to fabricate reinforcements at an ambient temperature under -5 °C.

The re-straightening (even partially) of a bent steel is prohibited other than for reinforcements with AFCAB certification “bending – re-straightening”.

Any reinforcement where excessive bending renders its shape incompatible with its function shall be rejected.

9.3.3.3.4 Tolerance limits

Unless otherwise specified in the construction drawings, the manufacturing tolerance limits must comply with the specifications of standard NF A 35-027.

Execution drawings shall take into account analyses implemented to resolve possible construction conflicts before commencing manufacture of reinforcements. These conflicts may be due to the design of reinforcements, working phases, or the addition of tolerances for the reinforcements which have been cut, worked and assembled.

9.3.3.3.5 Starter bar systems

In respect of bent reinforcement bars with a diameter over 6 mm, continuity systems/units shall be used, subject to the corresponding AFCAB certification or relevant datasheet justifying operating suitability and approved by THE PURCHASER .

It should be noted that free reinforcement bars must be fabricated or fitted to ensure there is no serious risk in terms of the safety of personnel. Provisions in this respect must be adopted when organising the various work phases.

9.3.3.3.6 Coupler bar systems

To ensure the structural continuity between reinforcing bars cast in two successive concrete operations, "coupler" continuity system/units can be used, subject to the corresponding AFCAB certification or relevant datasheet justifying operating suitability and approved by THE PURCHASER. The coupler system shall be seismically classified and provided with a certification document.

The connection between reinforcing bars is ensured by cylindrical threading in compliance to the NF A35-020 standard and certified NF-AFCAB or ISO 15835-1:2009 "Couplers of reinforcing bars intended for the mechanical connection of bars". The threading shall be metric ISO standardized.

The reinforcing bar is connecting by handle screwing and blocking using an appropriate spanner.

These devices shall be clearly shown on drawings. It should be noted that free reinforcement bars must be fabricated or fitted to ensure there is no serious risk in terms of the safety of personnel. Provisions in this respect must be adopted when organising the various work phases.

Only products manufactured by certified suppliers meeting the required specifications shall be considered. The Civil Contractor shall confirm the products meet these requirements.

## 9.4 Placing of reinforcements

### 9.4.1 *SCOPE*

This section applies to the installation of reinforcing steels for the concrete structures covered by the contract.

### 9.4.2 *DOCUMENTS QUOTED IN REFERENCE IN THIS SECTION*

#### *9.4.2.1 Standards*

NF EN ISO 6892-1 (10/09): Metallic materials – Tensile testing – Part 1: Method of test at room temperature

NF EN 13670 (06/09) Execution of concrete structures

NF A35-020-1 (06/11): Steel products – End coupling and anchoring steel devices for high-adherence steel for concrete reinforcement – Part 1: Requirements for mechanical performances. Only french version

NF A35-020-2 (06/11): Steel products – End coupling and anchoring devices for high-adherence steel for concrete reinforcement – Part 2: Test methods. Only french version

NF A35-027 (11/09): Steel products for reinforced concrete– Reinforcements. Only french version

FD A35-029 (09/99): Steel for concrete reinforcement. Welded connections. Approval of a welding procedure. Approval of welders. (Only french version: Fascicule de Documentation AFNOR – « Armatures pour béton armé - Assemblages soudés - Qualification d'un mode opératoire de soudage - Qualification des soudeurs»).

ISO 14654 :1999 : Epoxy-coated steel for the reinforcement of concrete.

NF EN 1504 (varies): Products and systems for the protection and repair of concrete structures. Definitions, requirements, quality control and evaluation of conformity. All Parts

## 9.4.3 *REQUIREMENTS AND RELATED CHECKS*

### *9.4.3.1 Placing*

9.4.3.1.1 General stipulations

Reinforcement bars between two concreting phases shall be protected against accidental bending and fitted with protection devices vis-à-vis the hazards they may create.

The stipulations of Section 9.3 regarding the bending and straightening of high-adherence steels shall be observed. In particular, the re-straightening (even partially) of a bent steel is prohibited other than for reinforcements with AFCAB certification "bending – re-straightening".

Unless justified, it is forbidden to use high-adherence reinforcements or meshes of different types in the same structure.

Binders, wedges and bracing systems shall be suitably solid and sufficient in number to ensure concrete cover is guaranteed and that the reinforcements cannot be displaced during the placing of the concrete, either as a result of stresses created by this placing (in particular due to vibration) or as a result of the passage of individuals.

Provision shall be made for any chairs and spacers which may be required to support the reinforcement layers.

It is forbidden to weld the steel with welding torch.

The reinforcements installed shall not indicate any defects, such as tears or cracks. At the time of concreting, the reinforcements shall be clean, free from non-adherent rust and free of any dirt (grease, earth, etc.) likely to adversely affect the adherence of the concrete.

Tolerances on the positioning of reinforcements given in the Engineering drawings, NF A35-027 and in section 5 shall be observed.

The reinforcement of moulded reinforced concrete elements in the ground shall be created in the form of rigid cages and held in place via the appropriate means.

The Civil Contractor is responsible for the estimation of all quantities of prefabricated reinforcement packages.

Whatever document or input data provided by THE PURCHASER either within the Call For Tender or within the construction document packages is purely to assist the Civil Contractor in evaluating the benefits and possibilities of pre-fabricating reinforcement.

Assumption on the percentage amount of prefabrication of the reinforcement is fully Civil Contractor's responsibility and cannot be linked to any PURCHASER document.

9.4.3.1.2 Fixing

The rigidity of the reinforcement cages and panels fabricated outside the formwork (for example, in a workshop manufacturing AFCAB-certified industrial reinforcements) shall be sufficient vis-à-vis any stress due to transportation and handling, duly ensuring that they do not cause any irreversible deformation in the whole assembly and any displacement of the reinforcements.

Reinforcement cages or prefab elements must be handled using appropriate slings for this purpose. The use of kinking is strictly forbidden.

The reinforcements shall be bound together via ties or field welds by resistance or electrode arc under the following conditions:

The ties shall be made from annealed mild steel wire tightened securely with pliers. They shall be arranged at the crossover points of the various steels and must allow for correct covering, any steel wire waste being removed prior to concreting,

Assembly welds must not alter the mechanical and geometrical characteristics of steels for concrete reinforcement (the welding operating modes and welders must be qualified according to the information in documentation FD A35-029 and standard NF A35-027).

A visual check shall be carried out on the welds for each manufacturing unit over a maximum period of 9 hours. This check shall be carried out on a reinforcement panel or a cage fastened by welding points in order to inspect the non-alteration of the basic steel.

For couplers, a particular cautious attention is to be paid on both localization and orientation. To avoid interferences on subsequent works, the installation of temporary threaded bars around openings, on THE PURCHASER's request.

#### 9.4.3.1.3 Wedging

For each construction, the Civil Contractor shall submit to THE PURCHASER (for information purposes) the density of the setting wedges (number of wedges per $m^2$ of structure) which it proposes to adopt in order to observe the covering of the reinforcements.

Only steel, concrete or mortar wedges shall be accepted. However:

- it is not permitted for steel wedges to enter into contact with formwork,
- the quality of concrete and mortar wedges shall be comparable with that of the concrete of the structure, and in the same colour.

Unless perfectly stable as a result of their shape, wedges shall be fitted with devices enabling them to be connected to the reinforcements in such a way that they are not displaced during concreting operations.

Concrete spacers or wedges types and distribution shall be designed and manufactured in particular:

- Not to stamp the formwork panels
- Not to hold mud, dust, water or any lose elements
- To ensure the compliance of concrete cover on all parts of the element poured
- To respect concrete exposure class

Concrete spacer distribution justification will be submitted to THE PURCHASER with validation for all types of formwork to be used. It must be adapted to reinforcement diameters and formwork panels dimension.

#### 9.4.3.1.4 Concrete cover

The concrete cover shall be at a distance between the surface of the reinforcement (including stirrup systems and frames, in addition to mechanical splices and fabric reinforcements, where applicable) which is nearest to the surface of the concrete and the latter.

The nominal covering is specified in the construction drawings. The minimum tolerance limits on the minimum covering shall be zero and the maximum as defined by the Norms.

The Civil Contractor should ensure that the specified quality control is exercised, for durability reasons, to avoid increasing the structural class and the concrete cover.

The Civil Contractor shall justify the number of reinforcement spacer used to guarantee the concrete cover.

#### 9.4.3.1.5 Reinforcement Laying

For large reinforced areas, the Civil Contractor must anticipate and include hoppers and entry points inside the reinforcement for access and safety purposes. Local rebars displacements, in

particular after reinforcement inspection and during pours, shall not be tolerated (solely threaded bar installation on positioning couplers).

The Civil Contractor must pay a very cautious attention to preliminary marking of the reinforcement to be laid, especially in case of couplers installation. Overlap areas, grid intersections and crossing sub-elements must hence be clearly identified on site sufficiently in advance.

The general erection phasing is submitted to THE PURCHASER for review prior to Works commencement. A method book detailing typical reinforcement erection configurations may be requested were complicated areas have been identified.

9.4.3.1.6 Continuity of steels

The continuity of the steels is normally ensured by overlapping and shall comply with NF EN 13670. The plane passing via the axes of two steels set in continuity shall be parallel to the nearest facing plane.

If other methods such as mechanical splices or welding are used, the additional stipulations of paragraphs 9.4.3.1.8 and 9.4.3.1.9 shall apply:

9.4.3.1.7 Mechanical Continuity Epoxy-coated reinforcement

If necessary, to ensure the electrical isolation of the reinforcement in some specific areas from the other standard areas, epoxy coated reinforcement will be used. These electrically isolated reinforcement areas will be specified on the construction drawings.

To reach this objective the reinforcement bars of an electrically isolated area which connect with bars of non-electrically isolated areas, shall be epoxy-coated at least on the overlapping length plus 0.20 m, in order to isolate them from the other bars

The overlap length of rebar in tension shall be increased at least by 20% by comparison with un-coated reinforcement. The lap length will be specified on the construction drawings

The full reinforcement bars, or only the part on the lap length plus 0.20 m, will be coated with a fusion bounded powder epoxy applied by electrostatic spray.

Epoxy coating shall comply with ISO 14654: 1999 Epoxy-coated steel for the reinforcement of concrete

Standard epoxy or epoxy with increased adhesion will be used (DuPont or Valspar or equivalent coating). Systems with a pre-treatment of uncoated steel with chromate prior to the application of the epoxy coating to improve adhesion are not authorized.

Special care will be required during shaping, transporting and placing the bars and during vibrating the concrete, in order not to deteriorate the epoxy-coating.

A detailed visual inspection of the reinforcement will be conducted prior to pouring the concrete, in order to check the integrity of the coating; touch-up coating will be done on the damaged parts.

The Civil Contractor shall draw-up and submit to the approval of THE PURCHASER a detailed specification describing the materials, the shaping operations, the transport, the placing and the final inspection of the installed epoxy-coated rebars.

9.4.3.1.8 Mechanical splice

Mechanical splices must comply with standard NF A35-020 (Parts 1 and 2) and have the corresponding AFCAB certification. Moreover, a compliance justification file shall be submitted to THE PURCHASER to demonstrate that tensile breaking, in accordance with standard NF EN ISO 6892-1 (during periodical tests to maintain the AFCAB certification or during additional tests organised by the Civil Contractor) occurs outside the device or the machined zone.

The choice of mechanical splice shall be submitted for the approval of THE PURCHASER.

The free ends of the devices shall be sealed with plugs. The threaded ends of the reinforcements shall be protected with hoods. These protection systems shall be held in place during transportation, storage, placing and concreting in order to avoid the penetration of concrete or any other foreign body and any deterioration which may harm the quality of the joint.

The implementation of mechanical splices shall comply with the supplier's stipulations. It shall be carried out by specialist and qualified personnel, subject to preliminary training.

9.4.3.1.9 Welded joints

To construct joints by welding (end to end or by overlap), a welding procedure shall be drawn up by the Civil Contractor. It shall be submitted for the approval to THE PURCHASER. The procedure shall describe the detailed conditions governing the welding operation.

The welding operating mode and the welders shall be classified by an approved regulatory organisation during qualification tests and in accordance with the information in documentation FD A35-029.

To that end, a tensile test and a bending test shall be carried out. The acceptance criteria shall be as follows:

- with regard to the tensile test: breaking must occur outside the welded joint and for a value greater than or equal to that of the reference standard of the steel used in concrete,
- with regard to the bending test: no penetrating crack in any of the reinforcements of the assembly unit before a bending angle of $45^{o}$ and no rupture before a bending angle of $90^{o}$.

Otherwise, the welding conditions (and the welder qualifications) shall be rejected.

Unless otherwise stipulated, during manufacture, a bending test shall be carried out on a welded assembly at the beginning of a manufacturing unit over a maximum period of 9 hours. The acceptance criteria shall be identical to those for the qualification test.

It shall also be permitted to weld two reinforcement bars in terms of the extension of one or the other, via a splice bar, where the plane passing via the axes of the two reinforcements and the splice bar must be parallel to the nearest face work plane.

### *9.4.3.2 Checking of position of reinforcements and concrete cover*

The position of the reinforcements and cover thicknesses must be systematically checked prior to concreting when the reinforcement placing phase is considered to be completed.

After form removal, the Civil Contractor shall carry out a concrete cover compliance check using a pre-calibrated electromagnetic measuring and detection system (pachometer in type).

This check shall be carried out by sampling in accordance with a procedure submitted for the approval of THE PURCHASER. The checking frequency (density of measuring points per surface unit) shall be adapted to the aggressiveness of the environment. If the concrete cover of

the steels is non-compliant, the Civil Contractor shall submit the treatment of the non-compliance (coating, mineralisers, etc.) for the approval of THE PURCHASER.

#### *9.4.3.3 Anchoring of reinforcement steel bar*

Anchoring of reinforcement steel bar shall be done:

- With the agreement of THE PURCHASER;
- Under a validated procedure including all necessary justifications;
- Using NF EN 1504, especially part 6

#### *9.4.3.4 Reinforcement in heavy concrete*

The Civil Contractor shall perform a survey after completion of the reinforcement in heavy concrete and before pouring. The accuracy of the process used for the measurement shall be sufficient to allow the location on site of the reinforcement without using detection apparatus.

## 9.5 Grounding for Civil Works Structures

### 9.5.1 *SCOPE*

This section shall apply to the grounding of reinforced concrete structures covered by the contract and the construction of the internal grounding network for the buildings.

It does not apply to the underground earthing circuit, or to the earthing network within the various buildings which are connected to earth bars or main earth conductors, nor to earthing of structural steel.

### 9.5.2 *REQUIREMENTS AND RELATED CHECKS*

The Civil Contractor shall refer to *EDH Part 4: Electromagnetic Compatibility (EMC) (ITER_D_4B523E)* and *EDH Part 5: Earthing and Lightning Protection (ITER_D_4B7ZDG)* for all technical requirements relating to grounding for civil work structures.

# 10 PREFABRICATION OF REINFORCEMENT AND CONCRETE ELEMENTS

## 10.1 Scope

This section applies to the prefabrication of reinforcement and concrete elements.

It covers the following operations:

- manufacture,
- transportation,
- handling,
- storage,
- placing,
- sealing.

## 10.2 Documents quoted in reference in this section

### 10.2.1 *Standards*

NF EN 206-1 (04/04) and Addenda A1 of April 2005 and A2 of October 2005: Concrete – Part 1: Specification, performance, production and conformity

NF EN 1991 (varies) Eurocode 1 – Actions on structures – All parts

NF EN 1992 (varies) Eurocode 2 – Design of concrete structures – All parts

NF EN 12390-3 (04/12): Test for hardened concrete – Part 3: Compressive strength of test specimens

NF EN 12390-6 (04/12): Test for hardened concrete – Part 6: Tensile strength via splitting of test specimens

### 10.2.2 *Other documents*

Recommandations pour la prévention des désordres dus à la réaction sulfatique interne of the LPC (Laboratoires des Ponts et Chaussées) August 2007.

## 10.3 Requirements and related checks

### 10.3.1 *General points*

This technical specification applies to construction elements pre-fabricated at a plant located either outside the site under consideration or in a prefab plant specifically constructed on site in the immediate vicinity of the constructions.

Only elements designed for prefabrication can be subject to prefabrication. The plans must stipulate “prefab elements”. The forces induced by handling operations must be taken into account in the design of the elements.

The hoisting systems on site shall be adapted to the weight of the prefab elements designed in order to allow for handling operations and the placing of these elements.

The Civil Contractor is responsible for the estimation of all quantities of prefabricated reinforcement packages.

Whatever document or input data provided by THE PURCHASER either within the Call For Tender or within the construction document packages is purely to assist the Civil Contractor in evaluating the benefits and possibilities of pre-fabricating reinforcement.

Assumption on the percentage amount of prefabrication of the reinforcement is fully Civil Contractor's responsibility and cannot be linked to any PURCHASER document.

## 10.3.2 *Location of prefab plants*

They shall be located on or near the site and existing plants may be adopted.

They shall be equipped with hoisting systems enabling the handling operations. Provision shall be made for storage and manoeuvring areas to ensure the maximum number of elements can be stored.

## 10.3.3 *Prefabrication of reinforcement cages*

### *10.3.3.1 Manufacture*

The stipulations of Sections 9.2 and 9.3 of the present specification shall be observed.

### *10.3.3.2 Marking*

All prefab reinforcement cages shall be subject to a specific marking to allow the identification thereof and specify the relevant operating conditions.

The marking shall comply with the information in the detail construction drawings. It shall also comprise the prefabrication date, type, grade, category and diameter of the reinforcements.

### *10.3.3.3 Transportation, handling and storage*

Transportation and handling operations shall be organised and carried out to ensure that the reinforcement cages are not subject to any alteration (permanent deformation, scoring, smudges or fractures of assemblies).

Reinforcement cages shall be stored in a special area either on the site or at the manufacturing workshop for assembled elements, if different from the site. The storage areas shall be clean and tidy, duly ensuring that the reinforcements do not come into contact with the ground and do not undergo any alteration.

### *10.3.3.4 Inspections and checks on delivery*

The mechanical characteristics of the steels shall be checked within the framework of the receipt of supplies from the prefab plant, in accordance with the stipulations of Section 9.2.

The acceptance of the prefab reinforcement cages on the site consists of checking their compliance with the delivery docket, in addition to a dimensional check via sampling concerning at least one element per delivery.

### *10.3.3.5 Placing*

The stipulations of Section 9.4 shall be observed. The tolerance limits regarding the positioning of the reinforcements are shown in Section 5.

In the case of a large use of mechanical splices (in shell joints in particular), specific provisions must be adopted by the Civil Contractor to enable the adjustment of the structures. These provisions (use of template, tightening of tolerance limits on the position of the reinforcements, specific topographical organisation, etc.) shall be submitted for the approval of THE PURCHASER.

## 10.3.4 *Prefabrication of concrete elements*

The stipulations of Technical Specification "Concrete works", Sections 7.7 and 7.8 relating to the study, composition, manufacture, implementation and control of concrete shall apply. Any adaptations must be justified by the Civil Contractor and submitted for the approval of THE PURCHASER.

A check to ensure compliance with the stipulations of the contract shall be carried out after the manufacture of the first element (reference element).

### *10.3.4.1 Manufacture*

Concrete reinforcing steels shall observe the specifications of Section 9.2, in particular the inspections and checks on delivery.

The construction procedure for prestressed prefab elements and the choice of the constituents thereof must be justified by the Civil Contractor and submitted for the approval of THE PURCHASER, on the basis of tests validating their suitability in respect of satisfying the stipulations of the contract.

The elements to be constructed shall comprise bonding areas with the adjacent concrete structure, principally ensured by steel reinforcement bars or coupling systems. The peripheral bonds devices shall be studied and taken into account on prefabrication.

The peripheral bonds devices must not entail any unit or specific modification to the elements of the formwork.

Steel reinforcement bars and mechanical splices shall observe the stipulations of Section 9.4.

The geometry of the shapes to be bonded must take into account the criteria governing rapidity and facility of implementation. The shape of the cavities to be filled must be compatible with a simple installation and not require additional injections.

The grasping and handling devices must be checked via calculation by taking into account, in particular, the nature of the hoisting systems. These devices must not adversely affect the durability of the part concerned and must not create any damage.

The handling stirrups (or hoisting hooks) put in place prior to concreting and used to handle the concrete element, shall be exclusively fabricated in the form of plain bars FeE235, and controlled by the specific test of the product. The reinforcements used in that respect shall be anchored via curvature and have a diameter greater than or equal to 10 mm. The diameter of the bending mandrel shall be at least equal to four times the nominal diameter of the reinforcement. Their shaping thereof shall be forbidden if the ambient temperature is under -5°C.

The duplication of the handling stirrups shall be excluded. The dimensions of the handling stirrups shall take into account the dynamic effects and the force transmitted to a stirrup must always fall within the plane thereof and parallel to its branches.

The use of a lifting beam fitted with a load balancing device on the hooking slings is mandatory.

With regard to diameters over 12 mm, industrial prefab anchors embedded into the concrete may be preferably used, with their specific lifting devices.

The operating tolerance limits shown in Section 5 shall be observed, in particular, with regard to the positioning of the reinforcements (tolerance tightened within the framework of the prefab operation) and embedded pieces in the first phase (pipe sleeves, plates, pre-sealed pieces, etc.).

The design and nature of the materials used for the formwork shall take into account the concreting constraints and rapid and efficient assembly and disassembly, in addition to the cleaning conditions.

The limit values applicable in France for the composition and properties of concrete in concrete products prefabricated at the factory (Table NA.F.2) in standard NF EN 206-1 shall be observed.

The temperature of the concrete used and in the plant must be in the region of 20°C, including during the maturing phase. The sites and concrete used may be heated to this end, if needed.

A procedure, drawn up by the Civil Contractor and submitted for the approval of the supplier, shall specify the mode of determining the maturity of the concrete to ensure that form removal, handling, storage and transportation operations are only carried out when the strength of the concrete so permits.

The bonding surfaces shall be roughened, in accordance with the provisions of Section 7.9.3.2.9 on construction joints, duly ensuring correct adherence between the prefab element and the binding mortar or concrete.

The prefab concrete elements shall be the subject of a curing operation in accordance with the provisions of Section 7.9.3.2.13.

#### *10.3.4.2 Accelerated hardening via heating*

Concrete elements may be steam cured, subject to the approval of THE PURCHASER.

The recommendations specified in the document entitled « Recommandations pour la prévention des désordres dus à la réaction sulfatique interne of the LPC (Laboratoires des Ponts et Chaussées) August 2007 » shall be stricly observed.

The process, equipment, steam-curing conditions (temperature gradient and maximum value), curing and control systems shall be the subject of a procedure drawn up by the Civil Contractor and submitted for the approval of THE PURCHASER, on the basis of a non harmfulness study for the purposes of checking that the heat treatment proposed does not cause any harmful alteration to the behaviour of the concrete in the medium and long term.

This non-harmfulness study shall comprise, in particular:

- the manufacture of at least one element to check for the absence of any harmful cracking after cooling,
- the creation of six test specimens, three of which shall be used for compressive strength tests at 28 days, in accordance with standard NF EN 12390-3 and three of which shall be used for tensile strength tests at 28 days by splitting, in accordance with standard NF EN 12390-6. The compressive strength must be attained, and the tensile strength must be greater than or equal to 90% of the tensile strength of the non-treated reference concrete,
- a measurement of the maximum temperature attained by the concrete. This temperature must remain under or equal to 65°C.

Sensors are arranged in the concrete to measure the temperature effectively attained and control tests shall be carried on test specimens in accordance with the same temperature change as the concrete.

Provisions shall be taken to avoid the evaporation of water from concrete exposed to air.

In the thermal treatment cycle, the pre-setting time (1st phase without heating) shall be at least equal to four hours and the temperature increase rate in the following phase shall be limited to 10°C per hour.

Under all circumstances, care shall be taken to avoid thermal shocks during the storage of the elements.

#### *10.3.4.3 Marking*

All prefab elements shall be subject to a specific marking to enable the identification thereof, duly specifying their operating conditions.

The marking shall comply with the information in the construction drawings. It shall also comprise the manufacturing date for the elements.

#### *10.3.4.4 Handling, storage and transportation*

Handling, storage and transportation shall not be undertaken until the prefab element has attained the minimum strength require to undergo these operations without damage. These operations shall be carried out in accordance with a procedure drawn up by the Civil Contractor and submitted for the approval of THE PURCHASER. It shall:

- avoid any unforeseen force and any excessive deformation,
- eliminate any risk of deterioration liable to have an adverse effect on the appearance or durability of the elements.

This procedure specifies in particular:

- the nature, strength and distribution of the suspension systems,
- the position in accordance with which the element must be hoisted and subsequently maintained during transportation or handling operations,
- the particular forces to be taken into account,
- the support and stacking conditions during storage (duly avoiding concentrated forces and supports on weak or fragile zones).

In particular, a calculation must prove that the forces created by the handling and transportation operations have been taken into account in the design of the prefab element.

Any incident which may occur during the handling operations shall be recorded. The element concerned shall be isolated until THE PURCHASER has reached a conclusion regarding the analysis of the consequences of this incident.

The hoisting systems shall be fitted with specific equipment adapted to the hooking devices incorporated into the concrete.

The storage areas, mode of removal and means of transportation shall take into accounts the shapes and weights of the various elements. The distribution of forces linked to the positions of the support points during storage (stacking) must not in any way jeopardise the integrity of the elements stocked.

Any reinforcements or linking systems left on stand-by between two concreting phases shall be protected against accidental bending and fitted with protection systems vis-à-vis the hazards to which they give rise.

The bending and straightening of high-adherence reinforcements shall be prohibited with the exception of the case of reinforcements with the AFCAB certification “Suitability for bending - re-straightening”. However, re-straightening may only be carried out in accordance with a specific procedure drawn up by the Civil Contractor and submitted for the approval of THE PURCHASER.

#### *10.3.4.5 Placing and linking of existing structural parts*

The prefab elements shall only be installed after the following has been checked:

- the delivery docket comprising the statement of their compliance with the specifications of the order. It shall show the information concerning the marking, plus the name of the transporter and date of delivery,
- their condition at the time they are received. The elements must not have suffered any damage during the handling, storage and transportation operations, in particular with regard to the support surfaces (stop ends of beams, in particular).

The placing and linking of the existing structural parts of the prefab elements shall be carried out in accordance with a procedure drawn up by the Civil Contractor and submitted for the approval of THE PURCHASER. It shall:

- avoid any risk of deterioration (shocks),
- ensure that the positioning complies with the construction drawings.

The operating procedures shall comprise all specific relevant information regarding the sensitive points of the operation, in particular the construction of temporary or definitive units, and specify the recommendations of a geometrical and mechanical nature to be observed, where applicable, in relation to the constraints concerning the element during handling and fitting operations.

Once they have been fitted, the elements shall be held in position so as to ensure:

- their stability vis-à-vis the forces applied, including forces due to wind,
- the geometry of the unit as a whole, taking into account the stipulated tolerance limits,
- the hardening, without any disorganisation, of the assembly materials.

The assembly product (binder mortar or concrete) with the construction parts in place must only be used after the justification of its characteristics are in accordance with the stipulations of the contract, and the approval of THE PURCHASER. The product used must be easy to install and its shrinkage shall be reduced to a minimum.

The stipulations of Section 7.8 and 7.9 on construction joints and concrete curing shall be observed.

The assembly operations shall be carried out by qualified personnel.

#### *10.3.4.6 Final facings*

The final facings of the structures must observe the specifications of Technical Specification for Formwork, for the category of facing concerned (specified in the construction drawings).

### 10.3.5 *Prefabrication of prestressed reinforced concrete elements*

#### *10.3.5.1 Scope*

This section applies to all concrete prestressed reinforced concrete elements.

#### *10.3.5.2 General requirements*

The prestressed concrete structural elements shall be designed according to the EUROCODE and the Engineering drawings in respect of the following considerations:

- The elements shall be manufactured by specialized and ISO 9001 certified companies only,
- The extremity of strands shall be protected against corrosion using a special coating product which must be proposed to THE PURCHASER prior to the use. His coating protection shall be efficient until the element is implemented and sealed in its definitive place.

- The handling (or lifting) rings and fixation points (if necessary) must be sealed in the first cast concrete only. Drilling of the prestressed element is not permitted.

### *10.3.5.3 Special requirements and related checks*

10.3.5.3.1 Consideration of the fire risk

The prestressed elements shall be designed according to the NF EN 1992-1-2 that deals with the design of concrete structures for the accidental situation of fire exposure and is intended to be used in conjunction with NF EN 1992-1-1 and NF EN 1991-1-2.

NF EN 1992-1-2 identifies differences from, or supplements to, normal temperature design, and with passive methods of fire protection.

The prestressed concrete structures or element are required to fulfil a specific and crucial function when exposed to fire, in terms of avoiding premature collapse of the structure (load bearing function). Limiting fire spread (flame, hot gases, and excessive heat) beyond designated areas (separating function) is also required (known as “Coupe-feu” in french).

10.3.5.3.2 Transporting, delivering, storing and placing the prestressed concrete elements

Transport

Pre-stressed elements shall be transported according to a delivery procedure previously forwarded to THE PURCHASER for agreement. The manufacturer shall board the elements and stabilized it so that it is not stressed by parasite constraints.

The manufacturer is fully responsible for the elements integrity until this one is delivered, stored and accepted by the Site manager.

Delivery and storage

The trucks used to deliver the elements are equipped with all the means of handling and lifting appropriated to the shape, length and weight of the elements. The procedure mentioned above shall also include a section for unloading the trucks.

The element shall be placed on wooden brackets and securely stabilised until they are implemented. A special area shall be especially dedicated to the storage of these works.

Delivery Report and Acceptance Sheet

The operative in charge of controlling the elements delivery shall be advised prior to delivering the prestressed concrete elements. Unloading and storing a prestressed element is forbidden if a site controller is not present.

Before unloading, the following checks shall be done, in presence of the Civil Contractor or representative and the site controller:

- Reference number,
- Dimensions of the elements,
- External visual control (facing, condition, etc…)
- Checking absence of cracks,
- Checking chocks evidence,
- Checking provenance of concrete and stands (certificate of origin to be furnished).
- Checking presence of anti-corrosion protection coating at the extremity of the strands.
- Checking (if necessary) position of the handling (or lifting) rings and fixation points.

If all the above items are found to be satisfactory, the site controller shall authorize unloading and storage.

10.3.5.3.3 Placing and identification of the prestressed elements

Placing

Pre-stressed elements shall be placed according to specific procedure previously forwarded by the Civil Contractor to THE PURCHASER for agreement.

Identification

Further to concreting and just after placing, the Civil Contractor shall identify the element by painting it all along and over its surface in red or yellow-black stripes.

# 11 GROUT, CORE HOLE DRILLING AND TEMPORARY OPENINGS

## 11.1 Scope

This section applies to the grouting up of temporary openings and core holes made in the superstructure concrete works. For the additional requirements relating to Nuclear Buildings opening finishes and infillings, refer also to section 11.5 of this specification.

## 11.2 Procedure for creation of temporary openings

### 11.2.1 *Scope*

This section applies to all designed temporary openings in the structural concrete Works and identified on engineering drawings.

These openings may be located in concrete slabs or within concrete walls, including basement walls. They shall be filled with structural reinforced concrete after use.

### 11.2.2 *DOCUMENTS QUOTED IN REFERENCE IN THIS SECTION*

NF A35-020-1 (06/11): Steel products – End coupling and anchoring steel devices for high-adherence steel for concrete reinforcement – Part 1: requirements for mechanical performances. Only French version

NF A35-020-2 (06/11): Steel products – End coupling and anchoring devices for high-adherence steel for concrete reinforcement – Part 2: test methods. Only French version

ISO 15835-1 (04/09) Couplers of reinforcing bars intended for the mechanical connection of bars

### 11.2.3 *Forming openings*

The Civil Contractor must take into account all the required procedures and equipment necessary to make provision for these openings.

The Civil Contractor is responsible for forming all temporary slab and wall openings shown on the drawings.

### 11.2.4 *Formwork*

The Civil Contractor shall ensure that his formwork is sufficiently rigid to prevent pressure from wet concrete distorting the formwork leading to out of tolerance openings. To prevent grout loss between cast-in frames and shuttering, a good seal shall be maintained between the frame and shutter.

### 11.2.5 *Reinforcement*

Perimeter steel reinforcement shall have mechanical reinforcement couplers to ensure continuity of the reinforcing bars after placing concrete infill.

The connection between reinforcing bars is ensured by cylindrical threading in compliance to the NF A35-020 standard and certified NF-AFCAB or ISO 15835-1:2009 “Couplers of reinforcing bars intended for the mechanical connection of bars”. The threading shall be metric ISO standardized.

All details shall be clearly shown on drawings.

The Civil Contractor shall only use recognised systems such as “BARTEC or GRIPTEC” (or technically equivalent) provided by specialized and certified manufacturers. The system shall be certified for dynamic loading.

### 11.2.6 *Concrete*

The temporary opening shall be filled with structural concrete. The infill concrete shall have the same characteristic as the surrounding concrete of the wall or slab in terms of grade and class of exposure.

After filling the openings in the walls or slabs the structural resistance of the concrete shall be unaffected.

### 11.2.7 *Temporary opening safety*

The Civil Contractor is responsible for providing and maintaining all safety handrails and temporary closures to openings to prevent accidents.

The Civil Contractor is responsible for the maintenance of these safety measures.

The safety measures shall be submitted to the HPSC for approval.

After Contract completion the Civil Contractor shall leave these safety measures in place:

- Safety equipment hire costs shall become the responsibility of THE PURCHASER.
- THE PURCHASER and HPSC shall be responsible for their maintenance.

## 11.3 Procedures for creating permanent openings and penetrations

### 11.3.1 *Scope*

This section applies to all permanent openings in the structural concrete Works and identified on Engineering and execution drawings.

These openings can be located either in concrete slabs or within concrete walls, including substructure walls. Their role is to enable the routing or crossing of various electrical or facilities networks.

### 11.3.2 *DOCUMENTS QUOTED IN REFERENCE IN THIS SECTION*

N/A

### 11.3.3 *Formwork openings*

The opening shall be formed by the Civil Contractor in the first cast concrete using adapted and strengthened formwork.

Methods for protecting steelwork and couplers (e.g. sacrificial concrete) shall be proposed by the Civil Contractor and approved by THE PURCHASER.

### 11.3.4 *Safety devices around openings*

According to its size and position, the temporary opening may represent a danger for the workers. If that was the case, the safety requirements detailed above shall be adopted.

### 11.3.5 *Infilling of openings*

The Civil Contractor is responsible for the infilling of the openings following the insertion of service networks.

The infilling of the openings shall be performed according to site procedures.

This infill procedure shall be issued by THE PURCHASER and forwarded to the Civil Contractor.

It is important that the openings in walls providing biological shielding and / or confinement boundaries are infilled such that the any cracking leading to potential gas leakage or shine path is prevented. In such cases, measures such as re-injectable injection hose system for sealing the construction joints shall be adopted.

### 11.3.6 *Specification for opening sealants*

The procedure shall specify, for each opening, the material or product to be used for sealing around services. According to the size or position, the following requirements can be used for core hole sealing (this list is not exhaustive):

- Nature of the filling product, (mortar, concrete, silicone, lead, wool, intumescent materials.)
- The firebreak requirements (if the case)
- Firebreak grade
- Airtightness
- Surface smoothness of the facing (to assist decontamination)
- Paintability of filling material,

Products shall meet the following requirements:

- compatible with adjacent materials
- fire proof (classified M0 or M1)
- prevent the distribution of flames along the wire supports
- shall not release toxic smoke during fires (Foam of polyurethane forbidden)
- shall not generate smoke
- humidity resistant
- no deterioration in time
- shall be flexible enough to withstand service pipe movements

Fireproof panels of rock wool (or other filler), shall have a minimum thickness of at least 60 mm with a density over 180kg/$m^3$.

## 11.4 Technical requirements for Core Hole drilling

### 11.4.1 *Scope*

This section applies to core holes drilled in structural concrete Works.

These core holes can be located either in concrete slabs or within concrete walls including the substructure walls.

They shall be filled with a product according to the nature of the services penetrating the hole.

### 11.4.2 *DOCUMENTS QUOTED IN REFERENCE IN THIS SECTION*

*N/A*

### 11.4.3 *Drilling procedure*

Core drilling shall be created using the following methodology:

- No drilling prior to acceptance by THE PURCHASER.
- The core hole is to be identified and drawn on plans or sketches.
- The core hole location may be provided by the survey team or representative of the service provider.
- The Civil Contractor shall mark the position of the reinforcing bars in the concrete using a portable scanner. For example Hilti products RV10 and RS10 can fulfil this function, as well as other similar approved products.
- The reinforcing bars are detected and drawn on the concrete,
- The concrete cover is locally and carefully removed (pneumatic poker) according to the location; reinforcing bars shall not be damaged at this stage.
- The core hole shall be positioned to ensure reinforcing bars are not damaged (considering each face of the concrete element).
- A report is to be raised by THE PURCHASER and signed by the person requiring the hole and the Civil Contractor that the Works have been carried out to everyone's satisfaction.

## 11.4.4 *Openings for services penetrating basement walls*

### *11.4.4.1 Scope*

This section applies to all openings in structural basement walls of buildings to allow the passage of underground services. These openings shall be identified on Engineering drawings. All openings in confinement and other sub-surface structures shall have a suitable water bar detailed around openings to ensure water and gas leak tightness.

### *11.4.4.2 Forming opening*

The below ground opening shall be formed by the Civil Contractor using the same method for temporary construction openings.

Special arrangements for underground openings

### *11.4.4.3 Steel sealing plates*

If the opening is created before the service pipe is in position, the Civil Contractor shall be responsible for providing, positioning and bolting steel plates over the openings prior to backfilling operations. These steel plates shall be strong enough to resist to the loads and vibration during compacting until the underground services are installed. These plates shall require providing a waterproof seal preventing the entry of ground water.

### *11.4.4.4 Embedded devices in concrete*

According to the type of service passing through the wall (pipe, cable…) and to the nuclear safety requirements relating to firebreak, fireproofing, earthquake and other factors, special devices might be necessary at the interface between the basement walls and the service pipe/cable. These devices shall be clearly identified on engineering drawings. These devices may require to be cast into the concrete.

If this is the case, the embedded device is provided by the Civil Contractor (who implements the crossing work). The Civil Contractor is responsible for placing the embedded component within the reinforcement before concreting. This device shall be securely and strongly implemented so that it shall not move during concreting operations.

It is advisable to use specialist approved devices such as MCT BRATTBERG (or technically equivalent) provided by specialized and ISO certified manufacturers.

The Civil Contractor is responsible for the protection of embedded devices before backfilling.
The methodology shall be submitted to THE PURCHASER for agreement before starting.

#### *11.4.4.5 Bolted to cast-in flange*

According to the nature of the service entry and to the nuclear safety requirements related to firebreak, fireproofing, earthquake and other, special devices might be necessary at the interface between the basement walls and the penetrating work.

- These devices shall be clearly identified on Engineering and execution drawings.
- Considering strength and waterproofing requirements, these devices might need to be anchored into concrete structures.
- Screwed devices are provided by the Services Contractor.
- The Civil Contractor is responsible for the manufacture, supply and fitting wooden or steel frames within the concrete to ensure that position of the opening is suitable for the screwed fixings.
- This frame shall be supplied and positioned within the formwork before concreting. This frame shall be secured adequately to ensure it shall not move during concreting.

#### *11.4.4.6 Specific case of earthquake-resistant devices*

Depending on the type of service and the nuclear safety requirements relating to earthquake-resistance, special devices might be necessary at the interface between the basement walls and service pipe/cable.
These devices shall be clearly identified on Engineering drawings.
In the same way as for the embedded frames in concrete (See above, embedded devices in concrete), the devices dedicated to earthquake-resistance of services passing through basement walls shall be designed and provided by the specialist Contractor who installs the services.
The Civil Contractor is just responsible for placing the device (by embedding or secondary fixing).

#### *11.4.4.7 Culvert penetration through basement walls*

Underground concrete service culverts might be installed on site (out of the scope of the Civil Contractor's work) to enable routing of medium and high voltage electrical cables. Penetration of these services through basement concrete works might require specific details before, during and after concreting.
However, the Civil Contractor shall prepare the sides of the opening before (formwork, dimensions, etc…) and after concreting (plain or basic finishing, etc...) so that further penetration of the culvert through the basement works is close fitting.
The Civil Contractor shall prepare his formwork in compliance with the culvert drawings (position and cross section drawing).
For reasons of coordination, the Civil Contractor shall be responsible for managing this operation (in terms or works interface) providing and installing a hydrophilic joint at the interface between the sides of the opening and the "fresh" concrete of the culvert.
The culvert shall penetrate the whole thickness of the wall so that the culvert and the wall internal wall face are perfectly aligned.
Inspection and monitoring of openings and fillings
The Civil Contractor is required to work with THE PURCHASER in carrying out inspections and monitoring of openings and sealing processes.
This procedure is initiated by THE PURCHASER and forwarded to the Civil Contractor, it is considered as part of the Civil Contractor's Contract.

#### *11.4.4.8 Temporary closures*

THE PURCHASER shall draw up and forward a list of temporary closures required for personnel protection. Each of these temporary closures shall be assigned to a Civil Contractor:

- During the worksite phase, the Civil Contractor shall set up the temporary closures.
- During the equipment installation phase, each Civil Contractor shall remove the temporary seals. The temporary protection pending shall be re-instated prior to final filling or caulking.
- At the commissioning stage, some openings shall not have been filled (air transfer, passage for later work construction Contractors, etc…). Therefore, the following devices shall be provided for the start-up of ventilation tests and delay and change over the cleanliness on the ground protection plates stiff enough to allow the handling of equipment, on webs, Plexiglas plates.

## 11.5 Opening finishes and infillings for the Nuclear Buildings (Tokamak Complex, Hot Cell, Radwaste)

### 11.5.1 *Standards*

| | |
|---|---|
| NF EN 1991 (varies) | Eurocode 1 - Actions on structures – All Parts |
| NF EN 1992 (varies) | Eurocode 2 : design of concrete structures – All Parts |
| NF EN 1993 (varies) | Eurocode 3 : design of steel structures – All Parts |
| NF EN 287-1 (09/11) | Qualification test of welders - Fusion welding - Part 1 : Steels |
| NF EN 10025 (03/05) | Hot rolled products of structural steels |
| NF EN 1090-2 (10/11) | Execution of steel structures and aluminium structures - Part 2 : Technical requirements for steel structures |
| NF EN ISO 5817 (11/07) | Welding - Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) - Quality levels for imperfections |
| NF EN ISO 8501 (varies) | Preparation of steel substrates before application of paints and related products – All Parts |
| NF EN ISO 8504 (11/01) | Preparation of steel substrates before application of paints and related products – All Parts |
| NF EN ISO 12944 (varies) | Paints and Varnishes - Corrosion Protection of Steel Structures by Protective Paint Systems – All Parts |
| NF EN ISO 13918 (07/08) | Welding - Studs and ceramic ferrules for arc stud welding |
| NF EN ISO 14555 (02/07) | Welding - Arc stud welding of metallic materials |
| NF EN ISO 15614 (varies) | Specification and qualification of welding procedures for metallic materials - Welding procedure test |
| EN ISO 6270-2 (07/07) | Paints and varnishes - Determination of resistance to humidity - Part 2 : Procedure for exposing test specimens in condensation-water atmospheres |
| ISO 9001 (11/11) | Quality management systems - Requirements |
| NF M62-233 (09/93) | Shielded enclosure bushing. Protection against gamma rays. Requirements for cast iron screws used for ventilation |

Other Documents

Arrêté du 22 mars 2004 relatif à la résistance au feu des produits, éléments de construction et d'ouvrages

Éléments de construction et d'ouvrages, consolidé 14 mars 2011

Load Specification for Buildings with Safety Requirements (2ERTXQ)

## 11.5.2 *Information provided by THE PURCHASER*

THE PURCHASER shall provide the Civil Contractor responsible for leaving openings with concrete outline drawings of the structures showing the openings and a list of openings and their details (Bill of Openings).
THE PURCHASER shall provide the Contractor responsible for infilling (hereafter Infill Contractor) with the main survey and levelling setting-out information (in Lambert and NGF reference systems) before the start of the works. THE PURCHASER will also provide concrete outline drawings of the structures showing the as-built openings and a list of openings and their details (As-built Bill of Openings).
THE PURCHASER shall install reference survey stations on the site and issue their location to the Infill Contractor.

## 11.5.3 *Technical requirements for opening finishes*

This part is applicable to the finish of openings left by the Civil Contractor for service crossings.
Temporary openings and doorways are excluded from this specification.

### *11.5.3.1 Infill requirements and associated properties for the opening finish*

The infill types required for each opening are given in the Engineering Drawings and/or in the Bill of Openings. Where there are no specific requirements highlighted the "basic requirements" given below are to be met. Where there are additional specific requirements this will be highlighted and will be one or more of the following types, their impact on the opening finish is discussed in turn below:

- metal edging
- surface finish
- fire break
- temperature and pressure resistance
- watertightness,
- decontaminability
- radiological shielding
- confinement boundary
- leak rate limit
- nuclear safety requirement
- other

All openings shall meet the basic requirements.

11.5.3.1.1 Openings for services – basic requirements

No rebar shall protrude beyond the clear opening dimensions given on the drawings.
The tolerances for the positions and dimensions of openings are in the main specification.

Each opening is to be labelled with its unique reference number using an indelible marker. The number shall be positioned underneath the opening on the right hand side and above on the left hand side where possible in order to ensure that the number is remains visible after installation of services and infilling.
The Bill of Openings gives the nominal opening dimensions which are the clear opening dimensions as shown on the construction drawings. Standard details for opening arrangements including any tubes or slopes required to facilitate backfilling shall be provided by THE PURCHASER.

11.5.3.1.2 Openings for services – metal edging

Some openings have an additional requirement for a metal edge, these openings are to have an embedded metal corner surround and are specified in the Bill of Openings.
The following general rule applies for openings of dimensions greater than 0.3 m x 0.3 m or with a minimum dimension greater than 0.3m:
In walls/slabs < 0.5 m thick, one face of the opening is to have metal edging
In walls/slabs ≥ 0.5 m thick, both faces of the opening shall have metal edging

Alternative solutions may be proposed by the Civil Contractor, subject to the approval of THE PURCHASER

At the corners of the opening where the edges meet, a corner piece will be required such that the metal edging forms one continuous welded frame with a flat surface in the room.
Where the opening is flush against a perpendicular wall, an alternative piece is to be proposed for that edge.

11.5.3.1.3 Openings for services – surface finish

All opening internal surfaces shall be left with a “rough” finish as defined in EN 1992 unless otherwise specified on the drawings or in the Bill of Openings.

11.5.3.1.4 Openings for services – fire break, temperature and pressure resistance, watertightness.

No particular requirement for opening finish.

11.5.3.1.5 Openings for services – decontaminability

The finish of the metal edging must be decontaminable.

11.5.3.1.6 Openings for services – Radiological shielding

Openings with shielding requirements must have a step of 20 mm through the thickness of the wall. An equivalent justifiable design that will ensure the shielding when the opening is closed could replace the step with prior written approval of THE PURCHASER.

11.5.3.1.7 Openings for services – on a confinement boundary

A confinement boundary can have confinement requirements that require “reinforced” leak tightness for penetrations. These openings may have an embedded metal corner piece (metal

edging) that could accommodate closure with a seal plate welded to the metal edging. The details for such penetrations shall be sent to THE PURCHASER for approval.

11.5.3.1.8 Openings for services – leak rate limit

No particular requirement for opening finish.

11.5.3.1.9 Openings for services – other

The Bill of Openings may specify another requirement for a given opening, such as the opening has a different form of metal edging. Such requirements are also to be incorporated and may supersede the above listed finish requirements.

#### *11.5.3.2 Inspection and monitoring of openings*

The Contractor is required to work with THE PURCHASER (when necessary) in carrying out inspections and monitoring of openings.
This procedure is initiated by THE PURCHASER and forwarded to the Contractor, it is considered as part of the Contractor's contract.

### 11.5.4 *Technical requirements for infilling of openings*

This chapter is applicable to the infilling of openings as performed by the Infill Contractor. This chapter may be used for information only by Infill Contractor responsible for the infilling of the openings following the insertion of IO service networks or shared openings.
The infilling of the openings shall be performed according to site procedures.
This infill procedure shall be issued by the Infill Contractor. The procedure shall specify, for each opening, the material or product to be used for sealing around services. According to the opening size and location there are various requirements to be respected. The procedure shall also identify when qualified personnel are required and specify what qualifications are required.
Further, the Infill Contractor shall also issue procedures for maintenance, repair and test.
It is important that the openings in walls providing biological shielding and / or confinement boundaries are infilled such that the any cracking leading to potential gas leakage or shine path is prevented – see below.

#### *11.5.4.1 IN-FILL REQUIREMENTS AND PROPERTIES FOR OPENING SEALANTS*

The infill requirements for each opening are given in the Engineering Drawings and / or in the Bill of Openings. Where there are no specific requirements highlighted the opening design is as per "basic requirements" given below. Where there are additional specific requirements this will be highlighted and will be one or more of the following types, discussed in turn below:

- fire break
- temperature and pressure resistance
- water-tightness
- decontaminability
- radiological shielding
- confinement boundary
- leak rate limit
- nuclear safety requirement

All infill products shall meet the basic requirements given below and the specifications for the services and for the concrete structure.

11.5.4.1.1 Openings for services – infill basic requirements

All infill products shall meet the following requirements:

- compatible with adjacent materials
- leave a surface flush with the wall surface on both faces (not necessarily required to be a solid infilling), unless specified otherwise in the Bill of Openings or by written agreement
- humidity resistant (the humidity resistance is to be shown by test as per EN ISO 6270-2)
- no shrinkage in order not to separate from the surrounding structure nor to apply loads to the surrounding structure or service crossings
- paintability of filling material (see Technical specifications for painting and coating)
- no deterioration in time (compatible with design life of the structure)
- shall not release toxic smoke during fires (polyurethane foam and any substance which may release halogen are forbidden in Nuclear Buildings (11 14, 21 and 23) and the stairways and airlocks that serve them)
- infilled openings in slabs shall withstand a load of $1kN/m^2$ on the infilling - not on or from the service crossing [reference EC1, access only for maintenance], unless this is impracticable and agreed as such by written agreement from THE PURCHASER.
- when in a seismically qualified structure then the infill must be designed accordingly also – the Nuclear Buildings are seismically qualified for an SL2 earthquake for stability and maintenance of confinement and shielding functions. All properties are to be resistant and this has particular relevance to any air-tight (confinement boundary), water-tight, shielding or fire break properties.
- remain unaffected by the magnetic field (retain the same properties)

11.5.4.1.2 Openings for services – fire break

If the opening is on a fire sector boundary the opening must be filled accordingly.

- The extent of fire resistance including fire duration is given in the Bill of Openings (eg REI 120 as per Arrêté du 22 mars 2004 relatif à la résistance au feu des produits, éléments de construction et d'ouvrages).
- Reaction to fire Euroclass A or B
- shall not release toxic smoke during a fire
- shall not generate smoke
- polyurethane foam and any substance which may release halogen are forbidden
- It may be that services at some openings require a fire protection sleeve for a certain distance on one or two side/s of the opening to complete the qualification of the crossing.

11.5.4.1.3 Openings for services – temperature and pressure resistance

For temperature resistance related to fire stop properties see 11.5.4.1.2.
Other incidents or accidents can lead to a temperature and pressure resistance associated to the opening. The potential accident cases associated with a given room is specified in the room book. The temperature and pressure associated to this accident is given in Load Specification for Buildings with Safety Requirements (2ERTXQ). The infill selected must be demonstrably suitable for this load.

11.5.4.1.4 Openings for services – infill water-tightness

These openings are to be infilled water-tight, for example, if a concrete or cement grout is used as the filler then a water bar shall be detailed around the opening.
The water-tightness is to be for 15 cm of water unless specified otherwise in the Bill of Openings.

11.5.4.1.5 Openings for services – infill decontaminability

If the opening is in a Nuclear Building (Tokamak Complex, Hot Cell, Radwaste) then all areas are to be decontaminable including closed openings. A Nuclear Building is one which may contain nuclear waste: for the Tokamak Complex this means in the Tokamak Building PBS62.11 or the Tritium Building PBS 62.14 or the stairways and airlocks that serve them. An appropriate finish to the closed opening may negate the requirement for paintability.

- Either surface smoothness of the facing (to assist decontamination)
- Or paintability of filling material.

11.5.4.1.6 Openings for services – infill radiological shielding

Openings with shielding requirements must be infilled respecting these requirements. In general the opening when closed must offer shielding equivalent to the requirement of the surrounding structure though the structure can be thicker than the shielding requirement. The thickness of the element and the equivalent thickness of concrete required for shielding is given in the Bill of Openings. For some elements the equivalent thickness required is not stated as it cannot be simply transcribed (for example the shielding can be provided by 2 walls in series). The source of radiation is various and is not always directly in line with the opening so there are a variety of different solutions possible. Guidance is given as to which solution is appropriate for each opening with PBS62 services. An alternative solution may be possible for a given opening with justification and prior written consent from THE PURCHASER. The typical design solutions proposed are given below:

- No particular measure required providing the service crossing dimensions, orientations and placements are as assumed in the guidance document and the infill has a density equivalent to standard concrete
- The opening around the service is infilled with dense material at ~5 tonnes/$m^3$ (~2x the density of standard concrete).
- The infill around the service is extruded.
- The shielding requirement can affect the design of any embedded part or piping – e.g. the service may not traverse perpendicular to the wall, a pipe may hold a helical spiral, a transit or sleeve may be filled to provide shielding.
- A separate shielding protection plate may be provided. The plate is provided by the service traversing the opening and is to be attached to specific embedded plates (not to any metal edging around the opening).
- The above solutions may be combined.

The final solution is to be indicated in the opening data sheet. The properties of this infill will vary according to all the safety requirements on the opening, see 11.5.4.1.

In all cases, except when specified otherwise in the guidance or with written agreement from THE PURCHASER, the infill material is to be homogenous, without air pockets and with a density at least equivalent to the primary concrete, i.e. 2.45 tonne/$m^3$. The procedure proposed by the Contractor must demonstrate that this requirement for homogeneity is met.

11.5.4.1.7 Openings for services – infill on a confinement boundary

Openings on a confinement boundary must withstand the pressure loads associated with the rooms on the either side as specified in the roombook.

Each opening will have a leak rate associated with particular design events and will undergo periodic pressure-leak tightness testing.

This type of opening is to be filled pressure resistant and air-tight and the method of filling can be any method suited to periodic pressure leak testing and that also meets the other requirements of the opening. All seals must be testable: between services/utilities and transits/sleeves (if there is one); between utilities or transits and infilling material; between infilling material and primary structure.

Note: if a concrete or cement grout or similar infill material is used a re-injectable hose joint detail is to be installed between the infill and the primary concrete structure.

The properties of this infill will vary according to all of the requirements on the openings, for example high density infill may be required for shielding, see 11.5.4.1.

11.5.4.1.8 Openings for services – infill leak rate limit

Openings for services on confinement boundaries have confinement requirements with a leak rate associated with particular design events and will undergo periodic pressure leak testing.
The Bill of Openings gives the allowable leak rate by opening – the sum of all leak rates through the entire opening area including:

- the infill,
- any joint between the infill and the concrete structure,
- any transit or pipe sleeve
- any joint between the infill and transit/pipe sleeve/service

For the pressures associated with the leak rates and for further information see Leak Tightness Test Procedures.

### *11.5.4.2 CONCRETE, FORMWORK AND REINFORCEMENT USED FOR IN-FILLING WORKS: TECHNICAL REQUIREMENTS AND RELATED CHECKS*

The specification for concretes, formwork and reinforcement used is as stated in the sections 7, 0 & 0 of this document.

### *11.5.4.3 INFILL MATERIAL*

Infill materials selected require the prior written approval of THE PURCHASER. Technical documentation justifying the suitability of the product considering all the requirements and loads applied must be submitted for approval.

Where possible recognised codes, standards and specifications should be used, a non-exhaustive list of examples is given below:

- General concrete and grouting properties are specified in section 7.
- Fire stop properties are to meet the Arrêté du 22 mars 2004 relatif à la résistance au feu des produits, éléments de construction et d'ouvrages, consolidé 14 mars 2011.
- Resistance to radiation, for example: NF T30-903 Paints and varnishes. Paints for the nuclear industry. Test of behaviour in ionising radiations (pwr).

#### *11.5.4.4 SECURING SLEEVES AND METAL EDGING*

The specification to use for securing sleeves and metal edging or more generally for embedded devices in concrete is section 0. Applicable for when the infill material is concrete; the principles apply when other infill material used unless over-ridden by a proprietary technical specification for that material.

#### *11.5.4.5 INSPECTION AND MONITORING OF OPENINGS AND FILLINGS*

The Infill Contractor is required to work with THE PURCHASER (when necessary) in carrying out inspections and monitoring of openings.
This procedure is initiated by THE PURCHASER and forwarded to the Infill Contractor, it is considered as part of the Infill Contractor's contract.
For openings on a confinement boundary that incorporate a seal plate detail, the assembly is to be tested prior to the opening infill for leak tightness.

#### *11.5.4.6 TESTS AND CONTROLS*

"Tests and Commissioning General Requirements" conducted by manufacturers and appearing on technical sheets, for functional tests, for receipt and installation checks shall be confirmed by THE PURCHASER.
In addition infilled openings may be subject to tests linked to particular requirements as follows:

- Openings with air-tight requirements will be tested for their leak tightness once infilled. They will tested by unit (the opening itself) and then again as part of a global test by zone. This will form part of the acceptance tests (and will also be performed periodically through life).
- Additionally for openings with a welded seal plate, the welded seal plate assembly will be tested for air-tightness before the opening is infilled.
- Openings with shielding requirements may be tested for the shielding protection they provide.
- All tests linked to a particular requirement (e.g. fire resistance, decontaminability).

### 11.5.5 *TECHNICAL REQUIREMENTS FOR SERVICE CROSSINGS*

This part is applicable to the section of the service that crosses the opening.

The service provider is to supply transits and pipe sleeves as appropriate to the opening and infill requirements and as agreed with the Tender Batch responsible for infilling.
The service provider is also to supply documents or certificates demonstrating the transit or sleeve properties.

### *11.5.5.1 IN-FILL REQUIREMENTS AND PROPERTIES FOR SERVICE CROSSINGS*

The service crossing must take into account the infill requirements on the opening. The infill requirements for each opening are given in the Engineering Drawings and/or in the Bill of Openings. Where there are no specific requirements highlighted the opening design is as per "basic requirements" given below. Where there are additional specific requirements this will be highlighted and will be of the following types, discussed in turn below:

- fire break
- temperature and pressure resistance
- water-tight
- decontaminability
- shielding
- confinement boundary
- leak rate
- nuclear safety requirement

All service crossings must be consistent and compatible with the required infill, see also 11.5.4.1 and the basic requirements given below.

#### 11.5.5.1.1 Openings for services – service crossing basic requirements

The openings are not designed to transfer loads from crossing services to the infill and/or the structure - the services have separate support points. The Nuclear Buildings are seismically qualified to SL2, the requirement not to load the openings also applies during a seismic event.
There is no requirement on the opening infilling to be flexible, therefore should a particular service line require flexibility in order not to generate stress in the service and not to transfer load to the closed opening, the service should provide a pipe sleeve or protection pipe. The pipe sleeve /protection pipe will be held in the closed opening and should be designed to allow the design displacements, deformations or expansions of the service within.

Examples (when suitably sealed) can be used where there is a requirement for a metal sleeve welded to a seal plate. A simpler alternative is to use a sleeve of flexible material around the pipe; this alternative is only possible where the following all hold true:

- the maximum total pipe displacement or expansion is 5 mm or less
- there is no requirement for a welded connection
- the infill material is rigid (optional).

Additionally, any service subject or potentially subject to vibration such as HVAC ducting, should use a sleeve or coating of flexible material if the infill material is rigid in order to prevent damage to or separation of the infill and service.
Any sleeve or protection pipe provided shall comply with all infill/service crossing requirements.
The service should always be at least 50 mm from the edge of the opening or 100 mm away if the service is greater than Ø100 mm. Any sleeve/ protection pipe/ transit provided must fit within this distance and remain at least 40 mm away from the edge of the opening.
The specifications for the service apply.

#### 11.5.5.1.2 Openings for services – fire break

See 11.5.4.1.2 for further information.

It may be that services at some openings require a fire protection sleeve for a certain distance on one or two side/s of the opening to complete the qualification of the crossing.

11.5.5.1.3 Openings for services – temperature and pressure resistance

For temperature resistance related to fire stop properties see 11.5.5.1.2.
The service crossing, transit or sleeve selected must be demonstrably suitable for the temperature and pressure loads associated with the rooms on either face of the opening, even if the service itself does not maintain functionality. For further information, see 11.5.4.1.3.

11.5.5.1.4 Openings for services –water-tight service crossings

A water-tight transit or sleeve may be required depending on the nature of the infill material.
The water-tightness is to be for 15cm of water unless specified otherwise in the Bill of Openings.

11.5.5.1.5 Openings for services – service crossing decontaminability

Any transit or sleeve arrangement provided shall be decontaminable.

11.5.5.1.6 Openings for services – radiological shielding

Openings with shielding requirements must be infilled respecting these requirements. See 11.5.4.1.6 for further information.
The shielding requirement can affect the design of any embedded part or piping – e.g. the service may not traverse perpendicular to the wall, a pipe may hold a helical spiral, a transit or sleeve may be filled to provide shielding.

Any shielding required within an HVAC duct shall be designed according to NF M62-233 (Shielded enclosure bushing. Protection against gamma rays. Requirements for cast iron screws used for ventilation.).

11.5.5.1.7 Openings for services – service crossings on a confinement boundary

Openings on a confinement boundary must withstand the pressure loads associated with the rooms on the either side as specified in the roombook.
A confinement boundary has confinement requirements for leak tightness for penetrations. Each opening will have a leak rate associated with particular design events and will undergo periodic pressure leak testing, which will be specified by THE PURCHASER.

These openings are to be filled such that they are pressure resistant and air-tight. The method of filling can be any method suited to periodic pressure leak testing and that also meets the other requirements of the opening.

If the service provider or Infill Contractor wishes a transit or sleeve at the opening then it shall be testable for leak tightness.

11.5.5.1.8 Openings for services – leak rate limit
The Bill of Openings specifies the leak rate by opening for the entire opening. The part of the total opening leak rate which is apportioned to a given service crossing is to be agreed with THE PURCHASER. See 11.5.4.1.8.

#### *11.5.5.2 INSPECTION AND MONITORING OF OPENINGS AND FILLINGS*
The Infill Contractor is required to work with THE PURCHASER (when necessary) in carrying out inspections and monitoring of openings.
This procedure is initiated by THE PURCHASER and forwarded to the Infill Contractor, it is considered as part of the Infill Contractor's contract.

#### *11.5.5.3 TESTS AND CONTROLS*
"Tests and Commissioning General Requirements" conducted by manufacturers and appearing on technical sheets, for functional tests, for receipt and installation checks shall be provided by THE PURCHASER.
In addition service crossings may be subject to tests linked to particular requirements as follows:
Openings with air-tight requirements will be tested for their leak tightness once infilled. They will tested by unit (the service crossing itself) and then again as part of an opening leak test and then as part of a global test by zone. This will form part of the acceptance tests (and will also be performed periodically through life). ["Leak Tightness Test Procedures" shall be provided by THE PURCHASER].
Openings with shielding requirements may be tested for the shielding protection they provide.
All tests linked to a particular requirement (e.g. fire resistance, decontaminability).

### 11.5.6 *METAL PARTS*

The metal edging and seal plates shall comply with the following.

#### *11.5.6.1 SEAL PLATE DESIGN*
The Contractor is design the seal plates to support the maximum accidental pressure load applied to either side and for the potential self-weight or seismic acceleration of the plate and the infill. The plate is to be welded to the metal edging. For large openings the plate may require stiffening or other support which could be provided by the sleeves or a second plate on the opposite face.
The seal plate is to be designed to Eurocode 3.
The seal plate design is to be submitted to THE PURCHASER for approval prior to installation.

#### *11.5.6.2 PROCUREMENT*
The plate material is to be procured in steel grade S235 J0 in compliance with NF EN 10025.

#### *11.5.6.3 WELDING*
The Contractor's Control Plan included in the Quality Plan to be submitted for approval to THE PURCHASER shall contain, as a minimum, the specifications for materials (electrodes), testing and acceptance criteria, and welder's qualification procedures.
The welded assemblies shall be executed in accordance with the requirements of NF EN ISO 14555 and of NF EN ISO 13918 with execution class EXC3 as in NF EN 1090-2. Defect assessment per severest quality class in NF EN ISO 5817.
The qualification of the welding procedures and of the welders shall comply with the requirements of NF EN ISO 15614 and NF EN 287.

Welds on the plates shall be 100 % visually inspected and the acceptance criteria of the defects shall be those of the severest quality class in NF EN ISO 5817 corresponding to the execution class EXC3 in NF EN 1090-2.
All full penetration butt welds shall be volumetrically inspected and the acceptance criteria of the defects shall be those of the severest quality class in NF EN ISO 5817 corresponding to the execution class EXC3 in NF EN 1090-2.
Welds on confinement boundaries will be subject to periodic inspection.

#### *11.5.6.4 FINISHING AND PROTECTION AGAINST CORROSION*

All steel surfaces that will be exposed after formwork removal shall be protected against corrosion by protection paint system, 100 micron DFT coating of 2 pack epoxy applied to the requirements of NF EN ISO 12944. For the face of the plate in contact with the concrete or infill, the first 20 mm along the edge of the plate shall be also protected.
This corrosion protection shall be decontaminable where such a requirement is highlighted in the Bill of Openings.
Before applying any protection paint system, a thorough cleaning, degreasing and scouring shall be done.
All surfaces (in contact or not with the concrete) shall be thoroughly cleaned and degreased before applying any protective system as in NF EN ISO 8504.

##### 11.5.6.4.1 Surface preparation

Surface preparation shall be made before application of the protection paint system. If any admissible and repairable welding defects are detected after scouring, they shall be clearly marked for repair with paint. Once the defects are repaired, the repaired areas shall be scoured again. Scouring shall be done by abrasive material projection as per standard NF EN ISO 8504 with a finishing roughness grade SA 2½ as per standard NF EN ISO 8501.
After scouring, all surfaces shall be carefully cleaned by a clean dry air jet or by aspiration

##### 11.5.6.4.2 Painting

The Contractor shall inform THE PURCHASER in due time to inspect surface preparation before application of the protection paint system.
The primary layer shall be applied not later than four hours after the scouring and shall rest for a minimum period of thirty minutes before application of any other layer of protective painting system.
The protection paint system shall comply with the requirements of NF EN ISO 12944.

##### 11.5.6.4.3 Surfaces in direct contact with concrete

All surfaces in direct contact with concrete shall be thoroughly cleaned, degreased and scoured. Should any protective system exist it shall be eliminated except in the first 20 mm close to the edge of the plate.

##### 11.5.6.4.4 Final painting

The final painting will be applied after installation of the equipment, or support of the equipment. It will be done by the owner of the seal plate if any otherwise by the owner of the part (metal edging / sleeve/ etc) and in accordance with the technical specification.

#### *11.5.6.5 Proprietary systems*

Proprietary systems shall be designed and manufactured under an independently audited and Registered Quality System complying with ISO 9001.

### 11.5.7 *MOCK UP*

The Infill Contractor shall implement all the necessary mock-up for the qualification and good execution of the works (infill, repair, formwork, reinforcement, seal plate assembly….).

# 12 BASE ISOLATION AND ELASTOMERIC BEARINGS

## 12.1 References and general assumptions

The base isolation of the Tokamak complex is made of elastomeric bearings. These elastomeric bearings shall comply with the standards quoted in reference in paragraph 6.1 of ITER STRUCTURAL CODE FOR BUILDINGS PART 1.

All the standards quoted in reference in the above documents, especially all the ISO norms concerning the elastomeric material, shall apply. These standards are completed or modified by the specific additional rules defined below.

### 12.1.1 *DOCUMENTS QUOTED IN REFERENCE IN THIS SECTION*

NF EN 15129 (01/10) Anti-seismic devices

NF EN 1337-3 (09/05) Structural bearings – Elastomeric Bearings

NF EN 1337-10 (02/04) Structural bearings – Inspection and maintenance

Other Documents

ITER STRUCTURAL CODE FOR BUILDINGS PART 1 (283B24)

## 12.2 Mechanical properties of elastomeric bearings

The elastomeric bearing selected for the Tokamak complex are square laminated elastomeric bearing 900x900x181 mm, made of 6 layers of elastomer of 20 mm in thickness with incorporated steel plates of 5 mm in thickness.

The main material properties of the elastomeric bearing are defined in paragraph 6.4.1 of ITER STRUCTURAL CODE FOR BUILDINGS PART 1.

## 12.3 Testing

Two different types of testing have to be performed on the bearings:

- Qualification testing (called type testing according to NF EN 15129:2010), whose purpose is to determine the detailed mechanical characteristics of products, for different situations and operating ranges.
- Delivery testing (called factory production control testing according to NF EN 15129:2010), whose purpose is to check the conformity of the provided product.

Euronorm NF EN 1337-3 and especially NF EN 15129:2010 define detailed specifications for these tests which concern both elastomeric isolator and elastomer material itself.

All of the tests defined in NF EN 15129:2010 § 8.2.4.1.2 (table 11) and 8.2.4.1.3 have to be performed: the exemption allowed for low damping isolators shall not apply. The list of tests is summarised in the following table.

| n° | Test | Type test requirement | Factory production test requirement (1) |
|---|---|---|---|
| 1 | capacity in compression under zero lateral displacement | support $2N_d$ without visible defects (where $N_d$ is vertical service load) | not applicable |
| 2 | compression stiffness | report value | within ±20% of type test value; no visible defects |
| 3 | horizontal characteristics $K_h$ and $\xi_h$ under cyclic deformation | report strain dependence; at design displacement $d_{cd}$, values within ±20% of design value | values within ±20% of required value |
| 4 | horizontal stiffness under a one-sided ramp loading | report value at design displacement $d_{cd}$ | values within ±20% of adjusted type test value |
| 5 | variation of horizontal characteristics $K_h$ and $\xi_h$ with frequency | report variation; maximum variation ±20% | not applicable |
| 6 | variation of horizontal characteristics $K_h$ and $\xi_h$ with temperature | report variation | not applicable |
| 7 | dependence of horizontal characteristics $K_h$ and $\xi_h$ with repeated cycling | dependence within limits | not applicable |
| 8 | lateral capacity under maximum and minimum vertical loads | force-displacement curve increasing up to $\gamma_b$ $d_{bd}$ without defects | not applicable |
| 9 | variation of horizontal characteristics $K_h$ and $\xi_h$ with ageing | variation within ±20% | not applicable |
| 10 | creep test under vertical load | total creep rate < 20% per decade | not applicable |

(1) These requirements are minimum requirements defined by NF EN15129:2010. In addition, the product characteristics have to be consistent with the calculation hypotheses defined in paragraph 6.4.1 of ITER STRUCTURAL CODE FOR BUILDINGS PART 1. Therefore, the following additional requirements have to be met:

- bearing stiffnesses (horizontal $K_h$ and vertical $K_v$) are within the range of values [$K_{min}$; $K_{max}$/1,20], where $K_{min}$ and $K_{max}$ are defined in paragraph 6.4.1 of ITER STRUCTURAL CODE FOR BUILDINGS PART 1. and the 1,20 factor takes into account the estimated ageing effect,
- damping ratio is greater or equal to values defined in paragraph 6.4.1 of ITER STRUCTURAL CODE FOR BUILDINGS PART 1 ($\xi_h = \xi_v = 5$ %).

## 12.4 Installation, inspection and maintenance

Isolators have to be fixed on structures at both sides: on supporting substructure and on super-structure. The typical fixing method recommended by NF EN 15129 § 8.2.3.2 is an anchorage on concrete structure by bolted plates.

The anchoring method may be replaced by recess or dowel methods (to avoid sliding) only if there is no risk of uplift.

As a guide, the conception of the bearing could be as follows:

- A thick steel plate equipped with concrete anchors is embedded at the top of each column,
- The elastomeric bearing is installed, adjusted, secured and its position is checked,
- A 40 mm thick non-shrink resin-grout is poured between the steel plate set at the top of the column and the bottom steel plate of the elastomeric bearing,
- The steel device to prevent any sliding of the elastomeric bearing is bolted or welded (after installing a protection of the elastomeric bearing) onto the steel plate at top of column,
- The upper steel plate to be embedded in the concrete of the upper slab, equipped with the steel device to prevent any sliding, equipped with its concrete anchors, is installed, adjusted, secured and its position is checked,
- A temporary protection around the elastomeric bearing is installed,
- The concrete of the upper slab is poured onto the upper steel plate equipped with concrete anchors.

The device provided to prevent any sliding of the elastomeric bearing shall resist the full horizontal load supported by the bearing and it shall not hamper the deformation of the first layer of elastomer.

The tolerances from the theoretical position for installing the bearing are specified below:

- For the bottom steel plate embedded on the top of the reinforced concrete column :
    - In vertical, measured at each corner: ± 5 mm
    - In horizontal measured at each corner: ± 5 mm

Rotation angle around each horizontal axis perpendicular to each side of the plate: ± 3/1000 rad

- For the bottom steel plate of the elastomeric bearing measured after grouting :
    - In vertical, measured at each corner: ± 2 mm
    - In horizontal measured at each corner: ± 5 mm
    - Rotation angle around each horizontal axis perpendicular to each side of the bearing : ± 1/1000 rad

The design of structures and isolators has to enable inspection of isolators and possible replacement.

The specifications for inspection and maintenance of isolators are defined in NF EN 1337-10 and NF EN 15129.

# 13 LEAKTIGHT METAL PARTS ON CONTAINMENT (STEEL LINER))

## 13.1 SCOPE

This paragraph applies to all metal parts participating in the leak tight containment, the following elements are concerned, in particular:

- Metallic liners with their anchoring system,
- Raft sumps

## 13.2 LIST OF DOCUMENTS CITED IN THE SPECIFICATION

| | |
|---|---|
| NF EN 287-1 (09/11) | Qualification of test welders |
| NF EN 287-1/A2 (09/11) | Qualification of test welders (Amendment 2) |
| NF EN 571-1 (09/97) | Non-Destructive Testing - Penetrant Testing Part 1: General Principles |
| NF EN 1011-1 to 3 (varies) | Recommendations for welding Parts 1 to 3 |
| NF EN 1090-1 to 3 (varies) | Execution of steel structures and aluminium structures Parts 1 to 3 |
| NF EN 1600 (05/12) | Welding consumables. Covered electrodes for manual metal arc welding of stainless and heat resisting steels. |
| NF EN 3581 (05/12) | Welding consumables - Covered electrodes for manual metal arc welding of stainless and heat resisting steels |
| NF EN 10029 (02/11) | Specification for tolerances on dimensions, shape and mass for hot rolled steel plates 3 mm thick or above |
| NF EN 10088 (all parts) | Stainless Steels |
| NF EN 10160 (12/99) | Ultrasonic testing of steel flat product of thickness equal or greater than 6 mm (reflexion method) |
| NF EN 10204 (01/05) | Metallic products —Types of inspection documents |
| EN 13318 (08/00) | Screed material and floor screeds – definitions |
| EN 13670 (06/09) | Execution of concrete structures |
| EN 13813 (06/03) | Screed materials and floor screeds - Screed material, Properties and requirements |
| EN 13892 (all parts) | Methods of test for screed materials - Parts 1 to 8. |
| NF EN 14171 (01/11) | Welding consumables |
| EN ISO 2560 (12/09) | Welding consumables — Covered electrodes for manual metal arc welding of non-alloy and fine grain steels |
| EN ISO 3506 (11/09) | Mechanical properties of corrosion-resistant stainless steel fasteners |
| NF EN ISO 3834 (04/06) | Quality requirements for fusion welding of metallic materials – Part 1 to 4 |
| EN ISO 5817 (11/07) | Welding - Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) - Quality levels for inspection |
| EN ISO 9001 (11/08) | Quality Management Systems - requirements |

| | |
|---|---|
| EN ISO 9692 (all parts) | Welding and allied processes - Recommendations for joint preparation |
| NF EN ISO 14341 (04/11) | Welding consumables - Wire electrodes and weld deposits for gas shielded metal arc welding of non-alloy and fine grain steels |
| EN ISO 14343 (01/10) | Welding consumables - Wire electrodes, strip electrodes, wires and rods for arc welding of stainless and heat resisting steels |
| EN ISO 15609-1 (09/05) | Specification and qualification of welding procedures for metallic materials — Welding procedure specification |
| BS EN ISO 15614-1+A2 (06/04) | Specification and qualification of welding procedures for metallic materials. Welding procedure test |
| NF EN ISO 17637 (05/11) | Non-destructive testing of welds - Visual testing of fusion-welded joints |
| NF ISO 68-1 (03/99) | ISO general purpose screw threads. Basic profile. |
| ISO 261 (03/99) | ISO general purpose metric threads. General plan |
| ISO 262 (03/99) | ISO general purpose metric screw threads. Selected sizes for screws, bolts and nuts |
| EU (Euronorm) 53-62 | European Wide Flange Beams HEA Sections (dimensions) |
| ASME Section III Div.2 | 2010 ASME Boiler and Pressure Vessel Code – Code for Concrete Containments |
| ASME Section V Art.2 | 2010 ASME Boiler and Pressure Vessel Code – Nondestructive Examination |
| ASTM A380 (02/13) | Standard Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems |

## 13.3 TECHNICAL REQUIREMENTS

### 13.3.1 *Information to be provided to the Contractor*

- General layout drawings.
- Details drawings.
- Additional information will be provided at the request of the Contractor.

### 13.3.2 *Materials*

#### *13.3.2.1 Stainless Steel Products*

Qualities

Material shall be stainless steel rolled sections (use X2CrNi18-9 No. 1.4307 according to EN 10088), fabricated sections, plates or bars. When specifying and ordering, full steel specifications shall be given including standard and steel number (eg. EN 10088-4 1.4307) so that the correct properties for fracture toughness and weldability are ensured. Generally the steel shall conform to standard EN 10088.

Inspection and Testing

Inspection and tests shall be applied as specified in the quality plan or inspection and test schedule. THE PURCHASER shall be given the facilities to enable inspection to be carried out at all stages of manufacture. All inspection equipment shall be provided by the Contractor. Any inspection carried out by THE PURCHASER in no way relieves the Contractor of his responsibilities under the terms of the contract.

All steel products for use in the Works shall have been specifically tested in accordance with the appropriate material product standard. The steel product manufacturer shall declare the results using an inspection certificate type 3.1 to EN 10204.

The Contractor shall have access to the inspection documents to EN 10204 provided by the manufacturers of all steel products used in the Works. The Contractor shall make these inspection documents available to THE PURCHASER. The requirements of EN 1090-2 with regard to execution classes will be followed.

All inspection equipment shall be provided by the Contractor.

All the Contractors Inspection Personnel shall be in possession of a current, nationally recognised, certificate (e.g. AFS, ASNT) appropriate to their duties. The Contractor shall submit to THE PURCHASER, for approval, copies of CV's for all Inspection Personnel he proposes to employ before work commences.

Production staff (e.g. welding Supervisor/Foreman) will not carry out inspection duties.

Contractors personnel performing vacuum leak testing must first demonstrate their competence to the satisfaction of THE PURCHASER prior to testing commencing.

#### *13.3.2.2 Dimensions and tolerance*

Dimensions and tolerances shall comply with the latest issue of EN 1090 Parts 1 & 2 Execution of Steel Structures.

Liner plates shall be in accordance with EN 10088-4 and EN 10029 unless stated in this specification. Liner sheets are generally up to 4 m length and 1.5 m width according to the liner layout. The liner plates should be supplied in accordance with flatness class S steel type L as described in EN 10029. Sheets shall not be constructed by welding pieces together. Tolerance on sheet size will be determined by the Contractor to suit the approved weld procedures. Sheet tolerances are to be approved by THE PURCHASER.

#### *13.3.2.3 Surface condition*

All sheets shall be supplied clean and free from damage and may be protected, on one side only, by self-adhesive plastic film. The Contractor may use a suitable alternative to self-adhesive film, providing it has been approved, prior to use, by THE PURCHASER. If plastic film is used it shall be easily removable and halogen free. Plastic films which oxidise to the sheeting and become difficult to remove shall not be used.

Surface defects in hot rolled sections, plates and wide flats revealed during surface preparation that are not in accordance with the requirements of EN 10088 or Euronorm 53-62 shall be rectified accordingly.

If ever liner sheets are to be welded to carbon steel angles or en-cast items the steelwork shall be thoroughly ground to bright metal in order to remove surface rust, mill scale and other contaminates.

Marking

All element receive an own marking, which allows it to be identified and specifies its usage conditions.

#### *13.3.2.4 Welding consumables*

Standards

Consumables for use in metal arc welding shall comply with the following table. It is anticipated that the welding parts will all be austenitic stainless steels. However, for completeness and in anticipation of possible future modifications, other types of materials (carbon steel) have been included in the table below.

| Material type | Weld consumables | | |
|---|---|---|---|
| | MMA coated electrode type | Manual/synergic MIG/TIG filler wire type | Submerged arc welding |
| Carbon steel | EN ISO 2560 | EN ISO 14341 | EN 14171 |
| 1.4307 stainless steel | EN 1600 | EN ISO 14343 | EN ISO 14343 |
| 1.4307 stainless steel to carbon steel transition | EN 1600 | EN ISO 14343 | EN ISO 14343 |

Table 13.1 Welding consumables.

The selection of weld consumables for specific weld applications or processes shall be by prior arrangement with, and the written approval of, THE PURCHASER.

Complete chemical certification of all weld consumables shall be provided by the Contractor.

The Contractor shall operate a formal system for the verification of electrodes, filler rods and wire prior to release for welding operations, to the approval of THE PURCHASER.

Certificates of test covering each batch and/or cast number of weld consumables shall be in accordance with EN ISO 9001 and shall be supplied to THE PURCHASER for approval before work is commenced. Packaged materials shall be marked conspicuously with the batch and/or cast number as appropriate.

The use of vacuum packed electrodes shall be subject to approval of the Contractors documented control procedure. Such electrodes shall be used in accordance with manufacturers' recommendations.

The Contractor shall satisfy THE PURCHASER that a documented system is operated which will identify the materials correctly and include relevant issue details.

Storage

Consumables on site shall be stored and handled in a manner described in EN 1011-1 and in accordance with the relevant standard. Any drying or baking of consumables before issue shall be carried out in accordance with the manufacturer's recommendations.

Filler wires shall be kept fully wrapped until required for use and shall be degreased and dried before issue if they have become contaminated.

Unused filler materials shall be returned to store at the end of the day or shift where they can be prepared for re-issue. Filler materials which cannot be identified shall be discarded.

#### *13.3.2.5 Steel products and structural fasteners*

For non-stainless steel products refer to section 15 of this document.

Declaration of Conformity

The Contractor shall make declarations of conformity provided by suppliers of structural fasteners available to THE PURCHASER, if requested.

Bolts

Stainless steel bolts and associated components shall conform to standard EN ISO 3506. Only A3 or A4 of bolts shall be admitted. Dimensions shall be in accordance with ISO 68-1, ISO 261 and ISO 262.

#### *13.3.2.6 Floor screeds (Second stage concrete)*

Floor screeds for Nuclear Buildings

Floor screeds for the Nuclear Building rooms with liners are either structural concrete or second stage screeding. They shall be produced and laid to the details shown on the drawings and the following standards:

EN 13318 : Screed material and floor screeds – definitions

EN 13813 : Screed materials and floor screeds - Screed material, Properties and requirements

EN 13892 : Methods of test for screed materials parts 1-8.

EN 13670 : Execution of concrete structures

The required design life shall be 70 years. An inspection and survey shall be made of the slab surface to ensure it is within the required tolerance and that it is free from all dust and debris.

EN 13670 Execution Class 3 and Curing class 4 shall apply.

Compressive strength of the screed shall be minimum class C50 according to EN 13813. Wear resistance tests shall be A6 class according to EN 13813. Compressive and wear resistance tests shall be carried out to EN 13892 requirements.

The Contractor shall submit proposal for the product to be used to THE PURCHASER for review and approval.

### 13.3.3 *Information to be provided by the Contractor*

#### *13.3.3.1 Information system*

The information system used for manufacturing steelwork components may include drawings and calculations prepared manually or by computer modelling.

#### *13.3.3.2 General Arrangement of Components*

Marking System

Every component which is to be individually assembled or erected shall be allocated an erection mark.

Components which are nominally identical in all respects may have the same erection mark.

General Arrangement Drawings

Drawings shall be prepared by the Contractor showing plans and elevations at a scale such that the erection marks for all components can be shown on them. Preferred scales are 1:100 or larger. The drawings shall identify member size, material quality, location relative to other members and the grid, and the specified surface treatment. They may include a reference system to connections. Details at an enlarged scale shall also be made if these are necessary to show the assembly of components.

#### *13.3.3.3 Concrete Floor and Wall Interface Information*

Information showing holding down bolts and the interface of steelwork components to floors shall include a plan showing base location, position and orientation of the liner grillage, the marks of all the members that form the grillage, any other components in direct contact with the foundations, their base location, level and datum level.

Similar information shall also be provided for components connecting to walls and any other concrete surfaces.

Complete details of fixing steel and bolts to the concrete floor or walls, method of adjustment and packing/grouting details shall be provided.

#### *13.3.3.4 Fabrication Information for Components*

Fabrication drawings and fabrication data

Fabrication drawings or fabrication data used in the manufacturing system need only provide details and dimensions necessary for the manufacture of components.

Attachments to facilitate erection

Details of holes and fittings in components necessary for safety or to provide lifting and erection aids shall be included. Lifting points shall be marked with the maximum safe weight that can be carried.

Liner plates are to be manually handed. No holes are allowed in the liner plates.

Welding

Any requirements for edge preparations for welds shall be indicated.

Hole sizes

Holes in components shall be shown to the nominal sizes given in EN 1090 – 2.

#### *13.3.3.5 Erection Information*

Erection drawings

If necessary to amplify the information given in the erection method statement the Contractor shall prepare Erection Drawings and handlings plans. The Erection Drawings should include as minimum following information:

- Details and arrangements of temporary steelwork for erection purposes shall be shown.
- Key stages of the construction process.

#### *13.3.3.6 Drawing or Information Review*

Drawings or electronic data shall be submitted to THE PURCHASER for approval in accordance with the Programme and instructions listed in Annex A- Management Specification.

The review and approval by THE PURCHASER means :

a) The principle levels, dimensions and typical details shown on the General Arrangement Drawings are a correct interpretation of design requirements.

b) The principles adopted for the design of connections between the components of the S/S liner system as well as between the S/S liner system components and the main structure are compatible with the design intent.

Approval does not relieve the Contractor of the responsibility for accuracy of the calculations, detail dimensions on the drawings, nor the general dimensions on the drawings and checking of the site set-out of parts to be assembled on site.

"As Built" Information

On completion of the contract the Contractor shall provide THE PURCHASER with:

a) Drawings and documents comprising:
   - General Arrangement Drawings
   - Fabrication Drawings
   - Connection design calculations
   - Drawings made after fabrication showing revisions
   - The drawing register

b) Two electronic copies (on CD Rom ) of all information.

## 13.3.4 *Welding*

The scope of work includes welding of the liner to en cast items. All the requirements in this specification, including inspections, apply also to the welds to en cast items.

### *13.3.4.1 Welding procedures*

Welding shall be a based on an arc welding process in accordance with EN 1011-1, the guidance given in EN 1011-3 as appropriate, together with other clauses contained in this section, in accordance with the agreed contract deviation process, unless otherwise permitted by THE PURCHASER.

### *13.3.4.2 Qualifications*

The Contractor's system for the management of welding shall meet the standard quality requirements described in EN ISO 3834 in applicable documents.

All welding documentation (welder qualifications, welding procedure, qualification records, and welding procedure specifications) shall be reviewed for applicability by the person responsible for welding coordination. The Contractor shall ensure that materials to be welded are compatible with the welding procedure being used.

### *13.3.4.3 Production welds*

Joints shall be prepared in accordance with EN ISO 9692-1 and EN ISO 9692-2. Welders shall be tested to meet the requirements of EN 287-1 and N 287-1 / A2.

Written welding procedure specifications shall be available in accordance with EN ISO 15609-1, and tested in accordance with EN ISO 15614-1 by the Contractor. They shall comply with the guidance of EN 1011-3 in the applicable documents.

The examiner shall verify that the welding procedure qualification records are in accordance with EN ISO 15614-1.

Welding shall not commence until THE PURCHASER is satisfied with the room conditions.

The Contractor shall ensure that joint fit-up conforms to the relevant welding procedure before commencement.

The fabrication environment shall be protected against excessive temperature changes and contamination from dust, moisture, chemicals etc.

The installation of stainless steel liner in the Nuclear Buildings shall meet the requirements of ASME III Div.2 Sections CC 3600, CC 3700, CC 3800 and the approved drawings. All backings for lining welds shall be fabricated from stainless steel.

Welding shall be carried out in a manner to minimize distortion, e.g. by using the 'step back' or 'skip' methods for manual welding techniques. Other techniques to control distortion may be employed, especially when welding is mechanized. To facilitate minimum distortion cladding sheets shall first be tack welded together, and then the edges of adjoining sheets shall be fully welded together with a minimum of weld runs.

Tack welds shall be equally spaced in such a manner as to maintain a regular joint gap and correct alignment during welding. The ends of all tack welds shall be ground to a shallow taper in order to achieve fusion with subsequent welding. Tack welds which have cracked shall be removed, by grinding, prior to the commencement of further welding.

Plug or slot welds shall not be used.

All tack and seam welding shall be carried out to approved weld procedures by approved welders.

When welding has stopped for any reason, care should be taken to ensure proper fusion on re-starting. This will normally necessitate grinding out the end of the previous run prior to re-starting.

Certain parts of the stainless steel liner, e.g. sumps, plinths, separation wall and corners will require prefabrication.

Where this is required the welding and examination shall comply with the requirements of this section. All welds shall be full penetration and shall be fully radiographed in accordance with section 13.3.5.5.

It is preferable that welding is continuous from sheet laying and tacking to completion; however if this is not practical the following procedure shall be followed:

If welding is not completed within three hours of tack welding then all open seams shall be protected from the ingress of dirt and contaminants by covering with a suitable approved adhesive tape. Before welding commences the tape shall be removed and the open seams cleaned by brushing with clean stainless steel brushes, followed by vacuum cleaning and degreasing with a suitable approved solvent in accordance with ASTM A380 or according to a procedure approved by THE PURCHASER.

The Contractor shall supply a complete set of welding records to THE PURCHASER. These records shall allow any weld or weld repair to be traced back to the welder responsible for its production. The records shall also identify the materials and consumables used in any weld joint.

The welding record shall be compiled concurrent with production and shall also show the status of work, i.e. when completed, tested, inspected, repaired if required and approved.

## 13.3.5 *Examination of welds*

### *13.3.5.1 Scope of inspection*

Unless otherwise agreed between THE PURCHASER and the Contractor the inspections techniques described in points a), b) and c) below shall be undertaken by the Contractor in that sequence in all welds. Radiographic examination, as described in point d) below, shall be

undertaken in pre-fabricated items prior to installation. However, for completeness and in anticipation of possible modifications the following inspection techniques may be considered for discussion:

a) Visual inspection of welds.
b) Dye penetrant testing.
c) Vacuum box examination.
d) Radiographic examination (pre-fabricated items prior to installation).
e) Ultrasonic examination.
f) Pneumatic pressure test.

Welding inspections shall be carried out to the requirements of ASME Section III Division 2 article CC-5500 unless otherwise stated in this specification.

#### *13.3.5.2 Visual inspection of welds*

Weld shall be examined by the Contractor's Engineer in accordance with EN ISO 17637 before and after grinding and/or blasting. The inspection methods and associated approval criteria are as specified in EN 1090 – 2 clause 7.6 (quality level B+), which refers to EN ISO 5817.

Additionally these requirements shall be met if they are more stringent than the ones described in EN 1090 – 2 clause 7.6:

- Surface porosity or pin holes -Undercut, i.e. not more than 10% of sheet thickness
- Excessive dressing (under flushing), i.e. not more than 10% of sheet thickness
- Welds shall have a positive reinforcement with a smooth and blended profile with no craters or undulations.

#### *13.3.5.3 Dye penetrant testing*

Weld examination shall be in accordance with EN 571-1. Welds shall be free of the unacceptable surface defects listed below:

a) exposed porosity (craters or pin holes)
b) surface cracks

The details of all dye penetrant fluids to be used shall be submitted to THE PURCHASER before testing is commenced to ensure that they are appropriate to use with austenitic stainless steels.

Acceptance standards as described in ASME Section III Division 2 CC-5544.

#### *13.3.5.4 Vacuum box examination*

The weld shall be tested by a vacuum box assembly. The test shall be carried out following Appendix VI of ASME Section III Division 2 unless specified below:

a) Each weld shall be brushed with a nominal 1 100 mixture of 'Synperonic N' (or similar approved product) and water (or other approved liquid) over a convenient length and immediately covered with an appropriately shaped vacuum box.

b) The vacuum box shall be evacuated so that the internal pressure is less than 350 mbar. This shall be held for a period of not less than 90 seconds. For the weld to be acceptable there shall be no evidence of bubbling on the surface.
c) The overlap on each vacuum box test shall be a minimum of 75 mm.

Vacuum gauges shall be re-calibrated at three monthly intervals and a current calibration certificate shall be available.

It is the responsibility of the Contractor carrying out the test to ensure that appropriately shaped vacuum boxes are available to cover all joint configurations. The Contractor shall propose alternative test or inspection methods for approval by THE PURCHASER should contracting parties agree that vacuum leak testing is impractical.

Acceptance standards as described in ASME Section III Division 2 CC-5547.

#### *13.3.5.5 Radiographic examination*

The Contractor shall radiograph the welds of pre-formed sections prior to installation. The radiographic technique shall comply with the requirements of ASME Section V Article 2 except that the geometric unsharpness shall not exceed the limits of T-251. The acceptance standard shall be as stated in ASME Section III Division 2 CC-5542.

#### *13.3.5.6 Ultrasonic examination*

The Contractor shall carry out an ultrasonic thickness test on the cladding sheets adjacent to those welds which have been under flushed. This is to ascertain the cladding thickness has not been reduced by greater than 10% of the parent plate thickness.

If submerged arc welding is utilised, ultrasonic examination shall be carried out, by the Contractor, to prove fusion of weld to backing section. The extent of fall ultrasonic examination is to be agreed with THE PURCHASER.

Acceptance standards as described in ASME Section III Division 2 CC-5546.

#### *13.3.5.7 Pneumatic pressure test*

The Contractor shall undertake, prior to installation, a pneumatic pressure test of pre-formed sections which, because of their shape, cannot be tested by a vacuum box.

The pre-formed items shall be subjected to a 350 mbar pneumatic pressure test during which all welds shall be inspected for leaks using a solution of water and 0.1%SynperonicN (or similar approved product). The items shall be pressurised for a period of not less than 90 seconds.

#### *13.3.5.8 Materials and labour for weld testing*

The Contractor shall supply all the apparatus necessary for testing the welded joints, including vacuum boxes of appropriate shapes and sizes, vacuum pumps, 'SynperonicN' (or similar approved product), ultrasonic paste etc, all subject to the requirements of ASTM A380.

The Contractor shall supply all labour necessary for conducting the tests and for attendance upon THE PURCHASER. All the Contractors Inspection Personnel shall be in possession of a current, nationally recognised, certificate appropriate to their duties.

#### *13.3.5.9 Dressing of Stainless steel sheet welds*

If necessary welds shall be dressed, suitable for NDT (dressing may involve grinding, linishing or an approved technique for vacuum blasting, dependent upon the welding process involved) and profiled to remain flushed with the surface. Any dressing shall cause only the minimum of under flushing and shall not exceed 10% of parent metal thickness.

The minimum surface finish quality required shall be produced by a technique, approved by THE PURCHASER, to achieve a surface finish which permits decontamination and non-destructive testing to the satisfaction of THE PURCHASER. Where vacuum blasting is inapplicable the surface finish quality required shall be produced by grinding or linishing using 80-120 grit size to 3.2 microns Ra or better..

In event of over dressing see clause 13.3.7.1 of this specification.

For pond cladding all welds shall be dressed to satisfy the above criteria and to produce a finish of 0.8μm Ra or better at the wind and water line.

The adequacy of the surface finish and the need for dressing shall be established by reference to standard samples. To assist in achieving consistent interpretation and prior to commencing welding the Contractor shall provide objective standard test welds of each combination of welding process/dressing procedure proposed, showing the minimum acceptable standard of weld finish. These samples shall be subject to the approval, in writing, of THE PURCHASER.

## 13.3.6 *Fabrication Workmanship*

### *13.3.6.1 General*

Refer to section 15 of this Technical Specification. The execution class is defined at EXC4 for all liner components in accordance with NF EN 1090-2. For execution class EXC4, the quality class is S1 as determined by NF EN 10160.

The Contractor shall implement a cladding protection procedure, approved by THE PURCHASER, during fabrication and welding. The procedure can be based upon the use of fire resistant tapes, approved spatter release agents and other approved protective techniques. Any weld spatter incurred shall be removed from the cladding sheets without serious damage - i.e. reduction of plate/sheet thickness. Dimensions given on liner drawings are for reference only and shall not be used to fabricate cladding sheets.

All stainless steel sheets shall be cut to fit to ± 1 mm, after site measurement of cast in frames or grillages. Dimensions given on liner drawings are for reference only and shall not be used to fabricate cladding sheets.

The liner plates shall be supplied in accordance with flatness class S steel type L as described in EN 10029.

### *13.3.6.2 Stainless steel liner components*

Inspection – General

Refer to section 13.3.2.1 in this technical specification.

Condition of surface under test

The surfaces of all areas under test shall be free, to the satisfaction of THE PURCHASER, of any foreign matter including removal of protective coating which would interfere with the application and interpretation of any test.

Condition of surface under test Cutting, Forming and Bending

Refer to ASME III Div.2 Section CC 4521.

Cleaning and protection stainless steel finished cladding

Prior to final handover, the Contractor shall remove:

a) All traces of any protective covering from the stainless steel sheet using an approved solvent -see ASTM A380 or the procedure approved by THE PURCHASER.
b) All traces of paint.
c) All traces of concrete.
d) Any other contaminants.

Following removal of contaminants the Contractors Engineer shall undertake a detailed visual inspection of the surface of the stainless steel to check for surface imperfections. The types of imperfections and their removal are detailed in clause 13.3.7.1.

All stainless steel surfaces shall then be washed down with clean water, source to be approved by THE PURCHASER, to remove all traces of 'SynperonicN' solution (or similar approved product), grease, dirt, etc. All surfaces including gullies and sumps shall be left clean and dry.

Following completion of areas of the work and approval by THE PURCHASER, all areas of cladding are to be protected as a minimum by the following:

a) All areas, vertical, horizontal and coved, to be covered with Portaliner FR -HF (or similar approved) flame retardant and halogen-free membrane. This will necessitate the removal of any stainless steel protective coating.

b) All horizontal areas are then to be covered with close fitting 19 mm plywood sheets with the joints taped.

c) All vertical areas are to be covered with close fitting 6 mm plywood sheets with the joints taped and top edges taped to the concrete. No taping will be permitted to the stainless steel surfaces. Particular care is to be taken when protecting corner areas.

d) The Contractor is to ensure that the protection maintains its position and condition until the end of the contract. The protection is to be left in position at the end of the contract.

e) All plywood protection sheets are to be flame retardant by surface treating the top surface only before laying.

Should any ingress of moisture occur once the surface protection has been laid and before contract completion, THE PURCHASER is to be informed immediately. The surface protection in all affected areas is to be lifted, the area cleaned and dried off, and new protection laid at no cost to ITER/F4E.

When considering protective materials reference shall be made to ASTM A380.

#### *13.3.6.3 Bolting*

Refer to section 15 of this Technical Specification.

#### *13.3.6.4 Packing, grouting and sealing*

Refer to section 15 of this Technical Specification.

The condition and location of supports shall be checked using appropriate visual and measurement means before commencement of erection. A non-shrink grout equivalent to Sika Grout 212 and approved by THE PURCHASER shall be used below all baseplates. The grout shall be placed fully in accordance with the manufacturer’s specifications.

## 13.3.7 *Erection*

### *13.3.7.1 General*

The Contractor shall establish and maintain a system for setting out the grillage and liner plates, deviations in the position of grillage for the Works shall be measured relative to this system.

Steel packs shall be supplied to allow the structure to be properly lined and levelled and of sufficient size to avoid local crushing of the concrete.

Base packs shall be placed so that they do not prevent subsequent packing, grouting or sealing, to completely fill all spaces directly under the base plates. Base packs may be left permanently in place.

Grouting or packing shall not be carried out under the grillage until a sufficient portion of the structure has been aligned, levelled, plumbed and adequately braced.

Work shall be protected from weld spatter, mechanical damage, surface contaminates such as oil and grease.

The steelwork shall be thoroughly ground to bright metal in order to remove surface rust, mill scale and other contaminates in order to be welded to liner sheets.

Surface damage, e.g. scratches, arc strikes, weld spatter, stains, particularly where decontaminability is affected shall be rectified by the Contractor, after requesting approval from THE PURCHASER:

a) Buffing.
b) Light grinding
c) Weld repair.

The scope of the repair shall be agreed with THE PURCHASER.

All welded joints shall be tested by the Contractor under the surveillance and with the verification of THE PURCHASER. Any defects revealed by the tests shall be rectified by the Contractor and the defective weld retested until passed as satisfactory.

### *13.3.7.2 Site Conditions*

Prior to the installation of the liner, the Contractor shall satisfy the following requirements:

a) All surface moisture to be excluded from the area to be lined for a continuous period of 7 days. Surface moisture includes precipitation, water spillage, leakage or any other form of water ingress. Should any surface moisture be found to be present in the area to be clad, it shall be cleaned off, the area dried out, and all surface moisture excluded for a further 7 days.
b) During the 7 day drying-out period, the ambient air temperature of the area to be clad is to be maintained above 7°C minimum. If heating is required for this purpose only, then electric fan heating will be allowed.
c) Any temporary structure that the Contractor may provide, at his own expense, to prevent the ingress of precipitation is to be designed by the Contractor, and details forwarded to THE PURCHASER for his approval before work commences. Any structure proposed is to be of a strong, rigid construction and must incorporate a drainage system for collection of precipitation and disposal into the existing site drainage system.

d) Prior to the installation of the liner, and at least on a daily basis during the liner installation, the area is to be kept clean by the use of vacuum cleaners.
e) During the period of the liner installation, surface moisture exclusion is to continue. THE PURCHASER is to be informed immediately should any ingress of water be discovered. The requirements of (a) and (b) above must be observed before lining work may recommence.

#### *13.3.7.3 Stability*

The Contractor shall design and provide the temporary bracing or restraints. The Contractor shall ensure that no part of the structure is permanently distorted by stacking of materials or temporary erection loads during the erection process. Wall frames shall be installed by the Contractor so as to lie flush and flat with the surface of the wall. To achieve this, the frames shall be securely attached to the shuttering using M12 bolts before the concrete is poured.

The floor grillage shall be positioned at the top of the primary concrete and secured.

#### *13.3.7.4 Lining and Levelling*

To ensure that the floor grillage can be accurately set to the levels and falls shown on the drawings, provision for adjustment of the grillage must be made.

Before fabrication of the floor grillage, the Contractor shall take site dimensions and if necessary adjust the plan dimensions of the grillages to allow for any discrepancies which may be found.

Each part of the structure shall be aligned as soon as possible after it has been erected. Permanent connections shall not be made between the liner plates until the grillage structure has been aligned, levelled, plumbed and temporarily connected to ensure that components will not be displaced during subsequent erection or alignment of the remainder of the structure. The reference temperature shall be within 15°C and 25 °C for setting out and dimensional checks.

The floor grillage shall be screeded in position by the Contractor to the satisfaction of THE PURCHASER and in accordance with section 7 of this Technical Specification.

#### *13.3.7.5 Installation Tolerances*

Before installation

Prior to commencement of installation the Contractor shall verify that all liner frames, grillages and encast items have been installed to the tolerances stated in this specification.

Installation Tolerances

Unless otherwise specified on the drawing, the maximum tolerance of installations items relative to cell datum shall be as follows:

- The tolerance for the first stage concrete on wall: ±5 mm
- Abrupt changes in line of stainless steel surfaces: Nil.
- Abrupt changes in line of sheet/concrete edges at joints: Nil.
- The surface of the panels shall be located between two parallel planes at a distance of 10 mm with the theoretical surface located in the middle
- Deviation from level specified gradient or other: ±6 mm in 3 m specified alignment of floor liner. If the air cushion transporter system is **not** to be used on the liner, then the following tolerance shall be met: the general measured tolerance of slope along the line of longest descent is 10% of floor slope. For straightness, in the slope direction ±3 mm; in the perpendicular to the slope direction ±5 mm.

- Deviation from vertical and other specified alignments: ±25 mm of true vertical over 15 m length in any of wall liner, but maximum ±5 mm in 1.5 m.

Other general installation tolerance is defined in section 5 of this Technical Specification.

Tolerances shall also comply with ASME III Div.2 and drawings. For fitting and aligning ASME III Div. 2 Section CC 4523.2 shall be met.

### 13.3.8 *Protective treatment*

Refer to section 15 of this Technical Specification.

## 13.4 TESTS ON SITE

Function test

After the completion of installation, a test of function of liner should be carried out by the Contractor. The test is to check the retention on floor liner, the criteria is shown below:

For a local surface area on floor smaller than 2 $m^2$: local retention<2 litre/ $m^2$

For the entire surface of floor: total retention<0.5 litre/ $m^2$

Volume verification

After the completion of installation, a verification of actual retention volume should be done by the Contractor. Site dimensions should be taken and the volume should be calculated in comparison with the required retention volume which will be confirmed by THE PURCHASER.

## 13.5 QUALITY ASSURANCE PROVISIONS

Refer to the General Management Specification as well as the requirements for Execution Class 3 specified in EN 13670 and those specified in this document.

## 13.6 IDENTIFICATION REQUIREMENTS

Apart from the requirements specified in this document all materials and products used shall be traceable to sources documented in the ‘as built’ document package to be produced by the Contractor.

# 14 METAL PARTS INCORPORATED IN THE CONCRETE

## 14.1 SCOPE

This paragraph covers sleeves and anchor plates incorporated into the concrete, excluding metal parts contributing to containment leaktightness and watertight metal liners lining the inner faces of the pools.

### 14.1.1 *DOCUMENTS QUOTED IN REFERENCE IN THIS SECTION*

### 14.1.2 *SLEEVES*

Metal sleeves are placed on supporting parts joined to the formwork or on fixtures independent of the formwork, which can be an integral part of the structure. The attachment mode is determined in response to the tolerances given in paragraph 5.5.

### 14.1.3 *ANCHOR PLATES INCORPORATED INTO THE CONCRETE*

Before welding, the parts (plates and connectors) are prepared at least in accordance with the requirements of class 1 of standard NF P 22-800. The sheet, section and plain bar delivery operations are performed either by thermal cutting or by shearing for thicknesses under 25 mm. The thermally cut edges shall be ground off to remove carbon deposits.

All drill-holes and their chamfers shall be made with a drilling machine bit. The weld joint of the connectors shall not affect the plate flatness.

Welding

The welded assemblies shall be executed in accordance with the requirements of standards NF P 22-470, NF P 22-471, NF P 22-472 and NF P 22-473. They shall be at least quality class 2 as per standard NF P 2247l.

The qualification for a vertical up-welding assembly qualifies all the positions for steel grades less than S235JO (as per NF EN 10025).

For qualification of the welding procedures (as per NF P 22-472) and welders (as per NF EN 287-1 and A 88-111), a tensile test shall also be carried out on the connector; the rupture must occur outside the weld joint. Each plate shall be identified by a marking cold-stamped at the time of its fabrication, on the face remaining visible after formwork removal.

Plate inspection

The welds of the connectors on the plates shall be 100 % visually inspected and the acceptance criteria of the defects shall be those of the severest quality class of standard NF P 22-471.

For plates supporting safety classified and pressure-retaining component, dye penetrant inspections shall be conducted in accordance with the provisions of paragraphs 1.1 to 0. The scope of this inspection shall be 100% of all the plates intended to accommodate a level N1 support (according to French regulation related to nuclear pressure-retaining components) and 100% of 10% of the support plates of the same production lot for plates intended to accommodate a N2 or N3 support.

For plates supporting civil works structures which have a safety role in plant, 100 % inspection of 10 % of the plates is conducted. The acceptance criteria of the defects shall be those of the severest quality class of standard NF P 22-471.

In addition, the production welds shall undergo a tensile test on the connectors, at least every 1000 connectors welded.

The production test sample for this tensile test is an anchor plate chosen from a lot which may include plates of all types and fabricated by several welders.

Rupture shall occur in the connector outside the weld for a stress between $R_{max}$ and $R_{min}$ (upper and lower values of the guaranteed rupture stress as per the corresponding standard of the connector steel grade); however:

- If the rupture occurs in the weld for a stress less than $R_{max}$, two additional inspections are conducted. If a defect is found during these additional tests, all the welds executed by the incriminated welder on the tested lot shall be declared defective and the corresponding plates discarded,

- If the rupture occurs outside the weld for a stress less than $R_{min}$, the whole fabricated lot is rejected (there is a doubt about the quality of the steel used),

- If the rupture occurs in the weld or outside it, for a stress greater than $R_{max}$, the lot shall be accepted, but an inquiry shall be conducted on the nature of the steel used.

Fabrication tolerances

The dimensional inspections of the plates shall provide assurance that the maximum deflection of the plates in all directions is less than $1/200^{th}$ of the plate length in the relevant direction; further, the hollows measured under a 0.20 m rule shall be less than 1 mm.

These inspections also relate to the compliance of the plates (length, width, thickness, special constructional features ...) and of the connectors (number, section, length, type of weld) with respect to the working drawings

Tolerance on position

The tolerances on the position of the embedded plates, measured after concreting and setting of concrete, are specified in paragraph 5.5

# 15 STRUCTURAL STEEL WORKS

## 15.1 Scope

This section applies to structural steelwork in structures covered by the contract. All materials must be subjected to acceptance tests before use and to check tests during their utilization.

The materials used and the services provided shall meet the requirements of this specification and the below reference documents.

## 15.2 List of Codes and Standards referenced in this section

| | |
|---|---|
| NF EN 10164 (05/05) | Steel products with improved deformation properties |
| NF EN 1998 Parts 1 to 6 (varies) | Eurocode 8 – Design of structures for earthquake resistance (all parts) |
| NF EN 10025 (03/05) | Hot-rolled products of structural steel |
| NF EN 1011-1 to 3 (varies) | Recommendations for welding Parts 1 to 3 |
| NF EN 10160 (12/99) | Ultrasonic testing of steel flat product of thickness equal or greater than 6 mm (reflection method) |
| NF EN 10163-1 to 3 (varies) | Delivery requirements for surface conditions of HR steel plates Parts 1 to 3 |
| NF EN 10204 (01/05) | Metallic products —Types of inspection documents |
| NF EN 10210-1 (07/06) | Hot finished hollow sections of non-alloy and fine grained steels |
| NF EN 10219 (08/06) | Cold formed welded structural hollow sections |
| NF EN 1090-1 to 3 (varies) | Execution of steel structures and aluminium structures Parts 1 to 3 |
| NF EN ISO 12944-1 to 8 (varies) | Paints and varnishes. Corrosion protection of steel structures by protective paint systems Parts 1 to 8 |
| NF EN 13381-4 (05/11) | Test methods for determining the contribution to the fire resistance of structural members - Part 8 : Applied reactive protection to steel members |
| NF EN 14399-1 to 10 (varies) | High strength structural bolting assemblies for preloading Parts 1 to 10 |
| NF EN 1991-1 Parts 1 to 7 (varies) | Eurocode 1 – Actions on structures Parts 1 to 7 |
| NF EN 1993-1 Parts 1 to 12 (varies) | Eurocode 3 – Design of steel structure Parts 1 to 12 |
| NF EN 20898-2 (08/87) | Mechanical properties of fasteners |
| NF EN 287-1 (09/11) | Qualification of test welders |
| NF EN ISO 10684 (12/04) | Fasteners - Hot dip galvanized coatings |
| NF EN ISO 1461 (07/09) | Hot dip galvanised coatings |
| NF EN ISO 14713 (03/10) | Zinc coatings -- Guidelines and recommendations for the protection against corrosion of iron and steel in structures |
| NF EN ISO 15614-1 (05/08) | Specification and qualification of welding procedures for metallic materials. Welding procedure test. Arc and gas welding of steels and arc welding of nickel and nickel alloys |

| | |
|---|---|
| NF EN ISO 2063 (05/05) | Thermal spraying - Metallic and other inorganic coatings - Zinc, aluminium and their alloys |
| NF EN ISO 2808 (04/07) | Paints and varnishes - Determination of film thickness |
| NF EN ISO 3834 (04/06) | Quality requirements for fusion welding of metallic materials Parts 1 to 4 |
| NF EN ISO 4042 (11/99) | Fasteners - Electroplated coatings |
| NF EN ISO 8501-1 (09/07) | Preparation of steel substrates before application of paints and related products - Visual assessment of surface cleanliness - Part 1 |
| NF EN ISO 8503-2 (04/12) | Preparation of steel substrates before application of paints and related products - Surface roughness characteristics of blast-cleaned steel substrates - Part 2 |
| NF EN ISO 898-1 (06/09) | Mechanical properties of carbon steel fasteners |
| NF EN ISO 9001 (11/08) | Quality Management Systems - requirements |
| NF EN ISO 9692 (varies) | Welding and allied processes - Recommendations for joint preparation Parts 1 and 2 |

## 15.3 Information to be provided to the Contractor

### 15.3.1 *General layout drawings*

Connection design information including forces, moments and their combination, to be transmitted at each joint or typical detail for main connections. (Does not apply to Contractor designed structures – See General Management Specification).

Types of connections used in THE PURCHASER's design, i.e. welded, bolted or mixed connections.

For structures which need to be seismically designed, THE PURCHASER shall provide information regarding their structural ductility class and the behaviour factor, according to EN 1998.

## 15.4 TECHNICAL REQUIREMENTS

### 15.4.1 *Execution Class*

The requirements of NF EN 1090 with regard to execution classes will be followed.

The execution class for buildings ref. 13 (Laydown and Assembly Hall) and 11 (Tokamak Building Crane Hall) the execution class shall be:

- EXC4 : main structures
- EXC3: all other elements (roof purlins, cladding, stairs and walkways,…)

For other buildings:

- EXC3 : main structures
- EXC2: all other elements (roof purlins, cladding, stairs and walkways,…)

For execution classes EXC3 & 4 the quality class is S1 as determined by NF EN 10160.

## 15.4.2 *Materials*

### *15.4.2.1 Qualities*

Material shall be steel in rolled sections, structural hollow sections, plates or bars. When specifying and ordering, full steel specifications shall be given including standard number, strength grade and impact quality (e.g. NF EN 10025-2 S275J0 ) so that the correct properties for fracture toughness and weldability are ensured. Generally the steel shall conform to standards NF EN 10025, 10210 and 10219. The qualities and grades of steel shall be specified by THE PURCHASER according to NF EN 1993-1-10.

The qualities of the steel to be used shall be defined by the Contractor and shall be at least equal to the values indicated in the following table:

| **Category** | **Limit thickness in mm** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **5** | **10** | **15** | **20** | **25** | **30** | **35** | **40** | **45** | **50** | **55** |
| I | | | | | | | | | J2, K2 Quality | | |
| II | | | | | | | J0 Quality | | | | |
| III | | | | | | JR Quality | | | | | |
| IV | | | | | | | | | | | |
| V | | | | | | | | | | | |

For borderline elements, the quality of the lower level is retained (for example, for a category 1 element and thickness 25 mm, the steel quality is: JR).

Category of parts (structural elements) in the above table is based on their loading, their manufacturing difficulty and their stress level. Five categories (I, Il, III, IV and V) are defined in the table below based on the following criteria:

Manufacturing difficulty and stress level criteria:

- high: parts having accumulations of welds or delicate welds (example: restrained welds),
- medium: parts featuring welds of normal difficulty, without special stress concentration and annealed elements having a high state of stress,
- low: easily welded parts and annealed elements having an average stress state.

Part importance criteria:

P: primary part having a decisive function in the load-bearing structure,

S: secondary part whose destruction would not seriously affect the structure's stability or normal service.

| Manufacturing difficulty and stress level | Part importance | Categories | |
|---|---|---|---|
| | | Element in compression | Element in tension |
| **High** | P | II | I |
| | S | III | II |
| **Average** | P | III | II |
| | S | IV | III |
| **Low** | P | IV | III |
| | S | V | IV |

For the plate elements subject to tensile loads perpendicular to their plane, i.e. elements subject to the risk of lamellar tearing, the products used shall comply with EN 10164 for the quality Z35.

Structural steel with a high level of recycled materials shall be chosen. The level of recycled steel to achieve shall not be lower than 10%. Structural steel for Nuclear Buildings shall comply with safety requirements and therefore cannot originate from former nuclear buildings (former nuclear activation forbidden).

#### *15.4.2.2 Testing*

All steel products for use in the Works shall have been specifically tested in accordance with the appropriate material product standard. The steel product manufacturer shall declare the results using an inspection certificate type 3.1 to NF EN 10204. The Contractor shall have access to the inspection documents to NF EN 10204 provided by the manufacturers of all steel products used in the Works. The Contractor shall make these inspection documents available to THE PURCHASER or Inspection Authority.

Need to define the frequency of testing (e.g. every 20 tonnes or part thereof)

#### *15.4.2.3 Dimensions and tolerances*

Dimensions and tolerances shall comply with NF EN 1090 Parts 1 & 2 Execution of Steel Structures.

#### *15.4.2.4 Surface condition*

Steel surfaces when used shall not be more heavily pitted or rusted than Grade C of NF EN ISO 8501-1.

Surface defects in hot rolled sections, plates and wide flats revealed during surface preparation which are not in accordance with the requirements of NF EN 10163 shall be rectified accordingly.

Surface defects in hot finished hollow sections not in accordance with NF EN 10210-1 shall be rectified. Surface defects in cold formed hollow sections not in accordance with NF EN 10219-1 shall be rectified.

## 15.4.3 *Welding Consumables*

### *15.4.3.1 Standards*

Consumables for use in metal arc welding shall comply with the documents listed in clause 2.2.3 of NF EN 1090-2.

### *15.4.3.2 Storage*

Consumables on site shall be stored and handled in a manner described in NF EN 1011-1 and in accordance with the relevant standard. Any drying or baking of consumables before issue shall be carried out in accordance with the manufacturer's recommendations.

## 15.4.4 *Structural fasteners*

### *15.4.4.1 Declaration of conformity*

The Contractor shall make declarations of conformity provided by suppliers of structural fasteners available to THE PURCHASER, if requested.

### *15.4.4.2 Bolts*

Ordinary bolts shall conform to standards NF EN ISO 898-1 and NF EN 20898-2. Only class 8.8 bolts shall be admitted.

High-strength bolts shall conform to standards NF EN 14399-1, 2 and 3. Only bolts of class 10.9 shall be used for the main assemblies. Bolts shall have an anticorrosion treatment of either galvanising to NF EN ISO 10684 or zinc plated to NF EN ISO 4042.

The bolts shall be covered by the marking NF "Bolts for steel structures", NF 070 or similar European marking.

### *15.4.4.3 Bolted joints*

They shall be designed in accordance with NF EN 1993-1-8 and made in accordance with standard NF EN 1090-2.

General Provisions

Bolted joints shall be used for the assembly of site members. Bolted joints can also be used for the assembly in the workshop.

Joints transmitting significant forces, where slip between joint faces is not permissible, shall be provided with preloaded bolts.

A minimum of two bolts shall be used for joints.

Non-preloaded bolts

The design of ordinary bolted assemblies working in shear shall meet the requirements of NF EN 1993-1-8, NF EN ISO 898-1 and NF EN 20898-2.

Shear resistance shall take place on the unthreaded part of the bolt.

Moment resisting joints with bolts "full hole" will be made by drilled holes, calibrated bolts and shear on the unthreaded part of the bolt. The clearance must not exceed 0.1 mm.

Preloaded bolts

The minimum requirements for high strength bolts are specified by standards NF EN 14399 parts 1, 2 & 3.

The bolts used will be class 10.9, avoidance of any contamination (with grease, oil etc) shall be ensured as it would reduce the capacity.

Unless otherwise indicated on the drawings, the friction factor taken into account in the calculation of joints will be taken to be 0.30. This coefficient corresponds to unpainted surfaces with rust and mill scale removed by wire brushing.

The value of K allowing the determination of the torque, depending on the diameter of bolts and preload stress, must be indicated on the fabrication drawings. This coefficient depends on the surface and the protection of the threads of the screw and nut.

Tightening of preloaded bolts

Tightening the bolts will be done by application of torque using a torque wrench set to the specifications of standard NF EN 1090-2, or by controlled rotation of the head of the nut after applying stress due to the torque defined in that standard.

## 15.5 INFORMATION TO BE PROVIDED BY THE CONTRACTOR

### 15.5.1 *Information system*

The information system used for manufacturing steelwork components may include drawings and calculations prepared manually or by computer modelling.

The system shall have means of identifying that the latest information provided by THE PURCHASER is being used and that superseded information has been withdrawn.

The system shall be open to audit.

The system shall meet all the requirements of General Management Specification.

### 15.5.2 *General Arrangement of Components*

#### *15.5.2.1 Marking system*

Every component which is to be individually assembled or erected shall be allocated an erection mark.

Components which are nominally identical in all respects may have the same erection mark.

#### *15.5.2.2 General Arrangement Drawings*

Drawings shall be prepared by the Contractor showing plans and elevations at a scale such that the erection marks for all components can be shown on them. Preferred scales are 1:100 or larger.

The drawings shall identify member size, material quality, location relative to other members and the grid, and the specified surface treatment. They may include a reference system to connections.

Details at an enlarged scale shall also be made if these are necessary to show the assembly of components.

### 15.5.3 *Foundation and Wall Interface Information*

Information showing holding down bolts and the interface of steelwork components to foundations shall include a foundation plan showing base location, position and orientation of columns, the marks of all columns, any other components in direct contact with the foundations, their base location, level and datum level.

Similar information shall also be provided for components connecting to walls and any other concrete surfaces.

Complete details of fixing steel and bolts to the foundations or walls, method of adjustment and packing/grouting details shall be provided.

### 15.5.4 *Fabrication Information for Components*

#### *15.5.4.1 Fabrication drawings and fabrication data*

Fabrication drawings or fabrication data used in the manufacturing system need only provide details and dimensions necessary for the manufacture of components.

#### *15.5.4.2 Attachments to facilitate erection*

Details of holes and fittings in components necessary for safety or to provide lifting and erection aids shall be included. Lifting points shall be marked with the maximum safe weight that can be carried.

#### *15.5.4.3 Welding*

Any requirements for edge preparations for welds shall be indicated.

#### *15.5.4.4 Hole sizes*

Holes in components shall be shown to the nominal sizes given in NF EN 1090-2.

Erection information if necessary to amplify the information given in the erection method statement the Contractor shall prepare Erection Drawings and crane lifting plans. Details and arrangements of temporary steelwork for erection purposes shall be shown.

## 15.6 Workmanship

### 15.6.1 *General*

All steel products to be used in the Works shall have a reference to a suitable declaration of conformity so that the properties are known and can be verified.

The material grade, quality and other relevant properties shall be identifiable within the manufacturing system.

Individual pieces shall be capable of being positively identified at all stages of fabrication. Completed components shall be marked with a durable and distinguishing erection mark in such a way as not to damage the material. Cutting and shaping of steel may be carried out by sawing, shearing, cropping, thermal cutting, nibbling, planning or machining.

### 15.6.2 *Welding*

Welding shall be a metal arc process in accordance with NF EN 1011-1, the guidance given in NF EN 1011-2 as appropriate, together with other clauses contained in this section, unless otherwise permitted by THE PURCHASER.

The Contractor’s system for the management of welding shall meet the standard quality requirements described in NF EN ISO 3834.

All welding documentation (welder qualifications, welding procedure, qualification records, and welding procedure specifications) shall be reviewed for applicability by the person responsible for welding coordination. The Contractor shall ensure that materials to be welded are compatible with the welding procedure being used.

Joints shall be prepared in accordance with NF EN ISO 9692-1 and NF EN ISO 9692-2. Welders shall be tested to meet the requirements of NF EN 287-1 and NF EN 287-1 / A2.

Written welding procedure specifications shall be available in accordance with NF EN ISO 15609-1, and tested in accordance with NF EN ISO 15614-1 by the Contractor. They shall comply with the guidance of NF EN 1011-2 Annex C, Method A to avoid hydrogen cracking, and Annex D to provide adequate toughness in the heat affected zone.

The examiner shall verify that the welding procedure qualification records are in accordance with NF EN ISO 15614-1.

### 15.6.3 *Scope of inspection*

Welding inspections shall be carried out to the requirements of NF EN 1090-2, 12.4. The inspections shall be based on the execution class of the element concerned. All welds shall be visually examined over their full length.

The inspection methods and associated acceptance criteria are as specified in NF EN 1090-2 clause 7.6.

### 15.6.4 *Bolting*

Bolting shall fulfil the requirements of NF EN 1090-2.

Any bolt assemblies which seize when tightening shall be replaced. Different bolt grades of the same diameter shall not be used on the same structure.

The bolt length shall be chosen such that, after tightening, at least one thread plus the thread run-out will be clear between the nut and the unthreaded shank of the bolt and at least one clear thread shall show above the nut.

If the bolt head or nut is in contact with a surface which is more than 3° from a plane at right angles to the bolt axis, a taper washer shall be placed to achieve satisfactory bearing.

### 15.6.5 *Packing, grouting and sealing*

The condition and location of supports shall be checked using appropriate visual and measurement means before commencement of erection. A non-shrink grout equivalent to Sika Grout 212 and approved by THE PURCHASER shall be used below all baseplates. The grout shall be placed fully in accordance with the manufacturer's specifications.

## 15.7 Accuracy of fabrication

Tolerances are stipulated in NF EN 1090-2 Appendix D and shall comply with a Class 2 deviation where an option exists.

For crane support beams, class 2 Tables D2.19 and D2.21 shall be applied and when the rail is not supplied by the Civil Contractor, the centre of the rail shall be taken equal to the centre of the flange (i.e. centre of supporting web) for horizontal position and the top surface of the rail by the top surface of the top flange of the crane support beam.

## 15.8 Erection workmanship

### 15.8.1 *General*

The Contractor shall prepare a written method statement in accordance with the general project requirements. It shall take into account of the information provided by THE PURCHASER on design, erection and programme. A method statement shall be submitted to THE

PURCHASER for approval in accordance with General Management Specification. Erection shall not commence before the method statement has been approved by THE PURCHASER.

Refer to Applicable Document AD34 for information on setting-out.

Steel packs shall be supplied to allow the structure to be properly lined and levelled and of sufficient size to avoid local crushing of the concrete.

Base packs shall be placed so that they do not prevent subsequent packing, grouting or sealing, to completely fill all spaces directly under the base plates. Base packs may be left permanently in place.

Grouting or packing shall not be carried out under column base plates until a sufficient portion of the structure has been aligned, levelled, plumbed and adequately braced.

### 15.8.2 *Site Conditions*

The Contractor shall maintain the working surfaces of the site and remove any standing water, provide a firm, properly graded working area and maintain site access roads. The Contractor shall be informed of all underground services which may be a hazard during lifting operations.

The Contractor shall ensure that the load spread under lifting and handling equipment is commensurate with the strength of the working platform.

The Contractor shall ensure that the operations comply with THE PURCHASER's rules for operating on the site and that appropriate safe systems of work are provided and maintained to discharge the duties under current safety legislation.

### 15.8.3 *Stability*

The Contractor shall design and provide all the necessary temporary bracing or restraints and any necessary additional temporary supports for all construction loads throughout the Works. THE PURCHASER shall provide sufficient information to enable the Contractor to design the necessary temporary works, excluding Contractor's own works. The Contractor shall take account of load cases and combinations induced from his method of construction and / or interfaces with other contractors. Designs and drawings of temporary works shall be made available to THE PURCHASER for review if requested.

The Contractor shall ensure that no part of the structure is permanently distorted by stacking of materials or temporary erection loads during the erection process. THE PURCHASER shall ensure that no other contractor places loads on the partly erected structure without the permission of the Contractor.

### 15.8.4 *Alignment and Levelling*

Each part of the structure shall be aligned as soon as possible after it has been erected. Permanent connections shall not be made between components until sufficient of the structure has been aligned, levelled, plumbed and temporarily connected to ensure that components will not be displaced during subsequent erection or alignment of the remainder of the structure. The reference temperature shall be within 5 °C and 15 °C for setting out and dimensional checks.

### 15.8.5 *Completion procedure*

When the steelwork, or a portion of the steelwork, has been completed the procedures specified in General Management Specification shall be followed to confirm acceptance of the steelwork by THE PURCHASER.

## 15.9 Erection accuracy

Refer to NF EN 1090-2 Appendix D for erection tolerances. Class 2 deviations apply where an option exists.

For crane support beams, class 2 Tables D2.19 and D2.21 shall be applied and when the rail is not supplied by TB03, the centre of the rail shall be taken equal to the centre of the flange (i.e. centre of supporting web) for horizontal position and the top surface of the rail by the top surface of the top flange of the crane support beam.

The Contractor will pay particular attention to the interface between the crane support beam in Building 13 and the rail mounting surface/ support beam in Building 11 with respect to the achievement of alignment and level across the joint.

## 15.10 Protective Treatment

The corrosion protection required for each structural steel building shall meet with the requirements of NF EN ISO 12944 – Paints and Varnishes – Corrosion protection of steel structures by protective paint systems. The external environment category is C3, the internal environment category is C2 and the durability requirement is high (H). A single source of coating supply shall be used unless otherwise agreed to ensure compatibility.

Before any work commences for the application or reapplication of protective coatings, a method statement shall be prepared and given to THE PURCHASER for approval. A copy of the approved method statement shall be available where the work is being carried out.

Coating materials shall be prepared, and coatings applied to surfaces, in accordance with the manufacturer's recommendations.

The procedures for the transportation, handling and storage of coated steelwork shall be so arranged as to minimise the risk of damage to the coating.

The Contractor shall repair any damage to protective treatment.

### 15.10.1 *Surface Preparation*

At the time of coating the surface cleanliness of the steelwork to be coated shall be in accordance with NF EN ISO 8501-1. The minimum standard preparation grade shall be Sa 2½ . The surface profile of the steelwork to be coated shall be compatible with the coating to be applied in accordance with NF EN ISO 8503-2. Measurement of the surface profile of steelwork to be coated shall be made using the methods given in NF EN ISO 8503.

Zinc or aluminium sprayed coatings shall be applied to the surface as required by NF EN ISO 2063 to a thickness given on the design drawings.

### 15.10.2 *Environmental conditions*

Surfaces should be clean, dust free and unaffected by moisture or frost. Steel temperature shall be at least 3$^{o}$C above the dew point, with conditions being stable or improving. Temperature shall not be so high as to cause blistering or wrinkling of the coating. Relative humidity shall be less than 85%.

### 15.10.3 *Hot dip galvanizing*

Galvanizing shall be carried out in accordance with NF EN ISO 1461 and have a minimum mean coating thickness of 85 microns. Components shall be subjected to a 100% post-galvanizing inspection to check for liquid metal assisted cracking. If cracking is identified, then the component and all similarly shaped components fabricated with similar materials and

weld details shall be identified and quarantined as non-conforming products. A photographic record of the cracking shall be made and used to establish the scope and origin of the problem.

Contractor's documentation shall be approved by THE PURCHASER regarding the position of vent and drainage holes in hollow components as laid down in NF EN ISO 14713, and any requirements for subsequent sealing.

### 15.10.4 *Paint treatment*

Surfaces shall be prepared in accordance with 3.9.1. Site weld areas and fasteners which are not suitably protected shall be painted with an approved paint system to ensure similar properties, performance and compatibility with the paint system used on adjacent surfaces.

Site applied coatings shall be subject to an inspection plan to monitor the quality of the materials being used, the thickness of the applied coatings, and that the process of application is in accordance with the product manufacturer's recommendations.

The Contractor shall check the thickness of each coat during application using a wet film thickness wheel or comb in accordance with NF EN ISO 2808.

Internal Steelwork : blast clean to Sa 2½ External Steelwork : blast clean to Sa 2½ (to be compatible with 100 microns DFT of 2 pack epoxy 200 microns DFT of 2 pack epoxy intumescent paint ) 50 microns DFT of 2 pack acrylic finish 50 microns DFT of 2 pack acrylic finish.

## 15.11 Fire protection

The Contractor shall provide an intumescent coating suitable for the defined periods of fire resistance and environment exposure indicated on the drawings.

The chosen system shall be suitable for final use and also for the conditions that may prevail from time to time during the application process. The Contractor shall be responsible for the determination of dry film thicknesses. Such thicknesses may be obtained from manufacturer's literature or determined by calculation methods. The system shall comply with NF EN 1993-1-2 and NF EN 13381-4.

The Contractor shall prepare a schedule of intumescent coating thicknesses required to provide fire protection to each of the steel sections to achieve the fire resistance periods given in the contract documents and submit it to THE PURCHASER for approval.

The intumescent coating product shall have been fire tested to the appropriate CEN Standard.

The Contractor shall satisfy THE PURCHASER that the intumescent basecoat material is compatible with the materials used for the steel primer and that the surface preparation of the sub-strata will be compatible with the coating system. The product data sheet, together with the product details shall be supplied indicating the anticipated life of the coating system to first maintenance.

The Contractor shall adopt application procedures that demonstrate quality control in accordance with NF EN ISO 9001. Where necessary, repairs shall be carried out to ensure that the standard of fire protection is in accordance with the original specification.

A copy of the appropriate fire performance assessment for the selected intumescent protection system shall be forwarded to THE PURCHASER for approval prior to procurement of materials.

The Contractor shall provide written confirmation that the intumescent system has been applied in accordance with the manufacturer's recommendations to achieve the specified fire resistance period (s).

In addition to the above, the Contractor can propose a different approach to ensuring a required level of fire resistance. The alternative approach must be in accordance to NF EN 1991-1-2 and NF EN 1993-1-2, and also need to take account of specific requirements of the structure. The proposal shall be submitted to THE PURCHASER for approval.

# 16 BURIED SIC CONDUITS

## 16.1 LIST OF DOCUMENTS CITED IN THE SPECIFICATION

Buried, safety-classified conduits shall be made from reinforced concrete with embedded steel cylinders. They shall meet the requirements of standards

NF EN 639 (03/95) « Joint requirements for concrete pressure pipes including gaskets and special-purpose parts »

NF EN 641 (03/95) « Reinforced concrete embedded steel cylinder pressure pipes, including gaskets and special-purpose parts »,

NF EN 1593 () Non-destructive testing. Leak testing. Bubble emission techniques

NF EN 1992 (varies) Eurocode 2 – Design of concrete structures – All parts

NF EN 10025 (03/05) Hot rolled products of structural steels

NF EN 10028-2 (09/09) Flat products made of steels for pressure purposes. Non-alloy and alloy steels with specified elevated temperature properties

NF EN 10021 (03/07) General technical delivery requirements for steel products

NF EN 10204 (01/05) Metallic products – Types of inspection documents

NF A35-019-1 (10/96) Reinforcing steel – Weldable indented steel – Part 1: Bars and coils

NF A35-019-2 (10/96) Reinforcing steel – Weldable indented steel – Part 2: Welded fabrics

supplemented by the following provisions.

## 16.2 GENERAL REMARKS - COMPOSITION

The conduits shall be assembled by field assembly of factory-fabricated elements such as straight lengths, special-purpose parts and expansion joints.

Straight lengths are mainly formed by:

- an embedded steel middle tube with flat steel fittings at both ends (end-pieces). It provides complete and permanent leak-tightness of the pipe,
- a concrete inner liner, which may be reinforced. This concrete avoids middle tube contact with the conveyed water, counteracts the formation of concretions on the pipe inner wall and ensures a low and constant hydraulic gradient,
- a reinforced concrete outer liner. This concrete avoids any middle tube contact with the soil and thus ensures that the metal portions are protected against external action. Together with the steel cylinder, it ensures pipe resistance to ground weight, surface overloads and internal pressures.

They are high frequency vibration cast.

The special-purpose parts (elbows, tees, flanges, elements of expansion joints, increasers and reducers ...) are formed in the same way; they can be high frequency vibration cast or made by manual or mechanical spraying.

The factory-fabricated elements are field assembled by welded joints, comprising:

- electric arc welding of the middle tube fitted with its end-pieces,
- jointing of the concrete inner and outer liners
- or jointing by elastomeric gasket

The end pieces accommodate the loadings sustained by the conduit, at the location of the welded joints. Their weld assembly ensures the transmission of the loads (self-stopping).

The inner and outer jointings do not participate in the mechanical strength of the structure, but are intended to protect the steels against corrosion. However, they are capable of providing transmission of the longitudinal compressive loads.

Expansion joints can be fitted between some elements at the locations shown on the erection drawings. They are:

- metal wave expansion joints welded to the middle tube,
- elastomeric wave expansion joints, assembled on flanges,
- linkage expansion joints, made up of three interlocking special-purpose parts fitted with linkages and seaI rings, and which may be self-stopped.

## 16.3 FABRICATION

### 16.3.1 *Materials*

Steels for embedded steel cylinder and end-piece flats

The products are described in standard NF EN 10025; they are classified by grade and, within each grade, by quality.

The grade used is S235.

The general technical delivery conditions are described in standards NF EN 10021 and NF EN 10204. The products are JR quality, ordered with non-specified inspection and are covered by either an inspection record or evidence of compliance with the order.

The use of rimmed steels is proscribed.

Steel for reinforcements

The requirements specified in chapter 0 “Reinforcement” shall be complied with.

In addition to these requirements, reinforcements consisting of grooved weldable wires (bars, rings, welded mesh), as described in standard NF A35-019-1 and 2, must be chosen from those belonging the mark « NF - Reinforcements for reinforced concrete » for a pre-determined quality produced in a designated factory.

Concretes

All the requirements governing the concrete constituents; design and fabrication in chapter 7 “Concrete” are applied. Any adaptations must be justified.

Further, the concrete strength class is C35/45. Concrete prepared in a concrete mixing plant shall have a minimum cement content of 375 kg/m$^3$ and a W/C ratio less than 0,45.

Seals

Seals shall meet the requirements of standard NF EN 639.

### 16.3.2 *Embedded steel cylinders*

Shells

Each middle tube shall consist of one or more shells comprising one or more longitudinal weld joints made on an automatic machine.

One end of each shell shall be folded in to facilitate its centering and assembling with the unfolded end of the neighbouring shell.

The girth weld shall be performed in the furrow formed by the interlocking of the two shells, thus resembling half-V welds.

The shells can be obtained from plates bent and helically welded on an automatic machine.

End-pieces

These are fabricated from wide flats. After cutting to length, roIling and longitudinal welding, the rings obtained are formed to the desired profile on a press by average permanent elongation not exceeding 3 %.

The rings are fitted to the folded-in end of the shells and girth-welded.

Welds

The requirements specified in 15.6.2 for structural steel are applied. Weld inspection is done by radiographic examination or dye penetrant examination.

### 16.3.3 *Reinforcements*

The reinforcement of the outer liner is made up of lines and spirals electrically resistance welded on an automatic machine, or of welded mesh. The reinforcement ensures the geometrical regularity and rigidity of the cage. The requirements on the securing and welding of the reinforcements set forth in 9.4.3.1 shall be applied.

Plastic centering shims ensure the positioning and cover of the reinforcements, and two diametrically opposite coloured plastic disks, visible from the outside of the pipes, mark out the vertical laying surface for ovalised pipes.

Reinforcement cover shall meet the requirements of Eurocode 2 (NF EN 1992), for each exposure class and structural class.

The inner liner can be reinforced with a welded mesh.

### 16.3.4 *Concrete placing*

For straight lengths, the concrete shall be placed by vertical casting.

For special-purpose parts (elbows, tees, flanges, elements of expansion joints, increasers and reducers, ...), the concrete shall be placed either by vertical casting or by manual or mechanical spraying.

For vertical casting, the concrete shall be placed by high-frequency vibration (100 to 150 Hz).

If necessary, the concrete can be steam-cured, with the average temperature reached in the concrete at about 70°C; the accelerated hardening guidelines in 10.3.4.2 shall apply.

### 16.3.5 *Fabrication of the expansion joints*

Metal-wave expansion joints

These expansion joints have two waves made of P265GH steel (as per NF EN 10028-2). They shall be grit- or sand-blasted, metallized inside and outside (thickness: 200 microns) and painted with a 50 to 70 micron thick coat of primer inside and outside.

They can also be made of stainless steel, whose grade is chosen in response to the physical/chemical properties of the conveyed water.

Elastomeric wave expansion joints

These expansion joints are sleeves with one reinforced elastomeric wave. The sleeves are one-piece assemblies made up of three constituents:

an inner tube adapted to the conveyed fluid, for providing leak-tightness, a set of cross-seams for conferring mechanical strength,

a liner providing outer protection of the sleeve.

When the sleeves also have to provide vacuum resistance of part of the line, they are equipped with a stiffener.

Linkage expansion joints

These expansion joints consist of three elements built with the same technique as for the special purpose parts of the conduits.

These three elements are fitted together by linkages with seal rings.

## 16.4 FINISHED PRODUCT

### 16.4.1 *Facings*

Facings shall be free of honeycombing and segregations.

The axes of the inner and outer surface of the straight lengths shall not deviate from straightness by more than the lesser of the following two values: 0,5 % of the barrel theoretical inner length or 10 mm.

The texture shall meet criterion E (2-0-0) of documentation booklet P 18-503, as follows:

- average bug hole characterized as a maximum by scale n° 5 (identical to print n° 5 of report n°24 of the CIB) (International Building Council for research, study and documentation),
- maximum surface area per bug hole: 1,5 cm2
- maximum depth of bug holes: 3 mm
- maximum surface area of bug holes: 3 % of total surface area.
- Cracking shall be non-propagating.

The requirements of section 8.2.3.2 governing defect repair shall be applied, provided that the surface area of each repair does not exceed about 0,5 $m^2$, irrespective of depth.

### 16.4.2 *Finished product tests*

An ovalization test shall be carried out under design load for a pipe randomly chosen from the lot. No evidence of permanent deformation or cracking shall be found.

A hydraulic pressure test shall be carried out as per the requirements of standard NF EN 641, even if the conduit is wholly tested on the site at test pressure.

### 16.4.3 *End of Fabrication Report*

An End of Fabrication Report shall be written to prove that the final quality of the elements (straight lengths, elbows, tees, flanges, ...) is to the required quality and to serve as a demonstration.

## 16.5 FIELD INSTALLATION

### 16.5.1 *Examination of the pipes before fitting*

All necessary precautions shall be taken to ensure that, especially during shipping and handling, the pipes do not sustain shocks causing their degradation (concrete crumbling, end-piece flat deformations).

Visual inspection of each pipe shall be carried out before fitting.

### 16.5.2 *Laying*

The handling machinery used to lay the pipes shall be chosen to avoid damaging the pipe being laid and the pipes already in place.

The type of laying surfaces shall be the focus of a dedicated study aimed at avoiding unwanted settling and hang-ups.

The conduits shall rest directly on the ground or on cradles.

The method for building the cradles must ensure that the pipes rest snugly on the cradles.

Laying level tolerance

The laying level tolerance must enable proper connection with the conduit end structures and rule out any risk of hang-up along the conduit.

Laying bed requirement

The level and quality of the laying bed shall be chosen to be compatible with the conduit seating level and to rule out any risk of differential settlings between conduit elements.

Densitometric tests at laying bed average depth or bearing plate tests shall be carried out to check the quality of the laying bed.

Fitting tolerance

The fitting tolerance shall ensure perfect joint leak-tightness.

Fitting tolerance for welding

The fitting tolerance of the end-pieces along the conduit axis and the radial gap of their fitting must ensure proper welding of the end-pieces.

Support or restraining block

ln some individual cases (passage under roads or railways, excessive backfill height, accommodation of special loads ... ) the conduits shall be laid on 120°, 180° support blocks or fully covered.

These blocks made of reinforced or non-reinforced concrete shall be made in accordance with the requirements in chapters 7, 0 and 0.

### 16.5.3 *Welding*

The requirements in 15.6.2 for structural steel shall be applied. The welds shall be inspected by capillary penetration test with dyed oil or by dye penetrant examination or by bubble inspection.

### 16.5.4 *Inner and outer joints*

The cement content of the mortar shall be 500 kg/$m^3$ ± 50 kg.

The aggregate size shall be 0 - 3 sand for the inner mortar and 0 - 5 sand for the outer mortar.

The mortar used for the jointing shall be accepted for the mark "NF - Special products for hydraulic concrete constructions authorized for use" as surface repair product.

It shall be manually or mechanically sprayed on for the inner joints.

It shall be poured into place for the outer joints. The outer formwork shall be a plastic strip which stays in place or a recoverable foil.

When the mortar is laid, the end-pieces shall be clean, without loose rust and without dirt detracting from mortar bonding. The concrete portions shall be stripped of their grout if necessary, cleaned, washed then generously wetted but without streaming.

### 16.5.5 *Expansion joints*

Expansion joints shall be placed in an initial deformation-free position, thus authorizing subsequent maximum movements in the 3 directions.

Metal-wave expansion joints

These shall be welded on the end-pieces of the middle tubes.

They shall also be internally and externally coated with paint systems adapted to the equipment environment.

To let the waves move freely after backfilling, a supple (honeycombed) material is placed between the waves; the expansion joint shall be externally protected by means of a wrapper in the form of a plastic sheet.

Elastomeric wave expansion joints

These parts are assembled on the conduit flanges.

Linkage expansion joints

Visible metal portions (linkages and seal rings) shall be given 3 layers of an epoxy coating before mounting and one layer of bitumen coating after laying and setting

All proper precautions shall be taken externally to let the linkages move freely after backfilling.

### 16.5.6 *Backfill*

Backfilling on each side of the conduits shall be carried out so as to avoid lateral thrust mismatches.

The backfill shall be compacted to 95 % OPM, including the portion providing the support arch of the conduit. The diameter of the materials is limited to 40 mm.

### 16.5.7 *End of Operation Report*

An End of Operation Report shall be written to prove that the final quality of the conduits conforms with the quality requirement and to serve as a demonstration.

## 16.6 LEAK TESTS

### 16.6.1 *General principles*

Leak tests shall be carried out on buried conduit sections before commissioning, as a supplement to the partial tests on the weld joints.

### 16.6.2 *Partial leak tests*

The leak test on the weld connecting the metal end fittings of two adjacent pipes shall be carried out:

- either by a capillary penetration test with dyed oil,
- or by a "bubble" leak test as per standard NF EN 1593.

### 16.6.3 *Overall leak tests - Acceptance test*

After pipe laying and before backfilling, each pipe or conduit section shall undergo a 1-hour hydraulic test at the test pressure determined in the design note.

The pressure decrease inherent in the additional concrete impregnation of the embedded steel cylinder conduits is monitored. This pressure decrease shall not be greater than 0.2 bar after one hour.

There shall be no evidence of permanent deformation, cracking or seeping.

# 17 FILLING OF JOINTS

## 17.1 FIELD OF APPLICATION

This chapter applies to linear construction joints of civil engineering structures. The following are not taken into account:

- Joints for penetrations of structures by piping, cable raceways, etc,
- Joints of doors, windows, air locks,
- Joints of tunnels and underground piping.

A "linear construction joint" is a free space between two civil engineering structural elements.

These joints aim to:

- Limit cracking in concrete structures,
- Avoid disturbances, either following a temperature variation or following differential movement between two structures, or following vibrations, seismic tremors, shocks, etc.

The civil engineering IPS “Important Pour la Sûreté", or in English, Safety Relevant) function of "Watertight" civil engineering structures is required in the context of joint filling.

This function is usually assured by using a mastic filler, embedded or inserted strips, or by incorporating a hydro-expansive section. Seismic gaps will not be provided with sealants that could transmit un-quantified loads between the buildings.

### 17.1.1 *Codes and standards quote in this section*

NF EN ISO 8339 (11/05) Building Construction - Sealants - Determination of Tensile Properties

NF EN ISO 7389 (05/04) Building construction - Sealants - Determination of elastic recovery of sealants

NF EN ISO 9047 (09/10) Building construction - Jointing products - Determination of adhesion/cohesion properties of sealants at variable temperatures

NF EN ISO 10590 (12/05) Building construction - Sealants - Determination of tensile properties of sealants at maintained extension after immersion in water

NF EN ISO 11432 (12/05) Building construction - Sealants - Determination of resistance to compression

NF P 85-522 (12/90) Jointing products. Sealants. Determination of adhesive and cohesive force by shearing to rupture

NF T 30-901 (08/95) Paints and varnishes. Paint for nuclear industry. Performance test for susceptibility to contamination and fitness to decontamination

## 17.2 PRINCIPLE

Associated with concrete structures, the filling of joints provides triple protection:

- in one direction, by averting the routing of all effluents deriving from the nuclear site, which may contain toxic, radioactive, inflammable, corrosive or explosive components, towards the natural subsoil, with the risk of dispersion of radionuclides in the natural ground and groundwater,
- in the reverse direction, by averting the penetration of external water (groundwater, rainwater, floodwater, accidental flooding linked to the rupture of hydraulic structures,

etc) in the civil engineering structure rooms, which risks causing the failure of equipment or, more generally, compromising the operational safety of the plant,

- Protect IPS equipment in case of internal flooding and provide a barrier to the escape of gases.

The location of the joints to be filled is determined from a risk analysis, for the nuclear site structures as a whole, to identify the possible presence of:

- Contaminated, or potentially contaminated, effluents found on the site,
- Liquids originating outside the structures,
- Liquids originating inside the rooms,
- Gas emissions

The filling of joints assures leak-tightness, with respect to all liquids and gases that may be found at the joint, throughout the lifetime of the plant in normal and accident design operating conditions (seismic event, fire, external and internal flooding).

To guarantee the durability of the leak-tightness function, the joint filler must

- Have properties which guarantee resistance to mechanical, thermal and chemical attacks,
- Be inspectable,
- Be repairable.

## 17.3 PRODUCT AND PROCESS QUALIFICATION

Joint fillers are classified by "systems", whose choice is determined by the environment surrounding the filler and the functions that are to be fulfilled by the system (potential "nuclear" properties, mode and frequency of application of loadings, strain rate, applied pressure, nature of joint edges, width of joint and potential supplementary specific properties).

Qualification tests on materials and products are defined in response to:

- The location of the joint, which is associated with its working mode,
- Extreme conditions associated with its installation,
- Mechanical (and hydro-mechanical), thermal and chemical requirements (in accordance with the principle in section 17.1.1),
- Maintenance conditions (example: changing frequency, if the lifetime is short),
- Specific conditions of the nuclear site, for example, conformity to PMUC (Produits et Matériels Utilisables en Centrales, or in English, Products and equipment usable in Nuclear Power Plants).

Qualification of the installation method is based on full-scale installation tests. This makes it possible to:

- Verify that the filler installation is compatible with the environment of the structures and equipment close by,
- Establish the on-site installation control,
- Establish the parameters for deciding the acceptance of the installation,
- Establish the procedures for inspection and monitoring throughout lifetime,
- Establish the maintenance procedures.

## 17.4 TYPES OF FILLER CONCERNED

Treatment by leak-tight strips

Leak-tight strips (reinforced or non-reinforced) may be embedded, mechanically fixed or glued. They may be:

- Embedded in the concrete or incorporated at the time of concrete pouring,
- Inserted with or without reinforcement, mechanically fixed or glued,
- Welded to pre-embedded plates,
- Reinjectable systems in confinement zones.

Treatment with mastic filler

The mastic filler must be adaptable to the dimensional variations of the joint, taking into account its working conditions (dilation, splitting, settlement, and environment). Elastic return is determined as per standard NF EN ISO 7389.

Elastomer mastics: under deformation, they essentially behave elastically and accommodate significant strains.

Plastic mastics: their behaviour is close to that of purely plastic material. The residual stresses induced in the mastic and resulting from movement of the joint; disappear rapidly.

Treatment by incorporation of hydro-expansive section

A hydro-expansive section is a manufactured sealing section combining the mechanical properties of traditional waterstops with the water-expansive properties of the material. Two types will be adopted:

- Those for construction or internal joints,
- Those for functioning or active joints.

## 17.5 USEABILITY

The useability of a joint filling system must be justified by tests and documents, in accordance with the applicable criteria governing joint operation.

Identification tests conducted by manufacturers and appearing on technical sheets

- Chemical analysis, including determinations of the constituents, infrared spectrum and specific determinations.
- Determination of the Rapid Identification Characteristics of compounds involving thermogravimetric analysis, density and ash content.
- Conformity to ITER list of authorized materials for ITER Project. Materials in conformity with PMUC, (Produits et Matériels Utilisables en Centrales, in English: Products and Equipment Usable in Nuclear Power Plants) will most likely be authorized for ITER Project. This PMUC list can be temporarily used as a guide document, up to the edition of the ITER list of authorized materials for ITER Project.

Functional tests

These useability tests are defined in response to the service conditions imposed, the joint functional criteria and the expected performance.

Taking into account the containment required, these tests may include the following:

- Determination of strain properties under tensile stress, as per standard NF EN ISO 8339,
- Adhesion-cohesion test by shearing until rupture, as per standard NF P 85-522,
- Determination of the compressive strength as per standard NF EN ISO 11432,
- Resistance to design water pressure,
- Determination of adhesion-cohesion characteristics by tensile-compressive cyclic tests (artificial ageing), as per standard NF EN ISO 9047,
- Test evaluating susceptibility to contamination and decontaminability, as per standard NF T 30-901,
- Adhesion-cohesion test under tensile stress until rupture after immersion in an aggressive liquid (borated water pH 6.8; boron concentration 2.5 g/litre), as per standard NF EN ISO 10590,
- Adhesion-cohesion test under tensile stress until rupture after immersion in an aggressive liquid (osmosised demineralised water pH 7.8), as per standard NF EN ISO 10590,
- Test to determine the repairability of the filler after artificial ageing, as per standards NF EN ISO 9047 and NF P 85-522,
- All tests linked to a particular requirement (e.g. fire resistance).

## 17.6 CONTROL OF INSTALLATION ON SITE

### 17.6.1 *Prerequisites*

- Certificate of professional qualification,
- Monitoring of the qualification of personnel responsible for the installation, Installation procedures,
- File on construction and suitability of filler systems with respect to the working of the joints.

### 17.6.2 *Receipt of products*

- Receipt and verification of products delivered,
- Sampling and tests to verify the conformity of materials with the qualified system (Rapid Identification Characteristics),
- Storage allowing the correct conservation of products on the site, in accordance with the terms of the technical sheets.

### 17.6.3 *Installation*

<u>Surface preparation of joint edges or contact areas</u>

- Conservation of the joint shape, with surface preparation by all appropriate techniques: manual brushing and cleaning, traditional sanding and stripping methods.
- Re-shaping by:
  - Adding material (localised or throughout the line of the shape)
  - Mechanical sawing of material in place
  - Embedding of angle bars or metal plates
  - Embedment of re-injectable joint sealant tubes
- The immersed joint profiles shall be pumped and dried.

The end of this "preparation" phase gives rise to a control.

Control during application of treatment by mastic filling:

The application of the system generally involves the following successive steps:

- Placement of the backup,
- Application of a primer to ensure bonding with the substrate,
- Laying of the mastic.

The following are particularly controlled during the application:

- The strength of the backup and its depth,
- The quality of compound mixes of the mastics (if bi-compound) and observation of their Practical Duration of Usage,
- The overlap time with the primer,
- Filling of the joint and tightening of the mastic.

A mechanical protection feature must protect the mastic fillers. It must be installed as soon as the mastic cross-linking is effective (as per the technical sheets of the manufacturers).

Control during application of treatment by leak-tight strips

The installation of a leak-tight strip must give rise to the following actions:

- Verification of the integrity and positioning of the strip before concreting or embedding,
- Check that for each hot vulcanisation, the maximum duration indicated by the test report is not exceeded,
- Ensure that a mechanical protection feature protects the strip from the elements; ultraviolet light and all other attacks, before and during concreting (for embedded strips),
- Inspection of the Omega (tension of the strip) for strips inserted with reinforcements,
- Checking of the best-before date of the glue and inspection of bonding (for glued strips),
- Inspection of the installation and the compactness of the concrete directly above the strips.

Control during application of treatment by incorporation of a hydro-expansive section

The installation involves the same actions as for leak-tight strips, together with a complementary check on the protection of the water-expansive material (which prevents premature absorption of water).

Final control

A final control is systematically performed at the end of the works, and comprises:

- Checking of the finalisation and completeness of the working files,
- The tests, to be defined in response to the nature of the filler and its function, on the basis of the following non-exhaustive list:
    - Shore A hardness measurements,
    - Bonding checks by application of manual pressure,
    - Possible sampling in order to check the presence of the backup, the mechanical performance of the material and the thickness of the product,
    - A general visual inspection of the appearance of the filler (metal fixture, Omega presence and integrity),

## 17.7 FILLER DURABILITY : FUNCTIONAL AND AGEING MONITORING

The loss of the mechanical properties of a material due to its ageing may prevent the re-application of the stresses due to the structural motions under accident conditions for the relevant filler.

The guarantee of permanent working of the system applied in normal or accident conditions requires the implementation of:

- A maintenance programme, comprising a visual examination and Shore A hardness measurements of accessible fillers,
- A hydraulic test programme on inaccessible fillers which are not situated under the lowest layer of the groundwater (permanent hydraulic test of the infrastructure).

## 17.8 Movement and construction joints in confinement and sub-surface structures

The Civil Contractor shall design and identify on his working drawings, the size of the individual concrete pours and the layout of construction joints he proposes to use to construct the Works. Construction joints shall generally be aligned vertically and horizontally with dimensions of pours designed to limit cracking. The profile of joints shall incorporate a "stepped key" forming an outstand in the joint to increase leak tightness.

A leak-tight strip system shall be built into all joints to prevent the penetration of gas or water. All joints and junctions in the leak-tight strip shall be formed strictly in accordance with the manufacturer's recommendations. The Civil Contractor shall prepare and submit to THE PURCHASER details of the materials he proposes to use and procedure for the installation of the leak-tight strip system on all joints.

# 18 Temporary works

The Civil Contractor shall be responsible for the design, supply, fabrication, installation, maintenance and removal of all temporary works, including, but not limited to: work platforms, shoring and formwork/falsework for cast-in-place concrete.

The Civil Contractor shall submit detailed designs and drawings for temporary works to a timescale defined in General Management Specification.

Care shall be taken not to damage any portion of the permanent works, should damage occur the Civil Contractor shall repair the damage at his own cost.

The Civil Contractor shall inspect temporary works on a daily basis to ensure that they are safe and have not been damaged due to construction activities or environmental exposure.