AFCEN RCC-CW

Cracow technical meeting on codification

ETC-C (RCC-CW) in France - Flamanville 3 Project

E Gallitre

Cracow

2017, September 7th

Summary

- French Nuclear Energy Sector
- What is RCC-CW
- From ETC-C to RCC-CW
- Impact of RCC-CW on activities
- Implementation of RCC-CW in other countries
- Lessons learnt from the first application in France of ETC-C

General organization

- ✓ **For NPP design: « new EDF-AREVA company »**

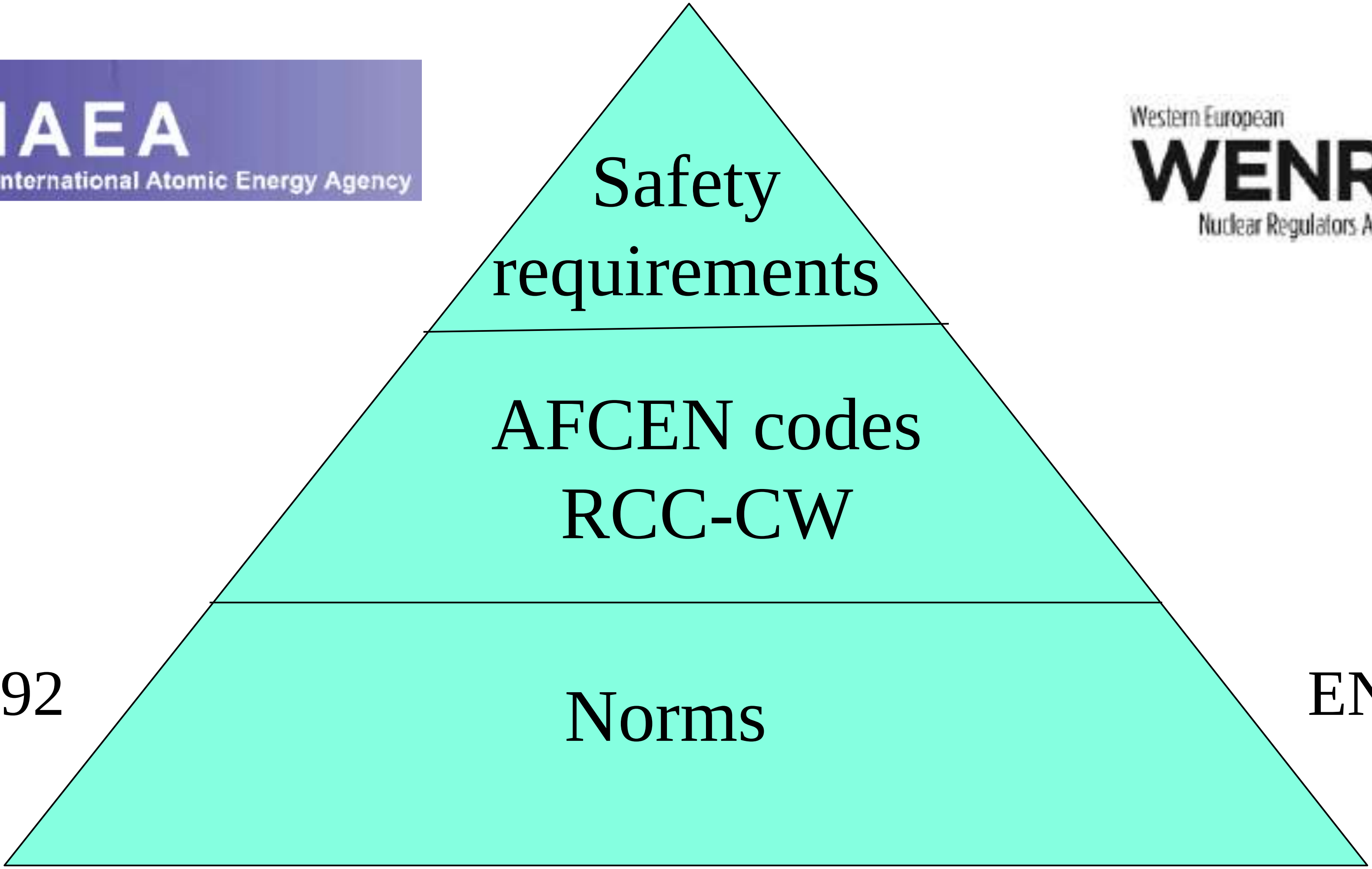
- ✓ **For construction itself: Mainly European Companies**
  - **Qualification process mainly focused on Quality Insurance**

- ✓ **For NPP operation: one operator EDF**
  - ➢ **For maintenance activities: EDF + National Industry**

- ✓ **Regulator : FRENCH ASN (National Safety Authority)**
  - ➢ **With the « strong support of IRSN (Institute of Radio-protection and Nuclear Safety »**

France NPP fleet

What is RCC-CW? At international level



Safety requirements

AFCEN codes RCC-CW

Norms

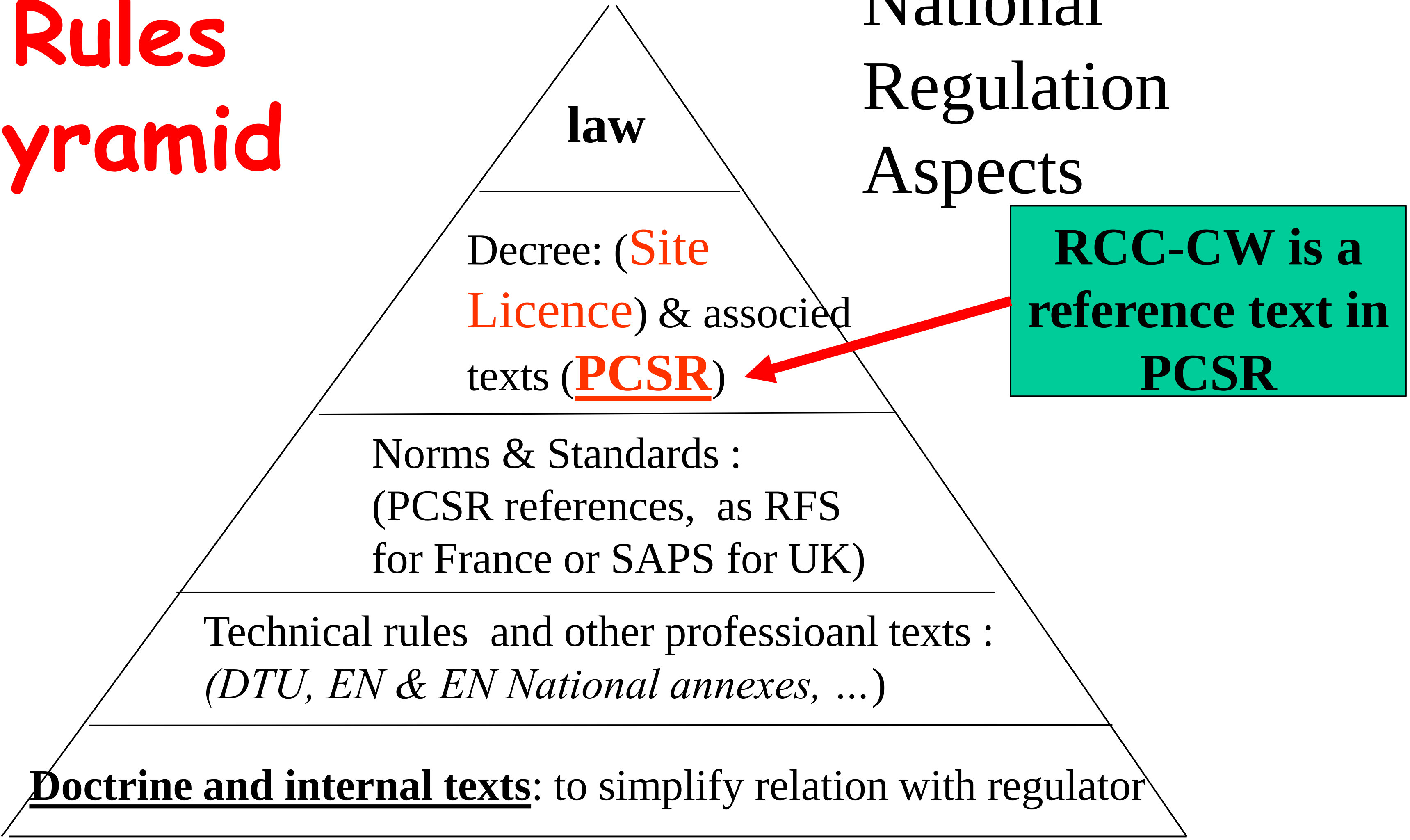
EN 1992

EN 206

What is RCC-CW? At national level

Rules Pyramid

National Regulation Aspects



law

Decree: (Site Licence) & associed texts (**PCSR**)

Norms & Standards : (PCSR references, as RFS for France or SAPS for UK)

Technical rules and other professioanl texts : *(DTU, EN & EN National annexes, …)*

Doctrine and internal texts: to simplify relation with regulator

RCC-CW is a reference text in PCSR

TARGET OF RCC-CW

- ✓ **RCC-CW facilitates the relationships :**
  - ➢ **with the regulator (complete and precise document –acceptance criteria-)**
  - ➢ **with the contractors and de design offices (translation of safety requirements into operational criteria based on existing standards)**

- ✓ **An additional national specific document cannot be avoided due:**
  - ➢ **local standards and national reference documents**
  - ➢ **industrial practice**

how it evolved from ETC-C to RCC-CW

- ✓ **RCC-G Series: based on French norms**
  - ○ **RCC-G 1980**
    - Applicable to 900 MWe series
  - ○ **RCC-G 1985 rev 2 (July 1988)**
    - Applicable to 1300 & 900 MWe series for maintenance & modifications
    - Applicable to N4 series
- ✓ **ETC-C: based on European norms**
  - ○ **ETC-C 2006**
    - Used for FLAMANVILLE3 Preliminary Safety Analysis Report
  - ○ **AFCEN ETC-C 2010 : issued end of 2010**
    - Based on ETC-C 2006
    - Reflects the experience gained from Flamanville3 development
    - Incorporates evolutions driven by the discussion with Safety Authorities (UK…)
  - ○ **AFCEN ETC-C 2012**
    - Improvement of ETC-C 2010 (updating)
- ✓ **RCC-CW: Explicit integration of Design Extension Domain**
  - ○ **AFCEN RCC-CW 2015**
    - To be used for next EPR projects (Poland, ...)
    - To be used for new “EPR-NM”
  - ○ **AFCEN RCC-CW 2016**
    - ○ Key Evolution of Anchors
    - ○ and updating.

GEN II Design

GEN III Design

Updated / Fukushima

how it is used in France – especially Flamanville 3 Project but also others?

✓ **In France AFCEN code is used**

- **in the Preliminary Safety Report as a reference ⇨ safety commitment**
- **in the Contrats for the detailled designed ⇨ piece of contract / for Design Offices**
- **in the Contracts for the construction ⇨ piece of contract / Construction Company**

Note: the revision in force is the one of the Safety Report (+ demands coming from regulator)

how it is used in France – especially Flamanville 3 Project but also others?

- ✓ For contractual aspects RCC-CW Code is not sufficient

- ✓ We need:
  - ➢ The “Client General Specifications” (generic document)
  - ➢ The Book of Technical Specifications (for the specific contract)
  - ➢ The code it-self (for example ETC-C)

There are some overlapping areas, but they can be managed from a contractual point of view

How it can be implemented in other countries (eg. Poland, UK, China,…)

1. A dedicated Working Group has to be organized (normally by AFCEN members belonging to this country)

2. This group has to propose a companion document that introduces amendments and/or complements to the main text

3. This group is supposed to “interface” with regulator in order to be confident in the acceptance of the “whole” in the license process

4. AFCEN board should endorse the companion document if an AFCEN publication is needed (that is strongly recommended)

5. To facilitate the process (in order not to have delay coming from AFCEN) the national working group should have a member coming from RCC-CW sub/committee who is supposed to convince the committee for the text in a “continuous” process.

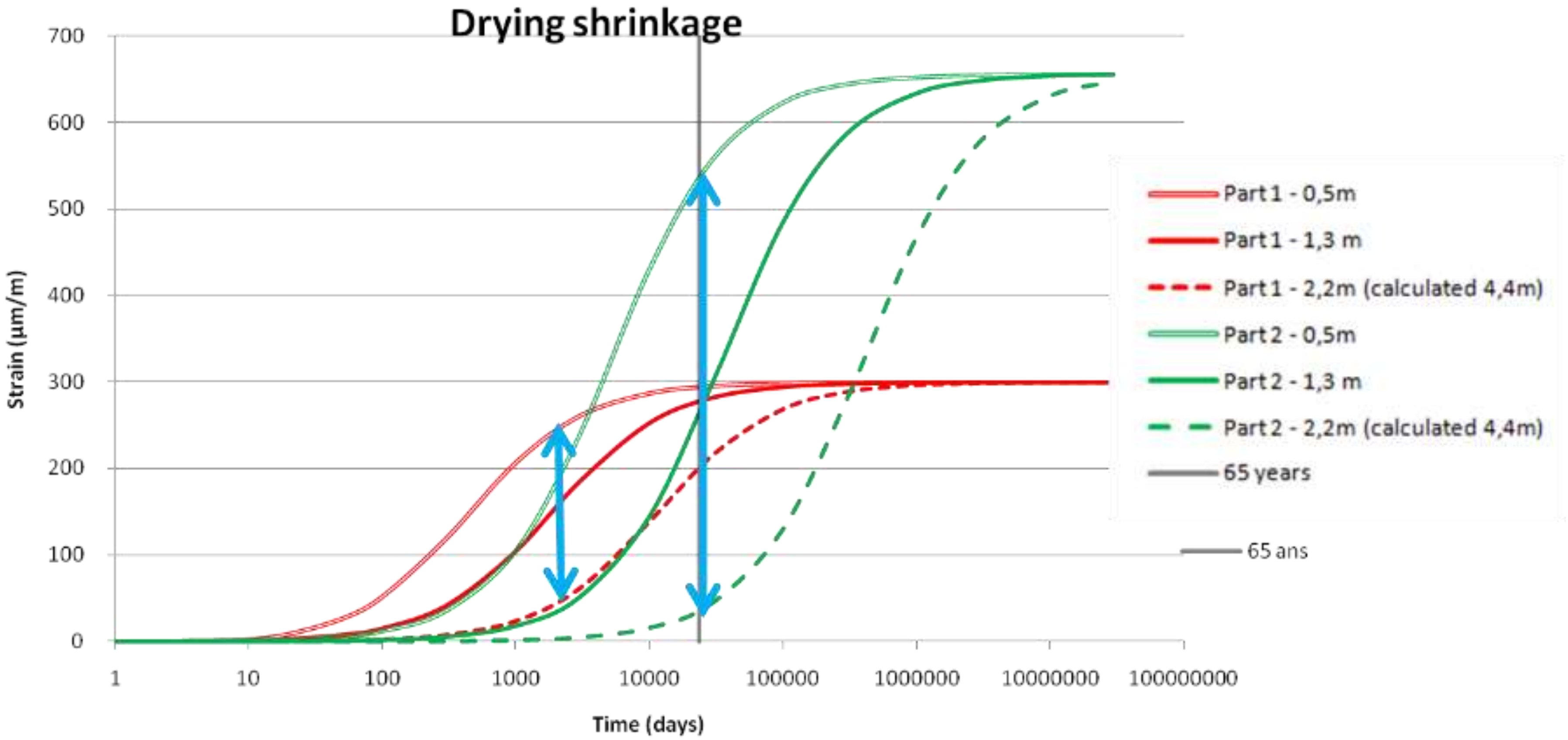
Flamanville 3 feedback

Lessons learnt from the first application in France of ETC-C

FA 3 technical feedback

- **Concrete shrinkage assumption and methodology**
  - – Had to be considered as imposed deformation (RCC-W)
- **Seismic calculation: foundation uplift criteria and methods**
  - – Calculation difficulties
- **Pool & tank liner: justification difficulties about thermal actions**
  - – Avoid numerous rigid areas
- **Containment liner: welding and geometry aspect for bottom area**
  - – Anticipate effect of welding on liner final geometry
- **Equipment Hatch ultimate capacity**
  - – Early assessment of ultimate capacity of containment (Rcc-CW)
- **Polar crane brackets**
  - – Need of geometry simplification
- **Steel works: consistency of load combinations**
  - – Unicity of load combination (RCC-CW)
- **Anchorages: design rules**
  - – Simplification + completion (RCC-CW)

Concrete shrinkage assumption and methodology



Concrete shrinkage assumption and methodology

- ✓ **The value of the shrinkage depends on the element thickness**

  - ➢ **That led to significant rebars ratio when the method consists in considering shrinkage as a equivalent thermal action (even when introducing « cracking factors »).**

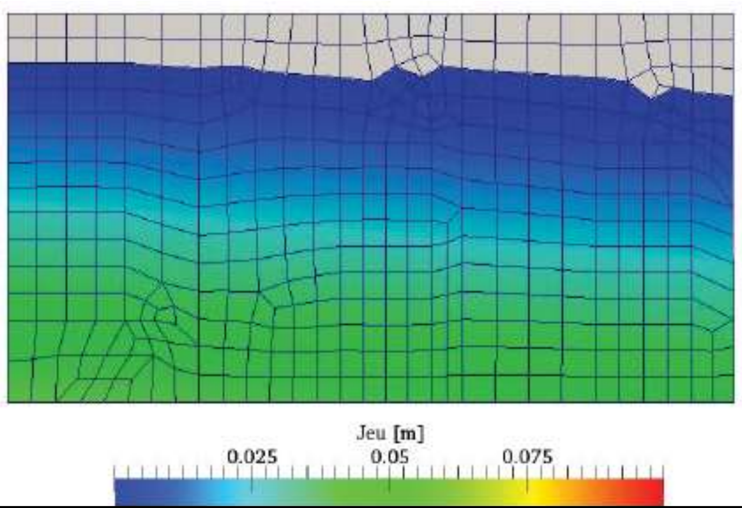
  - ➢ **The solution was to consider shrinkage as a « imposed » deformation that lead to an increasing of the crack width**

    - **So we introduce the concept of « consumed crack width by the shrinkage » and consequently a reduced allowable rebar stress**

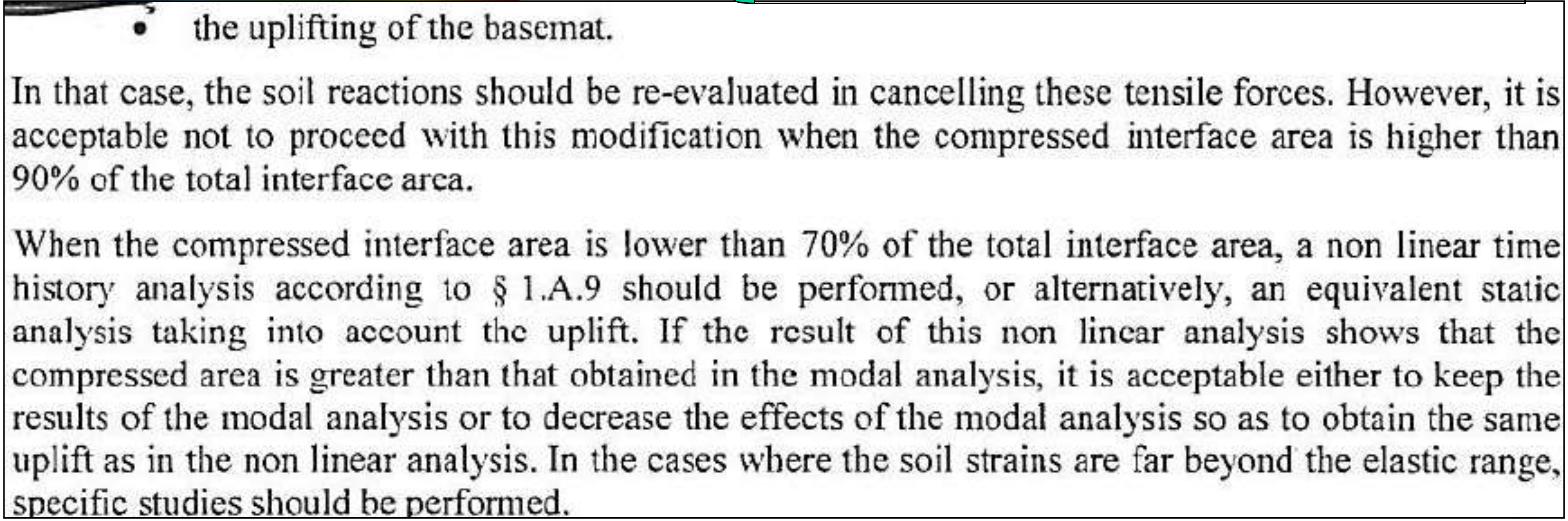
Concrete shrinkage assumption and methodology

- ✓ **The different steps:**
  1. **shrinkage strain calculation**
  2. **minimum reinforcement assessment**
  3. **distance between cracks assessment**
  4. **crack width which is used for shrinkage strain**
  5. **residual crack width**
  6. **allowable steel stress assessment**
  7. **steel section calculation for SLS combination with crack width limitation requirement**

Sesimic calculation: foundation uplift criteria and methods



- Energy based study to justify the limitation of uplift
- Non linear study to justify this limitation
- Non linear study if uplift remains > 30%
- Change the design (1 case / Fa3)



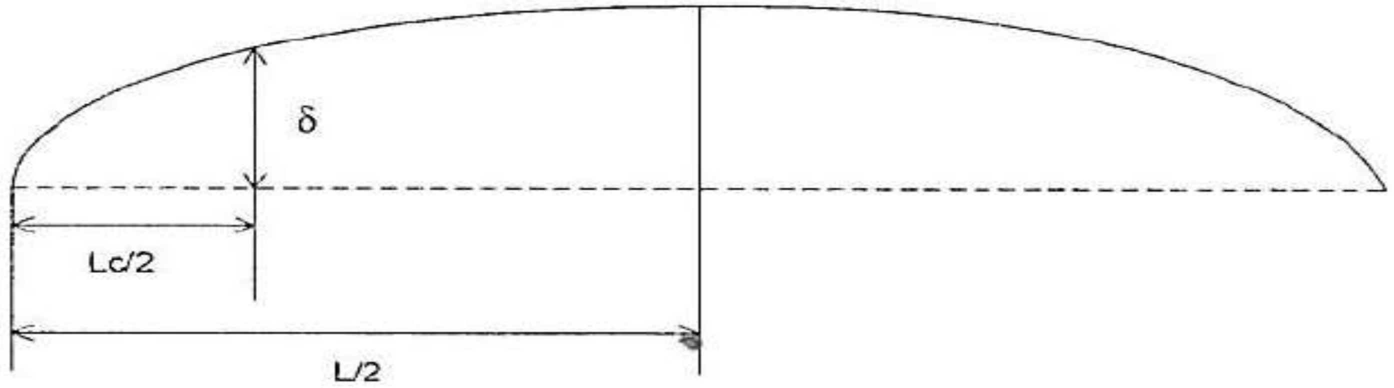
- the uplifting of the basemat.

In that case, the soil reactions should be re-evaluated in cancelling these tensile forces. However, it is acceptable not to proceed with this modification when the compressed interface area is higher than 90% of the total interface area.

When the compressed interface area is lower than 70% of the total interface area, a non linear time history analysis according to § 1.A.9 should be performed, or alternatively, an equivalent static analysis taking into account the uplift. If the result of this non linear analysis shows that the compressed area is greater than that obtained in the modal analysis, it is acceptable either to keep the results of the modal analysis or to decrease the effects of the modal analysis so as to obtain the same uplift as in the non linear analysis. In the cases where the soil strains are far beyond the elastic range, specific studies should be performed.

Pool & tank liner: justification difficulties about thermal actions

- ✓ **ETC-C 2006 liner criteria dealt only with buckling**



Pool & tank liner: justification difficulties about thermal actions

Thermal action lead to high level of stress in area with a thick liner sheet or massive plate of anchorages, the solution is to:

- **Avoid the thick sheets when not necessary**
- **Perform “flat position” welds (avoid “lap joint”)**

Type 4 : Butt joint with full penetration weld on anchored structure or permanent backing strip

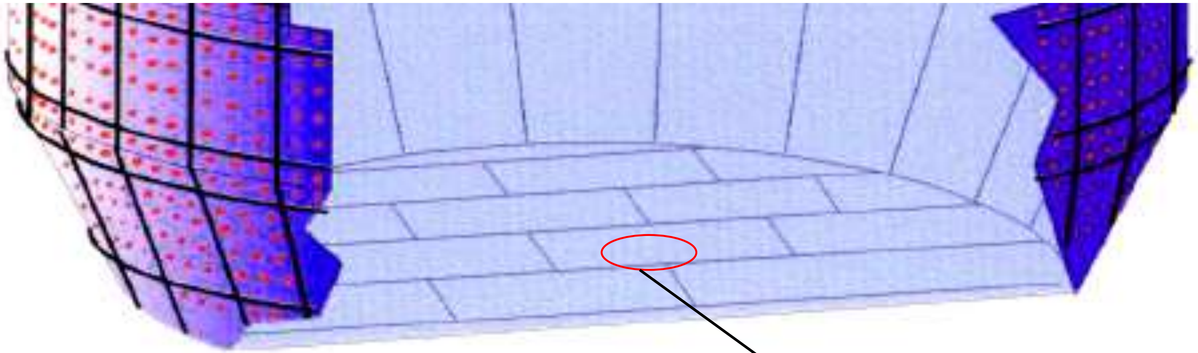
4.1: Welding on anchored structure

4.2: Welding on permanent backing strip

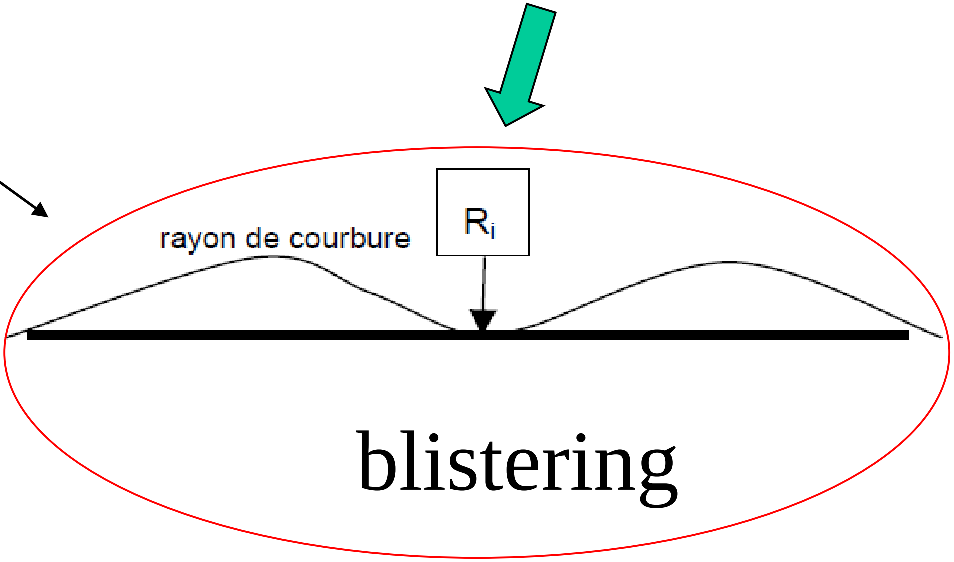
Good feedback in operation when controled during construction

Message: do not try to develop lap joint weld technics

Containment liner: welding and geometry aspect for bottom

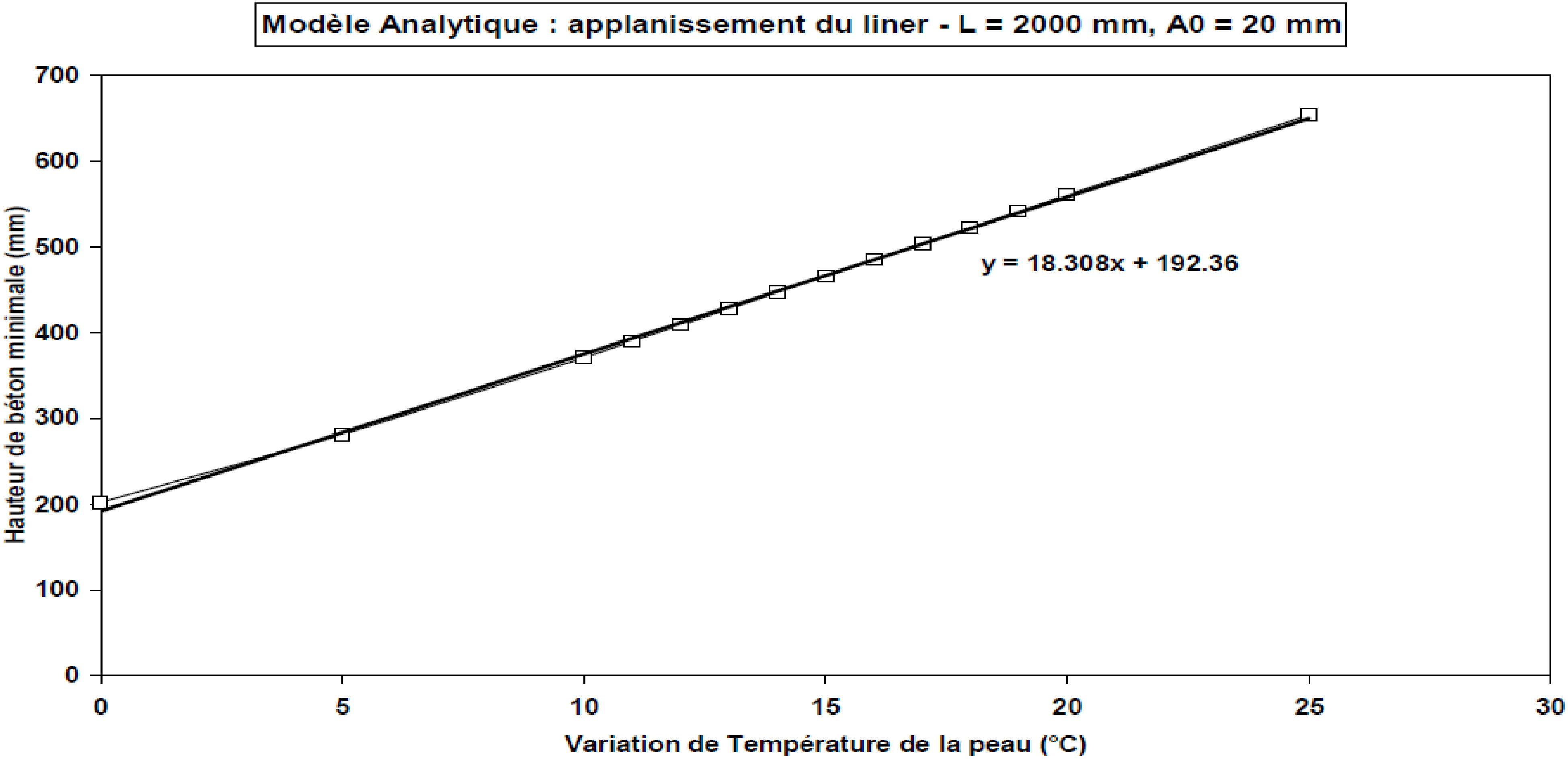


not enough anchored in the raft



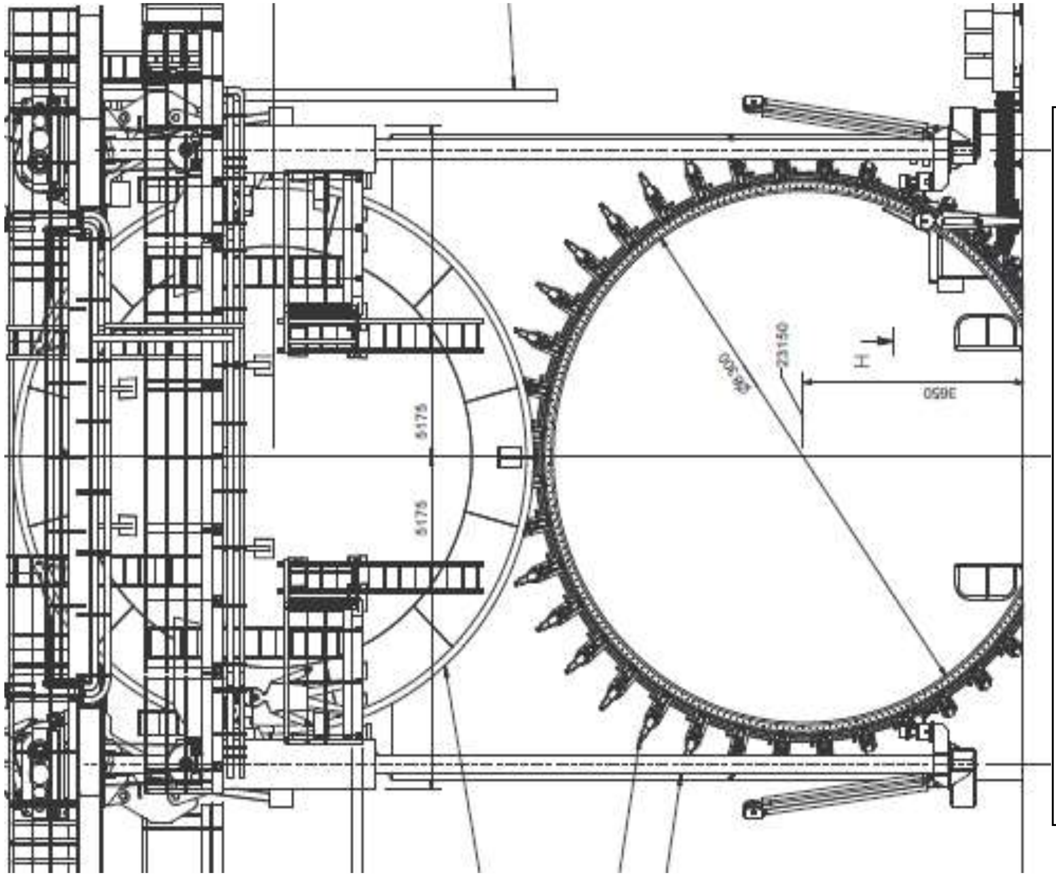
blistering

Liner botom part behavior



Minimum height of concrete layer to balance liner blistering

Ultimate capacity of Equipment Hatch

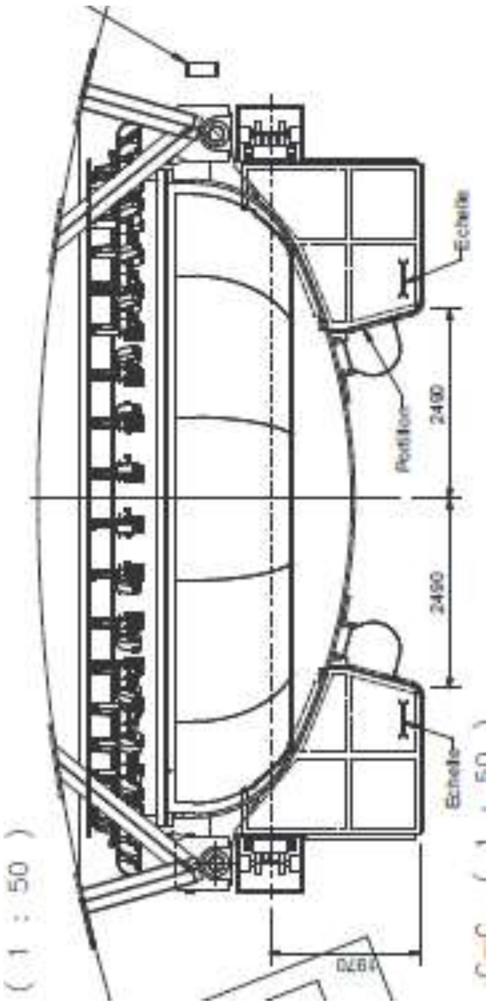


The contract for equipment hatch was initially based only on the DB and DEC accident but without any consideration of ultimate capacity

In parallel the PSA was based on OL3 Design (in order to be in position to have available data)

When performing the updated study with FA 3 data, we discover a « optimisation » of the hatch with a significantly different capacity (significantly < wall capacity) that was a « non sens »

Ultimate capacity of Equipment Hatch

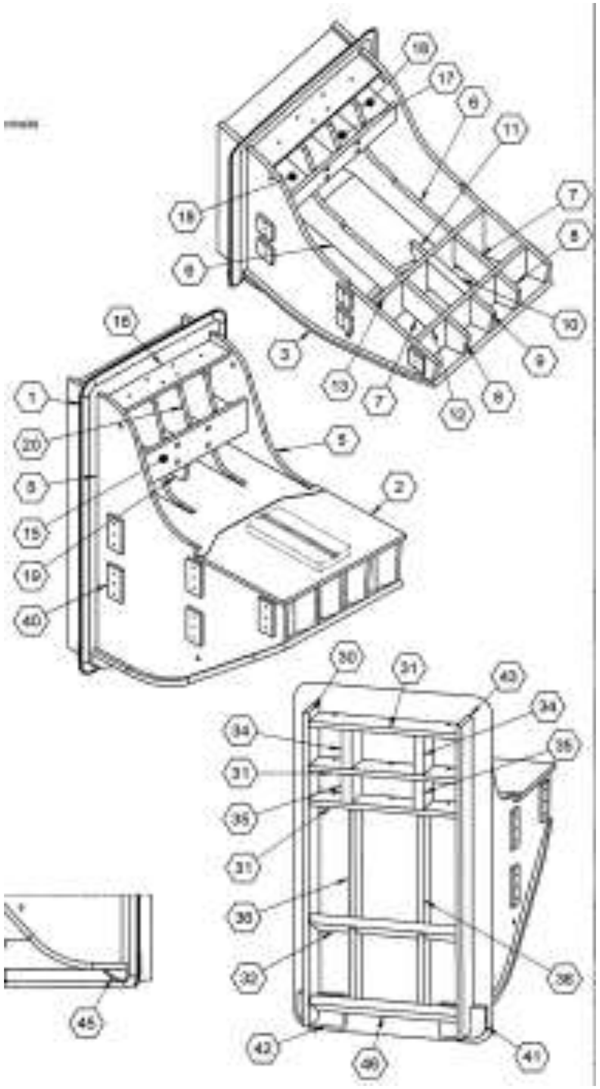


For this reason when decided to change the design and that led to contract modification after the signature……..!

RCC - CW

A prescription to asses the behavior of the containment in the Design phases (not only the wall) has been introduced in RCC-CW

Polar Crane brackets



Final control of welds showed defects that lead to significant delay

One of the feedback is that 3 points needed to be improved:

- The inspectability level
- The available space for welding
- The level of simplicity in the design

→ come back to “previous” design (or similar)

Steel works

- ✓ ETC –C 2006 had introduced different load combinations table for concrete structures en steel structures

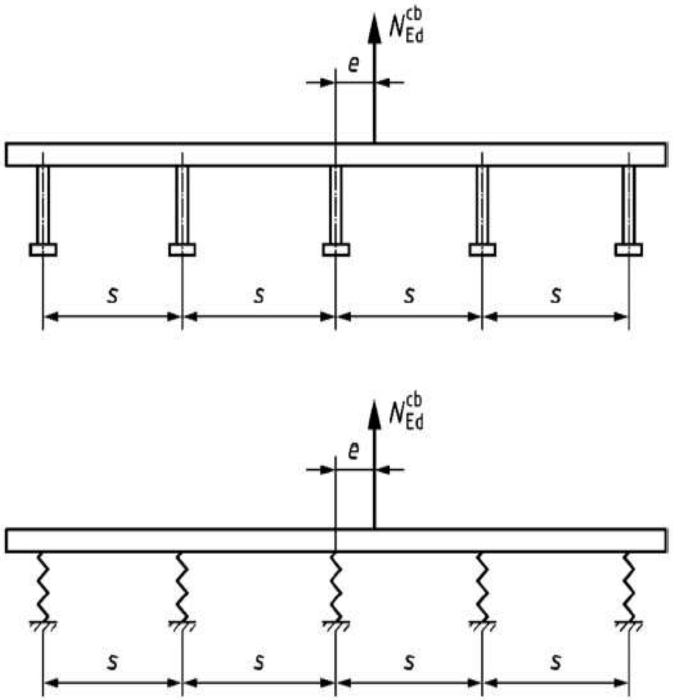
That lead to some temporary inconsistencies

- ✓ No detailing rules were given in ETC-C 2006

That lead to question for design phases

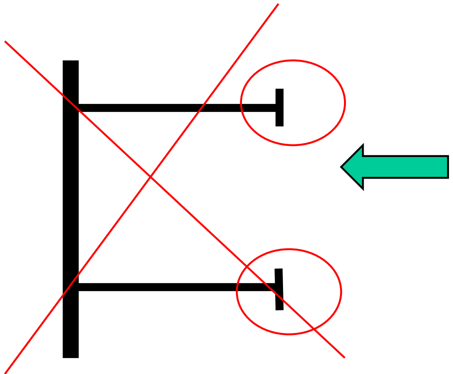
⇨ improvements in RCC-CW

Anchorages: design rules



- FA 3 ETC-C was backed on "CEB Guide of Fastening"
- The designed of anchored plate was based on thick washers welded at the end of the steel bars

Solution: industrial studs



Too difficult to put in place through the reinforcement

THANK YOU FOR YOUR ATTENTION

Shaping the rules for a sustainable nuclear technology

RCC-CW
CIVIL WORKS

RCC-M
MECHANICAL COMPONENTS

RCC-E
ELECTRICAL AND I&C SYSTEMS

RCC-F
FIRE
NAME OF THE NEXT EDITION OF THE CODE

RCC-C
FUEL ASSEMBLIES

RSE-M
IN-SERVICE INSPECTION RULES

RCC-MRx
MECHANICAL COMPONENTS

Concrete in AFCEN nuclear code for Civil Work
&
Concrete on EPR Flamanville 3

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Cracovie, Poland
September 7th, 2017

Agenda

1 – Nuclear code for Civil Work: ETC-C and RCC-CW

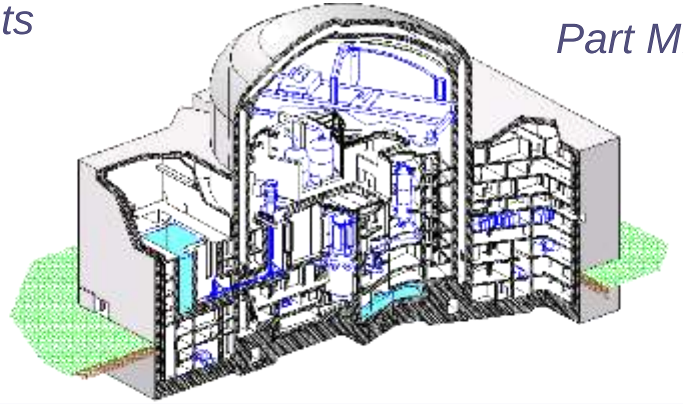
- 1.1 – Scope of the construction part
- 1.2 – Concrete (chapter CCONC)

2 – Concrete on EPR Flamanville 3

- 2.1 – Key data concerning construction materials
- 2.2 – Summary of construction techniques
- 2.3 – Summary of structural concretes

1 – Nuclear code for Civil Work

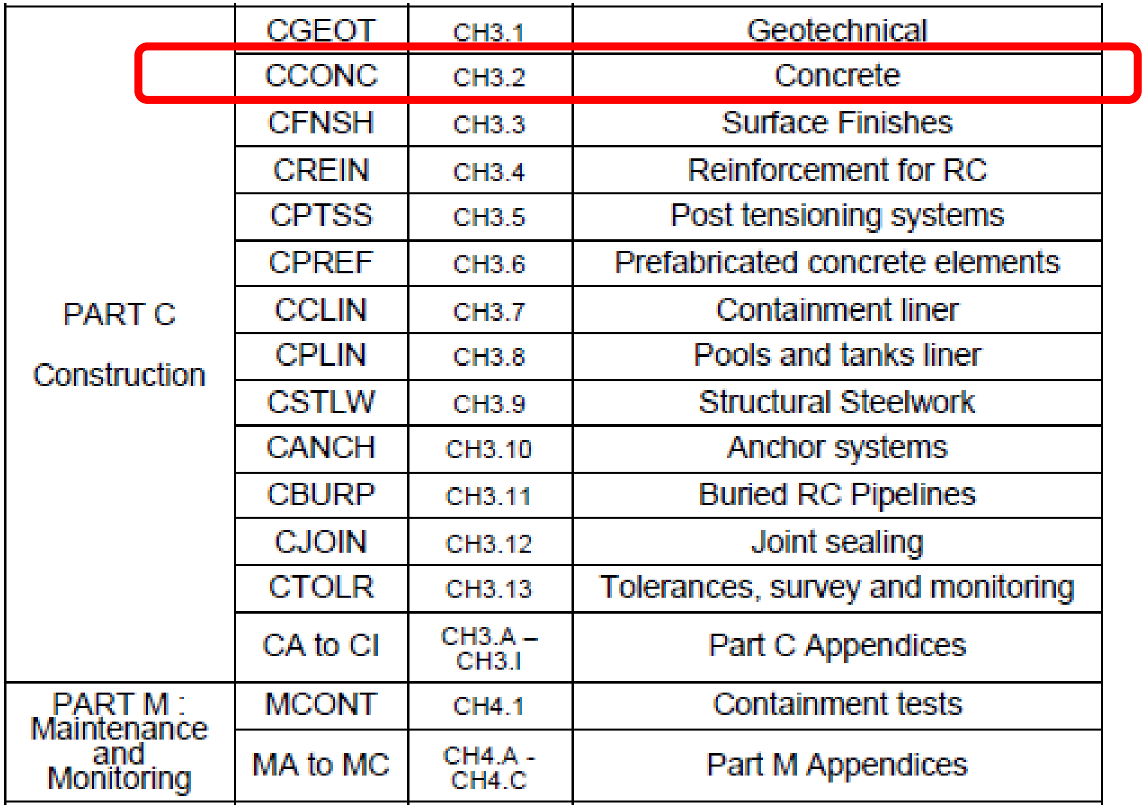
Name	***ETC-C*** *(2006, 2010, 2012)*	***RCC-CW*** *(2015, 2016)*
What is it?	***EPR*** *technical code for civil works.* ***EPR*** *is a type of* ***PWR****.* ***EPR****:* ***E****uropean* ***P****ressurized* ***R****eactor* ***PWR****:* ***P****ressurized* ***W****ater* ***R****eactors*	*Rules for design and construction of* ***PWR*** *nuclear civil works.*
Field of application	*For EPR projects*	*For PWR projects*
Scope	*Part 0: General* *Part 1: Design* *Part 2: Construction* *Part 3: Leak and Resistance Tests and Containment Monitoring*	*Part G: General* *Part D: Design* *Part C: Construction* *Part M: Maintenance and Monitoring*



1 – Nuclear code for Civil Work

1.1 – Scope of the construction part

Extract from RCC-CW 2015



PART C Construction	CGEOT	CH3.1	Geotechnical
	CCONC	CH3.2	Concrete
	CFNSH	CH3.3	Surface Finishes
	CREIN	CH3.4	Reinforcement for RC
	CPTSS	CH3.5	Post tensioning systems
	CPREF	CH3.6	Prefabricated concrete elements
	CCLIN	CH3.7	Containment liner
	CPLIN	CH3.8	Pools and tanks liner
	CSTLW	CH3.9	Structural Steelwork
	CANCH	CH3.10	Anchor systems
	CBURP	CH3.11	Buried RC Pipelines
	CJOIN	CH3.12	Joint sealing
	CTOLR	CH3.13	Tolerances, survey and monitoring
	CA to CI	CH3.A – CH3.I	Part C Appendices
PART M : Maintenance and Monitoring	MCONT	CH4.1	Containment tests
	MA to MC	CH4.A - CH4.C	Part M Appendices

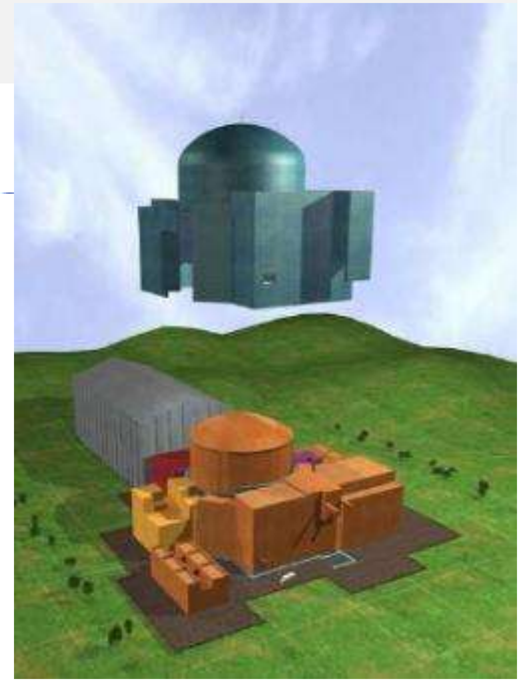
1 – Nuclear code for Civil Work

1.2 – Concrete (*CCONC*)

Safety functions applicable to concrete structures:

Concrete structures shall ensure:

- ✓ Protection of equipment
- ✓ Protection of the environment



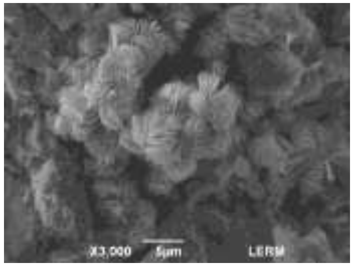
Safety functions applicable to concrete structures:

- ✓**Strength** (stability of the structures) : protection against internal & external agressions (Tornado, earthquake, airplane crash ….)
- ✓ **Leak-tightness (Liquids)**
- ✓ **Containment (Air, Gas)**

➔ ***In all cases to ensure all the structural functions (in normal, exceptional, accidental situation) for the full life time of the nuclear power plant (durability), including decommissioning***

These safety requirements are reflected in:

- ➢ The behaviour requirements in design
- ➢ The performance requirements in construction



1 – Nuclear code for Civil Work

1.2 – Concrete (*CCONC*)

Safety functions applicable to concrete structures:

For 'CONCRETE' material (Nuclear Authority safety report of FA3) :

« Concrete shall have the characteristics of performance (Strength, porosity, permeabiltity, shrinkage/creep…) suited to the operating conditions of the building and to its environment, in normal or accidental situation, and during the full life time of the building »

RESISTANT & DURABLE CONCRETE

- **Good concrete mix design**
- **Low porosity**
- **Adequate workability**
- **Resistant to external / internal attack**

CODE REQUIREMENTS

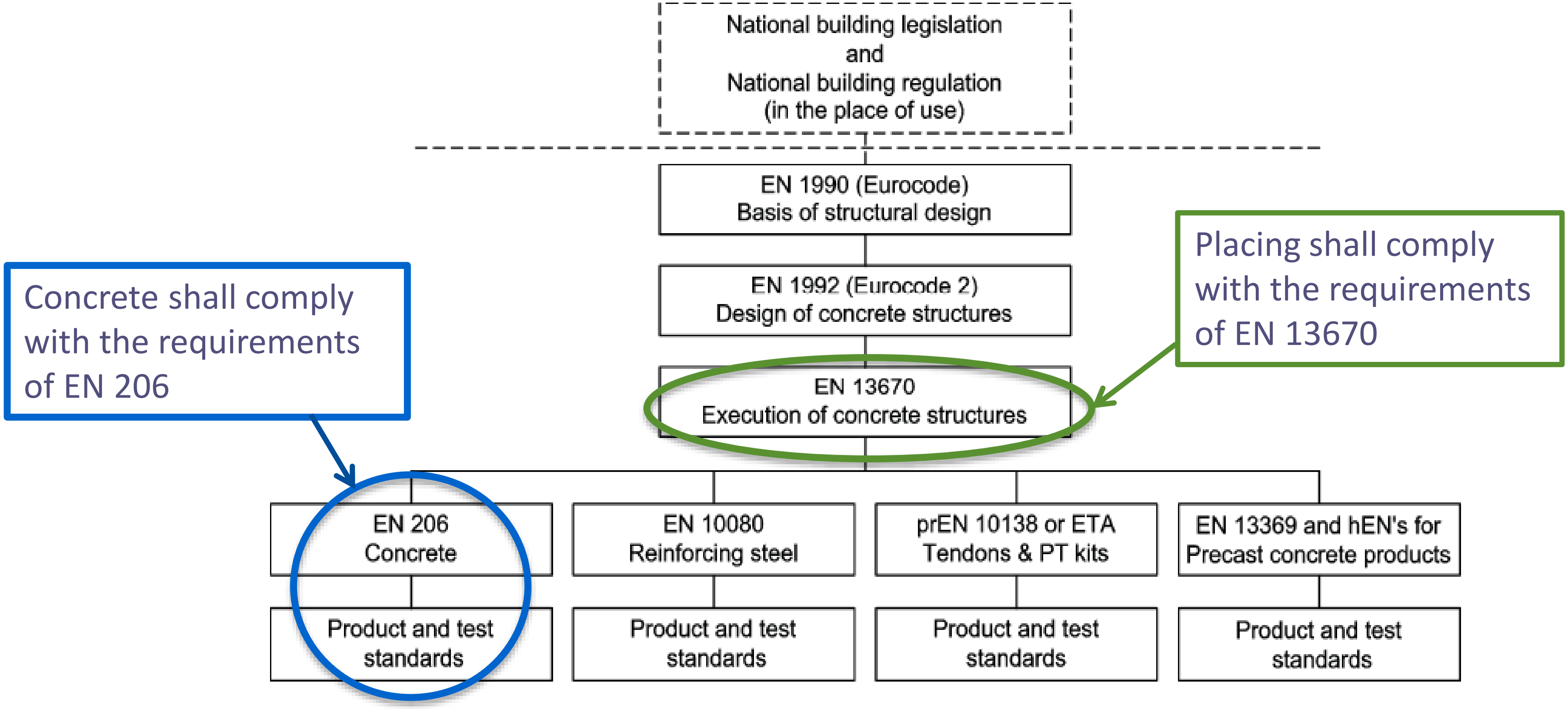
- **Based upon EN standards (and NF standards where no equivalent) + additional specifications (specificity of NNP civil works)**
- **Transferred to civil work contracts**
- **Can be adapted to a national context**

EN 206 = 50 years
EPR = 60-80 years

1 – Nuclear code for Civil Work

1.2 – Concrete (*CCONC*)

CCONC 2000 Qualification and composition
CCONC 3000 Manufacture



National building legislation
and
National building regulation
(in the place of use)

EN 1990 (Eurocode)
Basis of structural design

EN 1992 (Eurocode 2)
Design of concrete structures

EN 13670
Execution of concrete structures

EN 206
Concrete

EN 10080
Reinforcing steel

prEN 10138 or ETA
Tendons & PT kits

EN 13369 and hEN's for
Precast concrete products

Product and test standards

Product and test standards

Product and test standards

Product and test standards

Concrete shall comply with the requirements of EN 206

Placing shall comply with the requirements of EN 13670

1 – Nuclear code for Civil Work

1.2 – Concrete (*CCONC*)

Table of content of CCONC's chapter

CCONC	1000	Constituents
CCONC	2000	Qualification and composition
CCONC	3000	Manufacture
CCONC	4000	Transport of concrete
CCONC	5000	Placing of concrete
CCONC	6000	Sealing and levelling products
CCONC	7000	Additionnal leak-tightness measures for concrete structures: injections

1 – Nuclear code for Civil Work

1.2 – Concrete (*CCONC*)

CCONC 1000 Constituents

- Cements (CCONC 1200)
- Aggregates (CCONC 1300)
- Additions (CCONC 1400)
  - Fly ash,
  - Calcareous/siliceous add.
  - Silica fume
  - GGBS (slag)
- Admixtures (CCONC 1500)
- Mixing water (CCONC 1600)

⟺

- Characteristics, applicable standards
- Selection depending on the required concrete
- Delivery, storage conditions, conformity control tests

1 – Nuclear code for Civil Work

1.2 – Concrete (*CCONC*)

CCONC 2000 Qualification and composition
CCONC 3000 Manufacture

LABORATORY

- Mix design development
    - Composition, dosage,
    - Choice of admixtures,
- Qualification test (CCONC 2800)
- Information test (CCONC 2900)

ON SITE

- Suitability test (CCONC 3300)
- Conformity control test (CCONC 5900)

- Batching plant (concrete manufactured on site CCONC 3100)

1 – Nuclear code for Civil Work

1.2 – Concrete (*CCONC*)

CCONC 4000 Transport of concrete
CCONC 5000 Placing of concrete

- Transport:
  - Adequate working time,
  - Avoid any segregation

- Placing:
  - Shall comply with EN 13 670
  - Requirements on concrete temperatures, curing, vibration
  - Additional precautions in cold/hot weather
  - Construction joint treatment validated on mock-up

2 – Concrete on EPR Flamanville 3

2.1 – Key data concerning construction materials

- Excavation: 650 000 m^3
- Concrete: 600 000 m^3
  - Average: 10 000 m^3/month
  - Max: 20 000 m^3/month
- Steel liner: 850 tons
- Pools liners: 250 tons
- Steelworks: 7 500 tons

2 – Concrete on EPR Flamanville 3

2.1 – Key data concerning construction materials

- Reinforcement: 68 000 tons
- Prestressing steel: 1 950 tons
- 100 000 Anchor plates (1250 t.)
- 500 000 mechanical splices

31 octobre 2013 : les équipes installent les coffrages nécessaires à la prochaine levée de béton

2 – Concrete on EPR Flamanville 3

2.2 – Summary of construction techniques

- 16 tower cranes, incl. 1 Potain 3200 crane (46t at 50m)
- 3 batching plants (Couvrot):
  - 2x3 m^3 + 1x2 m^3
  - Theoretical max. production = 220 m^3/h
- 5 concrete pumps
- 11 concrete masts
- 7000 m² of formworks

2 – Concrete on EPR Flamanville 3

2.3 – Summary of structural concretes

Structure	Concrete Class	Constraints	Volume in m^3
Inner containment	C60/75	Strong prestressing. Small deformations over the life time. Significant reinforcement in particular zones (equipment hatch, bracket)	13400
Turbo alternator platform	C60/75	Mechanical stresses and vibrations. Requires increased strength and module of elasticity Concreting in a single pour.	2500
External containment	C45/55	Air tightness. Strength.	19000
Aircraft Protection Shell	C45/55	Significant reinforcement in particular zones - opportunity for a micro concrete or a self compacting concrete. Aircraft impact stresses.	29000
Common raft	C40/50	Limit the number of construction joints.	28150
Internal structure of the reactor building, Electrical building, Fuel building, Safeguard building	C40/50	Anchoring of safety classified material.	16700 35700 16050 13460
Pumping station and outfall structures	C40/50	Actions of sea water on the structures. Aircraft impact stresses. Certain particular structures in C60/75.	68000
Diesels infrastructure Effluent treatment building Underground outfall gallery	C35/45	Water permeability.	6800 11000 16000

Thank you for your attention !

Any questions ?