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Flamanville 3 EPR

Safety assessment and on-site inspections

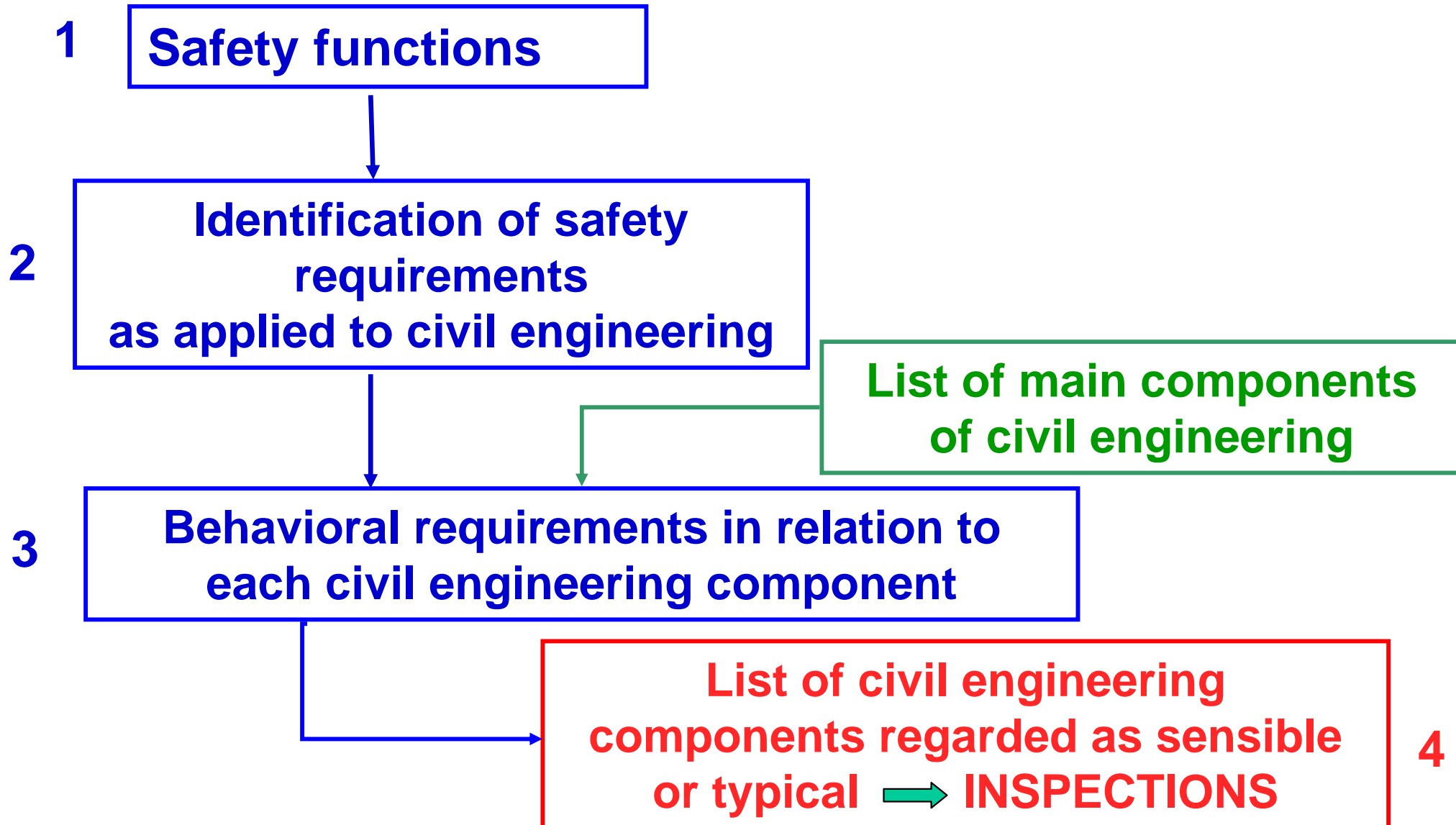
Flamanville 3 EPR – Safety assessment and on-site inspections

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Introduction

- IRSN : Technical Support Organisation of the French Safety Authority (ASN)
 - carries out the safety assessment of EPR project design;
 - participates in the ASN inspections performed at the construction site and in suppliers factories.
- Design assumptions and features are confirmed only if they are correctly implemented and maintained in the plant

Civil design safety assessment



Civil design safety assessment

- Civil engineering safety functions:
 - ensure containment (in particular a 3rd barrier), in all circumstances, including for serious accidents;
 - withstand internal hazards (operational accidents, flooding, fire, explosion...);
 - withstand external hazards (floods, earthquakes, plane crash, explosion, extreme weather conditions...).

Civil design safety assessment

- Civil engineering safety requirements:
 - leak-tightness and retention;
 - resistance, stability, supporting capacity for safety equipments and systems;
 - choice of materials and determination of their biologic thickness;
 - controllability and durability of the construction during the time designated for operation of the unit.

Civil design safety assessment

- Behaviour requirements are defined for each structure or part of structure.



- IRSN assessment consists in evaluating:
 - ETC-C: Technical Code for Civil works in which are defined design criteria and construction rules;
 - global models, calculations and results in term of consistency with assumptions and existence of margins, according to ETC-C;
 - robustness of design and demonstrations by carrying out a more detailed assessment.

Civil design safety assessment

- Results of IRSN civil design safety assessment:
 - Design studies were globally satisfactory;
 - Demands to EDF to provide additional justifications, sometimes involving significant modifications;
 - Definition of items whose construction should be inspected:
 - ✓ Importance for safety,
 - ✓ Execution difficulties.

On-site inspections

- Objectives and general overview:

The inspection program aims to check that:

- the technical specifications of the designers have actually been implemented in the operating procedures during structural construction;
- the master documents supplied by the designers have been satisfactorily accounted for by the civil contractors;
- good building practice has been followed during construction;
- management and survey of its site by EDF is sufficient.

On-site inspections

- IRSN has defined a methodology and an inspection program intended to ASN based on:
 - safety functions associated with civil works;
 - experience gained from the construction and operation of the existing plants;
 - experience of Olkiluoto 3 site (EPR construction in progress).
- IRSN takes part systematically in those inspections.
 - Non-conformities and bad practices can be identified;
 - Warning letters can be sent to ASN;
 - Corrective actions can be asked to EDF in order to ensure a higher construction quality level.

On-site inspections

- Examples of technical problems highlighted during inspections:
 - Water excess in structural concrete;
 - Lack of reinforcement in the nuclear island basemat;
 - Cracks in the concrete of the reactor basemat;
 - Welding process of the containment steel liner;
 - Unsatisfactory treatment of concreting joints.

Water excess in structural concrete

The water/cement ratio (0,50) of the structural concrete seemed to be too high to meet the objectives of durability of the project in marine atmosphere:

- Higher porosity of concrete;
- Additional cracking;
- Poor protection of steel reinforcement.

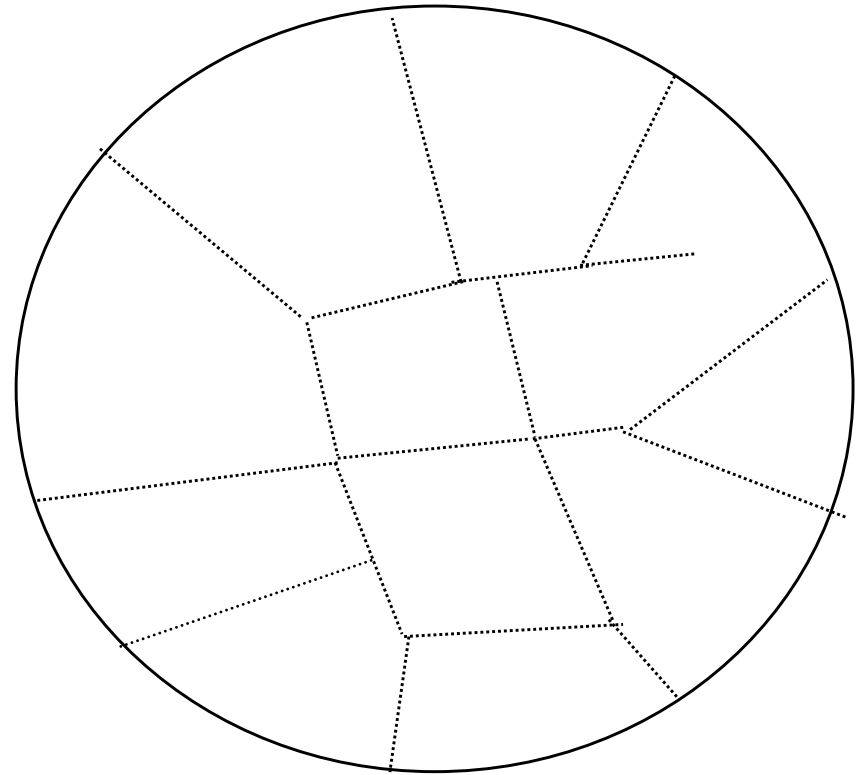
The formulation of concrete was changed to reach a better ratio (0,45).

Lack of reinforcement in the nuclear island basemat

- Noticed during the inspection of block number 2 of the fuel building while the concreting was in progress.
- The concreting work was rapidly stopped and resumed only after the reinforcement was completed.

Cracks in the concrete of the reactor building basemat

- December 2007: concreting for first time of common basemat on nuclear island under the reactor building (4225 m³, thickness 1.8 m)
- Several days later: open cracks of 1 mm to 3 mm
- After cooling: open cracks of 0.4 mm to 1 mm
- Repair: injection of cracks



Configuration of cracks in the circular basemat

Cracks in the concrete of the reactor building basemat

- Cause of this non-conformity:
 - thermal effect due to the heat of hydration of the cement during concrete setting (expansion and contraction due to exothermic reaction)
- Aggravating circumstance:
 - lack of reinforcement mesh in the upper part of the lift
- Risk:
 - reduced durability of the structure;
 - possible corrosion of the bottom reinforcement even if cracks are grouted;
 - presence of water below the basemat should be detected during the lifetime of the plant.

Cracks in the concrete of the reactor building basemat

- Comments:

- risk associated with the execution of large concrete blocks had been pointed out by IRSN in its technical assessment a few months before;
- proven techniques (cutting in pads, 1st lifting with a moderate height...) should have been better;
- the formulation of the concrete could have been better in order to limit temperature inside the block;
- there are specific constraints related to a continuous concreting during three days.

Welding process of the containment steel liner

- Inspection in September 2008

Detailed attention to the first welding activity carried out on site on an element endorsing a safety function: the liner manufacturing

- IRSN Technical assessment

- Deviations to technical requirements detected on the welding procedure → perform complementary examination tests and a 100% non destructive vacuum tests over all those welds;
- Perfectible conditions of welding (climatic conditions protection...);
- Non-conformity in documentations;
- Abnormally high rates of repairs for easily weldable steel
 - welding activity not completely controlled
 - 100% volumetric non-destructive tests until return to a normal situation.

Welding process of the containment steel liner

- Manufacturer actions :
- action plan to significantly improve the quality of works:
 - ✓ Optimization of welding procedures;
 - ✓ Improvement of their conditions of implementation;
 - ✓ Complementary training sessions and selections of welders.



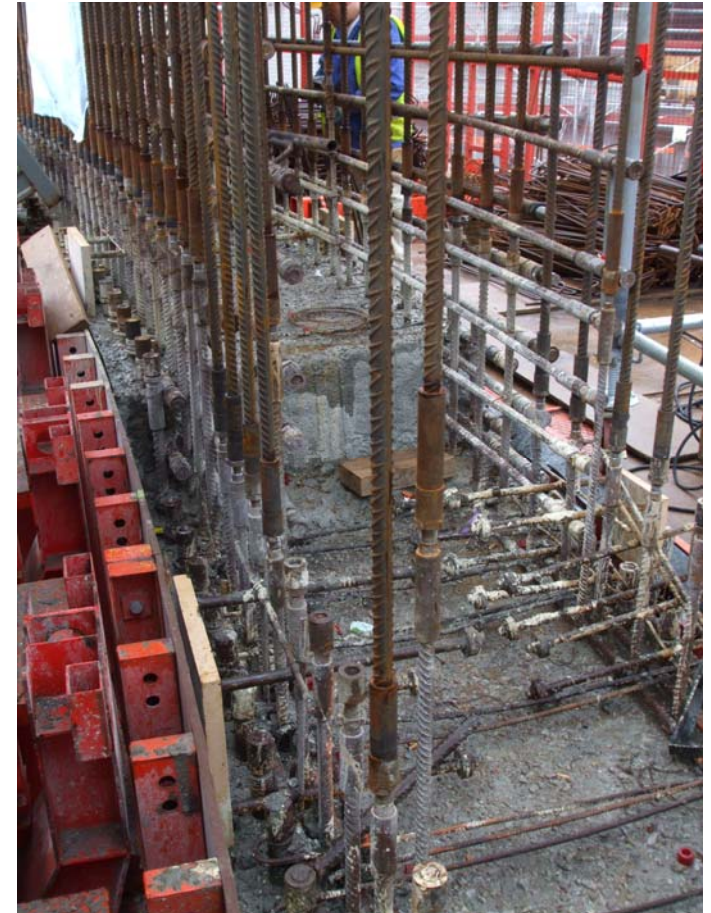
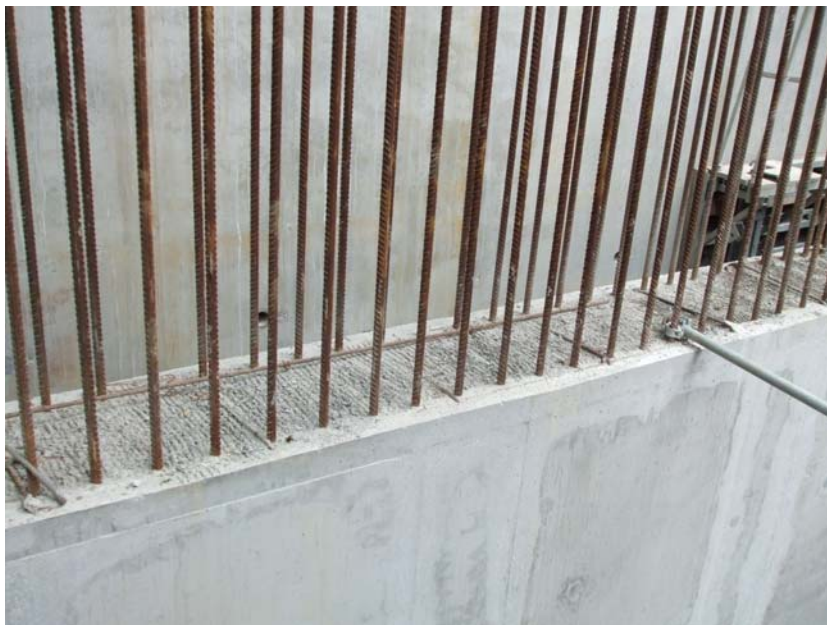
After a few weeks , clear improvement and a return to a normal situation

Unsatisfactory treatment of concreting joints

- According to ETC-C all horizontal construction joints must be treated.
 - When the concrete is setting, the surface must be completely cleaned of any grout using a compressed air and water hose in order to remove all crumbling and oily parts, taking care not to remove any aggregates.
 - However, before any concreting, it is necessary to check if the surface of hardened concrete is clean, otherwise cleaning is performed using a pressurized water jet (pressure > 10 Mpa).
 - The use of other construction joint treatment techniques must be justified and approved by EDF.
- The site procedure contains a deviation to ETC-C, which authorized a normal use of deactivator and chipping or bush hammering

Unsatisfactory treatment of concreting joints

- Site practice seen during 4 inspections
 - Gusset -6.25 m : no treatment
 - Rake
 - Deactivator



Examples of concreting joints

Unsatisfactory treatment of concreting joints

- IRSN Technical assessment >> ASN letter sent to EDF
- An unsatisfactory treatment of construction joints can lead to lower quality joints which jeopardize construction quality:
 - Robustness of structures;
 - Durability (faster than expected steel reinforcement corrosion).
- Structures are not conform to design hypothesis: design margins and expected lifetime can be lower than previewed.
- IRSN asks dedicated structural verifications, taking into account awkward joints treatments.

Unsatisfactory treatment of concreting joints

- EDF actions :
 - stopped using one of the « deactivators »;
 - undertaken a dedicated test program;
 - strengthened its survey in that field.

Conclusion

- The analysis of all the problems encountered during the inspections have revealed:
 - flaws in the organisation of the contractors teams together;
 - unsatisfactory control by EDF of the contractor's activities.
- However, three years after the beginning of the construction, the organization and strictness of the main civil contractor and of EDF construction team have improved.