Office for Nuclear Regulation

New Reactors Division

Step 4 Assessment of Civil Engineering for the UK Advanced Boiling Water Reactor

Assessment Report: ONR-NR-AR-17-013
Revision 0
December 2017

EXECUTIVE SUMMARY

Hitachi-GE Nuclear Energy Ltd is the designer and GDA Requesting Party (RP) for the United Kingdom Advanced Boiling Water Reactor (UK ABWR). Hitachi-GE commenced Generic Design Assessment (GDA) in 2013 and completed Step 4 in 2017.

This assessment report is my Step 4 assessment of the Hitachi-GE UK ABWR reactor design in the area of civil engineering.

The scope of the Step 4 assessment is to review the safety, security and environmental aspects of the UK ABWR in greater detail, by examining the evidence, supporting the claims and arguments made in the safety documentation, building on the assessments already carried out for Step 3. In addition, I have provided a judgement on the adequacy of the civil engineering information contained within the Pre-Construction Safety Report (PCSR) and supporting documentation.

My assessment conclusion is:

- I am satisfied with the claims, arguments and evidence laid down within the PCSR and supporting documentation for civil engineering.
- I consider that from a civil engineering view point, the Hitachi-GE UK ABWR design is suitable for construction in the UK subject to future permissions and permits beings secured.

My judgement is based upon the following factors:

- The civil engineering design follows the ALARP principle, as the civil structures have been appropriately classified on the basis of their safety function and significance to nuclear safety.
- The civil engineering structures have been generally designed to established codes of practice and industry accepted software.
- As a result of Step 3 GDA recommendations, Hitachi-GE has adopted finite element analysis methodologies in the seismic analysis of the civil engineering structures in accordance with relevant good practice.
- There are a number of conservatisms within the design to ensure that the civil engineering structures are robust.
- The RP has considered some construction aspects, such as construction sequences, hazard registers and mitigation of risks through the design for the Reactor Building showing understanding of the Construction (Design and Management) Regulations 2015. There is a commitment to develop this during the site specific design and construction.
- I have assessed the design holistically, considering interactions with other assessment areas, which include the assessment of civil engineering barriers to withstand internal hazards loadings and the assessment of the Reinforced Concrete Containment Vessel for beyond design basis accident loads.
- The RP has considered the through life performance of the civil structures and taken into account their examination, maintenance, inspections, testing and decommissioning requirements.

The following matters remain, which are for a future licensee to consider and take forward in their site-specific safety submissions. These matters do not undermine the generic safety submission but require licensee input/decision at a specific site. These matters have been captured in 19 assessment findings. The assessment findings focused on the following areas where further work is identified:

- The structural interfaces between buildings and tunnels, including waterproofing.
- Applicability of the geotechnical parameters assumed in GDA
- Use of appropriate design codes and standards in some areas.

- Effect of loadings and load cases, including internal hazards loads on civil engineering structural elements.
- Analysis modelling techniques.
- Design of structural elements.
- Assumptions on embedment and Structure Soil Structure Interaction in areas of the seismic analyses
- Validation of bespoke software.
- Leak detection systems

To conclude, I am satisfied that the claims, arguments and evidence laid down within the PCSR and supporting documentation for civil engineering. I consider that from a civil engineering view point, the Hitachi-GE UK ABWR design is suitable for construction in the UK subject to future permissions and permits being awarded.

LIST OF ABBREVIATIONS

ACI	American Concrete Institute
AIA	Aircraft Impact Assessment
AF	Assessment Finding
ALARP	As Low As Reasonably Practicable
AISC	American Institute of Steel Construction
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
BAT	Best Available Technology
B/B	Backup Building
BDB	Beyond Design Basis
BMS	Business Management System
BS	British Standard
BSC	Basis of Safety Case
BSL	Basic Safety Level
BWR	Boiler Water Reactor
C/B	Control Building
CDM	Construction, Design and Management
CE	Civil Engineering
CST	Condensate Water Storage Tank
C/T	Connecting Tunnel
DAC	Design Acceptance Confirmation
DAG	Diverse Alternative Generator
DB	Design Basis
DBA	Design Basis Analysis
DBE	Design Basis Events
DECC	Department of Energy and Climate Change
D/F	Diaphragm Floor
DLF	Dynamic Load Factor
DRP	Design Reference Point
D/W	Drywell
EDG/B	Emergency Diesel Generator Building
EMIT	Examination, Maintenance, Inspection and Testing
EUR	European Utility Requirements
GDA	Generic Design Assessment
GSE	Generic Site Envelope
HLW	High Level Waste

Hx/B	Heat Exchanger Building
IAEA	The International Atomic Energy Agency
IH	Internal Hazards
ILW	Intermediate Level Waste
ISRS	In-Structure Response Spectra
FE	Finite Element
FEA	Finite Element Analysis
FEM	Finite Element Modelling
FLSS	Flooding System of Specific Safety Facility
FS	Fault Studies
Fv/B	Filter Vent Building
L/D	Lower Drywell
LLW	Low Level Waste
LOCA	Loss of Cooling Accident
LOT	Light Oil Storage Tank
MC	Metallic Containment
MCCI	Molten Core-Concrete Interaction
OBE	Operating Basis Earthquake
ONR	Office for Nuclear Regulation
OPEX	Operational Experience
PCSR	Pre-construction Safety Report
PCV	Primary Containment Vessel
Pd	Design Pressure
PSA	Probabilistic Safety Assessment
PSR	Preliminary Safety Report
QA	Quality Assurance
R/B	Reactor Building
RC	Reinforced Concrete
RCCV	Reinforced Concrete Containment Vessel
RCW	Reactor Cooling Water
RGP	Relevant Good Practice
RO	Regulatory Observation
RP	Requesting Party
RPV	Reactor Pressure Vessel
RQ	Regulatory Query
RSW	Reactor Shield Wall
Rw/B	Radwaste Building
SAA	Severe Accident Analysis

SAPs	Safety Assessment Principles
S/B	Service Building
S/C	Suppression Chamber
SFC	Safety Functional Claim
SFIS	Spent Fuel Interim Storage
SFP	Spent Fuel Pool
SLA	Site Licence Application
S/P	Suppression Pool
SPC	Safety Property Claims
SPT	Suppression Pool Water Surge Tank
SQEP	Suitably Qualified and Experienced Person
SSC	System, Structure (and) Component
SSI	Soil Structure Interaction
SSSI	Structure Soil Structure Interaction
TAG	Technical Assessment Guide
T/B	Turbine Building
T/G	Turbine and Generator
TSC	Technical Support Contractor
U/D	Upper Drywell
UDL	Uniform Distributed Load
UK ABWR	United Kingdom Advanced Boiling Water Reactor
V&V	Verification and Validation
WEC	Westinghouse Electric Company
WENRA	Western European Nuclear Regulators’ Association
WST	Water Storage Tank
ZPA	Zero Period Acceleration

TABLE OF CONTENTS

Tables

Figures

Annexes

1 INTRODUCTION

1. This assessment report details my Step 4 Generic Design Assessment (GDA) of Hitachi-GE Nuclear Energy Ltd's UK ABWR reactor design in the area of Civil Engineering.

1.1 Background

2. Information on the GDA process is provided in a series of documents published on our website (**http://www.onr.org.uk/new-reactors/index.htm**). The outcome from the GDA process sought by Requesting Parties such as Hitachi-GE is a Design Acceptance Confirmation (DAC) for ONR and a Statement of Design Acceptability (SoDA) for the Environment Agency (EA) and Natural Resources Wales (NRW).

3. The GDA Step 3 summary report is published on our website (**http://www.onr.org.uk/new-reactors/uk-abwr/reports/step3/uk-abwr-step-3-summary-report.pdf**). Further information on the GDA process in general is also available on our website (**http://www.onr.org.uk/new-reactors/index.htm**).

4. Hitachi-GE commenced GDA in 2013 and completed Step 4 in 2017 and is the Requesting Party (RP). The Step 4 assessment is an in-depth assessment of the safety, security and environmental evidence. Through the review of information provided to ONR, the Step 4 process should confirm that the RP:

- Has properly justified the higher-level claims and arguments.
- Has progressed the resolution of issues identified during Step 3.
- Has provided sufficient detailed analysis to allow ONR to come to a judgment of whether a DAC can be issued.

5. During the Step 4 assessment, I have undertaken a detailed assessment, on a sampling basis, of the safety case evidence. The full range of items that might form part of the assessment is provided in ONR's GDA Guidance to Requesting Parties (http://www.onr.org.uk/new-reactors/ngn03.pdf). These include:

- Consideration of issues identified in Step 3.
- Judging the design against the Safety Assessment Principles (SAPs) and whether the proposed design reduces risks to ALARP.
- Reviewing details of the RP's design controls, procurement and quality control arrangements to secure compliance with the design intent.
- Establishing whether the system performance, safety classification, and reliability requirements are substantiated by the detailed engineering design.
- Assessing arrangements for ensuring and assuring that safety claims and assumptions are realised in the final as-built design.
- Resolution of identified nuclear safety issues, or identifying paths for resolution.

6. I have considered all the above bullet points during my assessment, but some areas, like the quality control arrangements, have been assessed in detailed by the other inspectors (management of safety and quality assurance inspector).

7. This is my report of the Step 4 assessment of the RP's UK ABWR design in the area of Civil Engineering and includes all the above bullet points.

8. The regulatory observations (RO) issued to the RP as part of the GDA assessment are published on our website, together with the corresponding RP resolution plan. I did not issue any ROs during Step 4 GDA.

9. During the Step 4 GDA assessment, 8 Regulatory Queries (RQ) were issued under the civil engineering topic. The responses made by the RP have supplemented the

submissions documents (Level 3 and Level 2 documents) and in some cases the safety case (Level 1 document).

1.2 Scope

10. The scope of my assessment is detailed in my assessment plan (Ref 1) and is based on assessing all civil engineering structures that have been submitted for GDA assessment. The term “all GDA civil engineering structures” includes:

- Reactor Building (R/B), including:
  - Spent Fuel Pond
  - R/B Stack.
  - Reinforced Concrete Containment Vessel (RCCV).
  - Internal components of the RCCV: RCCV Liner anchors, RPV Pedestal, Diaphragm Floor (D/F), Access Tunnel and Reactor Shield Wall (RSW).
- Control Building (C/B).
- Heat Exchanger Building (Hx/B).
- Turbine Building (T/B), including:
  - Internal Turbine/Generator Pedestal.
- Radwaste Building (Rw/B).
- Backup Building (B/B).
- Service Building (S/B).
- Filter Vent Building (Fv/B).
- Emergency Diesel Generator Building (EDG/B).
- Reactor Cooling Water (RCW) Tunnel.
- R/B – B/B Connecting Service Tunnel.
- R/B – EDG/B Connecting Service Tunnel.
- Light Oil Storage Tank (LOT) Base and Connecting Service Tunnel.
- Condensate Storage Tank (CST) Structure and Connecting Service Tunnel.
- Flooding System (FLSS) Water Storage Tank Base and Connecting Service Tunnel.

11. The scope of my assessment focused on:

- Chapter 10 of the Generic PCSR (Ref. 25),
- Basis of safety case documents for GDA nuclear safety related Civil Engineering structures and containments listed above,
- A sample of computer analyses of selected nuclear safety related Civil Engineering structures, selected during the Step 4 and informed by the Step 3 assessments,
- General arrangement drawings of GDA Civil Engineering structures, containments and foundations listed above,
- Detail drawings of a sample selection of key Civil Engineering components,
- Civil Engineering Design Reports with supporting calculations for nuclear safety related Civil Engineering structures, containments and foundations within GDA (listed above), and
- Design reports for all other Civil Engineering works.

12. The scope of my assessment is appropriate for GDA because it provides an in-depth assessment of the safety claims and arguments examined during Step 2 and 3 of GDA.

1.3 Method

13. My assessment complies with internal guidance on the mechanics of assessment within ONR (Ref 2). ONR assessment is undertaken in line with the requirements of

the How2 Business Management System (BMS) document NS-PER-GD-014 (Ref 3). The BMS states out the procedures, instruction and guidance to ONR inspectors in carrying on their assessments. In addition, How2 document No.697 on Guidance on Mechanics of Assessment (Ref 2) sets down the process of assessment within ONR and explains the safety case sampling process.

14. I agreed with the RP to assess a number of civil engineering documents (Basis of Safety Case and Design Reports) that will substantiate the claims within the PCSR on the civil engineering structures submitted for the GDA assessment.

15. My civil engineering assessment of the documents submitted by the RP during Step 4 also included regular meetings with the RP to present the design reports and discuss ONR's comments. I also provided support to other disciplines including Conventional Safety, Internal Hazards, External Hazards, Structural Integrity, Fault Studies, Severe Accidents Analysis and Probabilistic Safety Assessment.

16. I have considered the following principles during my assessment:

- Compliance with a suite of accepted standards and codes, that are themselves compatible with one another;
- Use of appropriate and reasoned engineering knowledge and judgement where codes are non-specific or ambiguous;
- Consider the variability, uncertainty and assumptions made by the RP, especially regarding soil parameters and conditions;
- Being mindful of, and working within, the limitations of software;
- Compliance of the RP with Construction Design and Management Regulations as a Designer;
- Interaction with other ONR disciplines to provide a holistic assessment of the UK-ABWR.

17. The above statements align to the ONR's Safety Assessment Principles, including but not limited to clauses for safety classification and standards (ECS), reliability (EDR and ERL), layout (ELO), and Civil engineering (ECE).

2 ASSESSMENT STRATEGY

2.1 Standards and criteria

18. The standards and criteria adopted within this assessment are principally the Safety Assessment Principles (SAPs) (Ref 4), internal Technical Assessment Guides (TAGs) (Ref 5, Ref 6, Ref 7, Ref 8, Ref 9), relevant national and international standards and relevant good practice informed by existing practices adopted on UK nuclear licensed sites.

2.1.1 Safety Assessment Principles

19. This assessment has been carried out with the aid of a number of applicable Safety Assessment Principles (SAPs) (Ref 4) which are principles against which regulatory judgements are made. The SAPs provide fundamental guidance in scoping an assessment topic and in carrying out an effective assessment. This approach ensures the assessment provides a targeted, proportionate, consistent and transparent consideration on the adequacy of the UK ABWR design.

20. The SAPs apply to the assessment of safety cases for nuclear facilities that may be operated by potential licensees, existing licensees, or other duty holders. The SAPs also provide nuclear site duty holders with information on the regulatory principles against which their safety provisions will be judged. However, they are not intended or sufficient to be used as design or operational standards, reflecting the non-prescriptive nature of the UK's nuclear regulatory system.

21. The SAPs assist inspectors in the judgement of whether, in their opinion, the duty holder's safety case has satisfactorily demonstrated that their design has reduced the risks to 'as low as reasonably practicable' (ALARP). A number of numerical targets are included in the SAPs to give guidance on risks that are so low that they may be considered broadly acceptable. However, the legal duty to reduce risk to ALARP applies at all levels of risk and extends below the broadly acceptable level and the requirement to meet relevant good practice in engineering and operational safety management is of prime importance. There is also guidance on risks that are unacceptably high and the associated activities would be ruled out unless there are exceptional reasons.

22. There are 26 Civil Engineering SAPs that cover design, construction, inspection, maintenance and decommissioning.

23. The key SAPs considered within this assessment are included in Annex 1.

2.1.2 Technical Assessment Guides

24. The use of the SAPs is supplemented with the Technical Assessment Guides (TAGs), which provide further interpretation of the SAPs and guidance on their application. The TAGs provide guidance in particular technical areas (Annex 2).

25. The TAGs that have been used as part of this assessment are listed below:

- NS-TAST-GD-017 Civil Engineering Revision 3 (Ref 5)
- NS-TAST-GD-020 Civil Engineering Containment for Reactor Plants Revision 3 (Ref 6)
- NS-TAST-GD-005 Guidance on the demonstration of ALARP Revision 8 (Ref 7)
- NS-TAST-GD-051 The purpose, scope and content of safety cases Revision 4 (Ref 8)

- NS-TAST-GD-009 Examination, Inspection, Maintenance and Testing of Items Important to Safety, Nuclear Safety Technical Assessment Guide Revision 3 (Ref 9)

2.1.3 National and International standards and guidance

26. The international standards and guidance that have been used as part of this assessment are set out in Annex 3.

27. The International Atomic Energy Agency (IAEA) is an independent intergovernmental, science and technology-based organisation in the United Nations family that serves as the global focal point for nuclear cooperation. The IAEA nuclear safety standards (see Annex 3) provide a system of fundamental safety principles, safety requirements and safety guides. They reflect an international consensus on what constitutes a high level of safety for protecting people and the environment from harmful effects of ionizing radiation.

28. The Western European Nuclear Regulators' Association (WENRA) has published the documents; Statement on Safety Objectives for New Nuclear Power Plants (March 2013) and Safety of New NPP Designs (March 2013) (see Annex 3) which has been considered during this assessment.

29. Generally the SAPs and TAGs capture the requirements of the IAEA Standards Series and the WENRA reference levels.

2.2 Use of Technical Support Contractors (TSCs)

30. The volume of information to examine and the level of expert knowledge required has led to the extensive use of TSCs to provide expertise across a wide range of areas. Whilst the TSCs have undertaken detailed technical reviews of a number of documents, this has been done under ONR's close direction and supervision. The regulatory judgement on the adequacy or otherwise of the UK ABWR civil engineering design has been made exclusively by ONR.

31. Two TSCs were employed under one contract with Ove Arup & Partners Ltd (ARUP):

- ARUP, lead TSC, has provided support on civil engineering and geotechnical design.
- ABS Consulting Ltd (ABS) has provided support on seismic analysis and design.

2.3 Integration with other assessment topics

32. GDA requires the submission of an adequate, coherent and holistic generic safety case. Regulatory assessment cannot therefore be carried out in isolation, as there are often safety issues of a multi-topic or cross-cutting nature. The following cross-cutting issues have been considered within this assessment:

- Radioactive waste and decommissioning – Interactions with radioactive waste and decommissioning assessment were required in reviewing how the civil engineering construction may influence decommissioning techniques.
- Structural Integrity – Interactions with the structural integrity topic were required on the Reinforced Concrete Containment Vessel (RCCV) and its Metallic Containment (MC) components due to their pressure retaining functions.
- Internal Hazards - Interactions with the internal hazards topic were required on civil and structural barriers identified to provide withstand against internal hazards. Discussions revolved around identification of the internal hazard

load case and the structural substantiation to assess the civil structure stability and capacity.

- External Hazards – Interactions with external hazards were required on the assessment of the seismic load cliff edge effect on civil engineering structures.
- Conventional Safety – Interactions with conventional safety were required in reviewing the RP’s approach to implementation of Construction (Design and Management) Regulations 2015 (CDM Regulations) and also in reviewing a sample of the Reactor Building temporary stability assessment.
- Severe Accidents Analysis (SAA) – Interactions with severe accidents were required during the evaluation of the RCCV ultimate pressure capacity. Civil Engineering also provided support to the SAA assessor on the evaluation of the RPV Pedestal and Access Tunnel under severe accident conditions.
- Fault Studies (FS) – Interactions with fault studies were required during the evaluation of the RCCV capacity.
- Probabilistic Safety Assessment (PSA) – PSA required the civil engineering support for the assessment of the RCCV ultimate pressure capacity.

2.4 Sampling strategy

33. It is seldom possible, or necessary, to assess a safety case in its entirety. Therefore sampling is used to limit the areas scrutinised and to improve the overall efficiency of the assessment process. Sampling is done in a focused, targeted and structured manner, with a view to revealing any topic-specific or generic weaknesses in the safety case.

34. The initial sampling strategy for this assessment consisted of undertaking a “broad brush” review of all the documents provided by the Requesting Party (RP) and then to carry out a deep dive detailed technical assessment. However, due to the timing of the Design Reports and the RP’s delivery programme, this approach was not feasible. Instead, all civil engineering reports were assessed in detail with the exception of:

    - RCCV Liner design report (see Table 3, Ref 50)
    - Drywell Head design report (see Table 3, Ref 52)
    - Personnel airlocks design report (see Table 3, Ref 53)
    - Equipment hatch design report (see Table 3, Ref 54)
    - Containment penetrations design report (see Table 3, Ref 55)

35. The above reports are mainly structural integrity reports and have been assessed by the Structural Integrity inspector (Ref 10). I have reviewed the civil engineering component within those reports, such as the liner anchors, and the traceability of the loadings from the structural integrity components to the civil engineering reports, see section 4.3.21.3.

36. The majority of the Design Reports were assessed in detail and this assessment included all the relevant text plus sampled checks of calculation, figures and tabulated data.

37. In addition, further detailed technical assessments were carried out on key topics in the Design Reports. The detailed assessment led to requests for supplementary information, including more detailed calculations, drawings and software validation. Where provided, this has been assessed on a sampling basis.

2.5 Out of scope items

38. The scope of ONR's assessment during GDA was agreed during Step 1, including definition of the out of scope items.

39. Table 1 sets out the items have been agreed with Hitachi-GE as being outside the scope of GDA.

Table 1: Items outside the scope of GDA

Plant Item:	**Associated Civil Structures:**
Tanks and Holding Down Bolts	Light Storage Tank, Condensate Water Storage Tank and FLSS Water Storage Tank
Suppression Pool Water Surge Tank (SPT)	NOT included - Suppression Pool Water Surge Tank (SPT) Structure - R/B-SPT Connecting Service Tunnel
Diverse Alternative Generator (DAG)	NOT included - Diverse Alternative Generator - R/B-DAG Connecting service tunnel
Spent Fuel Interim Storage (SFIS) Facility Chapter 32 of the PCSR includes a concept design for the operation of this facility.	NOT included - Building or facility for SFIS. - Infrastructure to service the SFIS facility from the R/B, i.e. service corridors, roads etc.
High Level Waste (HLW) Decay Storage Facility	NOT Included - Building or facility for HLW. - Infrastructure to service the HLW facility from the R/B, i.e. service corridors, roads etc.
Intermediate Level Waste (ILW) Store	NOT included - Building or facility for ILW. - Infrastructure to service the ILW facility from the R/B, i.e. service corridors, roads etc.
Low Level Waste (LLW) Store	NOT included - Building or facility for LLW. - Infrastructure to service the LLW facility from the R/B, i.e. service corridors, roads etc.
Garage for mobile emergency cooling related vehicles	NOT included - Garage for mobile emergency cooling related vehicles.
Fire Water Pump House	NOT included - Fire Water Pump House
Cylinder Storage House	NOT included - Cylinder storage house
Hazardous Goods Storage Facility	NOT included - Hazardous goods storage facility

Plant Item:	Associated Civil Structures:
Underground Water Storage Pit	NOT included - Underground water storage pit
Emergency Response Centre	NOT included - Building or facility for Emergency Response Centre
Switch Gear Building	NOT included - Switch Gear Building
Intake Screen Structure for Auxiliary Service Water System	NOT included - Intake Screen Structure for Auxiliary Service Water System
Intake Water Culvert Auxiliary Service Water System	NOT included - Intake Water Culvert Auxiliary Service Water System
Intake Water Structure	NOT included - Intake Water Structure
Circulating Water Pipe, Foundation	NOT included - Circulating Water Pipe, Foundation
Seal Pit	NOT included - Seal Pit
Discharge Water Culvert	NOT included - Discharge Water Culvert
Discharge Water Culvert for Auxiliary Service Water System	NOT included - Discharge Water Culvert for Auxiliary Service Water System
Outfall Facility	NOT included - Outfall Facility
Discharge Water Tunnel	NOT included - Discharge Water Tunnel
Ball Strainer Pit	NOT included - Ball Strainer Pit
Domestic and Fire Water Storage Tank, Foundation	NOT included - Domestic and Fire Water Storage Tank, Foundation
Generator Transformer, Foundation	NOT included - Generator Transformer, Foundation
Auxiliary Normal Transformer, Foundation	NOT included - Auxiliary Normal Transformer, Foundation
Excitation Transformer, Foundation	NOT included - Excitation Transformer, Foundation
Spare Generator Transformer, Foundation	NOT included - Spare Generator Transformer, Foundation
Auxiliary Standby Transformer, Foundation	NOT included - Auxiliary Standby Transformer, Foundation
T/B to Substation Connecting Service Tunnel	NOT included - T/B to Substation Connecting Service Tunnel

Plant Item:	Associated Civil Structures:
C/T to Hx/B Connecting Service Tunnel	NOT included - C/T to Hx/B Connecting Service Tunnel

2.6 Findings from GDA Step 3

40. The report, GDA Step 3 Assessment of the Civil Engineering & External Hazards Aspects of Hitachi GE's UK Advanced Boiling Water Reactor (UK ABWR) (Ref 11), includes a list of areas for further examination at Step 4. These areas have been developed during Step 4 by civil engineering and other specialist inspectors within ONR as described in the table below:

Table 2: GDA Step 3 areas to develop during Step 4

Item No.	GDA Step 3 – Civil Engineering & External Hazards areas to develop during Step 4	GDA Step 4
1	Items added to the UK ABWR GDA scope during Step 3.	See Section 3.1 & Table 4 of this report
2	Design safety requirements identified in Revision B of the PCSR.	Section 4.3.22 of this report
3	Further revisions to the PCSR.	Section 4.3.22 of this report
4	EDG relocation and balance of plant items.	In a separate report - Ref 12
5	Aircraft Impact Protection.	In a separate report – Ref 13
6	Detailed examination of design submissions and supporting documents.	See Section 3.1 & Table 3 See Section 4.3 of this report
7	Seismic analysis methodologies and reports.	See Section 4.3.12 of this report
8	Issues related to filtered containment ventilation.	See Section 4.3.21 of this report
9	Codes and standards comparison.	See Section 4.3.3 of this report
10	Design of barriers.	See Section 4.3.21.2 of this report
11	EMIT arrangements.	See Section 4.3.20 of this report
12	Design for construction and decommissioning.	See Sections 4.3.16 & 617 of this report
13	Leakage through structures.	See Sections 4.3.14.1 & 4.3.19.1 of this report
14	The extent of modularisation in the UK ABWR.	In a separate report - Ref 18 Also see Section 4.3.21.4 of this report
15	Use and validation of analysis and design software.	See Section 4.3.15 of this report
16	Detailed examination of External Hazards Topic Reports.	In a separate report - Ref 20
17	Detailed examination of the Generic Site Envelope Topic Report and supporting	In a separate report - Ref 20

Item No.	GDA Step 3 – Civil Engineering & External Hazards areas to develop during Step 4	GDA Step 4
	documents.	
18	The selection and processing of source data and the application of climate change in external hazards submissions.	In a separate report - Ref 20
19	The Generic Site Envelope seismic hazard definition.	In a separate report - Ref 20
20	Cross-cutting issues identified in other discipline areas.	See Section 4.3.21 of this report
21	The application of ALARP to the design.	See Section 4.3.23 of this report
22	The strategy and methods adopted for compliance with the CDM Regulations.	In a separate report - Ref 18 Also see Section 4.3.21.4 of this report
23	Support to the ONR PSA assessment.	See Section 4.3.21.5 of this report
24	Post-Fukushima lessons learned.	In a separate report - Ref 20

41. Following GDA Step 3, the GDA Step 4 of the civil structures commenced and this included the assessment of 14 Basis of Safety Case documents and 30 Design Reports. Nineteen further Design Reports were subsequently added to the GDA scope in reflection of the general increase of work scope. All the new design documents and the updated PCSR have been reviewed and I am able to judge that items 1, 2 and 3 have been addressed during Step 4 GDA.

42. ONR has questioned the Filtered Containment Venting System effectiveness and pressure relief set point to the primary containment ventilation and a number of assessment findings proposed (see Section 4.3.21). I am able to judge that item 8 has been addressed during Step 4 GDA.

43. The relocation of the Emergency Diesel Generator was reviewed with Hitachi-GE and other ONR assessors at a series of Level 4 meetings. The outcome is summarised in a topic report (Ref 12). I am able to judge that item 4 has been addressed during Step 4 GDA.

44. The aircraft impact assessment has been assessed by a specialist TSC and the outcome reported in (Ref 13). I am able to judge that item 5 has been addressed during Step 4 GDA.

45. Step 3 assessment continued during the early phases of Step 4 and this led to questions over the RP’s seismic analysis methodologies. Briefly, the ONR issued RO-ABWR-0068 (Ref 14) to the RP to request a demonstration that their use of “lumped mass on spring” type of seismic analysis models represented relevant good practice. I am able to judge that items 7 and 15 have been addressed during Step 4 GDA.

46. Detailed examination of the RP’s design submissions, supporting documents and the codes and standards comparison have been undertaken by a specialist TSC and the outcome reported in the Civil Design Assessment report, (Ref 15) and the Seismic Assessment report (Ref 16) I am able to judge that items 6, 9 and 21 have been addressed during Step 4 GDA.

47. Barrier design has been assessed by the ONR internal hazards assessor and the outcome reported in (Ref 17). I am able to judge that item 10 has been addressed during Step 4 GDA.

48. EMIT arrangements have been assessed and the outcome is reported in Section 4.3.20 of this assessment report. I am able to judge that item 11 has been addressed during Step 4 GDA.

49. Items 12, 14 and 22 have been considered by the ONR conventional safety assessor and the outcome reported by the ONR conventional safety assessor, reported at (Ref 18). The review of some of the civil engineering content is reported in section 4.3.21 of this report. I am able to judge that these items have been addressed during Step 4 GDA.

50. Leakage through structures has been considered by the presentation of example water-proofing systems, to be confirmed at later phases of the design, that will be applied to the below ground civil structures and services tunnels. The review of the waterproofing is reported in section 4.3.14.1 of this report. Further confirmatory design details will be necessary during the later phases of the work. However, I am able to judge that item 13 has been addressed during Step 4 GDA.

51. The civil engineering assessors have supported cross-cutting topics by reviewing technical details of external hazard, internal hazards, decommissioning, mechanical engineering, conventional safety, PSA and severe accident analysis. I am able to judge that item 20 has been addressed during Step 4 GDA.

52. Support has been provided to the ONR PSA assessment as requested and this included the assessment of the Beyond Design Basis performance of the RCCV. The outcome of this assessment is reported in Civil Engineering Assessment to Support the PSA Level 2 Containment Analysis (Ref 19), and explained in section 4.3.21 of this report. I am able to judge that item 23 has been addressed during Step 4 GDA

53. External hazards topics (16 to 19 inclusive and 24) have been assessed by the ONR external hazards assessor and reported at Ref 20. I am able to judge that these items have been addressed during Step 4 GDA.

54. In addition, Step 3 assessment continued during the early phases of Step 4 and this led to further questions and comments on the totality of Hitachi-GE's design for Step 3 GDA. The outcome of this assessment is recorded in (Ref 21) and was summarised in 4 Regulatory Queries and 1 Regulatory Observation, as follows:

RQ-ABWR-0847	Civil Design Assessment	Ref 22
RQ-ABWR-0848	Tunnels and Underground Structures	Ref 23
RQ-ABWR-0915	Seismic Analysis	Ref 24
RQ-ABWR-0849	Aircraft Impact Assessment	Ref 25
RO-ABWR-0068	Seismic Analysis	Ref 14

55. The RP submitted responses to these Step 3 queries and observations during Step 4 GDA. Any incomplete responses have been taken forward and included in the Step 4 assessment comment registers. As a result the RQs were closed. I am able to judge that these Step 3 questions and comments have been addressed during Step 4 GDA.

56. The RP also responded to RO-ABWR-0068 that requested a demonstration that their use of lumped mass on spring type of seismic analysis models represented relevant good practice. This was requested as ONR had an expectation that the more accurate finite element (FE) type models would be used for the design of these safety related nuclear civil structures, as it is considered relevant good practice. The RP responded by proposing a two-step FE type analysis and design process described in the Seismic

Design Methodology Report (See Table 4, Ref 46) and Seismic Validation Report for R/B (See Table 4, Ref 47). These were assessed and found to be broadly acceptable, subject to the Assessment Findings. This methodology was used throughout the Step 4 designs and it is understood that it will be used during later phases of the work. Hence the requirement to demonstrate that lumped mass on spring type of seismic analysis models represented relevant good practice had become obsolete. On this basis, RO-ABWR-0068 was closed.

57. In conclusion, based on the documents submitted during Step 4 GDA, I have judged that areas of the civil engineering design identified for further investigation during Step 3 have been addressed during Step 4.

3 REQUESTING PARTY'S SAFETY CASE

3.1 Safety Case Documentation

58. The RP's safety case for Civil Engineering is documented in a number of GDA submissions. These submissions split into four different levels, which are described below:

- Level 1 – Safety, security and environmental report – The level 1 report is the Pre-Construction Safety Report (PCSR).
- Level 2 – Documents referenced in the PCSR such as the Topic Reports and the Basis of Safety Case (BSCs)
- Level 3 – Supporting documents or Design Reports underpinning the claims made in the PCSR and the BSC. These supporting reports deal with aspects such as structural design, seismic analysis, geotechnical design, codes and standards, etc.
- Level 4 – Quality Assurance (QA) and project procedures supporting documents.

59. The civil engineering assessment has been focused on the Levels 1, 2 and 3 documents. The following documents have been assessed during GDA.

Table 3: Documents assessed as part of GDA

Subject	Document Level	Reference
PCSR – Chapter 10 – Civil Works and Structures	Level 1	Ref 26
Overview of UK ABWR Civil Structures	Level 2	Ref 27
Topic Report of CDM2015 Compliance	Level 2	Ref 28
Topic Report on Generic Site Envelope	Level 2	Ref 29
R/B - Basis of Safety Case	Level 2	Ref 30
C/B - Basis of Safety Case	Level 2	Ref 31
RCCV - Basis of Safety Case	Level 2	Ref 32
Hx/B - Basis of Safety Case	Level 2	Ref 33
T/B - Basis of Safety Case	Level 2	Ref 34
Rw/B - Basis of Safety Case	Level 2	Ref 35
B/B - Basis of Safety Case	Level 2	Ref 36
S/B - Basis of Safety Case	Level 2	Ref 37
LOT - Basis of Safety Case	Level 2	Ref 38
CST - Basis of Safety Case	Level 2	Ref 39
RB-BB - Basis of Safety Case	Level 2	Ref 40
EDG/B - Basis of Safety Case	Level 2	Ref 41
R/B-EDG/B - Basis of Safety Case	Level 2	Ref 42
RCW - Basis of Safety Case	Level 2	Ref 43
FLSS - Basis of Safety Case	Level 2	Ref 44
RCCV & R/B - Seismic Report	Level 3	Ref 45
Seismic Design Methodology Report	Level 3	Ref 46
Seismic Design Validation Report	Level 3	Ref 47

Subject	Document Level	Reference
RCCV & R/B - Design Report	Level 3	Ref 48
RCCV & R/B - Design Report – Sensitive Nuclear Information (SNI)	Level 3	Ref 49
RCCV Liner - Design Report	Level 3	Ref 50
RCCV Metallic Components - Design Report	Level 3	Ref 51
Drywell Head - Design Report	Level 3	Ref 52
Personnel Airlock - Design Report	Level 3	Ref 53
Equipment Hatch - Design Report	Level 3	Ref 54
Penetrations - Design Report	Level 3	Ref 55
RCCV Internal Structures - Design Report	Level 3	Ref 56
RPV Pedestal - Design Report	Level 3	Ref 57
Diaphragm Floor - Design Report	Level 3	Ref 58
Access Tunnel - Design Report	Level 3	Ref 59
Shield Wall - Design Report	Level 3	Ref 60
C/B - Seismic Report	Level 3	Ref 61
C/B - Design Report	Level 3	Ref 62
C/B - Design Report (SNI)	Level 3	Ref 63
Hx/B - Seismic Report	Level 3	Ref 64
Hx/B - Design Report	Level 3	Ref 65
Hx/B - Design Report (SNI)	Level 3	Ref 66
T/B - Seismic Report	Level 3	Ref 67
T/B - Design Report	Level 3	Ref 68
T/B - Design Report (SNI)	Level 3	Ref 69
Rw/B - Seismic Report	Level 3	Ref 70
Rw/B - Design Report	Level 3	Ref 71
Rw/B - Design Report (SNI)	Level 3	Ref 72
B/B - Seismic Report	Level 3	Ref 73
B/B - Design Report	Level 3	Ref 74
B/B - Design Report (SNI)	Level 3	Ref 75
S/B - Seismic Report	Level 3	Ref 76
S/B - Design Report	Level 3	Ref 77
S/B - Design Report (SNI)	Level 3	Ref 78
Stack - Seismic Report	Level 3	Ref 79
Stack - Design Report	Level 3	Ref 80
Fv/B - Seismic Report	Level 3	Ref 81
Fv/B - Design Report	Level 3	Ref 82
Fv/B - Design Report (SNI)	Level 3	Ref 83
EDG/B - Seismic Report	Level 3	Ref 84
EDG/B - Design Report	Level 3	Ref 85

Subject	Document Level	Reference
EDG/B - Design Report (SNI)	Level 3	Ref 86
LOT - Seismic Report	Level 3	Ref 87
LOT - Design Report	Level 3	Ref 88
CST - Seismic Report	Level 3	Ref 89
CST - Design Report	Level 3	Ref 90
RCW Tunnel - Seismic Report	Level 3	Ref 91
RCW Tunnel - Design Report	Level 3	Ref 92
RCW Tunnel - Design Report (SNI)	Level 3	Ref 93
R/B-B/B Tunnel - Seismic Report	Level 3	Ref 94
R/B-B/B Tunnel - Design Report	Level 3	Ref 95
R/B-B/B Tunnel - Design Report (SNI)	Level 3	Ref 96
R/B-EDG/B Tunnel - Seismic Report	Level 3	Ref 97
R/B-EDG/B Tunnel - Design Report	Level 3	Ref 98
R/B-EDG/B Tunnel - Design Report (SNI)	Level 3	Ref 99
B/B-WST Tunnel - Seismic Report	Level 3	Ref 100
B/B-WST Tunnel - Design Report	Level 3	Ref 101
R/B Hydrodynamic Vibration - Analysis Report	Level 3	Ref 102
Assumptions for Site Conditions	Level 3	Ref 103
AIA - Accidental Strategy	Level 3	Ref 104
AIA - Intentional Strategy	Level 3	Ref 105
AIA - Physical Damage Protection	Level 3	Ref 106
AIA - R/B Structural Integrity	Level 3	Ref 107
AIA - R/B Shock Damage	Level 3	Ref 108
AIA - Fire Damage	Level 3	Ref 109
AIA - Preliminary Assessment	Level 3	Ref 110
AIA - Assessment	Level 3	Ref 111
Examination, Maintenance, Inspection and Testing for Civil Engineering	Level 3	Ref 112

60. The ONR assessment of the RP's Aircraft Impact Assessment (AIA) is documented in a separate report (Ref 13).

61. Additional documents relevant to the civil engineering assessment submitted by the RP are listed below:

Table 4: Additional documents submitted for GDA

Title	Document Level	Reference
SSDP-2D Shimizu software validation report	Level 3	Ref 113
SSDP-ST Shimizu software validation report	Level 3	Ref 114
SSI Analysis Model Approach – Deliverables Plan and	Level 3	Ref 115

Title	Document Level	Reference
Schedule Plan in GDA		
Explanation of differences of drawings for R/B, FV/B, and S/B for Civil Engineering Design	Level 3	Ref 116
List of Safety Category and Class for UK ABWR	Level 3	Ref 117
Codes and Standards Full Comparison matrix Report	Level 3	Ref 118
Verification and Validation Plan for Design and Analysis Software used in Civil Engineering	Level 3	Ref 119
Verification and Validation of NASTRAN for FE analysis of RCCV components	Level 3	Ref 120
ONR/TSC Comment Response (Underground & Foundation) RQ-ABWR-1419 UK ABWR Step 4 Geotechnical Assessment	Level 3	Ref 121
ONR/TSC Comment Response (Underground & Foundation) RQ-ABWR-1406 UK ABWR Step 4 Civil Design Assessment	Level 3	Ref 122

Table 5: Cross Cutting Documents Assessed

Area	Title	Document Level	Reference
External Hazards	Seismic Evaluation Methodology of Cliff-edge Effect on Civil Structures	Level 3	Ref 123
PSA	UK ABWR Ultimate Capacity Evaluation for RCCV Concrete Structure	Level 3	Ref 124
PSA	RCCV Concrete Structure Ultimate Pressure Capacity Evaluation Report	Level 3	Ref 125
PSA	Verification and Validation Report for Ultimate Capacity Evaluation of RCCV Concrete Structure	Level 3	Ref 126
PSA	UK ABWR Ultimate Capacity Evaluation for RCCV Concrete Structure Update #2	Level 3	Ref 127
Internal Hazards	Internal Hazards Barrier Substantiation Report	Level 3	Ref 128
Internal Hazards	Topic Report on Dropped and Collapsed Loads	Level 3	Ref 129
Internal Hazards	Civil Structure Evaluation Report for Barrier Substantiation	Level 3	Ref 130
Internal Hazards	Topic Report on Combined Internal Hazards	Level 3	Ref 131

3.2 Safety Case Structure

62. The RP has applied the formal approach of Claims, Arguments and Evidence to the safety case. The PCSR (Level 1 document) states the claims on the civil engineering structures, the Basis of Safety Case (BSCs) and Topic Reports (Level 2 documents) provide the arguments and the evidence is within the Design Reports (Level 3 documents). The figure below summarises the links between the different safety case documents.

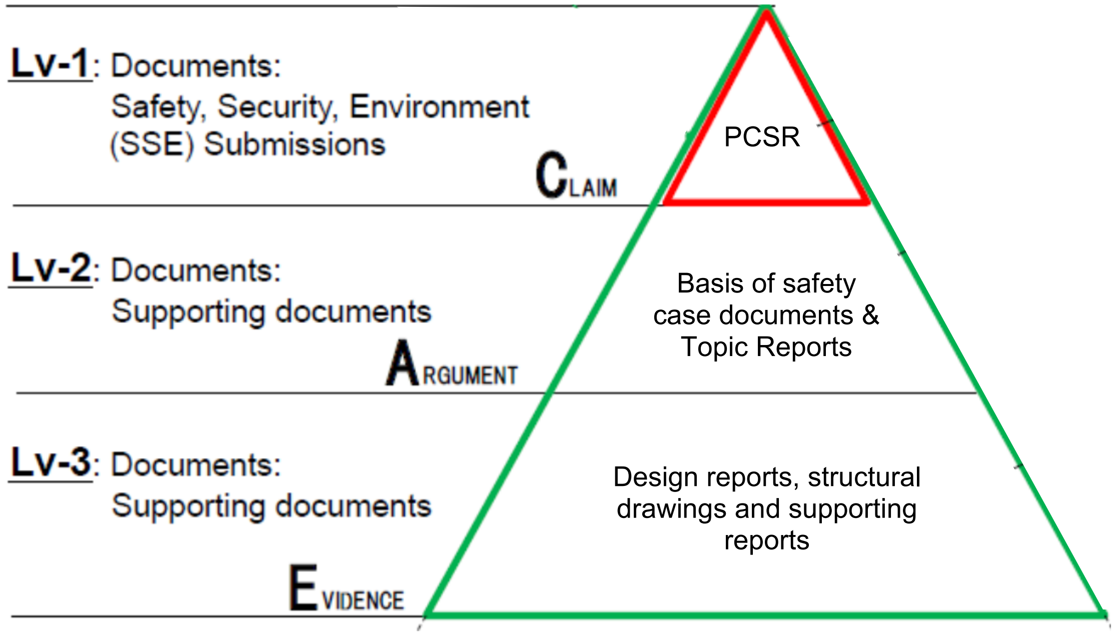


Figure 1: Safety Case Structure

3.2.1 Pre-Construction Safety Report (PCSR)

63. The PCSR is the lead document in the submission by the RP for Step 4 GDA. The most relevant chapters to this Step 4 assessment report for Civil Engineering are:

- Chapter 5 – General Design Aspects for approach and method for safety categorisation and classification and for seismic categorisation
- Chapter 10 – Civil Works and Structures
- Chapter 28 - ALARP Evaluation

64. I have reviewed the above chapters (see Section 4.3.22) as part of my civil engineering assessment. The PCSR is a "sign-post" document that provides the link between the RP's Nuclear Safety and Environmental Design Principles and the GDA Step 4 design. The PCSR Chapter 10 contains the structural descriptions and claims on buildings and tunnels. It also links the level 2 and 3 reports, providing a high level overview of the design and the interactions with other topic areas.

65. The safety case for the UK ABWR is based on multiple layers or key safety functions. The first layer of safety functions are the fundamental safety functions:

- Control of reactivity
- Fuel cooling
- Long term heat removal
- Confinement/Containment of radioactive materials
- Others

66. The second level of safety functions are the high level safety functions which are developed from each fundamental safety functions. The high level safety functions relevant to civil structures within GDA are:

- Function to provide physical support to the Structures, Systems and Components (SSCs)
- Function to maintain internal building environment appropriate for SSC

- Functions to provide confinement of radioactive materials, shielding against radioactivity.
- Function to cool spent fuel outside the reactor coolant system.
- Functions to limit the effect of hazards
- Function to minimise the release of radioactive material
- Supporting functions for on-site emergency preparedness

67. Each civil engineering structure will provide one or more high level safety functions and these are given as Safety Functional Claims (SFCs) and Safety Property Claims (SPCs) which are the third level of claims. SFCs are specific to each structure whereas SPCs are developed across all civil engineering designs. These are claims made on integrity, reliability, design principles and relevant good practice. I have included the SPCs in Annex 6.

3.2.1.1 RP'S DESIGN METHODOLOGY

68. The structural design of civil structures for the UK ABWR has been undertaken mainly to American codes. These codes are recognised within the UK as appropriate for nuclear structures. The main design standards are as follows:

- ACI 349-13: Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary
- ANSI/AISC N690-12: Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities
- ASME B&PV (Boiler & Pressure Vessel) Code, Sections II, III, V, VII, IX and XI

69. The analysis of the structures is based on ASCE 4 and comprises a two-step analysis. The Step 1 seismic analysis comprises a soil-structure interaction (SSI) analysis performed using dynamic finite element modelling (FEM) to obtain the seismic response. The Step 2 static stress analysis is performed using FEM where the seismic loads from Step 1 are combined with the other non-seismic structural loads. This analysis results in element force and moment demands which are then used to design the reinforcing steel and structural steel required for the structure.

70. To perform the two-step analysis the RP has used the following programmes:

- ACS SASSI is a Windows Software for linear and non-linear 3D seismic Soil-Structure Interaction. This programme is used to perform Step 1 – Seismic model for the buildings
- NASTRAN is a long established finite element code originally developed by NASA and now available to the public. The code can perform linear, non-linear, static and dynamic problems. This programme is used to perform Step 2 – Static stress analysis.
- STAAD Pro is a structural analysis and design computer program by Bentley Systems. It can perform traditional 1st order static analysis, 2nd order p-delta analysis, geometric non-linear analysis, pushover analysis (static-non linear analysis) and dynamic analysis. This programme is used to perform Step 2 – static stress analysis in tunnels.
- SAP2000 is structural analysis and design computer program by Computer and Structures Inc. It can perform linear, non-linear, static and dynamic analysis. This programme is used to perform Step 2 – static stress analysis.
- SuperFLUSH/2D is a 2-D strain dependent equivalent linear finite element program for efficient seismic soil-structure interaction analysis. This program is used to perform Step 1 – Seismic model for tunnels and tank foundations

71. I have discussed the software in sections 4.3.10, 4.3.12 and 4.3.15 of this report.

72. It should be mentioned that the full SSI analysis is only performed for the R/B, C/B and Fv/B and the rest of the structures are evaluated with a simplified analysis for the purposes of GDA (See Section 4.3.12).

73. The GDA design includes the design of the primary structural elements which form the main structural load paths and load resisting systems. Main areas of steel and section thicknesses are confirmed; however detailing of local elements and junctions is not within scope.

3.2.1.2 LOADINGS AND LOADING COMBINATIONS

74. The RP has designed the buildings to withstand a number of loads and fault conditions. This section describes the loadings and the fault conditions assumed in the design. The RP has considered the following Internal Hazard loads:

- Internal fire and explosion
- Internal flooding
- Pipe whip and jet impact
- Dropped and collapsed loads
- Internal conventional missiles
- Turbine disintegration
- Internal blast
- Electro Magnetic Interference (EMI) and Radio Emitted Interference (RFI)
- Miscellaneous internal hazards, e.g. onsite hazardous materials, transport accidents, pipeline accidents and natural gases from the ground
- Combined internal hazards
- Combinations of internal hazards with external hazards

75. I have assessed the capacity of a sample of walls and slabs to withstand some of the above internal hazards in Section 4.3.21.2 of this report.

76. The following external hazards have been considered on the UK ABWR design either in design basis or beyond design basis situation:

- Air temperature
- Wind
- Rainfall and ice
- Drought
- Snow
- Electromagnetic interference (EMI)
- Sea or river water temperature
- External flooding
- Seismic activity
- Loss of Off-Site power (LOOP)
- Aircraft impact
- External fire
- External missile
- External explosion

77. The generic design has used the seismic design spectra from the European Utility Requirements (EUR) and to account for some variation on the ground conditions two seismic spectra have been used, for hard and medium sites. The ground characteristics have been derived from EUR using lower bound, best estimate and upper bound soil properties for hard and medium sites. All ground characteristics have not been considered for all civil engineering structures during the seismic assessment and I have discussed this in Section 4.3.12.

78. Design basis faults have been divided into infrequent and frequent faults. Frequent faults are those design basis faults with an initiating event frequency greater than $1x10^{-3}$ per year. Infrequent faults have an initiating event frequency between $1x10^{-3}$ and $1x10^{-5}$ per year. Hitachi-GE has also stated that if a fault sequence made up of an initiating event plus the failure of the provided prevention or mitigation SSCs has a frequency greater than $1x10^{-7}$ per year, then that sequence is also considered a design basis fault (almost certainly an infrequent fault). The fault schedule for the civil engineering structure can be found in Chapter 10 of the PCSR. The design basis faults for the civil engineering structures include the above internal and external hazards and Loss of Cooling Accident (LOCA). I have discussed the interaction with Fault Analysis in Section 4.3.21.6 of this report.

79. PCSR Chapter 10 claims that UK ABWR civil structures are designed for normal and fault conditions. The RP claims that the following loads have been applied to the majority of civil engineering structures:

- Dead Load
- L: Live Load
- F: Fluid Load
- H: Lateral Soil Loads (Note: This includes vertical loads, i.e. weight of soil, lateral pressure and buoyancy loads)
- To: Thermal Loads (normal condition)
- Ta: Thermal Loads (fault condition)
- Ess: Seismic Loads
- W: Wind Load (basic wind)
- Wt: Wind Load (extreme wind)
- Ro: Pipe reaction loads (normal condition)
- Ra: Pipe reaction loads generated by a postulated pipe break
- Yj: Jet impingement load on the structure generated by a postulated pipe break
- Ym: Missile impact load on the structure generated by a postulated pipe break
- Yr: Load on the structure generated by a postulated pipe break
- Ccr: Crane load rated capacity – building crane with lifting loads. Monorail and lifting loads

80. The RP claims that the following loads have been applied to the RCCV:

- D: Dead loads, including hydrostatic and permanent equipment loads
- L: Live loads, including any movable equipment loads and other loads which vary with intensity and occurrence, such as soil pressures
- Pt: Pressure during the structural integrity and leak rate tests

- SRV: Loads resulting from relief valve or other high energy device actuation
- Pa: Design pressure load within the containment generated by the Design Basis Accident (DBA), based upon the calculated peak pressure with an appropriate margin
- Tt: Thermal effects and loads during the test
- To: Thermal effects and loads during normal operating or shutdown conditions based on the most critical transient or steady state condition
- Ta: Thermal effects and loads generated by the DBA including “To”
- Eo: Loads generated by the ½ DBE
- Ess: Loads generated by the DBE
- W: Loads generated by the design wind specified for the plant site
- Wt: Tornado loading including the effects of missile impact
- Ro: Pipe reactions during normal operating or shutdown conditions , based on the most critical transient or steady state condition
- Ra: Pipe reaction from thermal conditions generated by the DBA including “Ro”
- Rr: The local effects on the containment due to the DBA
- Pv: External pressure loads resulting from pressure variation either inside or outside the containment.
- Ha: Load on the containment resulting from internal flooding, if such an occurrence is defined in the Design Specification as a design basis even

81. I have included the load combinations for concrete structures, steel structures and the RCCV in Annex 7.

82. ONR’s assessment of the civil engineering structures, including the categorisation and classification of the structures, can be found in Section 4 of this report.

3.3 Description of the generic site

83. The final GDA layout for the UK ABWR is shown in the figure below:

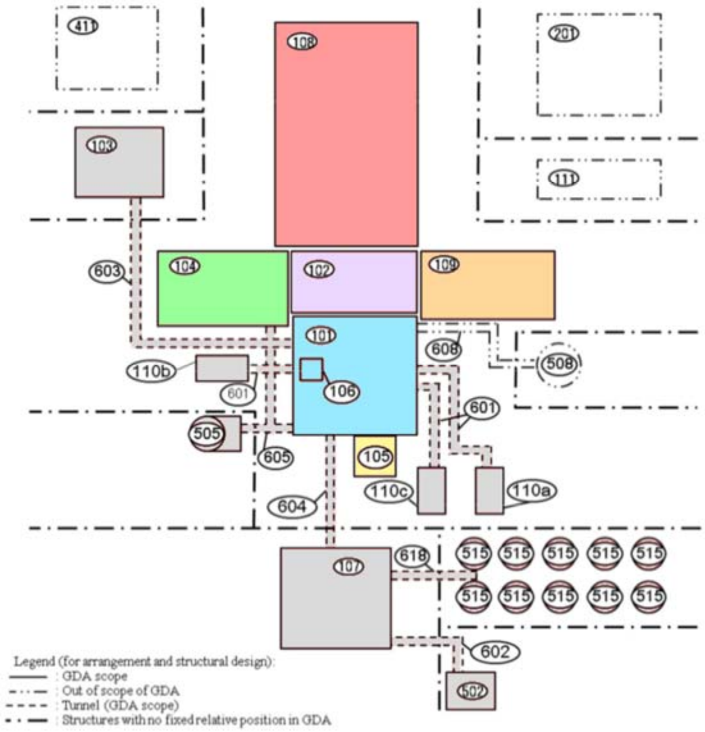


Figure 2: Revised generic site schematic layout assumed at the conclusion of Step 4 for GDA. North is defined to the top of this figure.

84. The buildings shown in colour in Figure 2 form the main cruciform of the nuclear island: Reactor Building, Service Building, Radwaste Building, Control Building and Turbine Building.

85. The building number, the safety category, safety class and seismic category are described below. This was previously assessed in Step 3 GDA. See also Section 4.3.2.

Table 6: Safety Category, Safety Class and Seismic Category of Structures

Building No.	Name	Safety Category	Safety Class	Seismic Category
	MAIN BUILDINGS / FACILITIES			
101	Reactor Building (R/B)	A	1	1
(101)	Reinforced Concrete Containment Vessel (RCCV)	A	1	1
102	Control Building (C/B)	A	1	1
103	Heat Exchanger Building (Hx/B)	A	1	1
105	Filter Vent Building (FV/B)	A	1	1
106	Main Stack	A/B	2	1
110 a,b,c	Emergency Diesel Generator Buildings (EDG/B) (three buildings, one for each division)	A	1	1
107	Backup Building (B/B)	A	2	1
108	Turbine Building (T/B)	B	2	2 /1A*
104	Radwaste Building (Rw/B)	C	3	2 /1A*

109	Service Building (S/B)	C	3	3 /1A*
	TANKS, UNDERGROUND FACILITIES			
502	Light Oil Storage Tank (LOT) Foundation	A	2	1
515	FLSS Water Storage Tank (WST) Foundation	A	2	1
505	Condensate Water Storage Tank (CST) Structure	A	2	2
	SERVICE TUNNELS/CONNECTIONS			
603	Reactor Cooling Water (RCW) Tunnel	A	1	1
601 a,b,c	R/B-EDG/B Connecting Service Tunnels (three tunnels, one for each division)	A	1	1
604	R/B-B/B Connecting Service Tunnel	A	2	1
602	B/B-LOT Connecting Service Tunnel	A	2	1
618	B/B-FLSS Water Storage Tank Connecting Service Tunnel	A	2	1
605	R/B-CST-Rw/B Connecting Service Tunnel	A	2	2

86. The classifications reflect the importance of each SSC to satisfy attributed safety functions.

- Safety Categories: The safety functions are categorised A, B or C in line with the ONR's SAPs. These safety functions are determined by the radiological hazards.
- Safety Classes: Individual SSCs are classified 1, 2 or 3 in line with the ONR's SAP ECS.2 – and according to the SSCs importance in delivering the corresponding safety function. The safety functions for the civil engineering structures can be found in Section 3.2.1.13.2.1 – PCSR of this report. The safety functions of each civil engineering structure can be found in Chapter 10 of the PCSR (Ref 26).
- Seismic Categories: Linked to both the safety categorisation and classification is the Seismic Category, 1, 1A, 2 or 3, which defines the seismic demand on the SSCs. The seismic categories are defined in Chapter 5 of the PCSR (Ref 147) and in section 4.3.2 –Structure classification of this report.

3.4 Main Building Structural Forms

3.4.1 Reactor Building (R/B) and Main Stack

87. The reactor building (R/B) houses the reactor pressure vessel (RPV), the primary containment vessel (PCV), major portions of the reactor steam supply system, steam tunnel, refuelling area, emergency core cooling systems, heating ventilation and cooling (HVAC) systems and additional supporting systems.

88. The PCV is provided by the reinforced concrete containment vessel (RCCV). The secondary containment is the R/B reinforced concrete building structure that forms the external weather envelope. The secondary containment boundary encloses the RCCV primary containment above the basemat.

89. The Reactor Building (R/B) is constructed of reinforced concrete with a structural steel frame that supports the reinforced concrete roof (dome). The R/B has four storeys above the ground level and three storeys below. The secondary containment, together

with the clean zone, comprises the R/B concrete structure and completely surrounds the RCCV. The R/B and the secondary containment share structural walls and slabs. The R/B slabs and fuel pool girders are constructed monolithically with the RCCV. The R/B, together with the RCCV and the Reactor Pressure Vessel (RPV) Pedestal, are supported by a common basemat.

90. The R/B is a 63.0 m x 61.0 m reinforced concrete structure that is 42.6 m high above grade. The total building embedment is 25.7 m. The basemat is 5.5 m thick. A series of arched steel frames are installed to support the reinforced concrete roof slab. The steel frames are supported by reinforced concrete columns above the operating floor. The R/B has six reinforced concrete floors which are monolithically connected to the primary containment. The operating floor level at +19.4 m is connected to the fuel pool girders, which are supported by the primary containment and the R/B. Inside the R/B, there are 18 columns supporting the floors.

91. The Spent Fuel Pool (SFP) is constructed monolithically with the RCCV and the R/B. The SFP is located just next to the reactor inside the R/B and the secondary containment but outside the PCV. The operating floor slab and the SFP are supported by the fuel pool girders, which are deep, reinforced concrete beams. These span north to south, between the RCCV and the R/B external walls. The reinforced concrete pool structure is lined internally with a stainless steel liner. The stainless steel liner is the first barrier and the SFP concrete walls form the second barrier. This second barrier is entirely within the R/B and so is not the final barrier to the outside environment.

92. The Main Ventilation Exhaust Stack serves the radiation controlled area within the plant, namely the R/B, Turbine Building (T/B), Radwaste Building (Rw/B), and a small portion of the Filter Vent Building (FV/B), Control Building (C/B) and Service Building (S/B). The Main Stack is a steel structure and it is constructed on the top of the roof structure of the R/B. The Main Stack houses the main plant exhaust duct and Standby Gas Treatment System exhaust piping. Its height has been calculated by the generic radiological dispersal assessment. This height will need to be confirmed for site specific design.

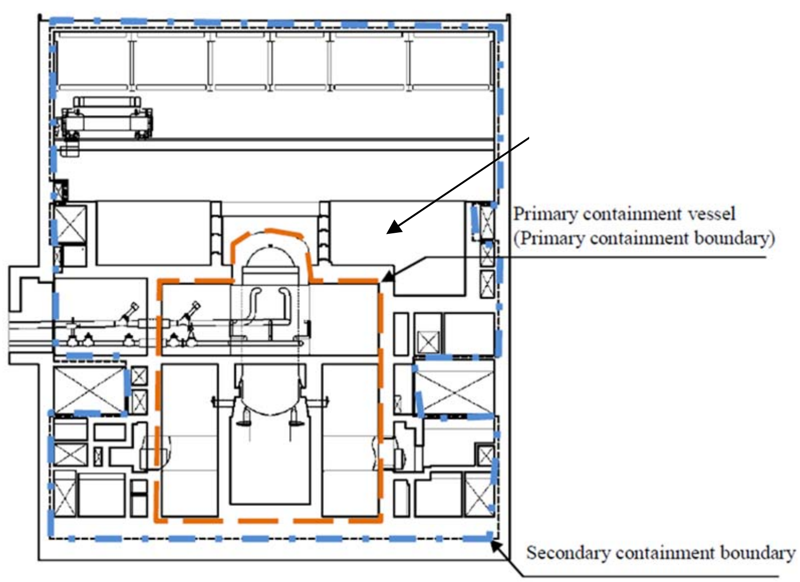


Figure 3: Section of reactor building structure with primary and secondary containment barriers identified

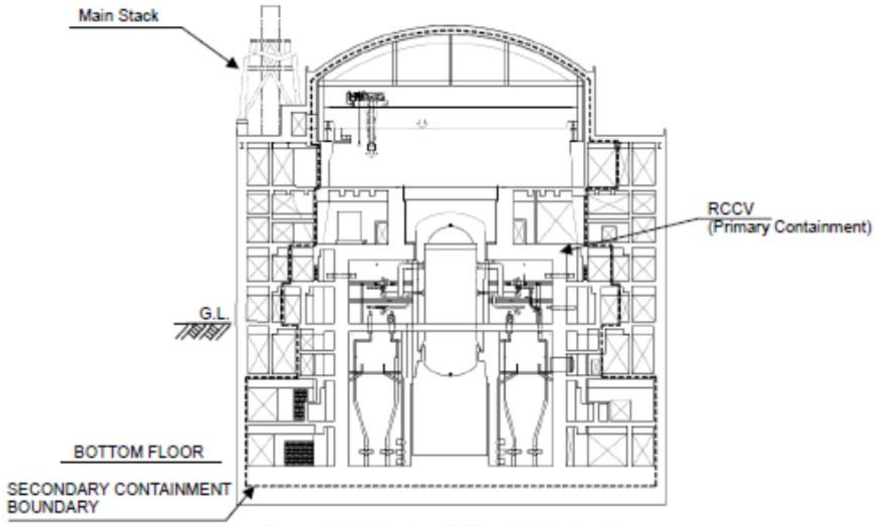


Figure 4: Reactor building structure

3.4.1.1 REINFORCED CONCRETE CONTAINMENT VESSEL (RCCV)

93. The primary containment vessel of the UK ABWR is a RCCV consisting of reinforced concrete (RC), the RCCV steel liner and Metal Containment (MC) components. The RCCV is integral with the R/B and is intended to provide a leak tight barrier against the uncontrolled release of radioactivity to the environment.

94. The RCCV is not pre-stressed and is formed of reinforced concrete with walls in the range of 2.0m thick; the base mat is in the order of 5.5m thick and the construction joints arranged to reduce the potential for through thickness cracking.

95. The RCCV Internal Structures provide equipment support, radiation protection, and are required for operation of the UK ABWR pressure suppression containment. The RCCV. Internal Structures include the RPV Pedestal, Vent Pipes, Reactor Shield Wall (RSW), Diaphragm Floor (D/F) and Lower Drywell Access Tunnel. The general arrangement of the RCCV is shown in Figure 5. The internal diameter of the RCCV is 29 m, and the height from the upper surface of the basemat to the upper surface of the Drywell (D/W) Head (also referred to as Upper Drywell (U/D) Head) is 36 m.

96. The RCCV, which is a pressure suppression type, is divided into the D/W that contains nuclear reactor primary system; the Suppression Chamber (S/C) that stores water; Vent Pipes that connect the D/W and the S/C by being embedded into the RPV Pedestal; and vacuum breakers. The Diaphragm Floor (D/F) partitions the RCCV into the Upper Drywell (U/D) and Suppression Chamber (S/C). The area inside the RPV Pedestal is called the Lower Drywell (L/D) and the area outside is the S/C. See Figure 5 below.

97. The thickness of the RC structural wall is 2m, which includes the steel liner thickness (6.4mm). Steel anchors (T sections) are welded to the steel liner and with the exception of the bottom liner, the liner is utilised as a permanent formwork when casting the concrete. Hence, the steel anchors are cast in the RC structure and will anchor the steel liner to the concrete. The liner provides leak prevention from the RCCV. The RC structure is supported by the RC foundation to provide the primary containment pressure barrier of the RCCV and is classified as ASME Boiler & Pressure Vessel Code Section III, Division 2, Concrete Containments.

98. Penetrations through the containment pressure boundary include the U/D Head, Equipment Hatches into U/D and L/D regions, personnel airlocks into U/D and L/D, a

combined personnel access and equipment hatch (wet well hatch) into the S/C, and pipe and electrical penetration sleeves. These Containment Penetrations are steel structures classified as ASME B&PV Code Section III, Division 1, Subsection NE, Class MC Components and are referred to as Metal Containment Components. These MC components are part of the Structural Integrity remit, and so they have been assessed within the Structural Integrity report (Ref 10). As explained in section 4.3.21.3, I have assessed how the forces from these components have been transferred to the RC.

99. The RPV Pedestal and the D/F separate the containment volume into D/W and S/C regions. The RPV Pedestal forms the L/D region and consists of two to five concentric steel cylinders, joined together radially by vertical steel diaphragms and filled with concrete. It is anchored to the basemat and supports the RPV through a support ring girder. The RPV Pedestal also supports the RSW.

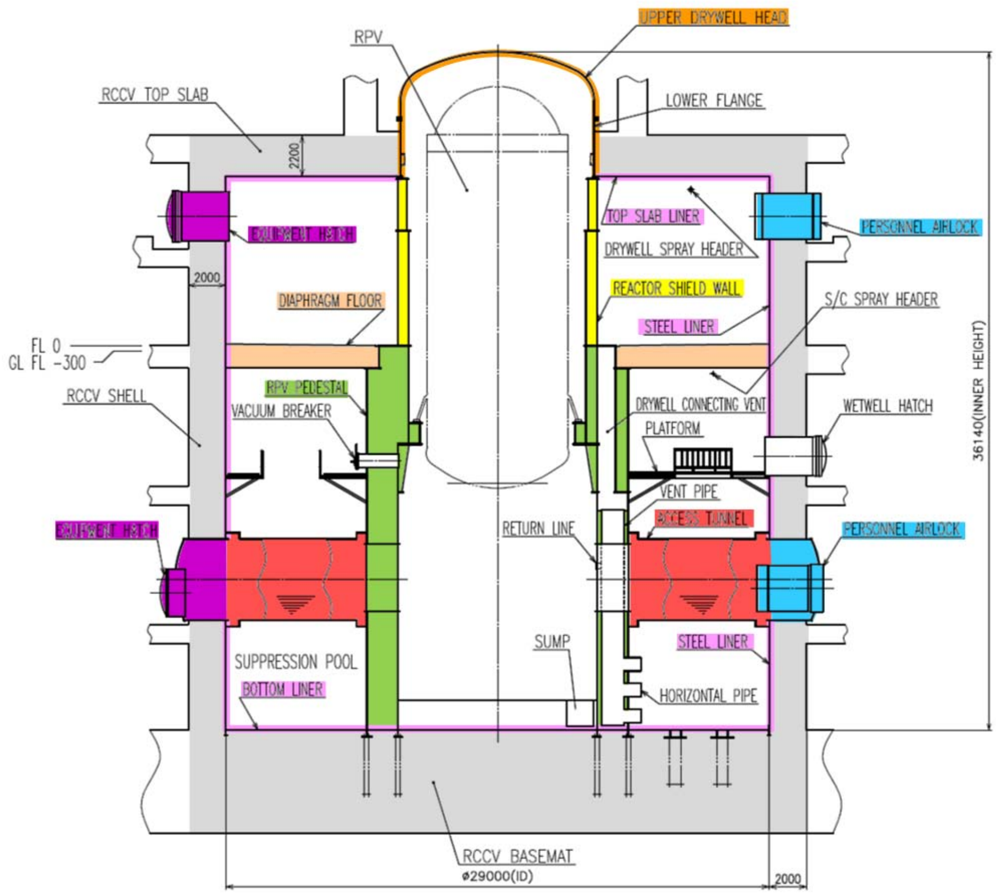
100. The RPV Pedestal, the D/F, the access tunnel and the RSW are also MC components. However, these components fall within the civil engineering remit, and so they have been assessed within this report.

101. Within this report, the term MC components refers only to the MC components assessed by civil engineering, which are:

- RPV Pedestal
- Diaphragm Floor
- Reactor Shield Wall
- Access Tunnel

102. From a civil engineering point of view, the RPV pedestal is the main load bearing structure as it carries the loading from the RPV, diaphragm floor, RSW and access tunnel to the RCCV basemat.

103. Figure 5 below shows the configuration of the RCCV and its MC components.



Grey = RCCV, Green = Pedestal, Yellow = Shield Wall (**RSW**), Salmon = diaphragm floor (**D/F**), Purple = Equip. Hatch, Blue = Person Airlock, Red = Tunnel, Orange = Drywell head, Pink = liner

Figure 5: RCCV Configuration

3.4.2 Control Building (C/B)

104. The Control Building is a 43.60m x 59.40m structure that is 16.80m high above grade (i.e., top roof level excluding shafts). The total building embedment is 25.50m. The basemat is 2.80m thick. It consists of five floors, three of which are below grade. It is a reinforced concrete structure consisting of walls and slabs. Steel girders and beams are used to support the roof slab. Inside the C/B, there are 15 columns supporting the floors.

105. The main steam tunnel runs through the C/B at ground floor level and connects the R/B and the T/B. The tunnel is closed at the R/B end and opens at the T/B end. The main steam tunnel is designed to withstand pressurisation effects that could occur within it as a result of postulated rupture of pipes containing high energy fluid. The tunnel has no penetrations into the C/B. The concrete thickness of the tunnel walls, floor and ceiling are designed to minimise the potential dose rate to operators.

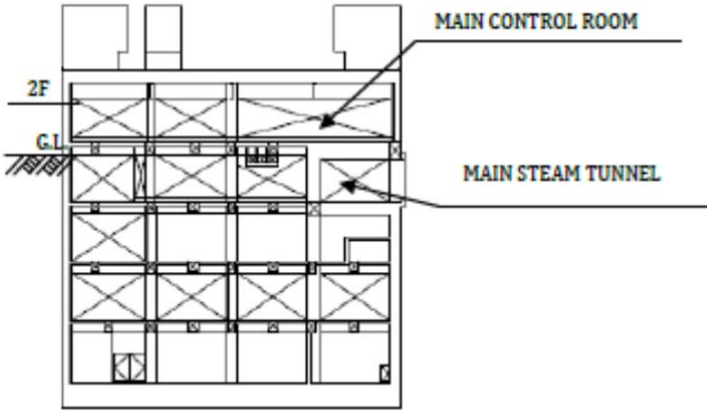


Figure 6: Section of Control Building

3.4.3 Heat Exchanger Building (Hx/B)

106. The Hx/B is a 61.0 m × 43.5 m, reinforced concrete and structural steel structure. The structure has two stories above ground level and one story below ground level. Design of the intake pond within the Hx/B will be a site specific aspect. The mechanical portion of the Hx/B consists of four separate divisional areas of Reactor Cooling Water and Turbine Cooling Water trains.

3.4.4 Filter Vent Building (FV/B)

107. The Filter Vent Building is a 25m × 43m, reinforced concrete structure. The structure has one floor above ground level and three floors below ground level.

3.4.5 Emergency Diesel Generator Building (EDG/B)

108. The EDG/B is a reinforced concrete structure which is 27.5m by 19.5m in plan. The structure has three stories above ground and one storey below. The roof level is 15.6m above general site datum level (ground level). The basement is 11.6m deep and the foundation slab is 3m thick. There are 3 EDG/B shown in Figure 1.

3.4.6 Backup Building (B/B)

109. The B/B is a 44.0 m x 44.0 m, reinforced concrete structure. The structure has three stories above ground and two stories below ground. The B/B is 23.2 m high above grade. The total building embedment is 15.8 m.

110. Mechanical components that have safety redundancy are housed with segregation as defence in depth safety enhancement. This building is located away from the other safety related buildings in order to enhance redundancy of core and spent fuel pool cooling capability against potential risks of damage to the main buildings such as the R/B, C/B and Hx/B.

3.4.7 Turbine building (T/B)

111. The T/B houses the main turbine generator (T/G) and other power conversion cycle equipment and auxiliaries. The T/B is located adjacent to the Safety Class 1 C/B. The T/B is a 114.5 m x 75.9 m, reinforced concrete and structural steel structure. The structure has three stories above ground and two stories below.

3.4.8 Radwaste Building (Rw/B)

112. The Rw/B is a 39.8 m × 52.0 m, reinforced concrete and structural steel structure. The structure has three stories above ground and three stories below.

3.4.9 Service Building

113. The S/B is constructed of reinforced concrete (RC). The S/B is 65.0 m x 43.6 m on plan. The maximum roof height is 21.1m above ground floor slab level, with parts of the roof at 4.9m and 16.0 m. The S/B has five main floors, including one basement level.

3.5 Tanks and Underground Facilities

114. The RP submitted the design of the civil structures supporting and enclosing the tanks (as stated below) but did not submit the design of the tanks themselves, or the holding down bolts, as part of GDA.

3.5.1 Light Oil Storage Tank (LOT) Foundation

115. The LOT is a vertical cylindrical steel tank, anchored to the LOT foundation structure. The foundation structure consists of a reinforced concrete slab that supports the tank and a peripheral bund wall. The bund wall is constructed monolithically with the LOT foundation structure.

3.5.2 Flooder System of Specific Safety Facility (FLSS) Water Storage Tank (WST) Foundation

116. The FLSS WST is a vertical cylindrical steel tank, anchored to the FLSS WST Foundation. The FLSS WST Foundation consists of a reinforced concrete slab (tank foundation). The external structural size of FLSS WST Foundation is 15.5m x15.5m by 3.5m height (1m for shear key). There are 10 of these tanks shown in Figure 1.

3.5.3 Condensate Water Storage Tank (CST) Structure

117. The CST is a vertical cylindrical steel tank, anchored to the CST Structure. The structure consists of a reinforced concrete top slab, bottom slab and a peripheral external shielding wall. The external shielding wall is constructed monolithically with the CST Structure bottom slab.

3.6 Service Tunnels/Connections

118. The GDA design for service tunnels is based on 15m longitudinal units and does not consider features such as bends, access chambers, drainage sump pits, intersections, merges, terminations and crossing points. Each unit is isolated by joints, provided to accommodate movement, particularly in a seismic event. However, since the final arrangement of the tanks and the tunnels will not be confirmed until site specific stage, the exact tunnel lengths are not known.

119. The alignment of the tunnels is also expected to include angled sections to facilitate changes in direction of the piping and cable routes.

3.6.1 Reactor Cooling Water (RCW) Tunnel

120. The RCW Tunnel is an underground reinforced concrete structure which is rectangular in cross section. There are two internal walls which divide the tunnel into three cells.

3.6.2 R/B-EDG/B Connecting Service Tunnels

121. The R/B-EDG/B Connecting Service Tunnel is an underground reinforced concrete structure consisting of walls and slabs. The transverse section of the tunnel consists of a single cell.

3.6.3 RB/-B/B Connecting Service Tunnel

122. The R/B-B/B Connecting Service Tunnel is an underground, reinforced concrete structure which is rectangular in cross section. There is a central, internal wall which divides the tunnel into two cells.

3.6.4 B/B-LOT Connecting Service Tunnel

123. The B/B-LOT Connecting Service Tunnel is an underground reinforced concrete structure, consisting of walls and slabs. The transverse section of the tunnel consists of a single cell.

3.6.5 FLSS Water Storage Tank Connecting Service Tunnel

124. The B/B-FLSS WST Connecting Service Tunnel is an underground reinforced concrete structure, rectangular in cross section with one internal wall, thus providing two segregated tunnels; A and B. The major systems housed within the tunnel are supported on cable trays and pipe support brackets attached to the inside faces of the walls. The external structural size of B/B-FLSS WST Connecting Service Tunnel in GDA is 8.3m width by 6.7m height.

125. The tunnel runs between the 10 FLSS Water Storage Tank Foundations and the B/B, so is expected to include angled sections to facilitate changes in direction of the piping and cable routes.

3.6.6 R/B-CST-Rw/B Connecting Service Tunnel

126. The R/B-CST Connecting Service Tunnel is an underground reinforced concrete structure consisting of walls and slabs. The transverse section of the tunnel consists of a single cell.

4 ONR STEP 4 ASSESSMENT

128. This assessment has been carried out in accordance with ONR internal guidance on the "Purpose and Scope of Permissioning" (Ref 3).

4.1 Scope of Assessment Undertaken

129. The scope of the assessment covers nine principal buildings, six service tunnels and three tank structures:

- Reactor Building (R/B), including:
  - Spent Fuel Pond
  - R/B Stack.
  - Reinforced Concrete Containment Vessel (RCCV).
  - Internal components of the RCCV: RCCV Liner anchors, RPV Pedestal, Diaphragm Floor (D/F), Access Tunnel and Reactor Shield Wall (RSW).
- Control Building (C/B).
- Heat Exchanger Building (Hx/B).
- Turbine Building (T/B), including:
  - Internal T/G Pedestal.
- Radwaste Building (Rw/B).
- Backup Building (B/B).
- Service Building (S/B).
- Filter Vent Building (Fv/B).
- Emergency Diesel Generator Building (EDG/B).
- Reactor Cooling Water (RCW) Tunnel.
- R/B – B/B Connecting Service Tunnel.
- R/B – EDG/B Connecting Service Tunnel.
- Light Oil Storage Tank (LOT) Base and Connecting Service Tunnel.
- Condensate Storage Tank (CST) Structure and Connecting Service Tunnel.
- Flooding System (FLSS) Water Storage Tank Base and Connecting Service Tunnel.

130. The RP divided the GDA buildings above into two design packages:

- Group 'A' structures are described as having full design packages for the GDA. The Group A structures includes the R/B, RCCV, Fv/B and C/B.
- Group 'B' structures are described as having reduced design packages for the GDA. These reduced packages include technical details of the civil structures that the RP believes to be appropriate to facilitate a meaningful generic design assessment. The Group B structures include Hx/B, T/B, B/B, EDGs, S/B and Rw/B.

131. I have provided more detailed information on the design packages in Section 4.3.1 of this report.

132. At this GDA stage, it has been acknowledged by the ONR that full construction information is not expected. Instead the RP has been expected to present a design that: is demonstrated to be viable; is based on relevant good practice; and recognises and makes clear the maturity of the design.

133. ONR's scope included the assessment of Chapter 10 of the PCSR (Ref 26), generic documents such the Examination, Maintenance, Inspection and Testing (EMIT) report (Ref 112) and a number of cross cutting reports (see Section 4.3.21).

4.2 Assessment Methodology

134. ONR has carried out an assessment of all Basis of Safety Cases and Design Reports submitted by the RP. The level of detail of this assessment has been done on a sample basis, and so some of the design calculations and methodologies have been examined in detail by ONR during the assessment process. Comments and queries are recorded in the comment registers (Ref 132, Ref 133, Ref 134 and Ref 135). This report records and summarises the deferred or open comments and queries.

135. At the beginning of Step 4, there were a number of Step 3 comments (Ref 132 and Ref 134) still open (see Section 2.6). All Step 3 comments were reviewed and assigned a final status during Step 4, as follows:

- Step 4 - The comment remained unresolved. It was transferred to the Step 4 comment register and assigned a new Step 4 comment ID.
- Deferred - Aspects of the comment remained unresolved, but there is agreement between the ONR and RP that further work will be conducted during the site-specific design.
- Closed - The comment had been resolved.

136. All Step 3 deferred comments have been included in this report with their original comment ID (all Step 3 comments start with a letter).

137. During Step 4, the RP provided responses to the Step 4 comments raised during this phase and to the Step 3 comments included in the Step 4 comment register.

138. Each comment raised during Step 4 assessment was assigned an initial Concern Level, defined as follows:

- Concern Level A Potential Regulatory Issue (RI)
- Concern Level B Potential Regulatory Observation (RO)
- Concern Level C Potential Regulatory Query (RQ)
- Concern Level D Potential Site Specific Issue

139. Responses and information received from the RP in response to the assessment comments are captured in the comment registers (Ref 132, Ref 133, Ref 134 and Ref 135) and have been considered during the assessment. In light of the responses and any other relevant additional information received, the Step 4 comments have been assigned a final status as follows:

- Open The comment remains unresolved and is of Concern B.
- Deferred Aspects of the comment remain unresolved, but there is agreement between the ONR and RP that further work will be conducted during the site-specific design. This is limited to Concern Level C and D comments.
- Closed The comment has been resolved.

140. All open and deferred queries and comments are discussed within this report and are identified in the text with the same ID as per the comment registers (Ref 132, Ref 133, Ref 134 and Ref 135). There are only 3 open comments, and these have been captured in three specific Assessment Findings (AF).

141. This assessment is divided into a number of technical themes. Some of the technical themes align with those presented in the TSC's reports (Ref 15 and Ref 16) and have been grouped as follows:

- Completeness of the GDA design/ Reduced Scope
- Structure classification
- Design codes and standards

- Site layout
- Structural interfaces
- Ground conditions and site envelope
- Structural discrepancies
- Loads & load combinations
- Materials
- Analysis
- Member and connection designs
- Seismic Design
- Stability
- Serviceability and fire
- Custom software – Verification and validation
- Construction
- Accuracy of the RP's Safety Case
- Reinforced Concrete Containment Vessel
- Leak detection systems
- Examination, Maintenance, Inspection and Testing (EMIT)
- Cross Cutting Topics
    - External Hazards - Cliff Edge effect
    - Internal Hazards
    - Structural Integrity
    - Conventional Safety
    - PSA – RCCV Ultimate Pressure Capacity
    - Severe Accident Analysis
    - Decommissioning
- PCSR – Chapter 10
- ALARP
- Reliability of the civil engineering design

142. The following RQs have been raised during Step 4 to ensure that the assessment comments are captured by the regulatory process.

Table 7: RQs raised during Step 4

RQ Number	Title	Reference
RQ-ABWR-0898	Reactor Building construction method statement	Ref 136
RQ-ABWR-1125	Civil Engineering Queries on Impacts of Construction Techniques on Decommissioning	Ref 137
RQ-ABWR-1387	UK ABWR Review of Cliff Edge Effects on Civil Structures	Ref 138
RQ-ABWR-1402	UK ABWR Civil Engineering Supporting Report Examination, Maintenance, Inspection and Testing for Civil Engineering	Ref 139
RQ-ABWR-1405	UK ABWR Step 4 Seismic Assessment	Ref 140
RQ-ABWR-1406	UK ABWR Step 4 Civil Design Assessment	Ref 141
RQ-ABWR-1411	UK ABWR Ultimate Capacity Evaluation for RCCV Concrete Structure	Ref 142
RQ-ABWR-1419	UK ABWR Step 4 Geotechnical	Ref 143

	Assessment	
RQ-ABWR-1488	UK ABWR Ultimate Capacity Evaluation for RCCV Concrete Structure Update #2	Ref 144

143. I have not raised any ROs during Step 4.

4.3 Assessment

144. During the Step 4 assessments the civil engineering structures listed above (Section 4.1) were assessed. The assessed structures were generally deemed to be designed using relevant good practice; however, as discussed in this report, a number of queries were raised as part of the assessment with most being answered satisfactorily with a number being deferred to the site specific stage. These outstanding queries are captured within assessment findings and none of these queries are significant to prevent the issuing of the DAC.

145. The following sections deep dive into a number of civil engineering design aspects and conclude in several assessment findings. Therefore, the first part of the assessment provides a very specific level of detail which reflects the queries made by ONR. I also present the overall assessment of the design in the ALARP and Reliability sections of this report, where I consider the civil engineering design holistically. These sections are critical to understand the civil engineering design as a whole and its suitability.

4.3.1 Completeness of the GDA design/ Reduced scope

146. Following Step 3 GDA, the Step 4 GDA of the civil structures commenced and this included the assessment of 14 Basis of Safety Case documents and 30 Design Reports. A specialist Technical Service Contractor (TSC) was appointed to assist with the assessment of the detail analysis and design. All the GDA civil structures and a range of MC structures were included. Nineteen further Design Reports were subsequently added to the GDA scope by the RP. A number of the Design Reports were further sub-divided to isolate Sensitive Nuclear Information (SNI) into Official-Sensitive documents. See also section 4.1 of this report.

147. As a result of delays to the RP's delivery Step 4 program, due to the change from "lumped mass on spring" type of seismic analysis models to the more accurate finite element (FE) type models, the RP proposed to reduce the scope of the analysis of a number of the GDA civil structures, and this was accepted by ONR. The proposal was presented to ONR in the document Soil Structure Interaction (SSI) Model Approach Deliverables Plan and Schedule Plan in GDA (Ref 146) and it is summarised in the Seismic Design Methodology Report (Ref 46).

148. Briefly, it was proposed that the scope of the seismic/structural analysis work was reduced as described below:

- Group "A" civil structures have a full analysis and design package to provide complete compliance with the requirements included in ONR guidance (Ref. ONR-GDA-GD-001, Rev.2). (No reduction in scope).
- Group "B" civil structures have a reduced design package that the RP believes to be appropriate to facilitate a meaningful GDA. (Major reduction in scope, see below).

149. The Group "A" civil structures include the Reactor Building with the RCCV, the Filter Vent Building and the Control Building. Comments regarding the assessment of this group of structures are captured in this report and detailed in the TSC assessments.

150. The Group “B” civil structures include the Heat Exchanger Building, the Turbine Building, the Backup Building, the Emergency Diesel Generator Building, the Radwaste Building and the Services Building. The reduction in scope involved a reduced design process with fewer load combinations, the use of best estimate soil properties to estimate SSI (the seismic load) and manual calculations of typical member details. This approach was accepted in principle and comments regarding the assessment of this group of structures are captured in this report and detailed in the TSC assessments.

151. Other structures included in the GDA, but not formally assigned to a group, include the RCCV internal structures, the Reactor Building Main Ventilation Stack, and a number of Tanks and Tunnels. The RCCV internal structures and the Reactor Building Main Ventilation Stack were analysed using the R/B seismic motion. The tanks and tunnels were dealt with as Group B and the detail of the submissions was limited as described above. The tanks that are excluded from GDA so the assessment comments within this report are given for the thank foundations only.

152. It is of note that the potential full scope of UK ABWR civil structures is outlined in the Overview of UK ABWR Civil Structures (Ref 27) and this indicates other major civil structures excluded from the GDA, as they were judged by the RP to be dependent on site specific criteria. These exclusions from GDA include major works including the cooling water intake and outfall facilities, along with any necessary marine structures.

153. I judge that, while the agreed GDA scope is largely complete, subject to the Assessment Findings and Minor Shortfalls, the RP intends that a significant number of key civil structures will be considered during later phases of the design. See also section 2.5 of this report.

4.3.2 Structure classification

154. The process for categorising safety functions and classifying the safety class of structures, systems and components (SSC) relevant to the design of the UK ABWR civil structures is described in Chapter 5 of the Generic PCSR (Ref 147).

155. The RP has used the ONR Safety Assessment Principles (SAPs) for guidance and developed the following criteria for the categorisation of safety functions, and this has been assessed by others within ONR. Three categories of safety function have been assigned, as follows:

- Category A safety functions play a principle role in ensuring nuclear safety, in that they are associated with the removal of intolerable risks from design basis (DB) faults, by either prevention of risks or the reduction of the risks to broadly acceptable levels.
- Category B safety functions make significant contribution to nuclear safety, in that they are associated with the removal of radiological risks outside the DB, by either preventing the risks or reducing the risks to broadly acceptable levels for foreseeable events and beyond design basis (BDB) faults, which are identified in fault studies. Functions whose failure would lead to a demand on a Category A safety function are also categorised as B.
- Category C safety functions are those that do not fall into either Categories A or B. They are mainly associated with support of Category A or B functions or identified from ALARP or Best Available Technology (BAT) analyses.

156. The RP has used the ONR Safety Assessment Principles (SAP) for guidance and produced the following criteria for the safety classification of the civil structures (SSCs), and this has been assessed by others within ONR. The civil structures have been assigned to one of three classes, as follows:

- Class1 SSCs are claimed as being the principal or first-line means of delivering Category A safety functions and referred to as A1.
- Class 2 SSCs are claimed as being the second line or diverse means of delivering a Category A safety function, or the principal or first line means of delivering a Category B safety function, and referred to as A2 and B2 respectively.
- Class 3 SSCs are claimed as providing a third line means of delivering a Category A safety function, a second line means of delivering a Category B safety function or as delivering a Category C safety function, and are referred to as A3, B3 and C3 respectively.

157. The response of the civil structures to seismic motions dictates many of the civil structure details and much of their form. Consequently, each civil structure is assigned to a seismic category that corresponds to the consequences of failure, either in terms of any requirement on the civil structure to provide its safety function during and following a seismic event or in terms of radiological dose (onsite / off-site consequences) as a result of the civil structure failing due to seismic event. The civil structures are assigned to one of the following seismic categories.

- Seismic Category 1 civil structures are designed to withstand the Design Basis Earthquake (DBE) (with an annual probability of exceedance of 10^{-4}) in combination with other coincident loads and are required to maintain structural and functional integrity. These civil structures are those necessary to prevent or mitigate the consequences of seismic events which could result in a potential on-site unmitigated dose consequence >200mSv or off-site unmitigated dose consequence >10mSv.
- Seismic Category 1A civil structures are designed to withstand the DBE in combination with other coincident loads to prevent interactions (including collapse) with Seismic Category 1 civil structures or other Seismic Category 1 SSCs.
- Seismic Category 2 civil structures are designed to withstand less than the DBE (an event with an annual probability of exceedance of 10^{-3}) in combination with other coincident loads and are required to maintain structural and functional integrity. These civil structures are those necessary to ensure the capability to prevent the consequences of seismic events which could result in a potential on-site unmitigated dose consequence >20mSv or off-site unmitigated dose consequence >1mSv.
- Seismic Category 3 civil structures are those not categorised as Seismic Categories 1, 1A or 2. These SSCs are designed for the Operating Basis Earthquake (OBE) value which is set at 10^{-2}/yr event.

158. I have considered the assignment of the civil structures to Seismic Categories 1 and 2, along with the corresponding level of earthquake resistance, against the Basic Safety Level (BSL) targets for effective dose received by any person arising from a design basis fault sequence as advised by the SAPs Target 4, and judge that the assignment of RP's Seismic Category 1 and 2 civil structures to their seismic categories satisfies the targets for both on-site and off-site doses.

159. The RP's assignment of each civil structure, within GDA, into safety categories, safety classes and seismic categories is summarised in the RP's document, Overview of UK ABWR Civil Structures (Ref 27). The requirements of this summary document are included in the Basis of Safety Case and Design Report for each civil structure. The majority of civil structures included in GDA are categorised as Seismic Category 1, 2 or 1A. Category 1A civil structures are Category 2 or 3 civil structures that must not damage adjacent Category 1 civil structures as a consequence of earthquake.

160. The classification of the civil engineering structures will govern the design codes, standards and design methods to be used for each class of structure. This ensures that the reliability of the design matches the safety significance.

4.3.2.1 CONCLUSION – STRUCTURE CLASSIFICATION

161. From a sample of the categorisation processes in the Basis of Safety Cases and Design Reports, considered against SAPs ECS.1 and ECS.2, I can judge that the civil structures have been appropriately classified on the basis of their safety functions and their significance to safety.

4.3.3 Design Codes and Standards

162. Design codes and standards are set out as a list of references within each Design Report and Basis of Safety Case Report. They are also presented in a consistent format across the structures in the overview report.

163. The strategy taken by the RP is:

- Adopt American codes for strength design (the Ultimate Limit State).
- Adopt a combination of American and European codes for serviceability design.
- Plan for material specification in accordance with European and British codes, by extensively comparing relevant American and European codes.

164. Noteworthy comments on the selected codes are discussed in the following subsections. All codes and standards used in the civil engineering assessment of Step 4 GDA are referenced in Annex 3.

4.3.3.1 DESIGN LOADS

165. In line with the adoption of American codes for strength design, ASCE 4 and ASCE 7 have been used for determining design loads.

166. ASCE 4 is a seismic code and its application is discussed in Section 4.3.12 of this report.

167. ASCE 7 defines static loads. The 2005 revision, ASCE 7-05, has been adopted by the RP consistently across all buildings. However, ASCE 7 has been revised twice since 2005 with a major revision in 2010 and a minor revision in 2016.

168. The RP is using the 2005 revision, ASCE 7-05, because it is referenced in ACI 349-13 and ASME III-2. It is therefore reasonable that it is considered. However, it would be expected that a comparison to the later revisions be undertaken to understand the potential impact of the updates made to ASCE 7. I would judge this to be relevant good practice and therefore this is captured in assessment finding AF-ABWR-CE-01.

4.3.3.2 MATERIALS

169. Where specified, materials are generally in accordance with European and British standards, namely BS 8500-1, BS EN 206-1, BS EN 10080, BS 4449 and BS EN 10025-1. These are all current standards at the time of reporting.

170. The significance of European/British material standards being used with American design codes is discussed further in Section 4.3.9.

4.3.3.3 STRENGTH DESIGN

171. Structural steel is designed to AISC N690-12 which references AISC 360-10 as the non-nuclear base code. AISC N690-12 is the latest revision at the time of reporting.

AISC 360 underwent a minor update in 2016; the update is not referenced in AISC N690-12 and has not been used by the RP.

172. Similarly, structural concrete is designed to ACI 349-13 with ACI 349.1R-07 and ACI 318-14. Each of these are understood to be current at the time of reporting.

173. Concrete and steel for the pressurised MC components within the RCCV are designed to ASME Sec. II and Sec. III as applicable. These are also understood to be current at the time of reporting.

174. Of the codes adopted, the principle codes (i.e. AISC N690, ACI 349 and ASME) have each been developed specifically for nuclear applications.

175. All the GDA civil engineering structures are nuclear safety significant structures and are designed to the above codes.

4.3.3.4 SERVICEABILITY DESIGN

176. There is limited attention to serviceability design within the GDA reports. Where it has been considered, the following codes are adopted:

177. Waterproofing, crack control and durability are based on Eurocode requirements, supplemented by complimentary British Standards and CIRIA guidance (see 4.3.14).

178. Deflections are judged using span to depth criteria defined in ACI 349-13.

179. See Sections 4.3.14.1 and 4.3.14.3 for further discussion on each of the above respectively.

4.3.3.5 FIRE RESISTANT DESIGN

180. The RP references BS 9999:2008 for guidance on fire safety.

181. A revision has been published in 2017, generally with minor updates to the cross referenced codes.

182. In response to Comment 01-RB04, the RP has stated that they will consider the changes at the site-specific stage. I consider the RP's response adequate.

4.3.3.6 USE OF METRIC AND IMPERIAL CODES

183. Many of the default American codes, including ACI 349 and ACI 318, are published assuming imperial units. Metric counterparts are generally available but formerly distinguished within their titles (e.g. ACI 349M vs ACI 349).

184. This becomes significant where using functions with parameters and/or constants that are dimensional; Figure 7 gives an example.

For members subject to shear and flexure only,

$$V_c = 2\lambda\sqrt{f_c'}\, b_w d$$

For members subject to shear and flexure only,

$$V_c = 0.17\sqrt{f_c'}\, b_w d$$

Figure 7: Comparison of formulae for shear resistance, from ACI 318 (upper) and ACI 318M (lower).

185. As presented, a number of the RP's reports for each of buildings, tunnels and tank bases did not state whether the metric or imperial code is assumed. Indeed, the original references imply imperial codes; meanwhile the calculations generally assume metric units. (Comments 01-RB07, 01-LO13).

186. Some, but not all of the references have been updated in response to the comments raised:

- The updated R/B and C/B design reports are among a number of the reports that still reference the imperial codes.
- The updated LOT and RCW tunnel reports are among a number of reports that reference a mix of metric and imperial codes.
- None of the Basis of Safety Case reports or the Overview report have been updated or define the units.

187. The responses also raise concern in that they do not demonstrate consistency.

188. The response to Comment 01-RB07 states, *"Hitachi-GE did not agree to use the metric version of US codes"*. Meanwhile, the response to Comment 01-LOT13 states, *"Please note that where American codes are referenced, the metric version is used, if available".*

189. While making the above statement in response to Comment 01-LOT13, ACI 318 has been updated to ACI 318M only in the associated tunnel and tank reports; ACI 349M is available but the references have not been updated.

190. No numerical errors or mistakes associated with units have been observed; however the inconsistency and lack of reporting clarity is a potential cause of confusion and errors, which could be substantial. (Note that the difference in the example given in Figure 7 is approximately a factor of 10).

4.3.3.7 CONCLUSION – DESIGN CODES AND STANDARDS

191. I judge that specific nuclear design standards have been selected appropriate to the circumstances in line with SAP ECE 5, and significant care has been applied when combining design codes. However, a consistent application (Imperial or metric) of the design codes and the effects of updated codes should be considered by the licensee. An assessment finding is raised to capture this and the specific comments relating to these issues are in the below table:

Table 8: Civil engineering comments relating to AF-ABWR-CE-01

GDA Comments	Comment ID	Section
Use of superseded design code	01-RB04	4.3.3.5, 4.3.3.1
Inconsistent use of design codes (imperial and metric)	01-RB07	4.3.3.6
Inconsistent use of design codes (imperial and metric)	01-LOT13	4.3.3.6

AF-ABWR-CE-01	The Requesting Party has mixed metric and imperial civil engineering design codes, therefore the licensee shall apply a consistent approach to the application of design standards and justify the impact that updated code versions have on the civil engineering design. Future licensee to refer to section 4.3.3 of Civil Engineering GDA Step 4 report for further information.

4.3.4 Site Layout

192. As described in Section 3, the site layout is comprised of the main cruciform arrangement (R/B, S/B, T/B, Rw/B and C/B), and a number of tunnels, tanks and other buildings.

193. ONR assessed the overall consistency of the site layout and found a number of inconsistencies across structures and on the interaction between buildings. The RP addressed these inconsistencies, but there are two aspects that remain noteworthy:

- The automobile missile impact load case assumes flat (or descending) terrain around the buildings and considers automobile impact for all exterior walls The design checks are only valid if surrounding ground altitude does not increase. It is an implied GDA assumption that may need to be revisited at the site specific stage (Comment 01-RB09).
- Based on the site layout, the gradient of the EDG/B-R/B tunnel is quite steep. This is not considered in the associated design report. The RP has since acknowledged the gradient, but it remains a concern the extent to which the GDA is a coordinated solution that satisfies all the requirements. There is also a relatively minor inconsistency with regards to tunnel drainage. (Comment 01-EDG06).

194. I consider that assumptions on terrain and tunnel gradients will be addressed during the site specific stage as part of normal business, as these design aspects need site specific information to be fully resolved.

4.3.4.1 CONCLUSION – SITE LAYOUT

195. I have assessed the proposed site layout against SAP ELO.4 and I judge that the design and site layout minimise the effects of initiating events. I found a number of minor inconsistencies that were addressed by the RP during the Step 4 assessment, with the exception of two minor points regarding the terrain and tunnels gradients. I consider that the above comments will be addressed during the site specific stage as part of normal business.

4.3.5 Structural Interfaces

196. Interfaces between structures have been identified from the Generic Site Layout.

197. Interfaces can be grouped into four types:

- Interfaces between adjacent buildings.
- Interfaces between tunnels and buildings.
- Interfaces between tunnels and tanks.
- Interfaces between tunnel segments.

198. Structural interfaces have been assessed considering each of:

- The compatibility of design parameters and assumptions between the Overview report, Basis of Safety Case reports and the Design Reports.
- The completeness of the design.
- The performance and detailing of the interface.

4.3.5.1 INTERFACES BETWEEN BUILDINGS

199. The interfaces between buildings affect the Structure Soil Structure Interaction (SSSI) and the modelling of embedment. These are discussed in Section 4.3.12. The assessment of the interactions between buildings has focused on the nuclear cruciform

(Figure 2) layout. The description of the building interfaces was initially ambiguous and clarity has been provided during Step 4. The building interfaces include:

- Lean concrete fill through the thickness of the basemats, resulting in a stiff compression-only interface at basemat levels.
- An air gap between buildings above basemat level. Although not dimensioned, the air gap has been scaled off a drawing to be 600mm wide. The air gap extends across the full area of each interface.
- A perimeter waterstop consisting of a cast-in waterbar, spanning a 100mm clear seismic movement joint between protruding concrete blocks. The protruding concrete blocks frame the air gaps.

200. Clarifications provided by the RP have led to a number of comments being closed. However, the following points remain open:

- The RP has raised construction of the closely spaced walls as a construction risk without current mitigation (See Construction Section 4.3.16.2). I share this concern; it is questionable whether any formwork could be removed from such a narrow gap and, similarly, there are challenges associated with fixing the reinforcement and the waterstop which are not explained. Furthermore, should the waterstop be damaged (e.g. in construction), it is not clear how it could be repaired or replaced. The remark that the “contractor [is] to review gap requirement” highlights the outstanding uncertainty. (Comments 01-G02 and 01-RB38).
  I anticipate that if the gaps had to be made marginally wider to reduce the above risk, this would have little impact on the structural design. Nevertheless, I consider that the interfaces between buildings have not been fully addressed during GDA, and so I have raised an assessment finding, AF-ABWR-CE-02. This Assessment Finding will include the above issue.

- The RP has provided details for the waterproofing across the interface joints in response to Comment 01-G02. I judge these details are sufficient for GDA but they require further development as it is not clear that the specified joint will accommodate the movement, as the quoted 100mm compressibility at the joint will not be achieved with a 100mm joint (as typically joints can accommodate a maximum of 30% to 60% of movement). I have raised an Assessment Finding on waterproofing in section 4.3.14.
  This comment also applies to the tunnel/building interface.

- The technical drawings contained in the individual design reports showed a misalignment of openings across buildings. From these, it is evident that, although many openings have been coordinated, some openings misalign across buildings while others are omitted on one side of the interface. (Comments 01-CB01 and 01-RW13).
  The RP has acknowledged this and presented a report (Ref.115) that also highlights omissions of internal walls. I queried the effect that these omissions and misalignments have in the seismic response of the structure. The RP showed that the global response of the structure does not significantly change. Whilst, this provides re-assurance that the difference does not affect the overall design and can be managed at a later stage, I consider that the local effects have not been assessed, and hence I have captured this within Assessment Finding (AF), AF-ABWR-CE-02.

4.3.5.2 INTERFACES BETWEEN TUNNELS & BUILDINGS, TUNNELS & TANKS AND TUNNEL SEGMENTS

201. I found inconsistencies at the interfaces between the tunnels and a number of the buildings, including buried depth of tunnels, arrangement on plan, and the number of chambers/cells (Comments 01-RCW03 to 01-RCW05 and 01-CST01).

202. The RP has stated, "*The generic site layout is indicative. This means the route, cell(s) and number of bend of the tunnel are also indicative"*. ONR accepts that, at GDA, the scope of the layout can be schematic. However the inconsistencies, omissions and lack of clarity on size and number of wall openings can be potentially un-conservative (Comment 01-RB35). The RP notes that, "*local effect check will be undertaken at the site-specific design stage when information is available".* As per the previous section, I have raised an assessment finding to capture the inconsistencies between structural interfaces.

203. In the original RP reports, it was unclear how the tunnel and tank structures interfaced and how the services were to be routed. Updates to the reports include revised figures that clearly identify the service routes and a compressible isolation joint between the structures. These updates demonstrate a solution that is likely to be viable, although further design is required to develop this into a detailed and verified design (Comment 01-LOT02). I consider the information presented sufficient for GDA.

204. I consider that the local checks on the openings and the isolation joints details between tunnels and tanks need to be developed during site specific stage, when the RP determines the final location of buildings, tunnels and tanks. As tanks are outside the GDA scope, I am satisfied that these areas have been developed in sufficient detail for GDA, and they will be designed as part of normal business.

205. The interfaces between tunnel segments have not been included in GDA and the displacements at structural interfaces are only considered for dynamic loading. (Comments 01-RCW05, 01-RCW09, 02-022). Whist the displacement due to static loading has not been considered, I expect this to be less onerous than the displacements due to dynamic loading. Hence, I judge that the interfaces between tunnel segments should be addressed as part of normal business during site specific stage.

4.3.5.3 CONCLUSION - STRUCTURAL INTERFACES

206. In my assessment of the structural interfaces I have considered SAP ECE.1, ECE.7, ECE.10 and ECE.25. The RP has provided details on the construction hazards during the construction of the R/B and information on how the foundations and below ground structures can be designed to avoid water ingress. I judge this to be sufficient for GDA Step 4, but there are two areas that need further work, and so I have raised two Assessment Findings.

207. I judge that the RP has not demonstrated adequate consideration of the structural interfaces, in particular between buildings and building/tunnels where a significant number of misalignments have been found. I have raised Assessment Finding AF-ABWR-CE-02 to capture all the interfaces issues between buildings and buildings and tunnels.

208. I judge that provisions for good waterproofing are essential to ensure adequate construction and maintenance of the structures; hence I have raised an assessment finding in Section 4.3.14.

209. My assessment of the structural interfaces, as well as highlighting a number of shortfalls that will be addressed by two assessment findings, it has clarified the RP's interface design and provided confidence that the details suggested at the interfaces can be achieved. I have included the comment regarding the incorporation of load

paths between buildings (section 4.3.13 – Stability) in the Basis of safety case within the AF below.

Table 9: Civil engineering comments relating to AF-ABWR-CE-02

GDA Comments	Comment ID	Section
Openings in walls and slabs	01-RW13	4.3.3.1
CDM 2015	01-RB38	4.3.3.1
Tunnel Interfaces	01-RB35	4.3.3.2
Depth of overburden	01-RCW03, 01-CST01	4.3.3.1
Tunnel interface with R/B	01-RCW04	4.3.3.2
Tunnel bend	01-RCW05	4.3.3.2
Load paths across building interfaces	01-CB14 (3)	4.3.13.2

AF-ABWR-CE-02 As the civil engineering design is at different stages of maturity and a number of misalignments between buildings and tunnels have been identified, the licensee shall consider the interfaces at buildings and tunnels and provide a design that facilitates constructible interface details. The Licensee to refer to section 4.3.5 of Civil Engineering GDA Step 4 report for further information.

4.3.6 Ground conditions and site envelope

210. The RP has selected a number of External Hazards to be considered at GDA stage in order to define a Generic Site Envelope (GSE). The stated goal of the GSE is "to ensure that the UK ABWR can be built on a variety of sites within the UK". The RP states that the GSE has been developed to identify 'representative UK conditions' which presumably offer the future licensee a reasonable level of flexibility in the location of the UK ABWR. It is worth noting that whilst the GSE has been developed taking cognisance of the eight candidate sites identified by the Department of Energy and Climate Change (DECC) in 2009, it does not necessarily represent an envelope of all possible conditions at the eight candidate sites.

211. Ground conditions are excluded from the GSE, and the consideration of ground conditions is deferred to a later site specific phase.

212. As ground conditions cannot be fully defined until the site specific stage, the RP has had to make assumptions in terms of ground conditions, this could have a significant impact on the geotechnical and foundation design of the various civil structures. Theoretically, these elements of the design cannot be developed without fully defined ground conditions. Practically, most of the reports provided by the RP contain some assumptions with respect to the potential ground conditions, and these have been accepted by the ONR for GDA, including:

- Geo-seismic characterisation of Hard and Medium sites (in accordance with the European Utility Requirements (EUR) seismic characterisation), but excluding consideration of Soft sites.
- Some assumed parameters for soil pressure, building stability evaluation and backfill material (e.g. at-rest pressure coefficients, unit weights and friction angles).
- The definition of soil layers including in situ soil, engineering fill and formation level; in particular, it is assumed that the formation level is rock.

- The requirement to excavate in situ soil of inadequate quality and to replace with engineered fill.

213. The following general comments are recorded the assumptions presented by the RP with respect to the GDA ground conditions, for future consideration during site specific stage:

- A comprehensive geotechnical design is not possible without fully determined ground conditions (Comment A10 and A11). Hence, in a geotechnical sense, the GDA (as a package of design work) is substantially incomplete. Outstanding design matters that are not being considered at GDA will require further work during the site specific stage.
- The EUR classification is a seismic definition of a site, and of limited relevance to static geotechnical design (Comments A8 and A9). A full derivation of geotechnical parameters will have to be carried out at a site specific design stage, which may result in reconsideration of elements of the GDA design.
- Three of the eight candidate sites identified by DECC are classified as EUR Soft. If the UK ABWR is located at a EUR Soft site, part of the GDA with respect to the geotechnical design and seismic design of the civil structures will have to be reconsidered.
- The range of values presented as ground parameters in the GDA does not cover all conceivable conditions, nor all ground conditions that can be expected at the eight candidate sites (comments 02-16 and 02-019). Different values may emerge at site specific stage outside the enveloped assumptions that will require further consideration.
- The US standards adopted in the GDA are only partly applicable to geotechnical design. Compatibility of US standards and UK standards for geotechnical design should be addressed during the site specific stage (Comment A4).

4.3.6.1 CONCLUSION - GROUND CONDITIONS AND SITE ENVELOPE

214. I have considered this item against SAP ECE.4 and judge that the range of geotechnical properties assumed during GDA cover a reasonable number of natural site materials in line with the generic nature of GDA. However, this range does not cover all scenarios and the site specific geotechnical properties utilising information derived from geotechnical site investigation, should be considered against the GDA design in line with SAP ECE.5. Where appropriate, elements of the GDA should be re-designed to suit these site properties. Consideration of UK standards, alongside US standards in the site specific design of geotechnical structures, should also be considered. The following assessment finding has been raised to capture the above points, together with the comments found in sections 4.3.8.2, 4.3.9.4, 4.3.10.5, 4.3.12.7, 4.3.13 and 4.3.14.4, as summarised in the below table:

Table 10: Civil engineering comments relating to AF-ABWR-CE-03

GDA Comments	Comment ID	Section
Compatibility of US standards and UK standards	A4 (Step 3)	4.3.6
Lack of static geotechnical properties (EUR classification)	A8 (Step 3)	4.3.6
Lack of static geotechnical properties (EUR classification)	A9 (Step 3)	4.3.6
Lack of site specific ground conditions	A10 (Step 3), A11 (Step 3)	4.3.6
All possible ground conditions not enveloped – soil	02-016	4.3.6, 4.3.8.2

properties		
Appropriateness of assumed soil types	02-019	4.3.6
Compaction criteria – negative arching	02-010	4.3.8.2
Ambiguity with regard to the characterisation of the ‘in-situ soil’ layer – Standard Penetration Test N-value	02-002	4.3.9.4
Ambiguity with regard to the characterisation of the ‘in-situ soil’ layer	02-003	4.3.9.4
Consideration of site specific cut-off frequency	E.11	4.3.12.7
Differential settlement effects	02-004	4.3.10.5
Differential settlement effects on raft design	02-020	4.3.10.5
Differential settlement effects on CST	02-025	4.3.10.5
Effects of cyclic loading of tanks	02-028	4.3.10.5
Longitudinal effects due to differential ground conditions	01-RCW02	4.3.12.7
Bearing Pressure and Capacity	02-009, 02-021	4.3.13
Unbalanced groundwater	02-013	4.3.13
Sliding stability calculations	02-026, 02-027	4.3.13
Ground movement	B4 (all buildings)	4.3.14.4

AF-ABWR-CE-03	Due to the assumptions made during GDA on geotechnical properties, the licensee shall re-visit the geotechnical design of the civil engineering structures using site specific geotechnical parameters, groundwater levels and suitable fill properties to demonstrate these assumptions are applicable and in line with UK relevant good practice. Future Licensee to refer to section 4.3.6 of the Civil Engineering GDA Step 4 report for further information.

4.3.7 Structural Discrepancies

215. Each Design Report starts with a structural description that describes, at high level, the structural form, function and primary structural system. These introductions also generally, but not always, acknowledge interfaces with adjoining structures.

216. Supplementary, more detailed descriptive information is often given where appropriate throughout the Design Reports, to describe specific features of the designs. This may be in the form of dimensions and other parameters used for design or description.

217. In this section I have assessed if the structural descriptions of civil engineering components have been adequately considered in the design. The following subsections highlights two specific areas of discrepancy between structural descriptions and design: roof drainage falls and MC components.

4.3.7.1 ROOF DRAINAGE FALLS

218. With the exception of the cylindrical roof to the R/B, roofs to the various buildings are generally 'flat', with nominal drainage falls identified by arrows on the plan drawings. Meanwhile the information provided on the elevation drawings and the roof element design calculations contradicts the plan drawings (Comment 01-CB01). In response to the comment the RP stated that the additional load for the gradient is included as part of the structural weight (1.8 kN/m^2). However, ONR believes that the additional load for a mono-pitch roof with a minimum gradient of 1:100 across the C/B requires a 400mm fall and this has the potential for significant additional weight, dependent on the material selected to create the fall. I have not found an allowance for this additional mass in the static or seismic analysis.

219. The roof drainage system can be confirmed during the site specific stage. However, the information provided in GDA does not provide sufficient evidence that the most conservative loading has been considered. I will capture the omission of the extra loading due to the roof drainage system under the AF raised in the loading section (Section 4.3.8 –AF-ABWR-CE-04).

4.3.7.2 MC COMPONENTS

220. The MC components have been described in section 3.3.

221. The Reactor Pressure Vessel (RPV) Stabilizer is a steel structure that links the RPV to the surrounding Reactor Shield Wall (RSW). A number of reports mentioned the existence of the stabilizer at 6.14m elevation, between the RPV and the RSW. However, other than stating that the RPV Stabilizer exists, no detail on its form or function was provided in the original Step 4 reports. This is a concern given its proximity to the RPV and suggested 'stabilising' function (Comment 01-MC02). The RP provided a general explanation on the function of the stabiliser and the loads applied. A general sketch was also provided. However, further details, such as the stiffness, mass and loads transmitted, are required to allow a meaningful assessment. Any change to the RPV Stabiliser could impact each of the RPV, the RSW and potentially the supporting structure (notably the RPV Pedestal).

222. There are numerous large diameter vent pipes and tubes within the thickness of the RPV Pedestal walls, as well as other pipes which penetrate the outer wall of the RPV Pedestal. Beyond being acknowledged as present, no information is given on these features (Comment 01-MC12). Being integral to the RPV Pedestal, more detail is needed on these pipes to fully assess their effect on the RPV Pedestal.

223. I have captured the lack of information on the stabiliser and on the large diameter pipes within the RPV pedestal in the AF (AF-ABWR-CE-09) in the Member and Connection Design Section (See section 4.3.11).

4.3.7.3 CONCLUSION – STRUCTURAL DISCREPANCIES

224. The RP has provided descriptions of certain structural elements and postponed their design to the detail design phase. I accept this approach but I expect the RP to consider the effect of these elements in the design (the loading effect, stiffness or the loadings transmitted). In general, the RP has considered the effects of the structural descriptions in the design, but there are two instances where I found structural discrepancies. I have assessed the effect that these structural discrepancies have in the design against SAPs ECE.1, ECE.2 and ECE.6. I judge that while I accept that the full details of the roof drainage system will be developed during the site specific stage, there is an inconsistency between the roof drainage system described and the loadings applied to the structure. All loadings during normal operating conditions need to be included in the design, and the RP did not consider the loading that a roof drainage system could impose into the buildings. I accept the GDA design provided by

the RP, because I do not consider that this extra loading will significantly change the design. I have included this finding within the Assessment Finding AF-ABWR-CE-04.

225. I judge that the RP has not provided sufficient information to allow a full design of the RPV stabiliser and the RPV Pedestal. I have raised an Assessment Finding (AF-ABWR-CE-09) on the MC component in Section 4.3.11 which includes the comments relating to these two MC components.

4.3.8 Loads & Load Combinations

226. In ONR, the loadings in the civil engineering structures are treated as follows:

- The External Hazards discipline will assess how loadings such as: seismic loading, wind loading, snow loading, flooding, etc. have been derived.
- The Internal Hazards discipline will assess how loadings such as: pipe whip loading, drop loads, etc. have been derived.
- Other loadings, such as pipework loads are assessed by the Structural Integrity discipline or specific equipment loads are assessed by the Mechanical Engineering discipline.
- Civil Engineering assesses the effect of loadings on the structures and also assess specific loadings linked to civil engineering, such as dead loads, imposed loadings and construction loads.

227. The full list of civil engineering loadings and loading combinations are in Section 3.2.1 and Appendix 2. The normal operating values and the design values of the external hazards considered in GDA are defined by the Generic Site Envelope and have been assessed by the external hazards inspector (Ref 20). The internal hazards considered during GDA are listed in Chapter 10 of the PCSR and have been assessed by the internal hazard inspector (Ref 17).

228. The loading types that each structure is designed for (e.g. dead load, live load, snow load, etc.) are listed in the Basis of Safety Case Report for each structure and then subsequently quantified within the Design Reports. Load combinations are set out in tabular format in each of the Design Reports.

229. The load types are aligned to the loads prescribed in the adopted codes of practice – ASCE 4 and ASCE 7 (Annex 3). The load combinations are derived in accordance with recognised design standards, mostly ASCE 7.

230. The load combinations for Group A buildings, tunnels and tanks are comprehensive, but the combinations for Group B buildings are a reduced set, based on the worst cases ascertained from the Group A analyses, see Section 4.3.1. The comments on load combinations apply only to Group A buildings.

231. I have divided this section into the following subsections:

- Standard Building Loads
- Ground Loads
- Solar gain thermal loads
- Crane loads
- Hydrodynamic loads
- Application of seismic accelerations and forces
- Loads on MC components
- Omitted loads
- Load combinations

4.3.8.1 STANDARD BUILDING LOADS

232. Live loads and superimposed dead loads are applied as uniform area loads. This is an acceptable approach if the uniform distributed load (UDL) envelopes any concentrated loads, local patch load and pattern load. However it has not been proven that the UDL considered by the RP envelopes some substantial concentrated loads (e.g. columns from the mezzanine, pipe and equipment loads).

233. Whilst the effect of concentrated loads has not been captured in the design, I consider that the self-weight of the structure is substantial and the error due to the simplified application of live and superimposed loads may be small for relatively uniform imposed loads. However, the local effects of some substantial concentrated loads (e.g. plant loads on the stack, column loads from mezzanine floors, pipe and equipment loads) need to be considered during the site specific stage (Comments 01-G04, 01-RB10, 01-RB16, 01-ST01, 01-CB01 part 2). Also, the RP needs to consider the eccentricity of pipe loads within the tunnels during site specific stage (Comment 01-LOT16).

234. Wind and snow loading have been considered in the design. However a more rigorous loading calculation is expected during site specific stage, as there are a number of omissions and errors in these calculations, such as:

- For snow loading, the calculations omit drift loads (Comment 01-RB11 and 01-LOT06)
- For wind loading, the calculations omit torsional/asymmetric and oblique loads
- For the Radwaster Building the wind load pressure coefficient appears incorrect (Comment 01-RW04)

235. I judge that the seismic loading is the governing load for Seismic Category 1 and 1A buildings; hence the omitted, ambiguous and erroneous wind load conditions are unlikely to govern. However, lower Seismic Category ancillary structures (outside the GDA) need a more thorough wind load assessment and these buildings need to be fully designed during the site specific stage.

236. Similarly, due to relatively large potential standing rain water and live roof loads, the overlooked snow conditions are unlikely to have global significance. One area where snow load may govern is at the eaves of the curved roof to the R/B, where snow drift has not been considered. The curved roof in the R/B has a parapet at its base and, hence, the curved roof could be subject to a governing snow load.

237. I consider that the future licensee should carry out a more rigorous loading (dead/imposed load, wind and snow loads) calculation during site specific, as more detailed information will be available at this stage. I have raised a consolidated Assessment Finding (AF-ABWR-CE-04) for loadings that will include the above comments.

4.3.8.2 GROUND LOADS

238. The ground loads depend entirely on the assumptions made in GDA and they will need to be fully developed during site specific stage, when the ground parameters are defined.

239. Some of the assumptions include not considering the effects of negative arching. Negative arching can occur where the material next to the buried tunnel wall settles and this can cause an increased in the load transferred to the structure as a result. The RP assumes that negative arching will not occur as the backfill materials adjacent to and above the tunnel is assumed to be compacted to 95% of its maximum dry density.

240. For GDA, the RP made the following assumptions that will need to be confirmed during the site specific stage:

- A specific compaction criterion was proposed to avoid negative arching (Comment 02-010).
- The RP stated that all below ground structures will be constructed in open-cut excavations, with the gap between the excavation face and structure being filled with lean concrete or engineered fill. The “at rest soil pressure coefficient” will be based on lean concrete or engineered fill (Comment 02-016).

241. Settlements are excluded from the site envelope definition (Comments 02-004 & 02-020). However, the RP has considered differential settlements as negligible as the vertical loading is uniform and the ground has been modelled as medium soil with uniform stiffness (see Section 4.3.10.5 – Modelling of the ground stiffness).

242. I consider that the Licensee should re-visit all the geotechnical assumptions made in the GDA during the site specific stage and re-define the ground loads. I have captured this in AF-ABWR-CE-03.

4.3.8.3 SOLAR GAIN THERMAL LOADS

243. ONR noted that the building and tank reports do not describe the strategy for managing solar thermal loads to external surfaces. These loads cause thermal strain cycles and can be significant (Comment 01-G07). The RP’s position on this matter is that thermal loads are omitted on the grounds that ambient temperature gradient and uniform change are each within ACI 349 limits.

244. I consider that structural elements subject to direct sun could experience surface temperatures above the ambient air temperature and possible solutions, such as external thermal insulation, should be considered during the site specific stage. I judge that the future licensee is best placed to resolve this, as the level of detail required will only be available during site specific design and it is outside of GDA. Hence, I judge that this will be completed as part of “normal business” during the site specific stage.

4.3.8.4 CRANE LOADS

245. Gantry crane loads are applied to each of the following buildings: R/B, Hx/B and T/B. The loads include the horizontal effects from the crane, and those are enveloped by the seismic lateral loadings. ONR noted that the original reports did not describe the extent to which the different crane positions had been modelled (Comments 01-RB18 and 01-HX02). The RP explained that only a small number of crane locations were considered. The RP considers that these locations are bounding and sufficient for GDA.

246. Accidental drop loads have been considered in the internal hazards section of this report (4.3.21.2). However, as stated in the internal hazards section, accidental drop loads and other internal hazards loads have not been documented in the civil engineering reports listed in Section 3.1 – Safety Case Documentation. The substantiation of the barriers is recorded in a number of internal hazard reports that I have assessed and summarised in Section 4.3.21.2.

247. The RP has considered the consequences of a drop on the SFP (Ref 145) and provided evidence that structurally the SFP can withstand the drop load and the damage to the liner will not result on a leak below the makeup rate capacity of the residual heat removal system.

248. ONR accepts this explanation but considers that additional checks will be needed during site specific stage to envelope all crane loading cases. I have captured this comment in the overarching Assessment Finding for loadings, AF-ABWR-CE-04.

4.3.8.5 HYDRODYNAMIC LOADS

249. Hydrodynamic loads can be found mainly in the Reactor Building (RCCV and Spent Fuel Pool) and in the Heat Exchanger Building.

250. The hydrodynamic loads include four main types of loads:

- Safety Related Valves loads are hydrodynamic loads in the Suppression Pool due to the inflow of vapour through the Safety Relief Valves
- Condensation oscillation and chugging loads are hydrodynamic loads in the Suppression Pool during a Loss of Coolant Accident (LOCA) event. They are generated by the condensation process of steam which flows into the Suppression Pool from the Drywell through Vent Pipes during a LOCA.
- The pool swell loads are applied to the suppression chamber during a LOCA.

251. Time-history response analysis under hydrodynamic loads has been undertaken using a finite element model of the Reactor Building (R/B) incorporating large internal structures and components such as the Reactor Pressure Vessel (RPV) pedestal, reactor shield wall and RPV. The analyses are used to derive peak accelerations and forces and in-structure response spectra for the R/B civil structure and components.

252. Damping ratios used for the analyses and in-structure response spectra are based on damping ratios for seismic analysis and this was queried in Comment 01-HV02. My concern is that hydrodynamic loads are not a seismic load case and that response levels, and hence damping levels, will be different. Damping values used for seismic analysis are generally elevated to be consistent with responses that cause residual damage i.e. steel yielding and/or concrete cracking. For fully elastic response vibration, it will be expected that lower damping ratios than for seismic analysis are adopted. Use of lower damping values may result in higher responses and loads than currently designed for. The RP has not provided enough evidence to justify the high damping values used in the design hence I will raise an Assessment Finding to capture this shortfall, AF-ABWR-CE-05.

253. Based on a comparison of static to dynamic stresses, a DLF (Dynamic Load Factor) of 2.0 has been used for the design of the RCCV and RPV Pedestal for condensation oscillation loads, chugging loads and loads due to safety relief valve actuation (Comment 01-HV08). I asked for further explanation of the differences in the respective load distributions (applied loads and inertial loads) to confirm that this approach suitably envelopes the results. The RP claims that the DFL factor of 2 will envelop the difference on load distribution, but I consider that the information provided was not sufficient to fully understand the rationale for the approach. Hence, I have captured this comment in the overarching Assessment Finding for loadings, AF-ABWR-CE-04.

254. I requested further information on the derivations of the sloshing hydrodynamic loads within the Heat Exchanger Building (Comment 01-HX01). The RP only presented the methodology. I accept the methodology, but I have not assessed the application of the methodology as no workings were submitted during the GDA assessment. Hence, I have captured this comment in the overarching Assessment Finding for loadings, AF-ABWR-CE-04.

4.3.8.6 APPLICATION OF SEISMIC ACCELERATIONS AND FORCES

255. This section describes how seismic forces are applied to the static models. Further discussion on the derivation of the seismic accelerations and forces can be found in section 4.3.12 of this report.

256. The RP has generally applied the seismic forces directly as accelerations or equivalent static forces. For the Rw/B and the S/B, the seismic forces are applied as accelerations at each floor level independently and when there is significant variation in the accelerations of a particular floor, the floor is divided into smaller areas and the different acceleration values applied. In this approach, the designer decides if the accelerations are sufficiently regular that no further subdividing is necessary. I queried this and found variability on the acceleration values that counters the designer's decision (Comment 01-RW06). Also, this analysis technique is not compliant with ASCE 4 (see Section 4.3.12– Seismic Analysis).

257. The approach taken by the RP could underestimate the seismic forces but only affects the Rw/B and the S/B. As these two buildings are not designed during GDA, to the same level of detail as other buildings (Group B buildings – See Section 4.3.1), a full detailed analysis is expected during site specific stage, which should address the comment above. Nevertheless, as a methodology issue, I judge that it should be recorded within this report as an Assessment Finding. This comment is linked to a comment on the seismic analysis section (section 4.3.12), and so I have consolidated the two comments together into one Assessment Finding in section 4.3.12.

4.3.8.7 LOADS ON THE MC COMPONENTS

258. I have raised a number of queries regarding the absence of detail in the original Design Reports for the MC Components. The replies from the RP have not fully addressed the queries and the remaining comments can be found below.

259. The seismic loads on the RPV Pedestal reported in the R/B Design Report (Ref 48) cannot be traced back to the R/B Seismic Report (Ref 45). (Comment 01-MC06).

260. Large concentrated forces are applied to the diaphragm floor and drywell head (e.g. jet force). The RP has evaluated the effect of these forces on a number of structural elements. However, the criteria for the selection of these elements are unclear. (Comments 01-MC15 and 01-MC21).

261. I questioned the construction loads from wet concrete pressures and locked in stresses and the RP explained that these loads are within the allowable code limits. However, this information has not been included in the RP reports. (Comment 01-MC11 and 01-MC14). I have discussed the locked in stresses in more detail in section 4.3.16.1.

262. As explained in the static loads section, it is unclear if the pipe reactions have been included in the load combinations. This comment also applies to the MC components and access tunnels (01-MC16 and 01-MC24).

263. Following one of my queries, the RP described the process of dynamic load derivation and application to the access tunnels, but it did not account for superimposed loads. (Comment 01-MC24).

264. The lack of clarity and omissions (01-MC19) in the design reports for the MC Components has been a topic that raised a significant number of comments during GDA Step 4. I have captured all the above MC comments on a single GDA assessment finding, see AF-ABWR-CE-09 in section 4.3.11.

4.3.8.8 OMITTED LOADS AND ACTIONS

265. The following actions have not been included in the analysis:

- Impact loads on steel members. The RP has only provided the methodology to design against impact. No examples or loads have been provided. (Comment 01-RB22). The RP design report mentions a missile impact load generated by a postulated pipe break. However, there is no further evidence that this impact load has been considered, except for the design of the RCCV where this load is considered. This is an internal hazard loading and I have raised a number of comments on this area (See below).

- The thermal effects due to flue gases have not been considered in the stack design. (Comment 01-ST02).
- Fatigue has not been considered in the design of the stack lattice support frame. (Comment 01-ST03).

266. The RP has stated that the above loads will be considered during site specific stage. I judge that GDA Step 4 should provide a robust design against expected loads and actions and I based my judgement against SAP ECE.6. The above loads are expected civil engineering loads and so the RP should have considered them in the design or made an allowance for them. I have captured the omission of impact loads within the overarching AF for loadings. The other two comments are against the stack design, and so I have enveloped all of them under one Assessment Finding for the stack, in section 4.3.11.

267. Within the civil engineering design reports, the RP has not documented the effect of Internal Hazard loads in the civil engineering structures. This is discussed in greater detail in section 4.3.21 and an Assessment Finding (AF-ABWR-CE-019) has been raised to capture the omission of Internal Hazard loadings in design reports.

4.3.8.9 LOAD COMBINATIONS

268. Load combinations are set out in tabular format in each of the RP Design Reports. These are derived in accordance with the design standards, most notably ASCE 7 (Annex 3).

269. For the ‘Group A’ buildings (see Section 4.3.1), the tunnels and the tank foundations, a comprehensive suite of combinations is considered; this suite is significantly reduced for the ‘Group B’ buildings (01-RW01 and 01-RW08). My review of the load combinations has focused on the Group A buildings. I have captured the comments against Group B buildings within the overarching Assessment Finding for loadings.

270. I have assessed the load combinations for the Group A structures and found:

- Load factors applicable to dead loads have been used for the miscellaneous dead load. However due to the uncertainty on the miscellaneous loading, it is good practice to apply higher load factors (Live Load factors). (Comment 01-CB03).

- The soil pressure has been combined with the live loading without considering the variability of the loadings. Hence, load combinations with minimum live load and maximum soil pressure and vice versa have not been considered. (Comment 01-CB04).

- I found a methodology error in the uplift buoyancy load combination for the tunnels. The RP acknowledged the error and updated the RCW tunnel calculation. The RP has updated the rest of the tunnel calculations. (Comment 01-RCW08).

- As explained in section 2.5, the tanks and the holding down bolts are outside the GDA scope, and so the load combinations governing the tank and the holding down bolts have been omitted. This information is not clearly stated in the design reports. (Comment 01-LOT07).

271. I found a number of inconsistencies in the sliding and flotation factors and I have discussed this in detail in Section 4.3.13 – Stability. I have included these comments (Comments 02-011, 02-012, 02-023 and 02-024) in the overarching AF for loadings and load combinations.

272. In general, I found that the approach of the RP to the load combinations is satisfactory. I judge that the minor observations stated above will be addressed as part of normal business during the site specific stage, with the exception of the soil pressure load combination. I consider that this finding can lead to underestimating the loading, and so I have included it in the overall Assessment Finding (AF-ABWR-CE-04) for loading.

4.3.8.10 CONCLUSION – LOAD AND LOAD COMBINATIONS

273. I have assessed the loadings and load combinations against SAPs ECE.6, ECE.13 and ECE.14. My assessment is based on the application of the loadings on the civil engineering structures. I have not assessed the derivation of loadings, as this has been carried out by other disciplines (mainly External and Internal Hazards).

274. In my assessment of the loads, I found that the RP has not taken a conservative approach in some of the loading assumptions; some of the loadings have been omitted and in some cases not enough evidence has been provided to justify the loading considered. However, I judge that the loadings for GDA are acceptable, because holistically the global loading is adequate, since the most onerous load combination envelopes the loads which may have been inappropriately derived. Nevertheless, local effects should be considered in greater depth during the site specific stage. I have captured the omissions of loadings in the assessment findings within sections 4.3.11 (see Stack section), 4.3.21 (see Internal Hazards section) and the overall Assessment Finding for loading within this section. I have included the comments regarding insufficient evidence and non-conservative approaches in AF-ABWR-CE-04 below.

275. I discussed the damping ratio used in the analysis of the hydrodynamic loads with the RP. However, it was not possible to reach a clear understanding of the RP's criteria for selecting the damping ratio. I judge this comment against SAPs ECE.13 and ECE.14, and I reached the conclusion that the data presented for the hydrodynamic loads has not been proved conservative, nor has it been substantiated with sensitivity studies. I have raised a stand-alone Assessment Finding for this comment as the RP has not demonstrated the adequacy of the damping ratio used in the design, and as a consequence, the hydrodynamic loadings could be underestimated. I judge that an assessment finding is appropriate for this shortfall, as the civil engineering design has enough margins to accommodate higher hydrodynamic loadings if the hydrodynamic loads are sensitive to lower damping ratios.

Table 11: Civil engineering comments relating to AF-ABWR-CE-04

GDA Comments	Comment ID	Section
Imposed loads	01-G04	4.3.8.1
Mezzanine dead load	01-RB16	4.3.8.1
Equipment load	01-ST01, 01-RB10	4.3.8.1
General areas with insufficient detail	01-CB01	4.3.8.1
Pipe Loads	01-LOT16	4.3.8.1
Snow	01-RB11	4.3.8.1
Snow Drift	01-LOT06	4.3.8.1
Report errors	01-RW04	4.3.8.1

Sloshing loads	01-HX01	4.3.8.5
Crane positions	01-RB18	4.3.8.4
Crane loads and supporting structure	01-HX02	4.3.8.4
Members resisting impact	01-RB22	4.3.8.8
GDA Scope	01-RW01	4.3.8.9
Load Combinations	01-CB04	4.3.8.9
Lack of reduction factor - floatation	02-011	4.3.13.3
Accurate calculation of favourable dead load - floatation	02-023	4.3.13.3
Accurate calculation of favourable dead load - sliding	02-012	4.3.13.2
Lack of reduction factor - sliding	02-024	4.3.13.2

AF-ABWR-CE-04	In the absence of detailed design loading information during GDA, Hitachi-GE has made a number of assumptions and simplifications in order to design the civil engineering structures. The licensee shall undertake an evaluation of future loadings and combinations for use in site specific design. Future licensee to refer to section 4.3.8 of Civil Engineering GDA Step 4 report for further information.

Table 12: Civil engineering comments relating to AF-ABWR-CE-05

GDA Comments	Comment ID	Section
Damping ratios	01-HV02	4.3.8.5

AF-ABWR-CE-05	To provide confidence on the hydrodynamic load analysis performed for the Reactor Building and Heat Exchanging Building design, the licensee shall provide a justification of the damping ratios used in the calculation of hydrodynamic loads. Future licensee to refer to section 4.3.8 of Civil Engineering GDA Step 4 report for further information.

4.3.9 Materials

4.3.9.1 JUSTIFICATION FOR STRUCTURAL MATERIALS

276. As introduced in section 4.3.3.2, structural materials are intended to conform to European and British standards. These are not automatically compliant with the American structural design codes and a comparison study has been completed by the RP.

277. Equivalent British concrete, structural steel, reinforcement and bolt grades have been identified, based on properties used in the existing Japanese (J-ABWR) plants. This is reasonable. However, justification based on the performance requirements of the new plant has not been presented and remains outstanding. (Comment 01-RB31).

278. Provided the new and existing ABWR plants are similar, this should not have significant impact.

4.3.9.2 LIMITING REINFORCEMENT DESIGN STRENGTH FOR SHEAR

279. ACI 349-13 limits the allowable design strength of reinforcement to 420MPa for shear design. This limit has been enforced in the workings and methodologies presented to date.

280. However, although currently adhering to this limit in the design work completed to date, the RP has proposed an option to surpass this limit in future design stages. This is presented in a number of reports, including the Reactor Building Design Report (Ref 48).

281. The justification for exceeding the limit has not been assessed as part of the GDA; should the RP wish to explore this option, it would be a breach of the ACI code for which we would expect a detailed justification to be put forward by the designer. (Comment 01-CB06 part 3).

282. It should be noted that the UK National Annex to Eurocode 2 (EN1992-1-1:2004) stipulates an upper limit on the concrete strength that can be used in the calculation of shear strength and this is below the strength recommended in the main body of Eurocode 2. This limit on concrete should be considered during the site specific stage.

4.3.9.3 BIMETALLIC (GALVANIC) CORROSION

283. The majority of steel is conventional carbon steel. However, some elements, including the RCCV liner, are stainless steel and there is a potential for bimetallic (galvanic) corrosion between the liner anchors (conventional carbon steel anchors) and the RCCV liner. Bimetallic corrosion between conventional steel and stainless steel is not overly concerning, but there will be some acceleration of this process which was not acknowledged in the Design Reports. (Comment 01-RB13).

284. In response to my comment, the RP acknowledges the heightened concern. However, they are deferring the associated checks and development of protective measures to the site specific stage.

4.3.9.4 BACKFILL AROUND TUNNELS

285. The initial reports provided by the RP contained ambiguity with regard to the characterisation of the ‘in-situ soil’ layer surrounding the tunnels above formation level (Comments 02-002 and 02-003). A clear distinction between engineered fill and existing ground in terms of properties and proposed treatment was not made.

286. The responses provided by the RP clarify that a range of properties has been considered, which appears sufficient for the GDA stage. These issues will need to be revisited at a site specific stage, when the Ground Conditions are fully characterised.

287. These outstanding issues on the fill material and ground conditions are covered under the assessment finding found in section 4.3.6 – Ground conditions and site envelope.

4.3.9.5 CONCLUSION

288. I have assessed that the selection of structural materials against SAP ECE.16 and judge that the materials are suitable for enabling the design to be constructed and then operated, inspected and maintained. However, when assessed against SAP ECE.2, the use of proven materials against the specific nuclear design standards has not been fully considered and therefore an assessment finding is raised on the licensee, who is best placed to develop material specification. The below comments are captured within assessment finding AF-ABWR-CE-06.

Table 13: Civil engineering comments relating to AF-ABWR-CE-06

GDA Comments	Comment ID	Section
Justification of materials based on plant performance	01-RB31	4.3.9.1
Justification required for exceeding code limit for shear (not used in GDA calculations)	01-CB06 part 3	4.3.9.2
Consideration of bimetallic corrosion	01-RB13	4.3.9.3

AF-ABWR-CE-06	The use of European civil engineering materials against the performance requirements of the plant has not been justified during GDA. The licensee shall justify the use of European materials in line with performance requirements and the use of European material properties beyond American code limits. The effects of bimetallic corrosion in civil engineering structures/components shall also be checked for the longevity of the plant. Future licensee to refer to section 4.3.9 of Civil Engineering GDA Step 4 report for further information.

4.3.10 Analysis

289. The RP has used the following commercially available software packages:

- ACS SASSI for seismic modelling, including soil structure interaction (SSI)
- NASTRAN or SAP 2000 for static modelling and application of the seismic loads to buildings
- STAAD.Pro for static modelling and application of the seismic loads to tunnels
- SuperFLUSH/2D is a 2-D strain dependent equivalent linear finite element program for efficient seismic soil-structure interaction analysis. This program is used to perform Step 1 – Seismic model for tunnels and tank foundations

290. The above packages are widely adopted and highly regarded in the construction industry. ONR’s assessment is based on the models documented in the RP’s reports and not on the model files. The model files were not provided in GDA.

291. The seismic analysis is performed in a two-step process. I have described the seismic modelling in ACS SASSI in the seismic assessment section (Section 4.3.12). The seismic forces and moments (with the exception of the RW/B and S/B that use accelerations) from the SASSI model (Step 1) are input into the NASTRAN model (Step 2) (for detailed explanation on how the forces and moments are distributed in the NASTRAN model see section 4.3.12). Results from the Step 2 process are extracted and input into the RP’s custom software that is discussed in detailed in section 4.3.15 – Custom software and tools.

292. During my assessment, I have considered the following areas:

- Model accuracy for building structures
- SASSI-NASTRAN comparison and “local checks”
- Mesh quality
- Modelling of connections (1D and 2D elements), Openings & MC Components
- Modelling of ground stiffness

4.3.10.1 MODEL ACCURACY FOR BUILDING STRUCTURES

293. The finite element (FE) models used for the static analysis of the buildings are not wholly representative of the building structures. Significant omissions include:

- Projecting shafts above roof level (Comment 01-CB13).
- Cantilevering extensions beyond the basemat footprints (Comment 01-CB20).
- Internal secondary structural walls – See SASSI-NASTRAN comparison and local checks.
- Analysis models have not been updated to incorporate updated element dimension – This is only applicable to Group B buildings (Comment 01-RW14)

294. The projecting shafts and the cantilevering extensions are not considered in the seismic model but represented in the static model by simplified static forces. The RP reported differences between the engineering drawings and the models, but provided evidence that the differences were minor and did not affect the seismic performance of the building (these differences have been discussed in section 4.3.5 – Structural Interfaces).

295. I consider that the omissions discussed above could change the design of some of the elements of the structure, but the RP has reduced the impact of this finding by considering the loading due to the omitted elements in the structure. The RP has also provided evidence that the seismic performance of the buildings (Group A buildings) remains the same despite the geometrical differences. However, I judge that the finite element model should represent the proposed design.; Hence omissions of large elements, such as the projecting shafts and cantilevering extensions, should be included in the model. I have recorded these omissions in the modelling Assessment Finding, within this Section.

296. The model inaccuracies on Group B buildings (lack of model updates to incorporate new element dimensions) could lead to design changes, but it is unlikely that these will affect the global behaviour of the buildings. I judge that the lack of modelling accuracy is captured within the overarching modelling Assessment Finding, AF-ABWR-CE-07.

4.3.10.2 SASSI-NASTRAN COMPARISON AND "LOCAL CHECKS"

297. The internal secondary walls in the majority of GDA buildings have been omitted from the NASTRAN model but they are included in the SASSI model., Hence the local stress concentrations due to the loading from these walls (mainly dead and seismic loads) are different (Comments 01-RB23 and 01-CB18). The RP carried out local stress checks in the R/B by comparing the results from both models and obtaining a ratio from these results. I proved that the method was not bounding, as it did not consider the interaction between axial force and moment or shear. The RP agreed to carry on the local effect check by computing the utilisation ratios from the SASSI results using a rigorous approach. This work has not been completed across all buildings where the static model omits secondary structural elements (Comments 01-EDG02 and 01-TB04).

298. I consider that the RP did not fully demonstrate, in all the buildings, that the omission of secondary structures, such as secondary walls, will not affect the results. I have raised an Assessment Finding, AF-ABWR-CE-07, to capture this comment.

4.3.10.3 MESH QUALITY

299. I completed a mesh sensitivity study for the R/B and the CST to judge the required fineness and the findings are described below.

300. The RP provided a sensitivity study to justify the mesh quality in the NASTRAN model. However, the mesh quality in the sensitivity study was more refined than the design model. Further investigation of the mesh quality will be required during site specific stage (Comment 01-RB27).

301. Mesh elements around openings and discontinuities have poor element aspect ratios. The RP's sensitivity study did not address this because similar-shaped elements were used (Comment MC-04).

302. The RP reported stresses at the element centres, potentially underestimating the peak moments that occur at the edge of the slabs. The RP proposed a post-process calculation to overcome this issue, but this has not been completed (Comment 01-RB39).

303. The analysis and design approach to apertures needs to be presented (see next section for further information).

304. The mesh quality affects the results provided by the structural models. However, I consider that the sensitivity study provided by the RP, despite highlighting areas for improvement, provides confidence in the global stresses obtained from the models. The issues reported above will affect the local stresses (mainly around openings), but the location of the openings and mesh quality will be developed further in the site specific stage as part of normal business. I am satisfied that the mesh quality is adequate for GDA, but a future licensee should consider the above comments in the detailed design. Hence I have captured this in the modelling Assessment Finding, AF-ABWR-CE-07.

4.3.10.4 MODELLING OF CONNECTIONS (1D TO 2D ELEMENTS), OPENINGS & MC COMPONENTS

305. I found it unclear how the RP was managing the stress concentrations in the connections between 1D frame elements to 2D shell elements. The RP provided the modelling approach for the T/G Pedestal within the T/B as an example, and I accept the approach. Nevertheless, the future licensee will need to confirm that a similar approach is used for other structures. However, based on the example provided, I accept the RP response.

306. I queried if MC components were modelled within the global R/B NASTRAN model and also the symmetry conditions. The RP confirmed that the MC components are modelled in full within the R/B NASTRAN model. I accept the RP response.

307. As explained in section 4.3.2, I found that there is a widespread misalignment between openings at building interfaces (Comments 01-RB35 and 01-RCW03). The RP has acknowledged these omissions and accepts that it may affect the walls/slabs around the non-modelled openings (Comment 01-RB39). I have captured this in the modelling Assessment Finding (AF-ABWR-CE-07) below and in the Assessment Finding (AF-ABWR-CE-02) within section 4.3.3 – Structural Interfaces.

308. I accept that there are a number of unknowns regarding the pipework layout and hence the location of some of the smaller openings is not fully defined. The RP has made a number of assumptions (such as opening location) and this should be consistent across the different buildings/tunnels. Nevertheless, I judge that the overall impact of the lack of clarity and miss-alignment of small openings is small, and these openings will be fully designed in the site specific stage as part of normal business.

4.3.10.5 MODELLING GROUND STIFFNESS

309. I questioned the adequacy of modelling the ground stiffness as uniform and linear for EUR medium sites (Comments 02-004, 02-020, 02-025 and 02-028), as a raft foundation will act in a flexible manner with the edge stiffness being larger than at the centre. The RP provided a sensitivity study for a medium soil considering a non-uniform array of springs (with higher stiffness at the corners and edges). The sensitivity study showed that the raft design is not particularly sensitive to the variation on formation stiffness. The assumption that the ground stiffness is uniform and linear is

acceptable if the formation material is rock; hence I accept the RP's modelling of the ground stiffness for a EUR hard site.

310. I consider that the RP has provided enough evidence on the modelling of the ground stiffness for GDA, but the ground stiffness assumptions will need to be revisited during the site specific stage. I have captured this within finding AF-ABWR-CE-03, in section 4.3.6 – Ground Conditions and Site Envelope.

4.3.10.6 CONCLUSION - ANALYSIS

311. I have assessed the analysis techniques against SAPs ECE.12, 13, 14, and 15. Based on the sensitivity studies, the validation methods presented and the modelling parameters, I judge the modelling techniques and modelling assumptions acceptable for GDA. However, I do not believe that the approach adopted by the RP is conservative in terms of assessing the local effects in some structural elements. Hence I have raised the following Assessment Finding.

Table 14: Civil engineering comments relating to AF-ABWR-CE-07

GDA Comment	Comment ID	Section
Structures on the roof	01-CB13	4.3.10.1
Completeness of model	01-CB20	4.3.10.1
Traceability of information	01-RW14	4.3.10.1
NASTRAN vs SASSI design check	01-RB23	4.3.10.2
SASSI- NASTRAN comparison	01-CB18, 01-EDG02, 01-TB04	4.3.10.2
Mesh quality and element results	01-RB27	4.3.10.3
FE mesh	01-RB39	4.3.10.3

AF-ABWR-CE-07	In the analysis of a number of civil engineering structures, there are cases of modelling simplifications that need further justification. The licensee shall justify key modelling simplifications in nuclear safety significant civil engineering structures, with particular attention to finite element mesh quality and the omissions of secondary structures from the model. Future licensee to refer to Section 4.3.10 of Civil Engineering GDA Step 4 report for further information.

4.3.11 Member and connections design

312. Within this section I have assessed the design of the following elements:

- Reinforced concrete elements (slabs, walls and columns)
- Steel members (excluding MC components)
- Tank bases and enclosures
- MC Components
- R/B Ventilation Exhaust Stack (Stack)

313. During GDA Step 3, it was agreed that the RP would provide typical example calculations and details of relevant and more complex civil structure connections in GDA Step 4. This was a difficult area in which to achieve agreement but the RP provided a number of examples of connection designs and details. However, in some cases such as Pedestal to shield wall connection, the RP did not provide those details.

My assessment of the connection design is discussed in each of the following subsections.

4.3.11.1 REINFORCED CONCRETE ELEMENTS

314. Reinforced concrete (RC) walls and slab elements have been modelled as 2D shell elements and analysed with an in-house software package, SSDP-2D. This software compares the stresses obtained from the finite element model against code criteria, but requires the designer to input the reinforcement area and the section thickness. I have raised a number of comments on the SSDP-2D (see section 4.3.15).

315. With the exception of the RPV Pedestal and diaphragm wall, the concrete structures are designed to ACI 349-13 (Annex 3). Concrete within the MC components is designed to ASME III-2 (Annex 3).

316. I raised the comments below when assessing the RC member design.

317. The compressive flexural stress check is completed according to code, but contains a simplification that could lead to a non-conservative answer if the reinforcement area is overstated (Comment 01-CB08).

318. Through thickness tension forces have not been considered at the junctions between members (Comment 01-RB37). Typical wall-slab connection drawings were requested to understand if the tension force is anchored through the thickness of the resisting element. The RP did not provide this detail.

319. The RP did not carry out a bi-axial bending check (Comment 01-CB09), but the RP provided a quick check on a sample column by combining the utilisation from different uni-axial bending checks and it proved to be non-critical.

320. The T/G Pedestal within the T/B will behave as a moment frame in the east-west direction. The RP has not checked the T/G Pedestal for the specific provisions within ACI 349 for lateral force resisting moment frames (Comment 01-TB02). The RP has justified the design by quoting low utilisation ratios.

321. I consider that the RP has overlooked a number of structural checks and the effect of certain forces (biaxial bending, through thickness tension forces and lateral forces on moment resisting frames) on some RC elements. I do not expect these shortfalls to significantly change the design, but it is my expectation that these checks and assessment are carried out by the future Licensee. Therefore, I have raised an assessment finding (AF-ABWR-CE-08) to capture this shortfall. Within this AF I have included a number of comments on the design of shear keys. These comments are explained in Section 4.3.13 – Stability.

4.3.11.2 STEEL MEMBERS (EXCLUDING MC COMPONENTS)

322. Steel members are included in the roofs of most structures, including the R/B, C/B, T/B and CST tank enclosure.

323. Across all structures (with the exception of MC components), steel members are being designed in accordance with AISC N690-12 using the load and resistance factor design method.

324. The RP has considered the interactions of most actions, with the exception of torsion. This practice is not uncommon and can be acceptable if there is a reduction on the torsional stiffness of elements. However, it is not clear if the torsional stiffness has been reduced (Comment 01-CTS03).

325. The design and detailing of all steel connections is outside the scope of GDA. However, the scope of GDA Step 4 includes design evidence from the RP of typical steel connections (Comment 01-RB21). The RP provided representative connection calculations for a moment and a pin connection. The calculations were in accordance with AISC N690-12.

326. I consider that the steel member design presented by the RP is reasonable and sufficient for GDA. The remaining steel design work (the design of all steel connections) will be completed in the site specific stage. I consider that the future licensee should include a clarification on torsion and torsional stiffness at a future design stage. This is a minor comment and I do not believe it will have a major impact in the design. Hence I judge this comment to be a minor shortfall.

MS-ABWR-CE-01.	The licensee should include a clarification on torsion and the torsional stiffness approach for steel member design.

4.3.11.3 TANK BASES AND ENCLOSURES

327. I also assessed the tank structures (tank bases and enclosures) and raised a number of comments on the RC design that were answered satisfactory by the RP. Only two minor comments remain open, as follows:

- The procedure for designing wall and slab elements is accepted by ONR, but there are inconsistencies in terms of sign conventions. (Comment 01-CST14).
- The RC corbels in the CST enclosure are designed using a shear friction model. This is acceptable but UK recommended good practice promotes the use of a strut or tie model. (Comment 01-CST05).

328. The points raised above are minor and I am satisfied with the design. My reasons for accepting the design are that the RP has taken a conservative approach to the combination of forces within elements (first bullet point above) and the reinforcement proposed for the corbel exceeds the calculated reinforcement (second bullet point above).

329. It should be noted that the tank and holding down bolt design is outside of the GDA scope.

4.3.11.4 MC COMPONENTS

330. As stated in section 3, the MC components assessed by the civil engineering discipline include: RPV Pedestal, D/F, RSW and the Access Tunnel.

331. The MC components include a mixture of thin-walled steel structures, reinforced concrete structures with sacrificial steel formwork (the D/F), and steel-concrete structures for which the benefit of the concrete infill is neglected (RPV Pedestal).

332. With the exception of traditional reinforced concrete, none of the structures are designed to act as composite systems.

333. The MC components design is one of the areas where the RP has provided an unsatisfactory level of detail. This was reported earlier in GDA Step 4 to the RP (01-MC09), and some detailed information was provided, but there are some important gaps in evidence provided.

334. Some of the MC components are thin-walled steel plates subject to high compressive forces, such as the RPV Pedestal, and so, the buckling should be checked (Comments

01-MC07, 01-MC08 and 01-MC23). The RP provided insufficient evidence to assess if buckling has been considered.

335. I asked for details on a number of critical, bespoke connections that support the MC components (Comments 01-MC03, 01-MC13 and 01-MC18). The RP provided detailed information for some of these connections, but for others, such as the RPV Pedestal to shield wall connection, the information provided was inadequate.

336. The access tunnel movement joints consist of flexible steel joints that can accommodate certain degree of movement and reduce stresses. However, these joints do not allow completely free axial movement of the access tunnel and, hence, will transfer some axial load. Therefore, it is possible for compressive stresses to exist in the access tunnel. (Comments 01-MC23 and 01-MC25). The RP has not checked compression and buckling in the tunnel.

337. The RP did not provide details of the welds connecting the steel plates on the RPV Pedestal or enough detail on the stress evaluation points for those steel plates.

338. The D/F is subject to large concentrated through-thickness shear forces resulting from jet loads (Comment 01-MC15). The RP has not made allowance for the different combinations of shear and axial forces (tension) in the evaluation of the shear resistance.

339. In summary, the initial RP’s submission on the MC Components was incomplete, but was supplemented by a number of calculations and connection details after my comments. After assessing the RP’s latest submission, I consider that the RP has not fully demonstrated the design of the MC components and there are a number of gaps in the design calculations. However, I judge that this justification can be provided by the future licensee at site specific stage and I have raised an Assessment Finding (AF-ABWR-CE-09) that captures all the aspects discussed above, plus the comments from previous sections (Section 4.3.5 and 4.3.8).

4.3.11.5 R/B MAIN VENTILATION EXHAUST STACK (STACK)

340. The stack is a triangulated steel lattice structure, made up of circular hollow sections. The RP has designed the major elements and provided the design intent for connections. The stack steel members are being designed to AISC N690-12.

341. My assessment of the stack member design found the following:

- The impact assessment (tornado borne missile) of the stack concludes that one circular hollow section will be perforated. The RP has not demonstrated that the damage will not compromise the function of the member and hence the stability of the stack (Comment 01-ST04).
- The base connection of the stack lattice structure has been modelled as a pin connection but it resembles a fixed connection. The sensitivity study performed by the RP confirmed that bending moments will be developed at the base and their effect is significant (10% increment in structural member with high utilisation factors) (Comments 01-ST06 and 04-007).
- The RP did not include the live load for maintenance in the stack design. I acknowledge that the effect is minor, but further justification is required during the site specific stage (Comment 04-006).
- The RP has not provided enough information to assess how the loads at the base of the stack have been transmitted to the R/B roof slab (Comment 01-ST06)
- The RP has not provided a suitable explanation for not considering the combination of seismic loading and ice loads on the stack. I do not consider this combination critical but a less simplistic and robust answer is needed

during the site specific stage (see section 4.3.12.2 –Seismic Analysis – Modelling Assumptions).

- Accidental torsion loads have not been included in the R/B stack analysis, as recommended in ASCE 4-16 (Comment 04-010)

342. The verification and validation information for the seismic analysis of the R/B stack was provided in response to an assessment comment (04-011). The information provided is reasonable but it has not been included in the design report for the stack. This finding alone will not become an Assessment Finding, however, for completeness; I have included it within the Assessment Finding for the stack.

343. As discussed in the loading section, 4.3.8, a number of loadings have been omitted for the stack design, so I have taken a holistic approach and captured the omission of loads in the stack design and all the above comments into one Assessment Finding (See below).

4.3.11.6 CONCLUSIONS – MEMBER AND CONNECTION DESIGN

344. I carried out my assessment of the member and connection design against SAPs ECE.1, ECE.6, ECE.12, ECE.13 and ECE.15. I judge that the data used in the structural analysis has enough conservatism to demonstrate the safety of the design and the sensitivity studies support the RP's methods of calculations. However, there are certain areas that need further consideration, and so I raised a number of Assessment Findings. I have summarised my assessment of the member and connection design below.

345. My assessment of the steel members and connections (excluding MC Components) showed that the RP's approach is adequate for Step 4 GDA.

346. My assessment of the concrete design of the tank bases and enclosures showed that the RP's approach is adequate for Step 4 GDA.

347. My assessment of the RC frame elements highlighted gaps in the design (such as biaxial bending, through thickness tension forces and lateral forces on moment resisting frames) and so I have raised an Assessment Finding (AF-ABWR-CE-08).

348. As discussed before, the type and quality of information initially presented by the RP on the MC components (RPV Pedestal, D/F, RSW and access tunnel) was not adequate for GDA. The RP improved their technical submissions after ONR raised a number of questions (see comment register, Ref 133), but there are still gaps in the design (buckling checks, connection design, etc.). I consider that the RP has not fully demonstrated the design details of the MC Components; however I judge that this justification can be provided by the future licensee at site specific stage, and I have raised an Assessment Finding (AF-ABWR-CE-09) to capture all the MC Components comments.

349. My assessment of the stack design showed a significant number of omissions and design shortfalls; hence I decided to capture all of them under one Assessment Finding, AF-ABWR-CE-010.

Table 15: Civil engineering comments relating to AF-ABWR-CE-08

GDA Comment	Comment ID	Section
Concrete section design – Wall and Slab Elements	01-CB08	4.3.11
Concrete section design – Columns and girders	01-CB09	4.3.11

Basemat shell elements	01-RB37	4.3.11
T/G Pedestal	01-TB02	4.3.11
RW/B and S/B Spreadsheets	01-RW07, 01-RW09, 01-RW10, 01-RW11	4.3.11
Performance of service building shear key	01-RW12 (4)	4.3.13.2
Detailed design of shear key	01-CST09, 01-FLSS02	4.3.13.2
Load paths across building interfaces	01-CB14 (1)	4.3.13.2
Deflection control	01-CB15, 01-CB16 & 01-CB19	4.3.14

AF-ABWR-CE-08	In the civil engineering design, a limited number of structural checks have been carried out on structural members. To address this limitation, the licensee shall ensure that a robust process for the detailed design of members and connections of reinforced concrete elements is in place. The licensee to refer to section 4.3.11 of Civil Engineering GDA Step 4 report for further information.

Table 16: Civil engineering comments relating to AF-ABWR-CE-09

GDA Comment	Comment ID	Section
Weld design	01-MC03	4.3.11
Allowable stress factor	01-MC07	4.3.11
Buckling analysis	01-MC08	4.3.11
Incomplete design	01-MC09	4.3.11
Connection Detail	01-MC13	4.3.11
Punching Shear	01-MC15	4.3.11
RPV Pedestal stress evaluation points	01-MC18	4.3.11
Minimum principal stress	01-MC23	4.3.11
Access tunnel movement joints	01-MC25	4.3.11
RSW buckling	01-MC26	4.3.11
Seismic loads	01-MC06	4.3.8
Construction loads	01-MC11 & 01-MC14	4.3.8
Pipe reactions	01-MC16	4.3.8
Report omissions	01-MC19	4.3.8
Jet load	01-MC21	4.3.8
Access tunnel dynamic loads	01-MC24	4.3.8
RPV Stabilizer	01-MC02	4.3.4
Drywell connecting vents	01-MC12	4.3.4
Anchor bolt shear	01-MC10	4.3.16

AF-ABWR-CE-09	As the information on the civil engineering Metallic Containment Components was limited, the licensee shall justify the design and construction details, including connections, of the Reactor Pressure Vessel pedestal, access tunnel, diaphragm floor, reactor shield wall and Reactor Pressure Vessel stabiliser. Future licensee to refer to section 4.3.11 of Civil Engineering GDA Step 4 report for further information.

Table 17: Civil engineering comments relating to AF-ABWR-CE-010

GDA Comment	Comment ID	Section
Impact assessment	01-ST04	4.3.11
Stack base connection details	01-ST06	4.3.11
Thermal effects	01-ST02	4.3.8
Fatigue	01-ST03	4.3.8
Stack live loads	04-006	4.3.8 & 4.3.12
Stack boundary conditions	04-007	4.3.8 & 4.3.12
Stack ice loads	04-008	4.3.12
Stack accidental torsion	04-010	4.3.8 & 4.3.12
Stack verification & validation	04-011	4.3.8 & 4.3.12

AF-ABWR-CE-010	Due to the simplified range of loadings and structural checks carried out during Generic Design Assessment, the licensee shall undertake a detailed design of the Reactor Building stack. This shall include impact, fatigue and thermal loads, accidental torsion loads and connection design. Future licensee to refer to section 4.3.11 of Civil Engineering GDA Step 4 report for further information.

4.3.12 Seismic assessment

350. For each of the buildings the seismic analysis was performed in two steps. The first step was to perform an SSI analysis using three dimensional (3D) finite element models in the SASSI computer program, principally using shell elements for the structures. The models were deemed sufficiently detailed to capture out-of-plane panel modes. Linear time history analyses were performed for different generic subgrade conditions with further sensitivity studies performed to cover numerous other input variables, including Structure-Soil-Structure Interaction (SSSI) effects. From these analyses, results were extracted and enveloped for input into the Step 2 static stress analysis models.

351. For the majority of buildings including the Reactor Building, forces and moments were extracted from the SSI analyses. At each major floor level post processing is performed to condense all of the nodal forces and moments into one single maximum value for each component of force. These were then distributed onto the separate Step 2 static stress analysis models, these being 3D models using the NASTRAN finite element program. To capture the out of plane response of walls and floors, the out of plane accelerations also derived from the Step 1 SSI analyses were applied, and for embedded structures, contact pressures at interfaces between exterior walls and the surrounding subgrade were also applied.

352. For the Services and Radwaste Buildings, a different Step 2 approach was adopted whereby the peak accelerations derived from the SSI analyses were applied instead of

the forces and moments. The 3D models for these static analyses used the SAP 2000 finite element program.

353. Results from the Step 2 static analysis models were extracted for design of the structures. At GDA, a further check was performed for some of the key buildings to make sure that the Step 2 static analysis results used for design bounded those from the Step 1 SSI analysis results. Where this was not the case, the static analysis results were modified for design.

354. The GDA assessment reported here considered the analyses performed in their entirety to assess whether they were considered to be in accordance with relevant good practice and current guidelines and standards.

355. In addition, adequate seismic margins for the loss of safety function have been demonstrated for the Beyond Design Basis Earthquake. RP document Seismic Evaluation Methodology of Cliff Edge Effect on Civil Structures (Ref 123) has been assessed and an RQ, RQ-ABWR-1387 (Ref 148), was issued to challenge the RP's methodology. I assessed the response to the RQ (Ref 148) to be adequate and the outcome is recorded in Section 4.3.21 of this report.

356. This section reports the findings of the seismic analysis assessment carried out for the building structures and service tunnels submitted for assessment by the RP. The assessment generated comments that relate to following technical themes:

- Finite Element Analysis Techniques
- Modelling Assumptions
- Treatment of Embedment
- Treatment of SSSI
- Reduced GDA Scope
- Verification and Validation
- Completeness or Thoroughness of Approach

357. Full details of the seismic analysis assessment comments are provided in the TSC Seismic Assessment Report (Ref 16), incorporating the formal responses and or clarifications received from the RP during the Step 4 programme.

358. Generally, the seismic analysis for the UK ABWR is relatively conventional in its adoption of established American codes of practice and industry accepted analysis software. Furthermore, the RP has taken reasonable steps to supplement American codes with British and European requirements, mixing codes with reasonable care. The RP has also taken some cognisance of a draft version of a significant American code in terms seismic analysis of nuclear structures, namely ASCE 4, prior to its formal issue in April 2017, very late in the GDA process.

359. I have summarised below the key findings of the seismic assessment, along with a brief description.

4.3.12.1 FINITE ELEMENT ANALYSIS TECHNIQUES

360. For all buildings, a two-step analysis is used. Generally this adopts a Soil Structure Interaction (SSI) analysis to generate the global forces in the building which are then applied to a separate stress analysis model (NASTRAN). This method, when combined with the RP's adopted additional checks, is considered acceptable. However, for the Radwaste Building and Services Building, rather than extracting the forces from the SSI analysis, accelerations are extracted which are then applied to the stress analysis model (as explained in the Analysis section of this report, 4.3.10). This approach is only appropriate for structures responding primarily in one mode in each of the horizontal directions.

361. I requested more information on the structural modes of the Rw/B and found that the fundamental modes in both translation directions contained less than 60% of the total mass (Comments 04-059 and 04-061). ASCE 4 states that the approach is only applicable where higher mode translational effects are insignificant. I consider that 40% of the structural mass is not insignificant and therefore the approach is not compliant with ASCE 4.

362. I have made a follow-on comment on how the accelerations are applied in the structural model (see Analysis section 4.3.10). In general, I judge that the RP has not demonstrated an adequate seismic/structural approach for the Rw/B and S/B. I decided to include my comments on the FEA approach for the Rw/B and S/B within the overarching assessment finding (Section 4.3.12.5) for Group B structures, as these buildings are part of this group.

4.3.12.2 MODELLING ASSUMPTIONS

363. Numerous assumptions have been adopted by the RP for the GDA. Generally these have been made where site conditions such as soil properties are unknown, or where design of plant and equipment has not yet been performed.

364. I have summarised the assumptions made by the RP in different categories and my view on these parameters and assumptions is provided below.

365. Generic site specific assumptions (Comments E.1, E.4, E.19, E.21, 04-012, 04-022, 04-045, 04-065 & 04-066) – I consider that the RP has selected conservative parameters in some areas, such as the ground water level. Other parameters that require further development during the site specific stage are:

- the effect of soil varying in depth.
- the soil modulus and damping variation adopted for backfill materials.
- the range of soil properties.

366. Plant item representation - The plant is represented in the model as rigid lump masses located at floor level. I consider that this could underestimate the overturning effects from the plant as its centre of gravity is above floor level. The RP acknowledged this shortfall but stated that plant information was not available during GDA. Comments 04-003, 04-023, 04-32, 04-38, 04-042, 04-043, 04-056 & 04-058.

367. Stack ice loads – The RP did not consider combined seismic and ice loads, and argued that the accumulation of ice on the stack would be “shaken off” during a seismic event. I do not consider this combination critical but a less simplistic and robust answer is needed during the site specific stage (Comment 04-008). I included this comment in the stack assessment finding AF-ABWR-CE-010 (see section 4.3.11)

368. Stack live loads and boundary conditions (Comments 04-006 and 04-007) – These are discussed in detail in section 4.3.11.

369. Crane Modelling – I queried on the effect that the crane will have on the building during a seismic event (Comment 04-051). The RP, initially, presented the time-at-risk argument, and ONR explained that this is not acceptable for new buildings. The RP provided two sensitivity analyses: one with the crane in the middle of the building and a second analysis that captured the dynamic response of the crane. I consider this approach appropriate for GDA, but further justification is required during the site specific stage.

370. Lower Dry Well Access Tunnel – I found that the access tunnel was not included in the R/B analysis model, with the exception of its mass (Comment 04-055). The RP justified this decision by claiming that the access tunnel joints can accommodate movement, hence, the load is not transmitted. However, these joints have a degree of stiffness

and they will transmit loads due to relative displacements. The RP carried out a sensitivity analysis, but only global forces were compared. The comparison did not include the localised effects of the access tunnel into the structures or the loads within the access tunnel (see section 4.3.11.4). I consider that the seismic analysis does not capture the loads generated by the access tunnel within the RCCV.

371. When the above information is known at the detailed design stage, I expect that such information will be adopted and the design checked. Additionally, there have been further assumptions, such as modelling of the Access Tunnels, which have not been fully substantiated at GDA. Hence I judge that further consideration will be required at the detailed design stage and I have raised an assessment finding that captures all the above comments.

Table 18: Civil engineering comments relating to AF-ABWR-CE-011

GDA Buildings Comment	**Comment ID**	**Section**
Generic / site specific assumptions	E.1, E.4, E.19 & E.21	4.3.12.2
Plant item representation	04-003, 04-023, 04-32, 04-38, 04-042, 04-043, 04-056 & 04-058	4.3.12.2
Crane modelling	04-051	4.3.12.2
Lower Dry Well Access Tunnel	04-055	4.3.12.2
GDA Tunnels and Tanks Comment	**Comment ID**	
Soil properties for seismic analysis	04-012, 04-022, 04-045, 04-065 & 04-066	4.3.12.2

AF-ABWR-CE-011	To address limitations on the level of detail and justification provided in the GDA seismic models of the civil engineering structures, the licensee shall validate the seismic analysis modelling with site specific soil properties, accurate representation of plant items, further crane loading combinations and include the lower dry well access tunnel in the seismic model. Future licensee to refer to section 4.3.12.2 of Civil Engineering GDA Step 4 report for further information.

4.3.12.3 TREATMENT OF EMBEDMENT

372. The treatment of embedment and fill materials in the seismic analyses was queried extensively at GDA.

373. The initial seismic analysis models for the R/B assumed rock properties on all four sides, ignoring fill materials and embedding all sides in rock. I expressed my concern on the potential for generating non-conservative results, since the above conditions will over restrain the building. (Comments E.70, 04-032 & 04-002).

374. The RP provided a definition of competent fill material (such as lean mix concrete), which I accepted.

375. I queried the modelling of the embedment conditions, since buildings like the R/B are not fully embedded on all four sides, in particular at the interfaces with the C/B and the Fv/B.

376. The RP presented a sensitivity study for the R/B, where the air gaps between the buildings were considered. However, in this study the model included full attachment to the soil interfaces. This meant that unrealistic conditions, such as normal tension forces resisted by the soil interfaces and shear forces that can overcome the frictional resistance, will take place and become a potential (unrealistic) load path. I requested a fully bounding analysis for the R/B where connectivity on the north-south direction was removed.

377. The result of the above assessment showed a reduction of the global forces as the fundamental frequency of the building shifted below the peak of the input spectrum. However, there was also a re-distribution of the forces (as the load path changed) and the design forces for some floors below ground level increased. The magnitude of some In-Structure Secondary Response Spectra (ISSR) also increased slightly. The RP argued that conservatism within the design will accommodate these increments in the forces.

378. Similar sensitivity studies are required for the remaining buildings in the cruciform arrangement (Fv/B, TB, Rw/B and S/B) with the exception of the C/B as a full four side embedment assumption is acceptable. I noted that, while for the R/B the assessment resulted on a reduction of the global forces, the remaining buildings in the cruciform arrangement could experience higher global forces if the fundamental frequency moves to the top of the spectrum. The RP has not carried out this assessment, so currently this remains a possibility. (Comments 04-032, 04-038, 04-058 & 04-061).

379. I consider that the effects of fill materials and embedment conditions are very important and could impact on the design. I judge that the RP has provided enough information to justify their embedment assumptions for the R/B for GDA. However, a further assessment is necessary for the rest of the buildings in the cruciform arrangement. I have raised an assessment finding for the future licensee to provide thorough consideration of the embedment and fill materials effects for all embedded or underground structures. I have combined the assessment finding with the Structure Soil Structure Interaction (SSSI) assessment finding (see below).

4.3.12.4 STRUCTURE SOIL STRUCTURE INTERACTION (SSSI)

380. A SSSI assessment will establish the effect that buildings/soil have on each other during an earthquake. This is critical when large buildings are closed together, as it is the case for the cruciform arrangement in the nuclear island. For GDA, the RP performed a SSSI analysis along the north-south direction to establish how the R/B, C/B and T/B and the soil respond in combination with each other. I stated that the SSSI analysis was not performed in the east-west directions (i.e. Rw/B, C/B and S/B) (Comment 04-024). The RP believes that the main SSSI effects are captured by the north-south analysis as the buildings are heavier than in the east-west direction. Also these effects (SSSI in the north-south direction) do not change the global loads of the structure.

381. The following points should be considered by the future licensee during the site specific stage:

- The interaction (and possible SSSI assessment) of structures such as LOT and the connecting service tunnel (Comment 04-048).
- The effect of the in-situ soil layer to the pump room basement in the CST SSSI model (Comment 04-062).

382. I judge that the SSSI effects were generally considered using 2-D slice models, although this was not rigorously applied for all structures, e.g. the Radwaste Building and Services Building. I judge that the future Licensee should carry out the SSSI in the east-west direction during the site specific stage and consider the results in terms of

local effects at the interfaces between the Rw/B, C/B and S/B. I have raised an assessment finding to ensure that this assessment takes place.

Table 19: Civil engineering comments relating to AF-ABWR-CE-012

GDA Buildings Comment	Comment ID	Section
Fill material	E.70, 04-032	4.3.12.3
Over claimed embedment	04-002, 04-032, 04-038, 04-058 & 04-061	4.3.12.3
Structure Soils Structure Interaction	04-024	4.3.12.4
GDA Tunnels and Tanks Comment	**Comment ID**	
LOT & Connecting Service Tunnel SSSI	04-048	4.3.12.4
CST SSSI results	04-062	4.3.12.4

AF-ABWR-CE-012	Due to simplifications and assumptions on the seismic analysis of the civil engineering structures, the licensee shall justify that the effects of embedment, fill material and SSSI on the design of nuclear safety significant buildings and tunnels is fully accounted for. Future licensee to refer to section 4.3.12.3 and 4.3.12.4 of Civil Engineering GDA Step 4 report for further information.

4.3.12.5 REDUCED GDA SCOPE

383. The in-structure response spectra (ISRS) are needed for the design of safety related plant. The RP only provided limited ISRS for the C/B, hence I consider that the future licensee should provide a full suite of spectra at site specific stage (Comments 04-028 and 04-032). I accept this answer, as some ISRS were provided for all the buildings, but I judge that these comments should be captured in an assessment finding.

384. ONR agreed with the RP to have a reduced scope for a number of buildings (listed in Sections 4.2 and 4.3.1) in terms of breadth of treatment and extent of results presented (Comments 04-039, 04-042, 04-043, 04-056, 24-058 & 04-061). I expect the future Licensee to produce full designs for all the buildings during the site specific stage. I have raised an assessment finding to capture the reduce scope (see below).

385. The reduced scope did not include the local design check to confirm that the NASTRAN results are bounding compared to the SASSI analysis results. I raised a specific comment on the T/B to capture potential for error due to the structural complexity of this building (Comments 04-040, 04-042, 04-043 & 04-056).

386. The seismic analysis for a number of buildings was simplified and the scope much reduced for GDA. I judge that the future licensee should provide a full scope and justification for all safety related structures at site specific stage.

Table 20: Civil engineering comments relating to AF-ABWR-CE-013

GDA Buildings Comment	Comment ID	Section
In-structure response spectra	04-028 & 04-032	4.3.12.5
Reduced GDA scope	04-039, 04-042, 04-043, 04-056, 24-058 & 04-061	4.3.12.5

Local design checks	04-040, 04-042, 04-043 & 04-056	4.3.12.5
Applicability of two step analysis	04-059 & 04-061	4.3.12.1
Application of seismic accelerations	01-RW06	4.3.8

AF-ABWR-CE-013 The reduced scope of GDA for the Radwaste Building, Service Building, Heat Exchanger Building, Turbine Building, Back-up Building and Emergency Diesel Generator Buildings meant that a reduced seismic and structural assessment was performed for these buildings during GDA. The licensee shall complete the seismic analysis of the above buildings in line with relevant good practice. Future licensee to refer to section 4.3.12.5 of Civil Engineering GDA Step 4 report for further information.

4.3.12.6 VERIFICATION AND VALIDATION

387. During GDA Step 3, I asked the RP to provide the verification and validation of the finite element models. The RP provided the verification and validation (V&V) of the R/B model during the Step 4, which included a fixed base modal analysis to demonstrate the global response of the building without the influence of soils. I requested fixed base modal analysis information for the C/B and other buildings to assess the verification and validation methods (Comments 04-023, 04-032, 04-038, 04-042, 04-043 & 04-058). However, the RP considers that V&V provided for the R/B covers the rest of the buildings as the methodology is similar therefore no further information has been provided. For generic modelling items, such as rigid spring modelling and finite element offsets, I accept that reference back to the R/B is sufficient, but there is building specific information that require further V&V. I have raised an assessment finding to capture this shortfall.

388. The determination of the seismic loads for the RCW tunnel design is based on computer-based analysis with assumptions and approximations made in the process. After raising a comment on this area, the RP provided the evaluation results which included a sensitivity assessment of the boundary conditions. However, I consider that a form of validation work is required in order to validate the computer-based SSI analysis for the RCW tunnel, and this comment also applies to the R/B to B/B Connecting service tunnel, R/B to EDG/B connecting service tunnel, the LOT basement and connecting service tunnel, the CST and connecting service tunnel and the FLSS and connecting service tunnel (04-020, 04-022, 04-045, 04-065 & 04-066).

389. I have included the verification and validation comments for the R/B stack within Section 4.3.11. (Comment 04-011).

390. I consider that there are some areas where the RP has not rigorously demonstrated the appropriateness of the seismic analysis models and procedures adopted or proposed. Hence, I have raised an assessment finding to capture this shortfall.

Table 21: Civil engineering comments relating to AF-ABWR-CE-014

GDA Buildings Comment	Comment ID	Section
Fixed base modal analysis results	04-023, 04-032, 04-038, 04-042, 04-043 & 04-058	4.3.12.6
GDA Tunnels and Tanks Comment	**Comment ID**	
RCW validation of SSI results	04-020, 04-022, 04-045,	4.3.12.6

	04-065 & 04-066	

AF-ABWR-CE-014	Some aspects of the seismic analysis models and procedures require further validation and verification. The licensee shall undertake suitable verification and validation methods for the Reactor Building, Control Building, Filter Vent Building, Turbine Building, Emergency Diesel Generator Buildings, Backup Building and Radwaste Building and connecting tunnels. Future licensee to refer to section 4.3.12.6 of Civil Engineering GDA Step 4 report for further information.

4.3.12.7 COMPLETENESS AND THOROUGHNESS OF THE GDA

TUNNELS AND TANKS

391. The tunnel design has not been completed to the same level of detail as the Group A buildings. The RP has argued that many of the parameters to detail design the tunnels are not available in GDA. I believe that GDA should be based on a number of assumptions to allow a meaningful assessment, so I do not fully agree with the RP's statement. However, on balance, the tunnels depend on multiple site specific parameters (from soil conditions to service loads and tunnel layout) and their design will normally change at site specific stage. Hence, I have captured the most significant comments regarding tunnel design within the assessment findings in this report, and the minor comments that will not affect the design as minor shortfalls.

392. I queried the seismic design approach for tunnels and found that, after assessing the RP's replies, some of the comments were not fully addressed, but the remaining points were minor. Hence I have raised three minor shortfalls:

393. The RP did not demonstrate that the services passing across the RCW tunnel joints can accommodate the displacements from phase difference of seismic response (Comments 04-021, 04, 022, 04-045, 04-065 & 04-066). I consider this a minor shortfall because the information on services within the tunnel is not available in GDA, but it should be considered in the site specific stage.

MS-ABWR-CE-02.	The licensee should determine if the tunnel joints can accommodate the differential displacements from seismic loadings.

394. In the preliminary seismic study of the RCW tunnel, responses obtained from using 1D soil column analysis showed good correlation with those obtained from 2D SSI analysis of the RCW tunnel. A 1D analysis was performed for each tunnel and the critical cases for each tunnel were based on this analysis. I accept this approach but I had an observation regarding tunnels that are structurally different, such as the LOT Connecting Service Tunnel and the RCW tunnel. The tunnels differ in the number of chambers and this structural difference could result in differences between the 1D and 2D SSI analysis if to be performed in the LOT tunnel (Comment 04-049). The RP provided a study for the LOT tunnel to confirm the 1D analysis critical cases with respect to the 2D SSI analysis. I am satisfied by the answers provided by the RP on this matter.

395. The RP did not include the seismic effects on the longitudinal direction and the inertia force effects in the RCW tunnel design (04-018, 04-022, 04-045, 04-065 & 04-066). I queried this design omission and the RP argued that these effects are small, but provided limited information to support the claim. The longitudinal effects in the tunnels are not considered in the structural design either (01-RCW02) and the RP stated that uniform longitudinal ground and overburden conditions were assumed, and so the

longitudinal effects are insignificant. I have captured the structural comment within AF-ABWR-CE-03 as it depends on the site characterisation. I judge that the RP's response to the seismic effects on the longitudinal direction is acceptable for GDA, but I have raised a minor shortfall to capture this comment.

MS-ABWR-CE-03.	The licensee should ensure that the effects of seismic loading in the longitudinal direction and inertial loading are taken into account in the Reactor Cooling Water tunnel design.

396. The tanks and holding down bolts are outside of the scope of GDA and so I am not including any comments on these two items. The future licensee should consider the seismic forces, calculated in the tank foundation design (within GDA's scope), when designing the tanks. I judge that a SQEP (Suitably Qualified and Experienced Person) designer will consider the seismic forces when designing the tanks, and I consider this normal business.

GENERAL DESIGN COMMENTS

397. As explained in Section 4.3.2 - Structure Classification, all of the civil engineering structures have been classified as Seismic Category 1, 2 or 1A.

398. Seismic Category 1 includes Type A and B structures (as defined in Section 4.3.1). The seismic assessment for Type A buildings includes all ground properties (upper, medium and lower bound conditions) and combinations. The seismic assessment for Type B structures has been simplified and only includes medium bound conditions. Seismic Category 2 includes Type B structures and so the assessment has been simplified as explained above.

399. Category 1A civil structures are designed to withstand the appropriate design basis earthquake for their safety class (e.g. Class 2 is 10^{-3}/yr seismic event) followed by a check of key elements to demonstrate that collapse against an adjacent Category 1 does not occur, during an earthquake with an annual probabilities of exceedance of 10^{-4} (DBE earthquake). I assessed the application of this process as presented in the Turbine Building Structural Design Report (Ref 68). In this document, the RP demonstrates that the Turbine Building does not impact on the Control Building due to the DBE using the following methods:

- The relative displacements between the two buildings predicted by the Soil Structure Interaction (SSI) studies were demonstrated to be less than the width of the "air gap" provided.
- The global in-plane shear resistance of the Turbine Building was demonstrated to be greater than the allowable in ACI 349-13.
- The global resistance to foundation sliding was demonstrated to be acceptable. I consider that the methodology applied to Seismic Category 1A structures is acceptable.

400. The RP increased the cut off frequency in the SSI analyses from 33 Hz to 40 Hz in order to envelop the ZPA frequency of a hard site (Comment E11). I consider this cut off frequency acceptable for GDA, but this should be revisited during the site specific stage, as very hard rock sites will have a higher cut off frequency. I have captured this comment in an assessment finding as the future licensee will need to consider the site characterisation during the site specific stage and address it as per Assessment Finding AF-ABWR-CE-03.

401. Other areas of the design that were not addressed satisfactorily are as follows:

- The OBE has not been considered in the loading combinations as it is less than one-third of the safe shutdown earthquake. However, the OBE should be considered by the future licensee during the site specific stage, as it could be governing some design cases (Comment E4). Alternatively the future licensee should provide a robust justification to exclude the OBE design case during the site specific stage.
- The GDA work regarding the GDA buildings does not include non-linear work or equivalent linear methods to address non-linear soil degradation. I judge that the selection and characteristics of real time histories should be revisited, particularly for soil degradation studies and other non-linearities, to fully comply with ASCE/SEI 4-16 (Comment E7).
- The RP has considered the effect of concrete cracking by halving the stiffness. This approach is not in accordance with ASCE 4 which promotes an iterative approach and would have the effect of redistributing stresses. This is not captured by reducing the stiffness and I do not consider the RP's approach bounding. I judge that concrete cracking should be treated with more rigour during the site specific stage (Comment E10).
- The RP has not included accidental torsion loads in the R/B stack design. I have commented on this in section 4.3.11.
- The RP did not present information for the soil degradation and final soil properties derived from the SSI analysis of the CST structure (Comment 04-063). I consider that this comment is linked to the soil properties and it will be fully resolved during the site specific stage. Nevertheless, I have captured the comment in Assessment Finding AF-ABWR-CE-015, as I judge it will support the safety case's accuracy.

402. I consider that in the above areas the simplified approach adopted in GDA does not fully meet relevant good practice in accordance with relevant seismic analysis guidelines and design codes. I expect that further consideration is given to these deferred comments at the detailed design stage, and therefore I have raised an assessment finding.

Table 22: Civil engineering comments relating to AF-ABWR-CE-015

GDA Buildings Comment	Comment ID	Section
Operating Basis Earthquake	E.4	4.3.12.7
Time histories	E.7	4.3.12.7
Concrete cracking	E.10	4.3.12.7
Soil degradation curves	04-063	4.3.12.7

AF-ABWR-CE-015	To address simplifications outside relevant civil engineering codes of practice for seismic analysis, the licensee shall justify its approach against relevant good practice with particular focus in the following areas: derivation of time histories, treatment of the operating basis earthquake and the approach to concrete cracking. Future licensee to refer to section 4.3.12.7 of Civil Engineering GDA Step 4 report for further information.

4.3.12.8 CONCLUSION – SEISMIC ASSESSMENT

403. I have considered the outcome of the assessment of the seismic analyses against SAPs ECE.12, ECE.14 and ECE 15 and judged, subject to dealing with the minor shortfalls and assessment findings during the site specific stage, that the RP's structural analysis demonstrates that the GDA buildings, tunnels and tanks will fulfil

their safety functional requirements over the full range of loading for the life time of the facility.

4.3.13 Stability

404. The global stability of each of the building, tunnel and tank base structures has been evaluated by the RP via specific calculations, independent of the primary analysis models.

405. The stability calculations are relatively simple in format, although this in itself is not a concern. Each structure has been checked for overturning, sliding, floatation (buoyancy) and ground bearing pressure.

4.3.13.1 OVERTURNING

406. Each of the structures is calculated to be resistant to overturning, generally with a large margin against failure. Checks have been performed to demonstrate that the restoring forces exceed the destabilising forces. The overturning stability of tanks has not been considered because the tank and holding down bolts designs are outside of the GDA scope.

407. I judge that adequate checks have been carried against the GDA design in line with SAP ECE.7 in regards to overturning as there is sufficient margin to supply its safety functional requirements. However the effects of site specific ground properties on overturning should be considered by the future licensee and is captured in Assessment Finding AF-ABWR-CE-03.

4.3.13.2 SLIDING

408. I have reviewed the sliding calculations presented by the RP for the civil engineering structures and I have made a number of comments in the following areas:

- Factor of safety
- Coefficient of friction
- Load paths across buildings
- Unbalance water

FACTOR OF SAFETY

409. Each of the structures has been demonstrated to have a factor of safety greater than 1.1 against sliding for seismic design. It is not clear what structural calculations have been undertaken for a static case, but I do consider that the lateral loading from the seismic analysis will be the governing design case for the sliding check. The forces used for stability calculations are based on the static application of seismic loads; hence there are conservatisms within this approach. The sliding calculations include the at-rest soil pressures (which are more conservative than active soil pressures) acting on the structure on the embedded sides.

410. A factor of safety of 1.1 is considered to be low if no reduction factor is applied to the dead load (Comment 02-024) as UK relevant good practice is to apply a reduction factor to dead load. The current approach adopted by the RP assumes that favourable dead loads can be calculated accurately and do not need factoring. I do not consider this approach to be satisfactory (Comment 02-012).

411. Provided a reduction factor is applied to the dead weight of the structure (or the dead load is accurately measured during construction) and the lateral displacement is acceptable, a factor on sliding of 1.1 is acceptable. A reduction factor should be selected, in line with UK practice, for the dead weight of the structure.

412. The RP has not applied a reduction factor in the dead load, as discussed above, but my review of the sliding checks suggests that taking the above into account still results in a factor of safety greater than 1.1. It should be noted that the addition of shear keys in the design of some of the buildings (as discussed below) is the result of unclear load paths and interfaces between the basemats of the buildings and not due to a reduction factor in the dead load. The two above deferred comments are captured within assessment finding AF-ABWR-CE-04.

COEFFICIENT OF FRICTION

413. As stated above, the sliding stability was assessed and an area that further queries were required was the coefficient of friction as this parameter affects the sliding resistance. The coefficient of friction is dependent on the interface between the structure and the formation soil, taking account of any membranes or other interlayers.

414. The RP assumed that there may be an external tanking membrane to each of the structures, thus leaving this option open for a tanked waterproofing strategy (4.3.14.1). However, while assuming an external membrane, the RP adopted a coefficient of friction, $\mu = 0.6$. This is higher than would be expected, (*the Concrete Society Advice Note No. 54 recommends a minimum coefficient of friction of 0.4 between soil and concrete, but states that this can be as low as 0.2 with a membrane interlayer*) and yields a potentially non-conservative resistance. Various comments were raised on this, with one comment outstanding (Comment 01-G02).

415. During the assessment process, I requested that the RP demonstrates that $\mu = 0.6$ is achievable. In response, the RP provided test data for specific products, tested in accordance with appropriate standards. This data supports the assumption.

416. It is unknown if a coefficient of friction of $\mu = 0.6$ is guaranteed by the supplier, or the variability of the product, or its suitability as a practical and durable water-resisting membrane. Further discussion on this is included in section 4.3.14.1. However, it is noteworthy that reactor building report has the statement, *“To ensure that the waterproofing membrane is protected during backfilling adjacent to the external walls, an appropriate protective measure could be installed”.* The RP would need to demonstrate that this ‘protective measure’, if used, will also not have a detrimental impact on the sliding resistance.

417. This outstanding comment has been captured in the waterproofing assessment finding (section 4.3.14, AF-ABWR-CE-016).

LOAD PATHS ACROSS BUILDING INTERFACES AND THE INTRODUCTION OF SHEAR KEYS

418. On assessing the design report for the C/B, I observed that the building was dependent on each of the surrounding buildings (the R/B and T/B north-south and the S/B and Rw/B east-west) to provide the necessary factor of safety against sliding. The RP’s report proposed that the excess sliding force would be transferred via lean concrete at basemat level to be resisted by the adjacent basemats of the surrounding buildings.

419. I had a comment on this (Comment 01-CB14).

420. It was unclear whether the basemats are suitably aligned to allow the force to transfer. Conflicting information on the building embedment depths was present through a number of reports.

421. The RP has since confirmed that the basemats are aligned in the north-south axis (Figure 8) and that this remains the assumed load path.

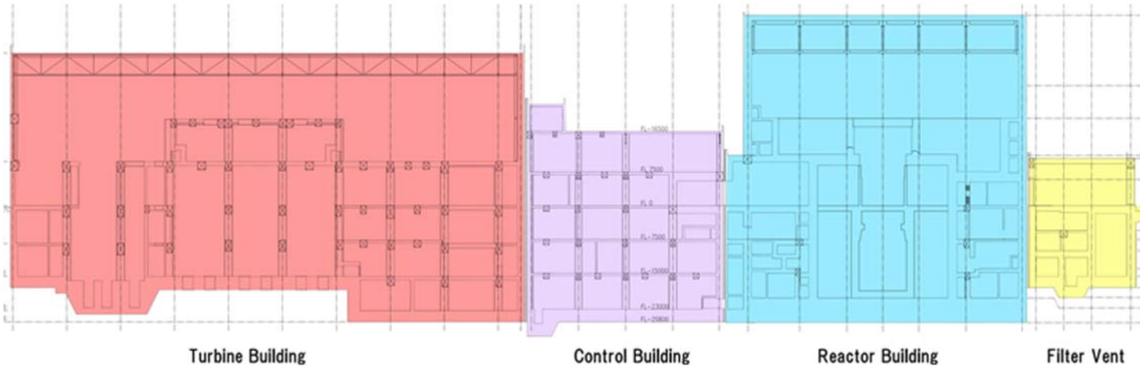


Figure 8: Cross section through the T/B - C/B - R/B - Fv/B (North-South axis)

422. In the east-west axis the basemats are not aligned. In recognition of this, the RP has revised the GDA design and introduced shear keys to the C/B to enhance the east-west sliding resistance sufficiently so that the building is self-stable. Two parallel shear keys are proposed (Figure 9) and the outline design and preliminary sizing of these was included in the submitted information.

423. The excess force transferred from adjacent buildings is not considered in the sliding check for the R/B.

424. The RP has completed a local check to show that the excess pressure can be transferred through the lean concrete at basemat level but has not considered the global impact that this force has once acting on the adjacent buildings. This check remains outstanding.

425. It is not envisaged that this will prove problematical, given the adjacent buildings have significant soil resistance in the respective directions, but the additional force may influence member design.

426. Associated with the point above, it is a notable omission that the various associated reports do not consistently communicate the load paths, where required between buildings.

427. Given the possibility that the individual buildings may be developed by independent sub-consultants at a future design stage, I consider that such information should be communicated in the overarching Overview and Basis of Safety Case reports.

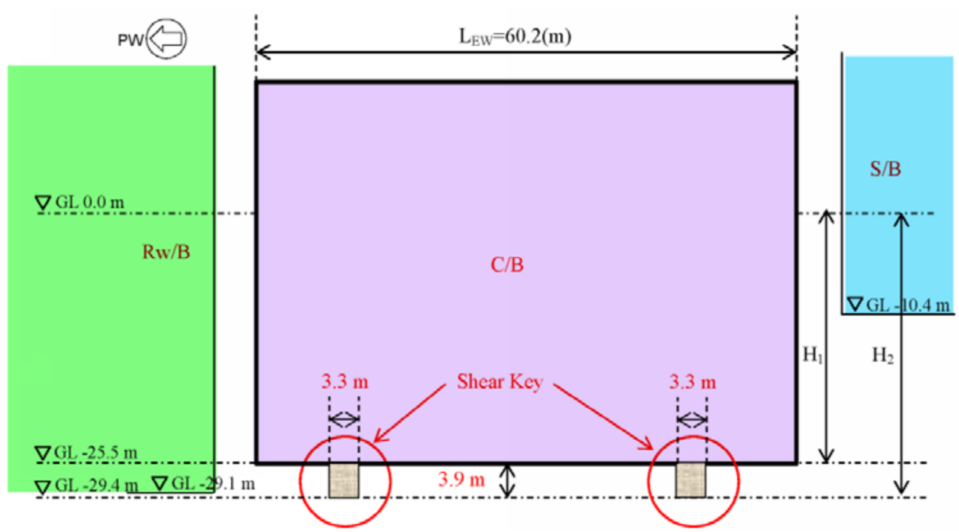


Figure 9: Shear keys to the C/B (Extract from [S17-5] with colour added)

428. In response to Comment 01-CB14, the RP introduced shear keys to the S/B and the Rw/B to resist sliding in the east-west direction (Figure 10). The deferred section of comment 01-CB14 has been captured within assessment findings AF-ABWR-CE-02 and AF-ABWR-CE-08.

429. Similar to the C/B design report, the S/B and Rw/B design reports present the outline design including equations and preliminary sizing. The detailed development of the keys, including code-based design checks of the key, local checks of the basemat and reinforcement detailing are outstanding.

430. I have queried the performance and viability of the S/B shear key, noting that the formation of the S/B is significantly higher than that of the C/B. (Comment 01-RW12 part 4). There is a relatively small risk that the founding soil strata could have insufficient shear strength to prevent a shear plane forming below the shear key, which could surcharge the wall of the C/B. This should be checked at the site-specific stage. This comment has been captured in AF-ABWR-CE-08.

431. The shear keys are not shown on the formal general arrangement drawings and these elements are omitted from the various analysis models.

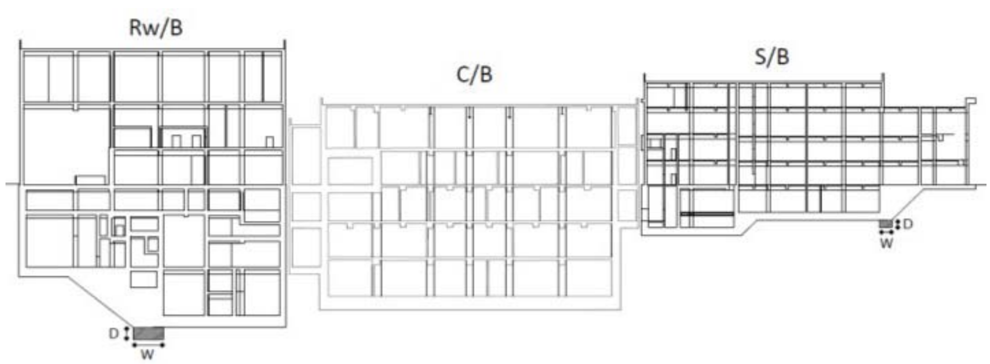


Figure 10: Shear keys to the Rw/B and S/B but omitting the key to the C/B

432. Shear keys have also been introduced during the Step 4 to each of the CST and FLSS tank enclosures. Preliminary calculations have been provided to demonstrate that keys have the potential to provide the necessary sliding resistance. However, more detailed calculations, including checks of the reinforcement, are outstanding (01-CST09 and 01-FLSS02). These two comments are captured in AF-ABWR-CE-08.

433. Throughout the GDA there appears to be an underlying assumption that the formation under each structure is rock. However, for the shear key design the assumption appears to be soil. Whilst the assumption of soil is conservative in some respects, it does ignore peculiarities of rock, such as preferential failure planes along natural discontinuities.

434. Preliminary estimates for shear keys have been presented and a concern regarding double counting mass in the resistance has been raised (Comments 02-026 and 02-027). The responses to these comments are accepted and it is expected that the shear key designs will be developed at the site specific stage. These two comments have been captured in AF-ABWR-CE-03.

UNBALANCED GROUNDWATER PRESSURES

435. Groundwater has been assumed by the RP to be uniform at ground level. However, local Ground Conditions may dictate more onerous conditions, including unbalanced water levels and pressures.

436. Large concrete underground structures, such as tunnels and basements, can result in an underground damming effect, which may increase unbalanced lateral water pressures (Comment 02-013). The RP has advised that they consider these to be site specific issues. This will need to be reviewed in detail. As this is based on the site specific ground conditions, this comment has been captured in AF-ABWR-CE-03.

CONCLUSIONS - SLIDING

437. I judge that the effects of sliding have been adequately addressed for the requirements of GDA in line with SAP ECE.7 where the foundations and sub surface structures are designed to meet their safety functional requirements. However, further consideration of the site specific ground properties, profile and detailed design of sliding stability should be undertaken by the future licensee and is captured in the assessment findings as stated above.

4.3.13.3 FLOATATION

438. Each of the structures has been assessed adopting a factor of safety of 1.1 for floatation.

439. It is considered that 1.1 is too low if no reduction factor is applied to the favourable loads (Comment 02-023). The current approach adopted by the RP is that favourable dead load can be calculated accurately and does not need factoring. I do not consider this approach to be satisfactory (Comment 02-011).

440. Provided a reduction factor is applied to the dead weight of the structure (or the dead load is accurately assessed) and the vertical displacement is acceptable, a factor on floating of 1.1 is acceptable. A reduction factor should be selected, in line with UK practice, for the favourable dead load of the structure.

441. A review of selected calculations undertaken by the RP suggests that taking the above into account still results in a factor of safety greater than 1.1. However, there may be situations where additional measures are required to achieve the factor of safety. An example of this may be a shallower tunnel and the RP has recognised this. However, they state that shallow tunnels were atypical of the design.

442. Note that I found that the way that buoyancy loads were applied to the tunnel analysis was originally non-conservative. A correction was implemented as described in section 4.3.8.9. This does not impact the stability calculations, only the member designs.

443. I judge that the effects of floatation have been adequately addressed for the requirements of GDA in line with SAP ECE.7 due to the review of calculations giving a reasonable margin above the 1.1 safety factor for supplying their safety functional requirements. However, a reduction factor in line with UK practice should be applied to the favourable dead load to be fully in line with ECE.6 which is captured within assessment finding AF-ABWR-CE-04.

4.3.13.4 BEARING PRESSURE AND CAPACITY

444. When queried, the RP stated that allowable bearing capacities are a site specific issue, excluded from the GDA. However, having noted relatively high bearing pressures, I suggested that there should at least be an approximate check against the values of bearing pressure calculated. (Comments 02-009 and 02-021).

445. It is recognised for tunnels that bearing capacity is not likely to be an issue. However, the methodology presented should still be rigorous, with appropriate ground parameters and load factors.

446. For the buildings and tank structures, the RP has assumed the formation is rock and I have stated that this is not necessarily the case, particularly for EUR Medium sites. The RP's calculations (based on rock) indicate that allowable bearing capacity is sufficient. In addition, the RP has also stated that if pressures are an issue, then ground improvement or replacement will be considered.

447. I judge that bearing pressure has been adequately addressed in GDA with methodologies for increasing bearing pressure capacity to within the design envelope outlined in line with SAP ECE.7. However, the site specific ground conditions will have large bearing on the required detailed design and this has been captured within assessment finding AF-ABWR-CE-03.

4.3.13.5 OVERALL CONCLUSION

448. I judge that the requesting party has supplied sufficient information in line with SAPs ECE.2, ECE.6 and ECE.7 for consideration of stability during GDA, but detailed calculations with site specific ground properties will be required at the site specific stage with consideration of UK practice. These outstanding comments have been captured in assessment findings AF-ABWR-CE-03, AF-ABWR-CE-04 and AF-ABWR-CE-08.

4.3.14 Serviceability and fire

449. The Design Reports describing the 'Group A' buildings, the tunnels and the tank bases, which are each predominantly reinforced concrete structures, include descriptions on the crack control, deflection control, durability, water ingress protection and fire protection. These reports are taken to indicate the form of detailing to be developed for all the civil structures.

450. These sections of the Design Reports are generally less detailed and prescriptive than the equivalent sections on loads and strength design. They acknowledge that both the construction process and also detailed concrete specification will have an impact, and both of these are deferred by the RP to the site specific stage. In line with this, the text given in the Design Reports is quite descriptive and presents an understanding of the issues, but is non-committal to specific solutions.

451. ONR's assessment has focused in the following areas:

- Waterproofing and crack control
- Serviceability and fire protection
- Deflection control
- Ground movement

4.3.14.1 WATERPROOFING AND CRACK CONTROL

452. The waterproofing grade has been set in accordance with BS 8102 (Annex 3) with a mixture of grades; for example, the Reactor Building is Grade 2, "No water penetration accepted, damp areas tolerable, ventilation might be required", while the various tunnels are Grade 1, "Some seepage and damp areas tolerable, dependent on the intended use. Local drainage might be necessary to deal with seepage". The safety function requirements of the civil engineering structures in terms of waterproofing are defined by the requirements of the equipment and systems housed within the structure. However, the RP claims that these requirements are unknown during GDA, and so has defined the waterproofing grades for the civil engineering structures without considering the internal systems.

453. The strategy for achieving the waterproofing grade via a compatible waterproofing system has not been confirmed within the GDA. Instead, the RP has presented an

understanding of the options (e.g. membranes, structural defence i.e. crack control and/or internal drainage) and their wider impact on design parameters.

454. One of the options described by the RP is an external tanked (membrane) solution. I had concern that this option was not consistent with the required coefficient of friction for sliding resistance and the RP was requested to demonstrate that the claimed value, $\mu = 0.6$, is achievable (See section 4.3.13 of this report).

455. Sliding performance aside, I have a number of comments on the waterproofing that will require a final response at site specific stage (Comments 01-RCW09, 01-RCW10 & 01-RCW11), and these are summarised below:

456. The appropriateness of the waterproofing grades is traditionally governed by the internal systems and equipment and the environmental conditions required. However an alternative approach is to design systems and equipment for the environmental conditions to which they will be exposed. Within the Design Reports and Basis of Safety Cases, the RP has not given a hierarchy in this regard and it is unclear what is dictating and/or responding to the assumed requirements. By stating the assumed Grades, the RP is committing the GDA to a performance level; I have not checked that these Grades are appropriate and coordinated.

457. The exposure condition for the concrete grade adopted for the tunnels failed to meet BS 8500-1 irrespective of the waterproofing strategies. This has been revised and is now appropriate for externally tanked structures. It would be relatively inconsequential to change this grade again to allow for a non-tanked structure in benign ground. However, if the structures are in an aggressive soil, the change could be more substantial.

458. Within the Reactor Building Design Report (Ref 48), the RP states, “It is noted that waterproofing membranes available in the UK generally have a design warranty for approximately 20-25 years, but testing undertaken by some manufactures has indicated that the PVC-P material has a service life expectancy of greater than 100 years. This will be confirmed by the manufacturer in the form of a ‘Lifetime Expectancy Statement’”. Any ‘Lifetime Expectancy Statement’ should cover both the waterproofing and friction performance (Section 4.3.13 – Stability). In recognition of possible seepage in the tunnels (plus possible other non-disclosed sources of water), drainage sumps and trenches are suggested for the tunnels. The detail of these has not been developed.

459. The RP has set out how crack control calculations will be completed, once the water-tightness requirements are set. ACI 349-13 and the Eurocodes adopt different calculation approaches and the RP has stated that both will be followed and the more onerous results adopted.

460. For early age thermal cracking of concrete, the various sub-consultants to the RP each quote CIRIA C660 (Annex 3) as the basis to the calculation. I agree that this is appropriate, however, I note that:

- Sample calculations are provided in each of the Tunnel and Tank Design Reports and also in the Reactor Building Design Report (to which the Control Building and Filter-vent Building Design Reports refer). However, while the Tunnel and Tank Design Reports adopt calculation spreadsheets that are published by CIRIA for use with CIRIA C660, the Reactor Building Design Report includes sample calculations that appear to be bespoke designer-authored spreadsheets. These should be reviewed in more detail if relied upon.
- CIRIA C660 is due to be republished shortly, although CIRIA has not announced a release date. I would expect that future design work takes notice of any updates.

461. I have captured all waterproofing comments from this section and from sections 4.3.2 and 4.3.12 into a single assessment finding (AF-ABWR-CE-016) for waterproofing within this section.

4.3.14.2 SERVICEABILITY AND FIRE PROTECTION

462. A 100 year design life is specified by the RP for each structure.; However, the RP also states that the design life of some protective measures (including fire protection and waterproofing) that are intrinsic to achieving the overall design life are to be confirmed at the site-specific stage. The RP goes on to say, “Materials shall be selected with consideration of the environmental conditions and exposure”, making reference to “several site-specific issues such as location, the environment, exposure conditions, etc.”

463. Fire resistance periods have not been specified for all structures. For some structures (e.g. the Reactor Building), a resistance period has been stated “for GDA purposes”. However, for other structures (e.g. the tunnels), the fire resistance is not stated and the latest reports simply state that fire resistance will be determined to ensure safe pedestrian egress. (Comment 01-LOT15 refers).

464. The planned measures to achieve durable concrete elements refer to both American and European codes and the description given by the RP rightly considers each of the concrete mix, cover to reinforcement and crack control. The concrete grade originally identified for the tunnels and tanks did not meet the code requirement. (Comments 01-RCW10 and 01-LOT08). The RP has corrected this.

465. Structural steelwork is believed to be subject to internal environments only. The RP is non-committal on the corrosion protection, but notes that each of galvanising, paint systems or sprayed coatings are to be considered at the site-specific design stage.

466. I consider that the RP’s approach to fire protection is adequate for GDA. However I expected the RP to define the fire resistance period for the tunnels as it was done for the buildings. I judge this to be a minor shortfall.

MS-ABWR-CE-04. The licensee should specify fire resistance periods for all the civil engineering structures.

4.3.14.3 DEFLECTION CONTROL

467. Serviceability deflection checks included by the RP are limited to a check of span to depth ratios, i.e. rules of thumb, independent of the analyses. Although this aligns with ACI guidance (for concrete) and AISC and Eurocode guidance (for steel), these checks are simplistic and will not satisfy any unusual requirements (e.g. particular requirements of specific plant and rotating plant items). (Comment 01-CB15 and 01-CB16).

468. The RP has confirmed that deflection limits for internal systems are unknown and will not be available until the site-specific design. Hence, the span-to-depth checks have been included at GDA as a preliminary study, to be reviewed at a future stage. The approach taken is reasonable and, with the knowledge that the RP has prior experience of similar plant design and construction, I anticipate it will prove adequate. However, I also flag that changing the stiffness of a structure to control deflections generally requires additional or reconfigured supports (columns or walls) or thickenings to the slab; altering the reinforcement has little impact. I note that the RP has used un-cracked section properties for the static analysis (Comment 01-CB19). Should a more detailed review of deflections be required that utilises analytical results, then the extent of cracking (under service loads) will need to be accounted for in the analysis models.

469. The deflection checks carried out by the RP are sufficient for GDA as specific plant information is not available and more extensive deflection checks will be carried out during the site specific stage. I do not expect the deflection checks to define the member sizes but I consider that my comments regarding deflection control are relevant and I have included them in the design assessment finding, in Section 4.3.11.

4.3.14.4 GROUND MOVEMENT

470. Ground movement can only be fully assessed when ground conditions are characterised. I raised concern as part the GDA that this is not being considered (Comment B4). The RP has stated this will be addressed at the site specific stage. This comment has been captured as part of assessment finding AF-ABWR-CE-03.

4.3.14.5 CONCLUSION – SERVICIABILITY AND FIRE

471. I have assessed the RP's submissions that relate to durability and fire protection against SAPs ECE.2 and ECE.16 and judge sound design concepts have been used and that it is probable that the civil structures can be designed and constructed to meet UK code requirements and relevant good practice. The following assessment comments relate to this topic:

Table 23: Civil engineering comments relating to AF-ABWR-CE-016

GDA Comment	Comment ID	Section
Crack width control	01-RCW09	4.3.3 & 4.3.14
Drainage dump and trench	01-RCW11	4.3.14
Cracks width and durability	01-LOT08	4.3.14
Building/tunnel interface details and waterproofing	01-G02	4.3.3 & 4.3.13

AF-ABWR-CE-016	The safety function requirements of the waterproofing systems are not currently linked to internal systems and equipment. Hence the licensee shall detail suitable waterproofing arrangements for the civil engineering structures, considering their safety function requirements, the interactions between structures and the effect on the coefficient of friction to resist sliding. Future licensee to refer to section 4.3.14 of Civil Engineering GDA Step 4 report for further information.

4.3.15 Custom software - Verification and Validation

472. I assessed the methodology behind the RP's custom software and computer programmes.

473. The RP provided information on the following custom software:

- SSDP-2D
- SSDP-ST
- Design spreadsheets (Rw/B, S/B and Tunnels)

4.3.15.1 SSDP-2D

474. Reinforced concrete slabs and walls designed by the RP are checked using SSDP-2D Version 0. This is a software package, internally-developed by the RP, which determines member design strengths for axial load, flexure and shear in accordance with ACI and ASME codes.

475. To allow the assessment of the software, the RP presented the underlying theory, plus simplified examples. The information provided did not include the data handling procedure. The RP stated that this is covered by the internal QA process, but it did not provide any information on this process.

476. I assessed how the SSDP-2D programme handles thermal strains (Comment 01-001). Thermal loads (thermal strains and thermal curvatures) are derived from thermal load cases in the analysis models. The programme assumes that the concrete has cracked, calculates the loss of stiffness and the residual thermal stresses.

477. Two different thermal load scenarios have been assessed: thermal curvatures combined with external loads and external loads with thermal curvature plus thermal strains. In both cases, the RP applies an established method (Gurfinkel – Annex 3). I found two issues with the implementation of this method, which are discussed below.

478. In the case of thermal curvatures with external loads, I believe there is an error in how the method has been implemented in the software. However, I judge that the magnitude of this error is small.

479. In the case of external loads with thermal curvature plus thermal strain, the RP has extended the Gurfinkel method (which is only applicable to thermal curvatures combined with external loads) to thermal curvature plus thermal strain. I judge that the applied method will underestimate the moment associated with the thermal curvature, in particular for high curvatures where the relation moment versus curvature is not linear.

480. The above issue only affects structures subject to significant thermal loads, e.g. parts of the R/B and the RCCV.

481. There are other minor points, such as an error in the calculation of equivalent section properties (Comment 01-003). The RP stated that the error is less than 2%, but the error can be higher in heavily reinforced sections.

482. Another minor point is that the data presented by the RP to justify the shear stiffness ratios is not comprehensive (Comment 01-005).

483. One of the GDA objectives is to review and agree the methodology proposed by the RP. In this particular case, I have not agreed with the RP on the methodology applied for a defined loading (thermal load) and errors have been found in this methodology. I judge that this is a significant issue, as it could lead to non-conservative designs of reinforced concrete structures subject to thermal loads, and I have captured it in an assessment finding, AF-ABWR-CE-017.

4.3.15.2 SSDP-ST

484. Steelwork in the building structures is checked using the RP's Section Design Program for Steel (SSDP-ST) Version 2.2. This is an internally-developed software package that determines member design strengths for axial load, flexure and shear in accordance with AISC codes.

485. To allow the assessment of the software, the RP presented the underlying theory, plus simplified examples (Comment 01-SSDP01). The information provided did not include the data handling procedure. The RP stated that this is covered by the internal QA process, but it did not provide any information on this process.

486. The software does not consider torsion and this is in line with the design process (see section 4.3.11 of this report).

4.3.15.3 DESIGN SPREADSHEETS (RW/B, S/B AND TUNNELS)

487. My review of the design spreadsheets found:

- The design spreadsheets used for the RW/B and the S/B are incomplete or simplified and they do not carry out the full breath of checks required by the design codes (Comments 01-RW07, 01-RW09, 01-RW10 and 01-RW11).
- The spreadsheets used for the tunnel design are inappropriate for discontinuous sections (bends, terminations, intersections, etc.) as this more complicated 'tunnel features' will develop 3-D effects that the spreadsheets cannot incorporate. Also the design assumes a uniform cross section without any influence of longitudinal effects.

488. The RW/B and S/B are Group B buildings which means that not all the assessment checks have been carried out.

489. The RP has stated that the spreadsheets will not be used during site specific stage. However as the use of these spreadsheets will lead to an incomplete design, I have captured these comments in the assessment finding for design, AF-ABWR-CE-08.

4.3.15.4 CONCLUSION – CUSTOM SOFTWARE - VERIFICATION AND VALIDATION

490. I have assessed this section against SAPs ECE. 13 to ECE.15 and I judge that the analysis is demonstrably conservative, with the exception of the load cases with thermal loads. I found a methodology issue in the way the in-house programme SSDP-2D determines the moments under thermal loads. I consider that, under certain conditions, the amount of reinforcement could be underestimated. However, the RP did not provide enough information to assess if these conditions take place and if the difference in reinforcement can impact the design. I have raised an assessment finding (see below) to capture this shortfall.

491. I was unable to check the RP's internal QA process that should take place to verify the answers provided by the software, as the RP did not provide information in this area. I consider this a shortfall in the RP's evidence and I have captured it in the assessment finding below.

Table 24: Civil engineering comments relating to AF-ABWR-CE-017

GDA Comment	Comment ID	Section
Residual rations of thermal forces	01-001	4.3.15.1
Reinforced concrete section properties	01-003	4.3.15.1
All buildings excluding Rw/B, S/B, Tank Bases and Tunnels	01-SSDP01	4.3.15.2

AF-ABWR-CE-017	The Requesting Party has not provided sufficient evidence of the assurance process associated with the custom software used in GDA to design the civil engineering structures and it has not justified the treatment of thermal strains associated with the Reactor Building design. The licensee shall demonstrate and validate the reliability of the data generated from the custom software. Future licensee to refer to section 4.3.15 of Civil Engineering GDA Step 4 report for further information.

4.3.16 Construction

492. The RP has been consistent in stating that matters defined by the construction sequence are outside the scope of the GDA, and are to be assessed and developed in

the Site-Specific PCSR. There are however, aspects of the construction that could impact the design of the permanent structure, and these are discussed below.

4.3.16.1 LOCKED IN CONSTRUCTION STRESSES

493. The GDA design for all structures assumes that locked in stresses resulting from the construction sequence are insignificant. This is reasonable in most scenarios, provided adequate back-propping and temporary works are provided during the construction. However, I note that:

- The MC component structures within the RCCV with concrete infill will be subject to a locked in stress generated by the fluid concrete. This stress will be a function of the concrete pour height (Comment 01-MC11).
- The Diaphragm Floor (within the RCCV) is supported on a ‘seal plate’. It is unclear whether this will require back propping in construction, or if it will be designed to withstand the temporary weight of concrete (Comment 01-MC14).
- Various floor slabs in the buildings are to be temporarily supported on ‘deck beams’. These are outside the GDA scope. However, like the Diaphragm Floor seal plates, they will lock in stresses.

494. I have captured the MC components comments in the overall assessment finding for the MC components in section 4.3.11.4.

495. Furthermore, noting the proposal in various of the Basis of Safety Case reports for modularisation and pre-fabrication, I note:

- Pre-fabricated construction can lock in stresses. Handling pre-fabricated components can also generate temporary load conditions that can govern the design. Neither has been considered in the GDA and the GDA does not prescribe the modularisation of the structural components.
- Pre-fabricated reinforcement cages will often involve tack-welding that can impact upon the ductility of reinforcement. A detailed welding procedure will need to be developed should this approach be adopted.

496. As the RP has not proposed a construction method in GDA and it is outside of the GDA scope, the above bullet points will be considered in detail during the site specific stage when the future Licensee proposes a construction method.

4.3.16.2 CONVENTIONAL CONSTRUCTION AND OPERATION SAFETY

497. The RP’s consideration of conventional construction and operation safety, as covered under UK CDM Regulations is presented in a standalone topic report and is discussed in section 4.3.21.4 of this report. I note that the current Design Reports make no reference to the risk registers and that there is little apparent emphasis on deriving risk-mitigating design decisions at this stage of the design (Comment 01-RB38). The RP has provided a hazard log for the R/B (see Section 4.3.21.4 –Conventional Safety) and I judge that for the R/B, the RP has partially addressed the designer’s responsibilities under CDM Regulations, since the risks have been identified but some of the risks are currently unmitigated. Also the RP has committed to address the CDM responsibilities during the site specific stage, when the construction techniques are known.

4.3.16.3 MISCELLANEOUS CONSTRUCTION COMMENTS

498. The following comments also relate to construction, but do not relate specifically to either safety or temporary stress conditions:

- The CST building structure encloses the tank and the RP has confirmed that the construction sequence assumes the tank will be erected prior to the building's walls and roof being completed. This enforces various constraints on each of the construction, maintenance and decommissioning, the details of which need to be developed (Comment 01-CST04).

- The bolted connection at the base of the RPV Pedestal is below the finish concrete level of the slab to which it is anchored and the concrete surrounding the steel gusset plates above the connection is required as part of the assumed load path. It is unclear how concrete will be compacted surrounding the gusset plates, or where site welds will be located (Comment 01-MC10).
- Geotechnical aspects of construction such as excavation sequencing, methods of excavation, excavation support and temporary structural stability are not addressed in the reports provided by the RP. Furthermore, some statements are made which conflict with the assumed ground conditions, and the methodology that is loosely proposed for GDA is inappropriate for many ground conditions (Comments B1, 01-LOT12 and 02-017)

499. In response to these comments, the RP stated that temporary stability is outside the scope of GDA and the compatibility between excavation techniques and ground parameters will be checked at the site specific stage. A different methodology will most likely be developed at site specific stage, and its consequence for the GDA will have to be carefully considered.

500. I judge that the level of uncertainty on ground conditions supports the RP's decision to exclude excavation temporary stability from GDA and this should be addressed during the site specific stage.

4.3.16.4 CONCLUSION – CONSTRUCTION

501. I have reviewed the RP's approach to construction against the guidance provided in SAPs ECE.17 and ECE.25 and judged that the RP has considered construction and conventional safety during construction only as was necessary to inform the GDA design of the R/B in response to ONR Regulatory Queries.

4.3.17 Accuracy of RP's Safety Case

502. From the sampling assessment of the Design Reports undertaken, a number of reporting errors omissions and inconsistencies have been identified in the RP's safety case that raise concern relating to their quality assurance procedures. These are detailed in the TSC reports (Ref 15 and Ref 16). There are errors, omissions and inconsistencies across various design and reporting processes. For each, the RP has acknowledged this and generally updated or committed to update the reports.

503. I have noted two examples below:

- The Overview and Basis of Safety Case reports have been inconsistent with the Design Reports for individual structures. The RP's explanation is that the Design Reports were prepared later than the Overview and Basis of Safety Case reports, and consequently contained more recent developments. This is understandable due to timescales and the large number of documents submitted during GDA. However, the Basis of Safety Case reports should be updated in a timely manner.
- I noted that the report structure varies substantially between the building and tunnel reports and, in the case of the tunnel reports, is fragmented. I have concern that this could lead to future design challenges and ultimately to errors..

504. I have also noted examples of heightened risk of errors due to the software issues as discussed in Section 4.3.15 or the comparison of results from Nastran and SASSI (see Section 4.3.10). The RP claims that their QA procedures will guard against error, but

there are examples where this is yet to be demonstrated. I have noted that the RP has adopted substantially different procedures for the design of building structures including:

- Use of different software and design tools.
- Different load intensities and also grouping/definition of loads.
- Different approaches for applying seismic loads to the static analysis models.
- Different concrete strengths.
- Different units on drawings.
- Different approach to modelling secondary walls.

505. Future designers and assessors need to be aware of these differences as they present a source of potential error that is a concern.

506. I noted that the Overview and various Basis of Safety Case reports are not prescriptive enough to ensure a common design approach for each structure. These reports have been updated in response to this and other comments. However, similar to earlier revisions, the updates set out the high-level performance requirements, including prescribing the adopted design standards, but do not prescribe software and design processes. I have an expectation that the Bases of Design documents will describe how the design work will be undertaken and in a consistent manner that reduces the potential for error during the design process.

4.3.17.1 CONCLUSION – ACCURACY OF RP'S SAFETY CASE

507. I have considered these points against SAPs ECS.3 and SC.7 and judge that the combination of different approaches, codes and standards needs further consideration to reduce the likelihood of design errors. I have addressed the different procedures for the design of buildings in previous sections and I have raised a number of assessment findings which should raise awareness of this issue.

508. I judge that the RP has made considerable efforts to update and add information to the Basis of safety case and Design Reports. However, I found a number of inconsistencies between the reports and this needs to be addressed during the site specific stage and I consider that this will be done as part of normal business. I have raised a minor shortfall to capture the updates to the reports which will improve the consistency of the safety case.

509. Relevant deferred assessment comments are listed below.

Table 25: Civil engineering comments relating to MS-ABWR-CE-05

GDA Buildings Comment	Comment ID	Section
Reactor Buildings	01-RB26	4.3.17
All buildings	01-RB21, 01-CB02, 01-CB18, 01-G05 & 01-RW02	4.3.17
GDA Tunnels and Tanks Comment	**Comment ID**	
All tunnels and tanks	01-LOT08, 01-RCW01, 01-LOT01	4.3.17

MS-ABWR-CE-05. The licensee should update the civil engineering design reports and technical drawings to reflect the comments within section 4.3.17 of the Civil Engineering GDA Step 4 report.

4.3.18 Reinforced Concrete Containment Vessel

510. The primary containment of the UK ABWR is a reinforced concrete containment vessel (RCCV) with an internal steel liner. The RCCV provides support and containment to the RPV and a number of MC components and penetrations. The civil engineering MC components include the RPV pedestal, the diaphragm floor, the reactor shield wall and the access tunnel. I have described the RCCV in detail in Section 3.4.1.1 of this report.

511. The RCCV is a civil engineering structure that requires the highest levels of reliability. I assessed the arguments presented by the RP and I focused on the capacity of the RCCV to deliver its safety functions under normal, fault and beyond design basis conditions.

512. The RCCV is a key structure with two safety functional claims:

- Confine radioactive materials, shield against radiation and reduce radioactive release
- Provide structural support to SSCs

513. I have assessed the RCCV design and its functional capabilities (mainly confinement of radioactive materials and support to SSCs) against normal, fault and beyond design basis conditions.

514. As discussed in section 4.3.21.3, there is an interface between Civil Engineering and Structural Integrity as the RC elements and part of the MC Components in the RCCV are assessed by Civil Engineering and the RPV, penetrations, pipework and steel liner are assessed by the Structural Integrity inspector. The two main areas of interactions between Civil Engineering and Structural Integrity are between the liner anchors and the RC structure and between the RPV and its structural support. The liner anchors are assessed by the civil engineering discipline as the anchors transmit the liner forces to the concrete, but the forces on the liner are part of the Structural Integrity assessment. The RPV is supported by the RPV pedestal which is a civil engineering MC component.

4.3.18.1 NORMAL CONDITIONS

515. The RCCV is integrated with the R/B structure such that the foundation and base of the RCCV is the R/B basemat and the RCCV walls provide support to the R/B floors, including the operating deck that forms the RCCV top slab.

516. The RCCV has been designed to ASME B&PV Section III (Annex 3 of this report) that is an industry accepted code of practice for pressure vessels.

517. The maximum temperature during normal operations is 57°C (in the D/W) and 5kPa inner pressure (in the D/W). Under these conditions the RCCV has been assessed for the loading combinations in Annex 7 of this report, and includes dead and live loads plus the thermal effects, pipe reactions, pressure variations and loads resulting from a relief valve.

518. I have assessed the above loads, the accuracy of the R/B model (the NASTRAN model contains the RCCV concrete structure, the RPV pedestal, the diaphragm floor and the access tunnels), and the application of the loads to the model in the previous sections of this report under normal and fault conditions. I have raised a number of assessment findings within this report, but my main assessment finding on the RCCV

relates to the MC components (See section 4.3.11.4 – MC Components) during normal and fault conditions. I consider that the RP has presented limited information to justify the design of the civil engineering MC components and I have raised an assessment finding to capture this shortfall.

519. The RP claims that RCCV has sufficient structural strength to withstand the loadings from normal conditions (and fault conditions as discussed below). I consider that the RP has provided enough evidence to substantiate the RCCV concrete structure under normal conditions (and fault conditions as discussed below), but further work is required on the MC components (See assessment finding AF-ABWR-CE-09).

4.3.18.2 FAULT CONDITIONS

520. There are a number of fault conditions associated with the RCCV, but the most significant condition is a Loss of Cooling Accident (LOCA). The RCCV has been designed to withstand the maximum pressure and temperature (310 kPa or 1Pd and 171°C) caused by defined LOCA events including piping break such as instantaneous, complete and double-ended guillotine break of one feedwater pipe or one main steam pipe. I have assessed the hydrodynamic loadings from a LOCA event, mainly gas/steam release, pool swell and steam condensation loads (oscillation and chugging loads) in section 4.3.8.5 – Hydrodynamic loads, of this report, and raised an assessment finding in this particular area.

521. It is considered that a DBE could be an initiator event for a LOCA condition, hence within Annex 7 there is a load case with these two events combined. As a result, the RP claims that the RCCV and structures within the RCCV have a structural strength that maintains integrity when assumed static load and dynamic load generated in fault conditions are combined with the relevant seismic load.

522. I have assessed the RCCV design under fault conditions including the hydrodynamic and seismic loadings (as discussed above and in previous sections) and their application to the model. I consider that the RP has provided enough evidence to substantiate the RCCV concrete structure under fault conditions, but, as explained above, further work is required on the MC components.

4.3.18.3 BEYOND DESIGN BASIS CONDITIONS

523. The RP provided evidence to substantiate the ultimate capacity of the RCCV concrete structure and identify a hierarchy of failure modes. This work supported the Level 2 PSA within GDA Step 4 (see Section 4.3.21 – Cross Cutting of this report).

524. The RP presented a FE model of the R/B (including the RCCV concrete structure without the MC components) that identified the areas with higher stresses within the RCCV concrete structure when high temperatures and pressures were applied in the RCCV as a result of a severe accident. After identifying the critical area with the global model, a second detailed model was developed of this location (the corner between the main steam tunnel room and the RCCV top slab) to evaluate the failure mechanism (transverse shear). I assessed the model (see section 4.3.21.5) and I concluded that the RCCV concrete structure can withstand severe accident conditions (200°C and 6Pd). The RCCV concrete structure is not the critical component as other RCCV components (the drywell head) will fail at lower pressures (approximately at 2Pd). Hence, I judge that the RCCV concrete structure has sufficient margin against high temperature and pressures.

525. The evidence presented for the civil engineering MC components under severe accident conditions is limited and full substantiation of these components for beyond design basis conditions has not been provided during GDA Step 4. However, the RP provided some information on the structural behaviour of the RPV pedestal and the

access tunnels under severe accident conditions and this is discussed in section 4.3.21.7 – Severe Accident Analysis of this report.

4.3.18.4 CONCLUSION - RCCV

526. I judge that the RCCV concrete structure design is robust and provides the level of reliability expected from a nuclear containment. My judgement is based against SAPs ECE.1, 2 and 6 and I consider that the following bullet points have been demonstrated:

- Use of specific design standards for pressure vessels (ASME B&PV Section III)
- The RCCV has been designed for a loading schedule covering normal and fault conditions
- The resilience of the RCCV concrete structure when subject to beyond design basis loadings during a severe accident has been demonstrated and the potential failure modes have been identified
- The inspection regime, the potential degradation mechanism and cast-in strain monitoring has been considered by the RP (see section 4.3.20 - EMIT)

527. The information presented on the MC components (design basis conditions) provided an understanding of the civil engineering design and load paths, but more evidence is required in some areas, such as the bespoke connections. I have raised an assessment finding in section 4.3.11.4 – MC components to cover this shortfall. The structural capacity of the MC components, mainly the RPV pedestal, under severe accident conditions have not been demonstrated during GDA Step 4 and an assessment finding has been raised (see section 4.3.21.7 – Severe Accident Analysis) to capture this shortfall.

528. The RCCV concrete structure is the primary containment and so it shall provide the main containment barrier during a severe accident. On this basis, I judge that the RCCV concrete structure provides the required safety functions (containment and structural support) under design basis and beyond design basis conditions.

4.3.19 Leak Detection Systems

529. I have assessed the arguments and evidence presented by the RP on the leak detection systems for:

- Spent Fuel Pool
- Suppression Pool

4.3.19.1 SPENT FUEL POOL

530. The Reactor Building contains a system of three adjacent stainless steel lined pools comprising the Spent Fuel Storage Pool (SFP), the Reactor Well (RW) and the Steam Dryer/Separator Pit (DSP) (See Figure 11). Each pool has a plan area within the range of 17.9m x 14.0m and a water depth in the range of 11.8m (Ref 150). During reactor operation only the SFP is filled with demineralised (un-borated) water. During reactor outages the whole system is temporally flooded by the removal of interconnecting gates using the R/B crane. There is a potential for low levels of radioactivity

(<370Bq/cm^3) to be present in the pool water.

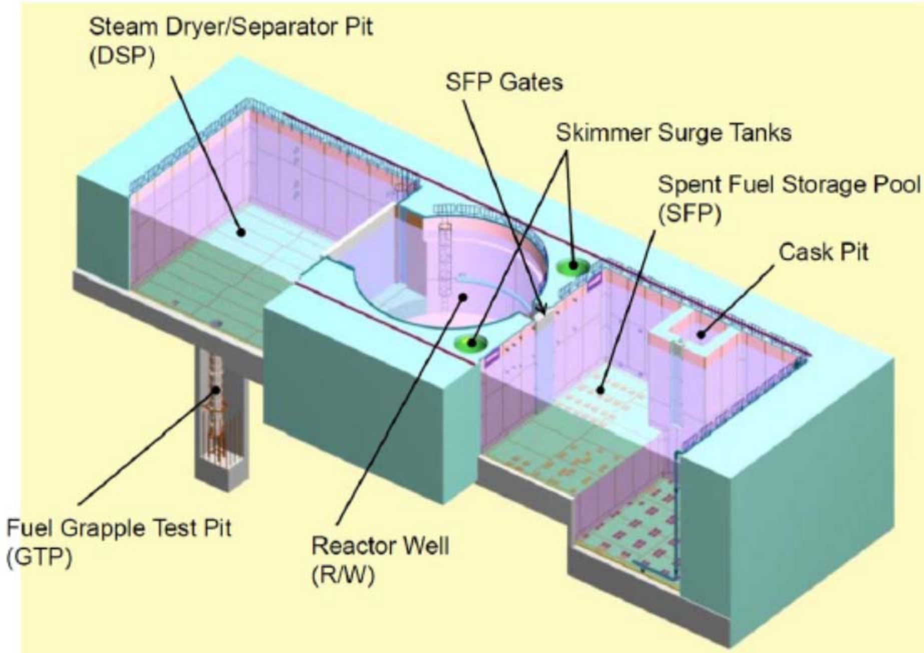


Figure 11: Spent Fuel Pool structure

531. The Seismic Category 1 pool system is constructed of substantial reinforced concrete walls and slabs integral with the Reactor Building and is internally lined with stainless steel panels that provide a leak tight barrier, proposed to be designed ASME Section III (Annex 3). The steel liner will provide the first barrier of protection against leaks (Ref.150).

532. The RP has recognised the welds between stainless steel panels represent a potential weakness in the containment and have introduced a weld leak detection system. This is formed on the stainless steel backing strip at the back of all liner welds and is piped to a leak collection/detection point outside the pools where it can be viewed via sight glass. The leak detection system includes a leak detector and alarm which is raised in the Main Control Room when a specified volume of water is accumulated.

533. After the first barrier (steel liner) and the leak detection system, the concrete walls of the SFP will provide the second barrier of protection against major leakage. The concrete structure forming the SFP, walls and slab, is part of the R/B structure and has been assessed within the different section of this report. The RP has considered a range of operational and hazard loads including dropped loads in the design of the SFP. I have assessed the RP's loadings application to the SFP and the structural design of the SFP to withstand these loadings, and I consider the SFP (concrete structure) design is adequate for GDA. The RP also provided a drop load analysis (Ref. 132) that substantiated the SFP, concrete structure, for a drop load of 150 tonnes; however this drop load will damage the liner (See section 4.3.21.6 – Fault Analysis). The analysis confirms that the volume of demineralised water loss during the fault could be replenished by the FLSS.

534. I have assessed the design against SAP ECV.4 that states that further containment barrier that has sufficient capacity to deal safely with the leakage resulting from a DBE should be provided. The design of the SFP has two containment barriers, the liner and the concrete. However, concrete is not an impermeable material and further specific bunding/containment barrier has not been included in the design. I consider that the GDA assessment has showed that there is a fault condition (drop load) where the liner

could be damaged, but the concrete structure will continue to provide a safety function as a second containment.

535. Following impact damage, it is possible that water will seep through the concrete resulting in contamination and possible damage to the concrete and reinforcement. However, the demineralised pool water is not greatly aggressive to the concrete and reinforcement (compared with borated water) and the rate of water leakage through the concrete due to hydrostatic pressure would be expected to be low. It is likely that such an event will prompt a fast response from the Licensee to repair the liner, and so I do not expect the damage to the concrete and reinforcement to be significant. The contamination in the concrete as a result of this event could pose a risk during decommissioning. OPEX from Magnox pool decommissioning has showed that the vast majority of contamination will be retained in the very top layer.

536. I judge that there are no fault scenarios that will cause the concrete structure to fail in a manner that will cause significant loss of secondary containment. However, should this occur and result in a major leak, the water would accumulate within the rooms surrounding the pools system and be contained for a time by the R/B until collected.

537. The leak detection system will not reveal any mid-plate leakage and this could be a possible scenario under a drop load. The RP argued that the leakage away from the liner welds could occur under a fault (such as drop loads) and this will prompt an investigation and inspection. If liner damage is identified repairs could be performed using submergible robotic welding.

538. Possible blockages of the leak system have been considered however Operational Experience (OPEX) has showed that this normally occurs due to boron crystallisations and the water in the SFP is non-borated water, hence less vulnerable to this type of leaks.

539. The RP has argued that leaks will occur at the welds and provided a leak detection system at this location. While I consider this approach acceptable, the leak detection system will need to be appropriately classified. An adequate classification of the leak detection system will ensure that the system is inspected on a regular basis and leaks are reported and dealt with accordingly.

540. The external face of the SFP concrete structure (walls and slab) can be visually inspected, so any leaks resulting in water seepage through the concrete of the SFP can be detected during routine inspections. I judge that routine inspections of the SFP structure should be considered in the EMIT plan.

541. I have discussed the maintenance and inspection of this system in Section 4.3.20 – EMIT of this report.

542. I judge that the RP has demonstrated that the risks associated with operating the pool system are ALARP and has considered the guidance in the SAPs and IAEA guidance along with international pool design and operational experience. I consider the approach taken by the RP regarding further specific bunding/containment barrier acceptable since the second containment (the concrete structure) will not catastrophically fail under a drop load and for smaller leaks, inspection regimes can be put in place to monitor them.

543. I have considered the RP's report (Ref 150) against SAPs ECV.1, ECV.2, ECV.4 and ECV.7, and judged that radioactive material will be contained with minimal release to the environment. I have also judged that as long as the leak detection system is adequately classified, the SFP design is robust as it has two containment barriers (steel liner and the SFP concrete structure), a leak detection system and visual inspections to the external side of the concrete structure are expected.

4.3.19.2 SUPPRESSION POOL

544. The lower outer areas of the RCCV structure contain the Suppression Pool (S/P) that acts as a heat sink and contamination trap during reactor operating accidents; it contains demineralised (un-borated) water at 35°C during normal operating conditions. There is a potential for low levels of radioactivity (<370Bq/cm^3) to be present in the S/P water (Ref 151).

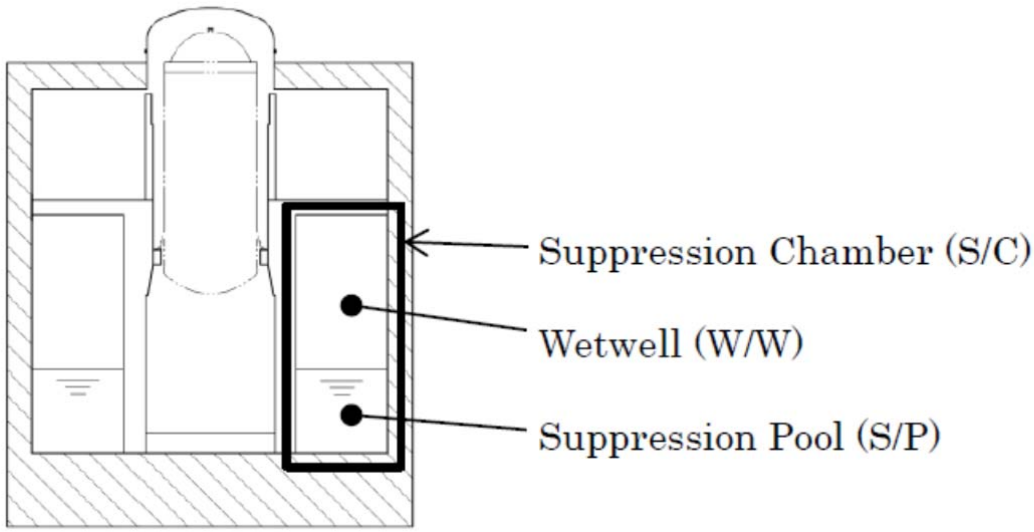


Figure 12: Suppression Pool section

545. As described in Section 3.4, in the Suppression Pool (and RCCV) there is a steel liner that prevents leak from the RCCV. I have not assessed the claims on the liner as this part of the Structural Integrity assessment.

546. The RP recognises (Ref 151) that the welds between the liner panels present a vulnerability to leakage and intend to construct the liner to high standards with radiographic, liquid penetrant and vacuum testing to be applied to the welds. However, radiographic testing is not possible in sections that are welded in-situ against anchors previously cast into the base mat concrete, and the RP acknowledges this.

547. There is no leak detection and collection system incorporated into the design and this is contrary to ONR expectations and contrary to the philosophy adopted for the adjacent pool system (See previous section - SFP). There is a potential for long term minor undetected leakage through damaged areas and weld defects in the liner. There is to be a waterproof membrane around the perimeter of the R/B basement to prevent ground water ingress; this would supplement the containment of leakage through the liner into the R/B, but there are no proposals to monitor or prove this membrane by test. The construction of the base mat without vertical construction joints may also supplement the prevention of the passage of leaks. However, I have the view that cracks are an intrinsic property of cast in-situ concrete and are difficult to predict or prevent; there is no way of proving that chronic leakage through the liner into the base mat would not eventually pass through.

548. The RP claims that there is no OPEX of leakage from S/P in BWRs, however, the BWRs do not have a leak detection system to detect the leaks. It also claims that damage to the liner in the S/P is less likely than in the SFP as the potential for drop loads is lower.

549. I have considered the RP's arguments against SAP ECV.2 and judge that the proposed containment will minimise radioactive releases to the environment in normal

operation, fault and accident conditions. Given the life-span of the structure, a weld failure is possible (I have sought the SQEP opinion of my Structural Integrity colleagues), hence suitable detection systems should be available. I have considered this against, ECV.7 and judge that insufficient sampling and monitoring has been provided outside the containment to detect, locate, quantify and monitor leakage from the containment. I judge that an assessment finding that requires the RP to justify the lack of leak detection system or provide sufficient monitoring to detect leaks from the S/P.

AF-ABWR-CE-018	The Suppression Pool design submitted under GDA does not incorporate a liner leak detection system. The licensee shall either justify this design choice or incorporate a system to monitor leakages or escapes of radioactive material from the containment boundary. Future licensee to refer to section 4.3.18 of Civil Engineering GDA Step 4 report for further information.

4.3.20 Examination, Maintenance, Inspection and Testing (EMIT)

550. The EMIT report on civil engineering structures is a high level report and specifies the RP's measures to enable inspections and tests through the life of the plant. The document provides a list of structural elements, their degradation mechanism (e.g. carbonation, chloride penetration, etc.) and the effect that degradation could have on the structure. It also provides general information on the RCCV tests and inspections, inspections on inaccessible areas and provisions for access to roofs, cranes and external walls.

551. I reviewed the EMIT report (Ref 112) on civil engineering structures and raised a number of comments in RQ-ABWR-1402 (Ref 139).

552. The majority of my comments were addressed in the final revision of the EMIT report. The RP included the following in the final revision:

- Mitigation/control practices to reduce the effect of the degradation factors.
- Settlement and tilt monitoring on the RCCV.
- A section on confined spaces.

553. The RP has provided a commitment within the EMIT report that the full set of EMIT procedures will be tailored to support the claims in the safety case. While this commitment is adequate for Step 4 GDA, further work is necessary.

554. There will be a number of strain gauges installed on the reinforcement of the RCCV for the initial structural integrity test. These gauges will be used during the life of the RCCV to provide information on the performance of the structure, but they will not be maintained. From experience with the UK existing fleet, the operator relies heavily on the information provided by these gauges to support changes to the Safety Case as the structure ages. Hence, the RP should consider options to maintain these gauges.

555. The RP has suggested a number of EMIT requirements for the SFP (Ref 150) and provided an argument for not performing routine maintenance and clearing of the leak chase channels (as these channels are not accessible). The RP's argument is based on:

- The pool water in the UK-ABWR is not borated; hence boric acid crystal cannot form in the leak channels and block them.
- The water quality is maintained high by the fuel pool cooling and clean-up system.

556. I accept the arguments provided by the RP regarding the maintenance of the leak chase channels and I based my opinion on the above bullet points and integrity of the liner which should prevent water leaks. I judge that the RP should undertake visual inspections of the SFP walls and slab to supplement the leak detection system.

557. I am satisfied with the evidence provided by the RP on the EMIT general procedures. I have judged this section against SAPs EMT.1, ECE.8, ECE.18, ECE.20 and ECE.21. The RP has considered the inspection and maintenance of the civil engineering structures during construction and normal operations and the proof pressure tests on the RCCV to an adequate level of detail for GDA.

4.3.21 Cross Cutting Topics

558. External and Internal Hazards provide inputs to civil engineering by defining the loadings to be resisted by the civil structures. Equally, civil engineering provides an input to disciplines including Probabilistic Safety Analysis and Severe Accident Analysis. Structural Integrity and Civil Engineering work together in the assessment of the RCCV, with each discipline leading in different but interlinked areas.

559. The following subsections identify the cross cutting topics and the assessment and reviews carried out by the Civil Engineering discipline.

4.3.21.1 EXTERNAL HAZARDS - CLIFF EDGE EFFECT

560. The seismic cliff edge effect is one of the cross cutting topics, as the derivation of the loading is assessed by the External Hazards Inspector but the effect of the loading on the structures is undertaken by the Civil Engineering Inspector. The seismic methodology for mitigating against cliff edge effects (Ref 123) contains the procedures for confirming that the probability of failure is less than about 10% probability of unacceptable performance for a ground motion equal to 150% of the DBE ground motion. This design criterion in the figure below is based on ASCE 43-05 (Annex 3 of this report).

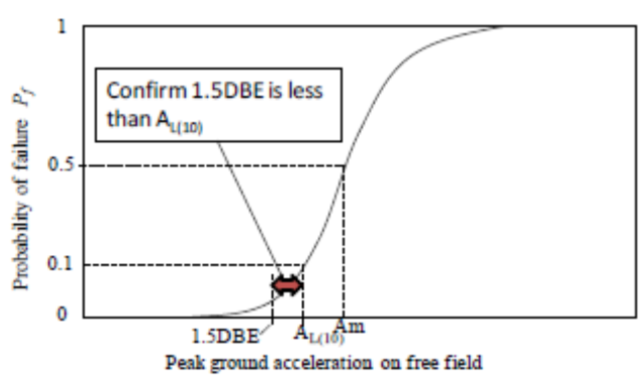


Figure 13: Graph of 10% confidence level

561. The fragility evaluation method is based to estimate a margin against failure of the structure. This method has been assessed by the PSA inspector (Ref 155) and concluded the method is acceptable for GDA.

562. I reviewed Ref 123, which described the seismic methodology that the RP will follow (during the site specific stage) to determine the cliff edge effect on civil structures. As a result of the review, the following points were raised (Ref 138):

- The methodology does not include descriptions of anticipated failure modes and measures taken to ensure good Beyond Design Basis performance, such as ductile detailing.

- Discrepancies were found between the values adopted for the parameters associated with spectral shape factor and damping.
- The RP did not consider the shear failure of walls as a possible failure mode for the buried tunnels. I questioned the fragility of the corner segments within the buried tunnels.

563. The RP answered the comments above by providing the following commitments and clarifications (Ref 162):

- The RP presented the hierarchy of failure for the R/B, confirmed that ductile detailing will be adopted and committed to provide similar descriptions for other seismic categories 1A and 2 structures. All final design reports submitted for GDA contain the hierarchy of failure.
- The RP corrected the inconsistencies with the damping factor and explained the differences with the spectral shape factor.
- The RP confirmed that the shear failures for sway frame action and bend segments of the tunnels will be prevented by following provisions of ACI-349-13.

564. I am satisfied with the evidence provided by the RP on the seismic methodology of the cliff edge effect. I have judged the information presented by the RP against SAPs ECE.1, ECE.6 and EHA.7 and EHA.18 and, as result of my assessment, I conclude that the cliff-edge effects and the fault sequence initiated by a seismic event beyond the design basis have been adequately consider for the Step 4 GDA assessment.

4.3.21.2 INTERNAL HAZARDS

565. The general principles for protection against internal hazards are described in Chapter 7 – Internal Hazards (IH) (Ref 149) of the PCSR and the Civil Engineering requirements are described in Chapter 10 of the PCSR (Ref 26). The civil structures will be designed to be tolerant of IH and to provide required barrier functions. Civil structures will provide passive barriers against the postulated internal hazards.

566. To support the ONR Internal Hazards assessment of the UK ABWR I have reviewed the following documents submitted by the RP:

- Internal Hazards Barrier Substantiation Report (Ref 128).
- Topic Report on Dropped and Collapsed Loads (Ref 129).
- Civil Structure Evaluation Report for Barrier Substantiation (Ref 130).
- Topic Report on Combined Internal Hazards (Ref 131)

567. Also, I held discussions with the Internal Hazards inspectors where interactions were required on civil engineering barriers to provide withstand against internal hazards. Discussions revolved around identification of the internal hazards load cases and the substantiation required to assess the civil structure resistances to these loads.

568. In my review, I noted that barrier substantiation to provide withstand against internal hazards is considered to be a cross cutting topic by the RP, as the derivation of the loading is assessed by the RP's Internal Hazards specialism but the effect of the loading on the structures is generally examined by the RP's Civil Engineers.

INTERNAL HAZARDS BARRIER SUBSTANTIATION REPORT

569. The Internal Hazards Barrier Substantiation Report (Ref 128) describes the assessment process, from initial internal hazard identification through to a substantiated barrier. The methodology provided in this document is "high level" and describes the processes used by the RP's Civil Engineering design team to assess the barriers under hazard load, refine the assessment method, define barrier assessment methodology and define acceptance criteria. To ensure that the methodology has been

applied correctly I undertook a sample check on a slab identified as a barrier against dropped loads, as described below.

TOPIC REPORT ON DROPPED AND COLLAPSED LOADS

570. I reviewed the RP's dropped load slab assessment for the Operating Deck (Floor 4F) in the Reactor Building. The assessment has been undertaken by a specialist subcontractor on behalf of the RP and is based on simple hand calculations. The calculation shows that the floor slab did not provide an adequate barrier to the identified dropped loads and subsequently considers a thicker slab which is able to provide the required withstand. The assessment is a very simplistic hand calculation which has been undertaken using a variety of conservative assumptions on both the analysis and design (e.g. the slab is assumed as one-way spanning). The majority of utilisation factors for the thicker slab show a good degree of safety margin; however shear utilisation for an impact close to the slab supports is 0.97. I noted that the finite element analysis (FEA) model produced by the RP's Civil Engineers, which was used for the seismic and static analysis of the civil structure during GDA, has not been used and the structure is simplified significantly for the hand calculations. I judge that, if the dropped load scenario was assessed using the global FEA model, far greater safety margins would be demonstrated.

571. The RP has not demonstrated that the dimensional changes to civil engineering elements, such as increasing the slab thickness to accommodate the drop loads (as described above), can be accommodated in the design or considered the impact in terms of extra dead load imposed upon the structure. This work has not been done in GDA and I have raised an Assessment Finding (AF-ABWR-CE-019) to capture this shortfall.

572. I have assessed the RP's submission against the guidance in SAP ECS.3 and judged that appropriate codes and standards have been used that will provide a conservative design and that the level of detail provided in the RP's methodology regarding evaluation of Class 1 barriers against dropped load hazards is adequate. I am also content with the iterative process used by the RP's civil designers to assess barriers, using incrementally more refined assessment methods and to eventually propose design modifications if required.

CIVIL STRUCTURE EVALUATION REPORT FOR BARRIER SUBSTANTIATION

573. I have also reviewed the Civil Structure Evaluation Report (Ref 130), against the guidance in SAP ECE.1 and judged that safety functional performance of civil engineering structures under normal operating, fault and accident conditions have been appropriately identified in the RP's assessment. The Civil Structure Evaluation Report (Ref 130) states that the input parameters for barrier assessment are based on the general arrangement drawings for the Design Reference Point (DRP), October 2015. Given that there have been multiple changes to the DRP based on ongoing work from the Civil Engineering and Internal Hazards teams during GDA, there will need to be checks in future to ensure that internal hazard barrier designs are not compromised. This should include structures which have been optimised (i.e. reduced strength members/section sizes) during the civil engineering design process.

TOPIC REPORT ON COMBINED INTERNAL HAZARDS

574. I have reviewed the civil engineering content of the RP's Topic Report on Combined Internal Hazards (Ref 131) in more detail. This document states that it considers the effects of combined hazards on Class 1 barriers in all the GDA buildings, excluding the Radiological Waste Building and the Service Building. It also excludes the Primary Containment Vessel and the Main Steam Tunnel Room. Class 1 divisional barriers are designed to prevent a hazard (single or combined) in one division from affecting a safety system in an adjacent division.

575. The document also states that it considers a range of internal hazard combinations although, in reality, most of the load combinations are screened out. I have not assessed this IH screening process.

576. The civil engineering assessments by the RP have employed two key methodologies:

- BS-EN-1992-1-2:2004. Eurocode 2 Design of concrete structures Part 1-2: General Rules - Structural fire design (See Annex 3).
- BE Generation, R3 assessment procedure, 2008 (See Annex 3).

577. The British Standard is a national standard and R3 is an industry standard that is accepted by the ONR as representing relevant good practice. I have considered this against SAP ECS.3 and judged these standards to be appropriate as they should, if correctly applied, lead to conservative designs.

578. The BS has been used to determine the reduction in strength of a sample of reinforced concrete (RC) walls due to fire loading from a standard 3 hour fire curve. No floor slabs or other structural members have been considered. The RP states that it has been demonstrated that this fire curve bounds fire hazards in the UK ABWR. The methodology assumes that concrete at or above 500°C becomes “inactive”, as per the Fig A.2.1 in the BS. Appendix H of the Topic Report (Ref 131) includes examples of the application of the methodology.

579. R3 has been used to determine damage to the walls due to design basis impact and blast following the strength reduction due to fire. A limiting rotation of 2° at notional yield lines in the walls has been compared to the rotation at the yield line due to blast and impact. The 2° limit is claimed to avoid plasticity at the joints (as per R3), which could require special reinforcement bar (rebar) detailing and could result in instability.

580. Flexural and shear stresses have also been calculated and compared to ACI 349 code allowable. The RP has reduced the load factors for all loads to 1.0 for these load combinations on the basis that, although they are part of the design basis, they consider these loads to be “accidental”. As the walls will also be designed to ultimate limit states, with factors applied to both dead and imposed loads, the RP claims an intrinsic conservatism in the design. This has not been proven, but it is not an unreasonable assertion for GDA.

581. Topic Report Appendix H (Ref 131) includes samples of design assessments that are of most interest to CE. Three samples of the RP’s assessments are presented that include walls subjected to combined loading after a 3 hour fire. The combined loadings include pipe jet, steam pressure, steam and flood as appropriate for each sample of wall.

582. I have reviewed a sample of the detailed assessments contained within Appendix H and recorded the following comments:

- The assumptions on the existence of shear links and the continuity of rebar influence the outcome of the assessments and it is important that these assumptions are realised in the final rebar details.
- The assumptions that there is no concurrent axial load on the walls are unrealistic and should be considered further during site-specific designs.
- The application of the methodology is thorough and the outcome of the assessments is clear.
- The minimum thickness of the doubly reinforced concrete wall required to provide fire resistance is 150mm and this will probably be exceeded by the wall thicknesses confirmed by the site-specific designs.
- The thickness of wall “removed” by the design fire (standard 3 hour fire curve) is 50mm.

- The RP assessments demonstrate that the sample walls will withstand the blast and impact loads following the design basis fire, but shear reinforcement may be required and some increase in flexural reinforcement may be required. The final wall thicknesses should accommodate this.

583. Topic Report Appendix G (Ref 131) acknowledges that there is the potential for distal face ejection of concrete (scabbing) due to impact that could potentially damage A1 SSCs in adjacent areas. The RP has presented arguments based on engineering judgement as to why the effects are expected to be minimal. The RP's judgements are based on the safety function of the plant items located on the distal faces of the walls; I have not assessed this IH process.

584. I have considered the guidance in SAP ECS.3 and judged that the Topic Report for Combined Internal Hazards presents a reasonable appreciation of the effects of likely combinations of loads, from identified internal hazards, on typical RC walls within the UK ABWR GDA civil structures. Although I have assessed a limited sample of the RP's assessments, that are in turn a representative sample of walls, I anticipate that a conservative design will result when the site specific details are produced. No floor slabs or other structural members have been considered by the RP.

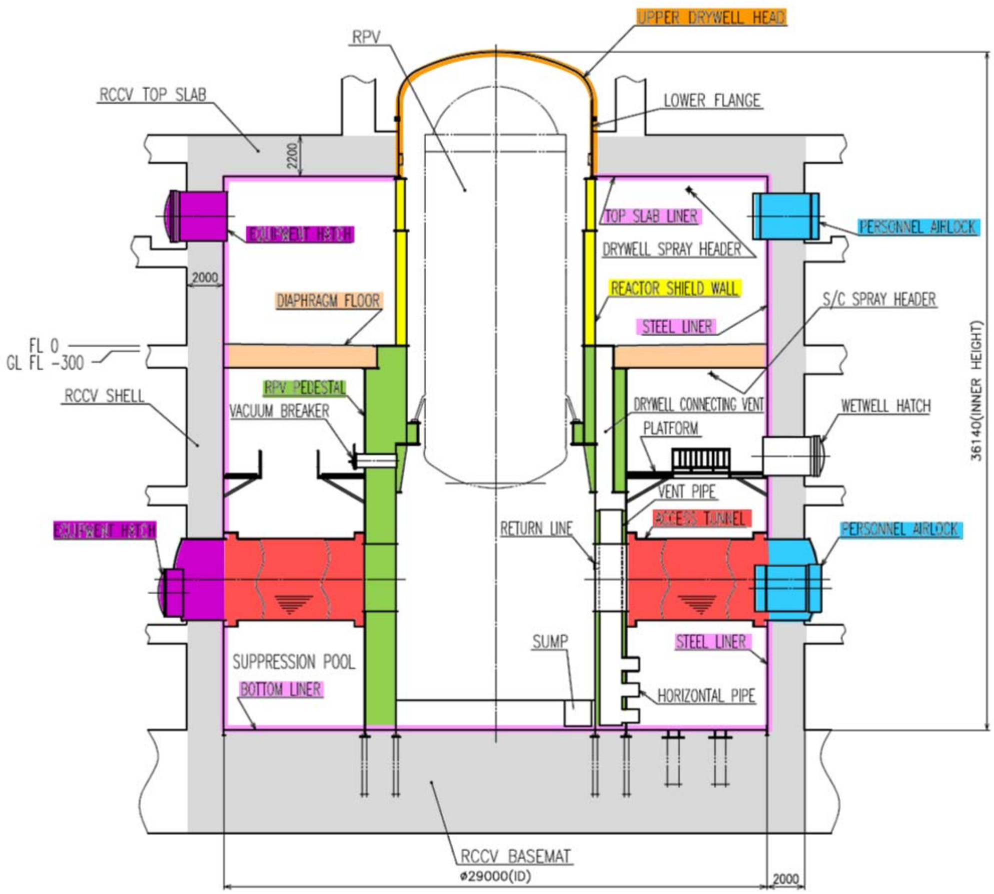
CONCLUSION – INTERNAL HAZARDS

585. To support the ONR Internal Hazards (IH) assessment, I have considered the guidance in SAP ECS.3 and judged that these four sample reports on the effects of internal hazards on the Reactor Building provide a clear indication that use of the proposed methodologies will produce appropriately conservative designs. The methodologies should be employed across the full range of civil structures as commensurate with their safety functions.

AF-ABWR-CE-019	During GDA only a limited number of civil engineering elements have been checked for internal hazards loads. The licensee shall take account of the final Internal Hazards loads and update/perform the structural designs of the civil engineering structures that provide claimed barriers and assess the effect that this could have on the rest of the structure.

4.3.21.3 STRUCTURAL INTEGRITY

586. In order to adequately assess all areas of the Reinforced Concrete Containment Vessel (RCCV) and its MC components, the division of work between structural integrity and civil engineering was required. The RCCV containment and its MC components form a pressure boundary, which comprises civil engineering structures and structural integrity components. The work was divided as described in the table below using the coloured diagram (Figure 14). It should be noted that the RPV is assessed by the Structural Integrity inspector.



Grey = RCCV, Green = Pedestal, Yellow = Shield Wall (**RSW**), Salmon = diaphragm floor (**D/F**), Purple = Equip. Hatch, Blue = Person Airlock, Red = Tunnel, Orange = Drywell head, Pink = liner

Figure 14: Diagram of RCCV with Components Identified

Table 26: Division of Work between Civil Engineering and Structural Integrity

Component	Description	Civil Engineering	Structural Integrity
RCCV	This is the main reinforced concrete structure.	Fully within Civil Engineering Scope	Not considered
Pedestal	Steel-cell, concrete filled structural element, providing support to the RPV, RSW, D/F, tunnels, and anchored at base to the RCCV basemat. Concrete is considered to be non-structural (although its mass is considered).	The Civil Engineering Inspector assessed the load-bearing capacity and structural design assessed. The civil engineering Inspector assessed the forces from embedded pipework onto the structure assessed.	Structural integrity assessed the embedded pipework.
Diaphragm Floor	Barrier between drywell and the suppression chamber. RC slab with non-structural steel ‘seal’ plate. Moment connection to containment wall / simple connection to pedestal.	Assessment of connections, load paths and element design has been completed by the Civil Engineering Inspector.	Not considered.
RSW	Shield to attenuate radiation.	As D/F.	Not considered.

	Stiffened steel plates filled with grout.		
Equipment hatch	A non-structural component fitted both within a penetration within the RCCV wall and within the access tunnel.	The Civil Engineering Inspector completed a compatibility check of the assumptions made for the penetration in the RCCV vs. assumptions used to design the hatch, these include: - That the design input parameters are consistent with the surrounding structure. - That the loads from the hatch are considered in the design of the surrounding structure.	Structural Integrity assessed the design of this MC component.
Personal airlock	A non-structural component fitted both within a penetration within the RCCV wall and within the access tunnel.	As Equipment hatch.	Structural Integrity assessed the design of this MC component.
Access tunnel	Bridges from the RCCV wall to the pedestal, with movement joints at each end. Steel construction.	As Equipment hatch. The Civil Engineering Inspector checked the adequacy of the movement joint (magnitude of allowable vs. anticipated movement). The Civil Engineering inspector checked forces/moments transmitted to the RCCV and pedestal from the access tunnel. Broad structural assessment completed by the Civil Engineering.	Not considered.
Drywell head	Steel pressure vessel-type element. Fixed to the Liner.	The Civil Engineering considered the connections between the Drywell head and the RCCV top slab.	Structural Integrity assessed the design of this MC component.
Liner	Non-structural steel liner.	Civil engineering completed a compatibility check of the crack widths in the RCCV vs. the allowable strains in liner. Civil engineering considered the cast-in items forming the connection of the liner to the reinforced concrete (anchors).	Structural Integrity assessed the design of this MC component.
Miscellaneous	Penetrations design report. MC Components of RCCV.	Civil Engineering checked the sections of these reports that correspond to sections of the individual component reports for compatibility and completeness of the information. Civil Engineering checked that penetrations are considered in the civil engineering design. Civil Engineering checked any structural fixings/connections to the concrete.	Structural Integrity assessed these reports.

587. The civil engineering assessment of the components stated above is discussed throughout this report in section 4.3.11.4 - MC Components and further discussion of the RCCV is within section 4.3.18 - RCCV.

588. The liner anchors are an area of interaction with Structural Integrity, as the forces in the anchors are derived from the stresses in the liner (the liner is assessed by the SI inspector). I assessed the liner anchors which checked against displacement limits and various pull-out conditions (pull-out strength, bearing strength, flange bending stress

and web tensile stress). I consider that these checks show appropriate margin and I judge them to be adequate against SAP ECE 2 with regards to use of nuclear specific design standards and appropriate margin.

589. I assessed the seismic loadings applied to the pedestal from the RPV model. I had a number of discussions with the RP on the RPV seismic model and the verification and validation of the seismic analysis (Comment 04-050). This comment clarified that the modelled structure adequately resembled the UK ABWR RPV and the forces transmitted to the pedestal were appropriate.

4.3.21.4 CONVENTIONAL SAFETY

590. The RP's arrangements for conventional safety have been assessed by the ONR conventional safety assessor and reported at Ref 18. A sample of civil engineering aspects of conventional safety during construction have been assessed in support of the assessment of conventional safety.

591. I have the view that the RP has considered construction and conventional safety during construction only as was necessary to inform the GDA designs of the civil structures in response to ONR Regulatory Queries (Ref 137) regarding the Reactor Building. The RP intends that details of the site construction and risk reduction methods will be developed further and extended to other buildings during the following site specific design and construction phases.

592. A number of broad assumptions have been made by the RP when designing the civil structures that are generally formed as reinforced concrete "boxes", with internal reinforced concrete walls and floor slabs. The intended forms of key GDA civil structures are summarised in the document Overview of UK ABWR Civil Structures (Ref 27), in the Basis of Safety Case documents and in the Design Reports for each GDA civil structure. The assumptions and intended form of structures are based on previous ABWR designs. It is notable that a number of the civil structures will require significant excavation (> 20m deep), probably below ground water level, for the construction of foundations.

593. In response to RQ-ABWR-1184 and RQ-ABWR-1413, the RP prepared the document Topic Report of CDM Compliance (Ref 152). The topic report demonstrates a good understanding of the requirements of the CDM Regulations 2015, but only a limited demonstration of how they will be applied during subsequent phases of the design and construction of the civil structures. This is due to reluctance on the part of the RP to commit to specific construction methods at this GDA stage of the project.

594. However, it is clear that the RP intends that some of the reinforced concrete buildings be constructed using the "open top" method (otherwise known as the advanced construction technique) that includes the installation of large scale plant modules using heavy-lift mobile cranes. The conventional safety aspects of this have been assessed in more detail by the ONR conventional safety assessor and have been reported at Ref 18.

595. Also, I have assessed a small sample of the available construction methodologies by questioning the temporary stability of the Reactor Building reinforced concrete perimeter walls. These are intended to remain stable as free cantilevers for an unknown period during construction while awaiting the installation of plant through the space that will later become the building roof. I am able to judge that the topic report (Ref 152) includes an adequate response to the question and the RP has provided adequate demonstration of the stability of these perimeter walls during construction.

596. This response to this sample question, in conjunction with other information presented in the topic report, provides an indication that the RP is aware of

conventional safety requirements, including the CDM Regulations, required to be implemented during the construction phases of the project. I have considered this against SAPs ECE.17 and ECE.25 and judged based on the information provided that it is probable that the civil structures can be designed and constructed in accordance with relevant good practice that will ensure the achievement of the design specifications and the required level of safety. However, the RP's intended construction methodologies have yet to be defined for the majority of civil structures, and the designers have not fully discharged their duty under the CDM Regulations to remove or reduce risks during construction and future maintenance of the buildings.

4.3.21.5 PSA– RCCV ULTIMATE PRESSURE CAPACITY

597. In order to support the Level 2 Probabilistic Safety Assessment (PSA) work, ONR Civil Engineering has reviewed the RCCV concrete structure ultimate pressure capacity Finite Element Model (FEM). This model was developed by the RP to support their PSA claims by investigating the failure modes.

598. Two RQs were raised in this area by ONR Civil Engineering. RQ-ABWR-1411 (Ref 142) questioned the PSA report (Ref 153) and was focused on omitted loading conditions. RQ-ABWR-1488 (Ref 144) summed up the comments from the civil engineering review of the RCCV model. The RP updated the model and provided responses to the comments and four reports (Ref 124, Ref 125, Ref 126 and Ref 127) to address both RQs.

599. As explained in section 4.3.18 – RCCV, two FE models were developed by the RP. The global model of the R/B and RCCV showed that at 200°C the RCCV can withstand pressures up to 6Pd. The aim of the global model was to identify the critical areas within the RCCV (top slab area), after that a second detailed model was developed to evaluate the failure mechanism (transverse shear) in detail. The RP included a number of loading conditions such as temperatures up to 300°C and non-homogenous load distributions.

600. My civil engineering review (Ref 154) of the models included:

- Geometric and dimensional checks of the model against the civil General Arrangement drawings to ensure that the FEM accurately represents the UK ABWR GDA design
- Checks on the accuracy of the civil engineering assumptions
- Comparison of the RCCV ultimate capacity modelling results with the results from previous Boiling Water Reactors (BWRs) models.

601. I found that the model was representative of the RCCV and R/B design. The accuracy of the civil engineering assumptions was generally acceptable, with minor points that required further evidence. For those cases, the RP provided sufficient evidence, such as a sensitivity study for the embedment conditions or further explanation on the transfer of boundary conditions. The liner anchor performance assessment during severe accidents was also provided. The RP has used the same methodology for this assessment as used under design basis loading. This methodology was assessed as part of the RCCV liner anchors assessment and I found the approach acceptable.

602. The RP also provided the results from scaled BWR models, but the extrapolation of the results to the UK ABWR is not entirely applicable, since the models are structurally different. However, the scaled models provide an approximate indication of the maximum pressure.

603. The Level 2 PSA assessment (Ref 155) confirmed that the RCCV and the liner anchors have sufficient capacity to withstand high pressures and they are not part of the critical failure path under severe accident conditions. It should be noted that the

RCCV ultimate pressure capacity analysis model is based on an approximation to the mean value of the material properties (this complies with the PSA requirements), and not in the characteristic values used in civil engineering design. I consider that this approximation was adequate for GDA but a more rigorous approach to calculate the best estimate values will be required during the site specific stage.

604. My assessment of the ultimate capacity of the RCCV concrete structure included the assessment of the loadings and loading conditions and the assessment of the FE models and the civil engineering parameters. I assessed the RCCV FEM against SAPs ECE.1, ECE.2, ECE.12, ECE.13 and ECE.15. I found that the RCCV model reflects the information within the technical drawings and the civil engineering assumptions are acceptable. The RP provided a number of sensitivity studies and evidence that the data used in the structural analysis was based on best estimate values, as well as an approximate validation method. Hence, I judge that the RCCV ultimate pressure capacity is suitable to support the PSA assessment.

4.3.21.6 FAULT ANALYSIS

605. The objective for DBA and BDBA of reactor faults is to demonstrate that there is no, or at least very limited, consequential damage to fuel in the reactor core as a result of the event in question. The reactor faults and their validity are assessed by the Fault Analysis inspectors and I have assessed the capacity of the civil engineering structures to withstand the faults.

606. The civil engineering structures have been designed for a number of fault conditions, and these faults are initiated by an internal hazard or external hazard event (See Sections 4.3.21.1 and 4.3.21.2). One of the main fault scenarios is a LOCA event and the loading from this event is withstood by the RCCV. Under a LOCA event the maximum design temperature (in the D/W) is 171°C and the maximum pressure in the RCCV is 310 kPa (1 Pd) (Ref 156). I confirm that the design of the RCCV under a LOCA event assumes the above conditions and develops a number of time histories following a LOCA event.

607. The Fault Analysis inspector has identified in his report (Ref 156) that the peak D/W temperatures in the vicinity of the two line breaks considered are predicted to be above the design temperatures for several minutes. However, the RCCV ultimate pressure capacity assessment (see previous section) was carried out for two temperature conditions, 200°C and 300°C, and in both cases the estimated failure pressure of the RCCV is the same (around 6Pd). The RCCV remained mainly within the elastic range under the pressure level of 2.4Pd (at which the initial failure of the drywell head flange occurs) and 200°C. Hence, I consider the short-term increase of temperature predicted in the Fault Analysis report (Ref 156) at 1Pd can be withstood by the RCCV concrete structure.

608. In the early portion of many design basis transients, decay heat from the core is rejected to the S/P water. However, over time, the S/P will also heat up and the pressure in the PCV will increase. The emergency core cooling system is the principal means of cooling the PCV and reducing the pressure. However, if this is unavailable for some reason, the operators can use the hard-wired backup system to open one of two vent lines to the stack to discharge excess heat and pressure to the atmosphere. One line is ‘hardened’ to the pressures likely to be experienced during accident conditions but is not filtered. It is assumed that it will only be used when there is limited radioactivity in the PCV. The second line is also hardened, but it additionally includes a filter. This filtered containment vent system (FCVS) is primarily designed for severe accidents but is available for design basis and beyond design basis events.

609. For a design basis event, it is assumed the operators will initiate containment venting once the PCV design pressure of 310 kPa is reached (if they are satisfied there is no

significant fuel damage and they are not having a severe accident). If the pressure reached twice design pressure and manual venting had not been initiated, the bursting disc of the passive containment overpressure protection system is designed to open, resulting in venting through the filtered FCVS route (the severe accident assumption). A detailed design for either venting route is not currently available and the analysis presented showed that the resulting flow area proved to be insufficient to achieve the RP's assumed flow rate. Hence ONR have on-going questions regarding the Filtered Containment Venting System effectiveness and pressure relief set point to the primary containment (RCCV) ventilation that have not been resolved by the RP and related assessment findings are proposed by Fault Studies (AF-FS-08), Severe Accident Analysis (AF-FS-08) and Reactor Chemistry (AF-RC-34). Modifications to the venting system may result in changes to the civil structure and penetrations and I judge that a civil engineering minor shortfall is appropriate.

MS-ABWR-CE-06.	The licensee should consider the effects that possible modifications to the venting system may have in the civil engineering structures.

610. The RP has stated that the limiting design basis event in the SFP has been assumed to be a failure of all the welds in the liner, resulting in a maximum flow rate of 30m^3/hour. I provided support on this area and confirmed that the drop load assessment on the SFP is enveloped by the maximum flow rate assumed. The FEM assessment confirmed that the concrete walls of the SPF will not be perforated but scabbing may occur and the liner will be damaged resulting in leakage but this will not exceed 30m^3/h. This was later refined to 6m^3/h, which is well below the makeup rate capacity of the FLSS.

611. I assessed the civil engineering structures against the faults within the fault scheduled and against SAP.6. I judge that the UK-ABWR design has adequately considered design basis faults.

4.3.21.7 SEVERE ACCIDENT ANALYSIS

612. The SAA assesses the integrity of the PCV due to the following failure modes:

- Overpressure and over-temperature of the containment – I have covered this in detail in Section 4.3.21.5.
- Fuel Coolant Interaction (FCI) outside of the RPV (ex-vessel) – See below
- Molten Core Concrete Interaction (MCCI) – See below
- Direct Containment Heating (DCH) –The RP claims that the RPV pressure is reduced by the time of RPV failure and the occurrence of DCH is prevented. This has been assessed in Ref 157
- Direct debris interaction – See below
- Hydrogen combustion – The RP has presented a strategy to prevent hydrogen combustion and this has been assessed by the SAA inspector (Ref 157)

613. I provided support to the ONR severe accident analysis Inspectors by discussing the structural configuration and load cases of the RPV pedestal and the access tunnels.

614. One finding has been raised in the Step 4 severe accident analysis report (Ref 157) against the RPV Pedestal. I explained to the severe accident analysis Inspector that molten core-concrete interaction (MCCI) is not considered in the RPV Pedestal reports. Hence the claims under MCCI (the pedestal can provide its supporting function without the inner plate) have not been substantiated in the civil engineering reports, neither the effect of this in the base connection.

615. The RP argues that the supporting function of the pedestal wall will not be lost due to the impulse load from the FCI. The RP has presented an analysis which suggests that the inner steel plate of the pedestal wall is unlikely to fail as the energy (27MJ) from an ex-vessel steam explosion (due to FCI) is significantly lower than the energy required for the structural failure of the pedestal wall (1500MJ) . I did not assess the claims on the energy values quoted by the RP, but I discussed with the SA inspector that the effect of the ex-vessel steam explosion on the pedestal in terms of deformation and its effect on the load paths have not been assessed. However, I do believe that the MCCI failure will envelope the FCI and the assessment finding raised by SAA inspector against the RPV Pedestal should also address this shortfall.

616. The RP claims that direct debris interaction following a High Pressure Melt Ejection would not lead to a breach of the access tunnels. The flexible joints on the access tunnels and their movement were also discussed with the SAA Inspector because the movement could provide a potential Suppression Pool (S/P) bypass route if the tunnels are exposed to severe temperature loads. It was the judgement of the SAA inspector that this should be considered during the detailed design phase (Ref 157).

617. I assessed the civil engineering aspects of the claims made on the RCCV and MC component during a severe accident against SAP.6. I judge that further work is required to substantiate the RPV Pedestal for a MCCI fault, the SAA has raised an assessment finding that will address this shortfall.

4.3.21.8 DECOMMISSIONING

618. The RP’s arrangements for decommissioning have been assessed by the ONR decommissioning assessor and reported at Ref 158. In support of this, I requested a view of a sample of civil engineering proposals for construction (techniques and details) and I raised RQ-ABWR-1125 to question how the construction techniques could influence decommissioning.

619. The RP’s response in document, Influence of Construction Techniques on Decommissioning (Ref 159), does not commit to any firm building details but acknowledges the requirement to produce building details, during the site specific stage, that will enable effective decontamination of the civil structures to be carried out before and during the decommissioning of the plant.

620. During Level 4 meetings with the RP, I discussed minor modifications to construction details that could be applied to improve the decontaminability of in-cell areas of the civil structures, and these were accepted by the RP. Potential de-construction methods were not presented.

621. The RP’s response to the RQ also comments on the intended prompt timescales for decommissioning but acknowledges that the long term integrity of the civil structures should be ensured in the event that deconstruction is delayed. No firm proposals to achieve this were presented.

622. I have also reviewed the Topic Report on Decommissioning: Impact of Construction Techniques on Decommissioning (Ref 160) in support of the assessment of decommissioning and I have the view that the RP has considered the impact of construction techniques on decommissioning only as far as is necessary to inform the GDA designs. The RP intends that details of the construction and decommissioning techniques will be developed further during the site specific design and construction phases. However, the report does discuss aspects of the following decommissioning topics of interest, and the RP’s approach to advanced construction methods appears reasonable from a civil engineering perspective:

- Embedded pipework.

- Access restrictions.
- Intact removal of large items.
- Advanced construction methods that include the installation of large modules of plant.

623. I have considered the RP’s response to the RQ, the topic report and the discussions on improvements to construction details (the outcomes to be implemented during the construction phase of the project) against SAP ECE.26 and judged that it is probable that features to facilitate decommissioning will be incorporated into the construction details of the civil structures.

4.3.22 PCSR – Chapter 10 - Civil Engineering

624. I assessed the civil engineering chapter of the PCSR (Chapter 10) and supporting chapters (ALARP - Chapter 28 and General Design Aspects – Chapter 5). As mentioned in section 3, the PCSR is a “sign-post” document that describes the safety functions, safety claims and design principles of all the civil engineering structures within the GDA design.

625. My assessment of the PCSR highlighted areas that needed to be included, such as conventional safety, construction, EMIT, links to beyond design basis assessment and severe accident analysis. I commented on the list of civil engineering GDA assumption within the PCSR and the fact that the assumptions on ground conditions were not part of that list. I requested further information on the external and internal hazard section and for the RP to include the aircraft impact protection in the ALARP section.

626. The RP included all my review comments above and provided a document map to address ONR’s generic comments regarding traceability within the Safety Case. The document map provides the link between the PCSR chapters and the Basis of Safety cases (Level 2 documents).

627. The RP also provided internal and external hazards mapping that provides a summary of the hazards which are to be considered applicable for each building inside the GDA civil structures’ scope. This information is very useful, but, in the case of internal hazards, the information within the PCSR does not match the information in the civil engineering Level 3 design reports. Currently, none of the design reports state any internal hazards. I have highlighted this shortfall in section 4.3.21 of this report and captured it as an assessment finding.

628. In general, I consider that Chapter 10 of the PCSR provides a good overarching summary of the structures within GDA and their safety function. However, as discussed before, there is a gap between civil engineering and internal hazards, but I judge this to be an assessment finding within the Level 3 design reports and not in the PCSR. I based my judgement on the fact that the PCSR states that the substantiation of the civil engineering barriers is within the IH reports (Ref 128, Ref 129, Ref 130 and Ref 131), so as a “sign-post” document, the PCSR is fulfilling its requirements.

629. I have assessed the civil engineering chapter of the PCSR against SAPs SC.1, SC.4, ECS.1, ECS.2 and ECS.3. I consider that the safety case identifies the hazards, demonstrates that the civil engineering structures conform to relevant good practice and safety principles and demonstrates that the civil structures have been designed for normal operations, fault and severe accidents conditions. I judge that Chapter 10 of the PCSR is adequate for GDA.

4.3.23 ALARP - Civil Engineering

630. I have assessed the application of the ALARP principle to civil engineering by considering the high level safety functions of the civil engineering structures, the

nuclear safety risks associated with them and their reduction through the design process. The civil engineering structures have two principal safety functions: provide support to nuclear safety related plant and the barrier functions. The barrier functions are mainly: protection against outside environment, prevent release of radioactivity to the environment or spread internally and as internal barrier for segregation (See section 3.2.1 – PCSR). There are a number of risks associated with the high level safety functions and so I have sampled a number of areas where the design should demonstrate that the risks are ALARP:

- Assessing the categorisation and classification of the civil engineering structures according to their safety functions – Function to provide structural support
- Assessing the civil engineering design against recognised and accepted codes of practice.- Function to provide structural support
- Assessing major ALARP modifications to the UK ABWR design Function to provide structural support
- Avoiding spread of contamination – Barrier Function
- Barriers to Internal Hazards – Barrier Function

631. Section 4.3.3 of this report contains my assessment of the categorisation and classification of the civil engineering structures. The classification will govern the design codes and standards and design methods to be used for each class of structure. This ensures that the reliability of the design matches the safety significance. I consider that the RP has provided sufficient evidence to demonstrate that the safety functions of the structures have been adequately considered. Hence the categorisation and classification of the structures follows the ALARP principle.

632. The RP claims that the civil engineering structures have been designed according to established codes of practice and the loads are conservative. I have assessed these claims in sections 4.3.3 and 4.3.8 and raised two assessment findings. However, holistically I consider that the RP's approach to codes, standards and loadings contributes to the ALARP principle and substantiates the function to provide structural support.

633. The RP has provided a number of design changes and improvements that contribute to the overall argument that nuclear risks are ALARP. For civil engineering the three main changes are:

- Introduction of Aircraft Impact Protection.
- Assessment of the RCCV ultimate pressure capacity.
- Adoption of finite element analysis methodologies.

634. The protection of the UK ABWR from potential aircraft impact is a beyond design basis event that has been introduced to the design. This is a requirement not only for nuclear safety but also for security. Buildings have been provided with either enough strength to prevent an aircraft impact from affecting the SSCs within that building; or enough separation from other SSCs such that diversity of systems is ensured. I have assessed the aircraft impact protection claims within Ref 13. I consider that this modification to the design is an example where the RP has reduced the risks to ALARP levels.

635. The RP has identified a number of nuclear accident scenarios. I have sampled the RP's assessment of the RCCV ultimate capacity (See Section 4.3.21.5) and I consider that the risk associated with the failure of the RCCV under high temperatures and pressures is ALARP.

636. The RP changed their approach to seismic modelling and adopted finite element analysis methodologies. This approach is more accurate and captures the local

responses. In general, I consider that the modifications discussed above contribute to the ALARP principle claimed by the RP.

637. The RP claims that there are a number of features that collect accidental spillages avoiding the spread the contamination (such as bounded areas around floor drains where there is a potential for leakage). Other typical features are drainage channels and sumps; those have been used in the leak detection system for the SFP. However, as explained in section 4.3.19 – Leak detection systems, the Suppression Pool does not have a leak detection system and for this particular case I do not consider that the RP has reduced the risks to ALARP levels and as a result I have raised an Assessment Finding.

638. However, there are a number of ALARP claims within Chapter 10 of the PCSR that need further development in order to be considered as part of the overarching ALARP argument. Some of these claims are in the civil engineering barriers against Internal Hazards. As discussed in section 4.3.21, those barriers have not been documented in any of the civil engineering assessment reports and there are areas that need further development, such as combined hazards, so I do not believe that they can be fully claimed in the ALARP argument.

639. I based my assessment of the ALARP argument on guidance in SAPs. SC.4, ECS.1, ECS.2 and ECS.3, and I judge that the RP has provided an argument for why risks are ALARP. I consider that the RP has provided a civil engineering design that complies with the ALARP principle by adequately classifying the safety functions of the civil structures and designing them using relevant good practice. However, I judge that there are some areas, mainly in incorporating the internal hazards loads to the civil engineering design and the lack of leak detection in the Suppression Pool, that require further work during site specific phase in order to contribute to the ALARP argument. I have raised assessment findings in sections 4.3.19 - Leak Detection and 4.3.21.2 – Internal Hazards, to capture the shortfalls.

4.3.24 Reliability of the Civil Engineering Design

640. Engineering structures, systems and components need to be designed to deliver their required safety function with adequate reliability, and so provide confidence in the robustness of the overall design.

641. The level of reliability of the civil engineering SSCs is defined and achieved by:

- Classification of the civil engineering structures in accordance to their nuclear safety claims
- Civil engineering design against codes and standards applicable to the nuclear safety claims placed on the civil structure
- Conservative input parameters (loadings) to achieve the require reliability for normal and accident conditions.
- Structural resilience under severe accidents (beyond basis of design conditions) and identification of failure modes
- Design life of the structure and through life EMIT plan

642. I have assessed the classification of the civil engineering structures within GDA (see Section 4.3.2 – Structure Classification) and concluded that they have been classified in accordance to their nuclear safety claims. I judge that the reliability provided by the design is appropriate to the safety significance of the civil engineering structure.

643. The civil engineering design is a deterministic design based on industry accepted codes, standards and other relevant good practice that are specific to the nuclear industry. I have assessed the codes and standards used for the civil engineering design of the UK-ABWR (see Section 4.3.3 – Design Codes and Standards) and

concluded that they will ensure an adequate reliability. Within these codes and standards there is a margin and a level of reliability built in (e.g. loading factors), however to achieve an adequate level of reliability the input parameters used with these codes must be compatible with the design codes and standards used.

644. The input parameters in civil engineering design includes the loadings and some of these loads (such as dead, live loads and wind load) are derived from compatible (in terms of ensuring the level of reliability) codes of practice. Other inputs are not derived from compatible codes, such as the seismic design spectra, but this is judged acceptable as I explain below.

645. The seismic assessment of the UK-ABWR has utilised the EUR seismic design spectra for hard and medium soils and the RP has applied the requirements of a Seismic Category 1 structure to withstand a 10^{-4}/yr hazard and seismic category 2 structures to withstand a 10^{-3}/yr hazard.

646. The EUR seismic design spectra are the average plus 20% margin of the peak ground acceleration values (from the uniform hazard spectra) of the UK nuclear sites, and these values represent the 84% confidence level (or non-exceedance level). ASCE 4 states that if alternative methodologies are used to provide the seismic input (as it is the case in the UK-ABWR GDA), the seismic design input should be at the 80% non-exceedance level. Therefore, I judge that the seismic design spectra used in the UK-ABWR GDA assessment has sufficient confidence level to be used with the chosen seismic design codes (ASCE 4) and the outcome is a civil design that has the reliability provided by the seismic design code. In the seismic design there are also some areas that contain conservatism, like the use of response-spectrum analysis and equivalent static methods.

647. As stated before, the civil engineering design is a deterministic design and hence in reliability terms the civil engineering structures should withstand a number of normal and accident conditions. For normal conditions the structure should be able to withstand 10^{-2}/yr hazards and, depending on the hazard and the classification of the SSC, a 10^{-3}/yr or 10^{-4}/yr hazard for a DBE event. The civil engineering structures have been assessed for DBE events, and the most significant of those (for a civil engineering structure) is a seismic event. A number of fault sequences have been analysed as a result of a seismic event, and the most significant of them for the RCCV is a LOCA event. The RCCV has been assessed under a LOCA event (see Section 4.3.21.6 – Fault Studies) and I judge that the RP has shown that the civil engineering structures can withstand a DBE event and achieve the level of reliability inherent in the design codes.

648. The RCCV is a key civil engineering structure that needs to provide confinement of radioactive material and shielding during a DBE event and also during and following severe accidents. Hence the RCCV is an SSC that requires high reliability levels. The RP has provided evidence that substantiates the RCCV capacity to withstand high temperatures and pressures, as a result of a severe accident. I have assessed the evidence (see Section 4.3.21.5 – PSA – RCCV Ultimate Pressure Capacity) and I judge that the design margins of the RCCV are consistent with the nuclear safety claims and required reliability.

649. The RP has also determined the failure modes of the civil engineering structures under seismic loadings, as this load normally dominates the design (see Section 4.3.21.1 – External Hazards – Cliff Edge Effect). Consideration of the failure modes allows the designer to avoid unsafe failure modes and predict areas of weakness in the structure. I consider this to be an important factor contributing to design for reliability of the civil engineering structures.

650. The final argument that contributes to the overall reliability of the civil engineering structures is the through life examination, maintenance, inspection and testing regime. The civil engineering structures will be maintained through the design life to ensure that the reliability claimed during the design process is satisfied. The RP has presented high level information on the EMIT for the civil engineering structures (see Section 4.3.20 – EMIT), I consider that the information presented summarises the general EMIT procedures and the detailed EMIT regime will be developed during the site specific stage. I judge that the RP has acknowledged the importance of the EMIT regime and its contribution to the reliability argument.

651. I have assessed the reliability of the UK-ABWR civil engineering design against SAPs EDR1, ERL1 and ERL2 and I consider that the reliability claims, failure modes and the measures to achieve reliability have been demonstrated by the evidence presented during the UK-ABWR Step 4 GDA assessment. I judge that the civil engineering structures are robust and achieve the reliability required of a nuclear power plant design.

4.4 Comparison with standards, guidance and relevant good practice

652. The RP's submissions in civil engineering have been assessed against the 2014 SAPs that set out relevant good practice (RGP). The submissions and generally meet ONR expectations. The SAPs include the recommendations of the WENRA Safety Reference Levels and the IAEA guidance and standards.

653. ONR's document "Guidance to Requesting Parties" (Ref 161) sets out ONR's expectations to RPs with regard to the GDA process for the safety and security assessment of nuclear power stations intended for construction and operation in Great Britain. It provides further high-level guidance on RGP for the consideration of external hazards and the generic site envelope within GDA. The external hazards assessments have considered the lessons learned from the Fukushima event. I have assessed the RP's submissions against the expectations set out in this guidance and in my view the submissions are in line with the guidance provided.

654. I have also considered the design codes and standards used by the RP against ECS.3 (see Section 4.3.3) and judge that, from a civil engineering perspective, the use of these internationally recognised and accepted nuclear-specific codes and standards has led to an acceptable civil engineering design that will meet the reliability requirements of the civil structures. I have judged that these codes and standards reflect RGP to a level appropriate to GDA.

4.5 Assessment findings

655. During my assessment, 19 residual matters were identified for a future licensee to take forward in their site-specific safety submissions. Details of these are contained in Annex 4.

656. These matters do not undermine the generic safety submission and are primarily concerned with the provision of site specific safety case evidence, which will usually become available as the project progresses through the detailed design, construction and commissioning stages. These residual matters are captured as assessment findings.

657. I have recorded residual matters as assessment findings if one or more of the following apply:

- site specific information is required to resolve this matter;
- resolving this matter depends on licensee design choices;

- the matter raised is related to operator specific features / aspects / choices;
- the resolution of this matter requires licensee choices on organisational matters;
- to resolve this matter, the plant needs to be at some stage of construction / commissioning.

658. Assessment findings are residual matters that must be addressed by the future Licensee and the progress of this will be monitored by the Regulator.

4.6 Minor shortfalls

659. During my assessment, 4 residual matters were identified as minor shortfalls in the safety case. These are not considered serious enough to require specific action to be taken by the future licensee. Details of these are contained in Annex 5.

660. Residual matters are recorded as a minor shortfall if it does not:

- undermine ONR's confidence in the safety of the generic design;
- impair ONR's ability to understand the risks associated with the generic design;
- require design modifications;
- require further substantiation to be undertaken.

5 CONCLUSIONS

661. This report presents the findings of my GDA Step 4 Civil Engineering assessment of the Hitachi-GE UK ABWR.

662. To conclude, I am satisfied that the claims, arguments and evidence laid down within the PCSR and supporting documentation for civil engineering. I consider that from a civil engineering view point, the Hitachi-GE UK ABWR design is suitable for construction in the UK subject to future permissions and permits being awarded.

663. Several assessment findings (Annex 4) were identified; these are for a future Licensee to consider and take forward in their site-specific safety submissions. These matters do not undermine the generic safety submission but require Licensee input/decision.

5.1 Key Findings from the Step 4 Assessment

664. I consider that, from a Civil Engineering view point, the UK ABWR design is suitable for construction in the UK, subject to future permissions and permits beings secured.

6 REFERENCES

Ref 1. ONR-GDA-AP-15-001 - Step 4 Assessment Plan - Civil Engineering, 18 September 2015. TRIM Ref: 2015/349738

Ref 2. ONR Guidance on Mechanics of Assessment, 31 May 2013, TRIM Ref: 2013/204124

Ref 3. NS-PER-GD-014 Revision 6 - Purpose and Scope of Permissioning, November 2016. TRIM Ref: 2016/448079

Ref 4. Safety Assessment Principles for Nuclear Facilities, 2014 Edition, Revision 0, Office for Nuclear Regulation, November 2014. http://www.onr.org.uk/saps/saps2014.pdf

Ref 5. Civil Engineering, Nuclear Safety Technical Assessment Guide, NS-TAST-GD-017 Revision 3, May 2013. http://www.onr.org.uk/operational/tech_asst_guides/ns-tast-gd-017.pdf

Ref 6. Civil Engineering Containments for Reactor Plants, Nuclear Safety Technical Assessment Guide, NS-TAST-GD-020 Revision 3, November 2014. http://www.onr.org.uk/operational/tech_asst_guides/ns-tast-gd-020.pdf

Ref 7. Guidance on the Demonstration of ALARP (As Low As Reasonably Practicable), Nuclear Safety Technical Assessment Guide, NS-TAST-GD-005 Revision 8, July 2020, http://www.onr.org.uk/operational/tech_asst_guides/ns-tast-gd-005.pdf

Ref 8. The Purpose, Scope, and Content of Safety Cases, Nuclear Safety Technical Assessment Guide, NS-TAST-GD-051 Revision 4, July 2019, http://www.onr.org.uk/operational/tech_asst_guides/ns-tast-gd-051.pdf

Ref 9. Examination, Inspection, Maintenance and Testing of Items Important to Safety, Nuclear Safety Technical Assessment Guide, NS-TAST-GD-009 - Revision 3, , November 2015. http://www.onr.org.uk/operational/tech_asst_guides/ns-tast-gd-009.pdf

Ref 10. Step 4 Assessment of Structural Integrity for the UK ABWR, Generic Design Assessment – New Reactors Programme, ONR-NR-AR-17-037, TRIM Ref: 2017/98277

Ref 11. UK ABWR GDA - ONR-GDA-AR-15-001 - Step 3 Assessment Report - Civil Engineering & External Hazards, TRIM Ref: 2015/229244

Ref 12. Topic Report of the Emergency Diesel Generator Locations Optioneering Study, LE-GD-0192, Rev 0, Hitachi-GE Nuclear Energy Ltd., 16 December 2015. TRIM Ref: 2015/476626

Ref 13. Step 4 Assessment of Civil Engineering Aircraft Impact for the UK ABWR, Generic Design Assessment – New Reactors Division, ONR-NR-AR-17-035, TRIM Ref: 2017/252951

Ref 14. RO-ABWR-0068, Civil Engineering Step 3 GDA Observation on Seismic Analysis Methodology. TRIM Ref: 2016/382958

Ref 15. ABWR GDA Step 4 ARUP Civil Engineering Technical Assessment - Civil Technical Assessment Report, ARUP, TRIM Ref: 2017/444256

Ref 16. ABWR GDA Step 4 ARUP (ABS) Seismic Analysis Technical Assessment - Seismic Technical Assessment Report, ARUP (supported by ABS), TRIM Ref: 2017/444257

Ref 17. Step 4 Assessment of Internal Hazards for the UK ABWR, Generic Design Assessment – New Reactors Division, ONR-NR-AR-17-033. TRIM Ref: 2017/98141

Ref 18. Step 4 Assessment of Conventional Safety for the UK ABWR, Generic Design Assessment – New Reactors Programme, ONR-NR-AR-17-28, TRIM Ref: 2017/98337

Ref 19. Step 4 Assessment of PSA for the UK ABWR, Generic Design Assessment – New Reactors Division, ONR-NR-AR-17-014. TRIM Ref: 2017/98147

Ref 20. Step 4 Assessment of External Hazards for the UK ABWR, Generic Design Assessment – New Reactors Division, ONR-NR-AR-17-027. TRIM Ref: 2017/98329

Ref 21. Summary of Step 3 Civil Engineering Safety Assessment Comments, UK ABWR Generic Design Assessment, 20 May 2016. TRIM Ref: 2016/208053.

Ref 22. Civil Engineering Step 3 Closeout Queries – Civil Design, RQ-ABWR-0847, 15th April 2016. TRIM Ref: 2016/155388

Ref 23. Civil Engineering Step 3 Closeout Queries – Tunnel Design, RQ-ABWR-0848, 15th April 2016. TRIM Ref: 2016/155406

Ref 24. Civil Engineering Step 3 Closeout Queries – Seismic Analysis, RQ-ABWR-0915, 20th May 2016. TRIM Ref: 2016/207966

Ref 25. Civil Engineering Step 3 Closeout Queries – Aircraft Impact Assessment, RQ-ABWR-0849, 15th April 2016. TRIM Ref: 2016/155436

Ref 26. Generic PCSR Chapter 10: Civil Works and Structures, LE-GD-0035, Rev C, Hitachi-GE Nuclear Energy Ltd., 31 August 2017. TRIM Ref: 2017/335066

Ref 27. Overview of UK ABWR Civil Structures, LE-GD-0077, Rev 4, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM 2017/253834

Ref 28. Topic Report of CDM2015 Compliance (Response to RQ-ABWR-1184 and 1413), XE-GD-0706, Rev 1, Hitachi-GE Nuclear Energy Ltd., 31 May 2017. TRIM Ref: 2017/211434

Ref 29. Topic Report on Generic Site Envelope, XE-GD-0183, Rev F, Hitachi-GE Nuclear Energy Ltd., 12 Apr 2017. TRIM Ref: 2017/255241

Ref 30. Basis of Safety Case on Reactor Building Civil Design, LE-GD-0021, Rev 6, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/247481

Ref 31. Basis of Safety Case on Control Building Civil Design, LE-GD-0022, Rev 6, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/247488

Ref 32. Basis of Safety Case on Reinforced Concrete Containment Vessel (RCCV), DD-GD-0003, Rev 7, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/255122

Ref 33. Basis of Safety Case on Heat Exchanger Building Civil Design, LE-GD-0088, Rev 4, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/247501

Ref 34. Basis of Safety Case on Turbine Building Civil Design, LE-GD-0089, Rev 4, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/247495

Ref 35. Basis of Safety Case on Radwaste Building Civil Design, LE-GD-0090, Rev 4, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/247426

Ref 36. Basis of Safety Case on Backup Building Civil Design, LE-GD-0091, Rev 4, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/247479

Ref 37. Basis of Safety Case on Service Building Civil Design, LE-GD-0166, Rev 2, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/247439

Ref 38. Basis of Safety Case on Light Oil Storage Tank Basement and Connecting Service Tunnel Civil Design, LE-GD-0079, Rev 5, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/247384

Ref 39. Basis of Safety Case on Condensate Storage Tank Basement and Connecting Service Tunnel Civil Design, LE-GD-0078, Rev 5, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/247347

Ref 40. Basis of Safety Case on R/B-B/B Connecting Service Tunnel Civil Design, LE-GD-0080, Rev 5, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/247355

Ref 41. Basis of Safety Case on Emergency Diesel Generator Building Civil Design, LE-GD-0093, Rev 4, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/247480

Ref 42. Basis of Safety Case on R/B-EDG/B Connecting Service Tunnel Design, LE-GD-0081, Rev 5, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/247386

Ref 43. Basis of Safety Case on RCW Tunnel Civil Design, LE-GD-0044, Rev 5, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/247340

Ref 44. Basis of Safety Case on FLSS Water Storage Tank Basement and Connecting Service Tunnel Civil Design, LE-GD-0168, Rev 4, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/247366

Ref 45. Civil Engineering Supporting Report Reinforced Concrete Containment Vessel and Reactor Building Seismic Analysis Report, JE-GD-0025, Rev 10, Hitachi-GE Nuclear Energy Ltd., 3 Jul 2017. TRIM Ref: 2017/257215

Ref 46. Seismic Design Methodology Report, JE-GD-0160, Rev 0, Hitachi-GE Nuclear Energy Ltd., 11 Oct 2016. TRIM Ref: 2017/399156

Ref 47. Seismic Design Validation Report for R/B, JE-GD-0161, Rev 0, Hitachi-GE Nuclear Energy Ltd., 11 Oct 2016. TRIM Ref: 2017/399167

Ref 48. Civil Engineering Supporting Report Reinforced Concrete Containment Vessel and Reactor Building Structural Design Report, LE-GD-0024, Rev 7, Hitachi-GE Nuclear Energy Ltd., 30 June 2017. TRIM Ref: 2017/255299

Ref 49. Civil Engineering Supporting Report Reinforced Concrete Containment Vessel and Reactor Building Structural Design Report (SNI), LE-GD-0305, Rev 3, Hitachi-GE Nuclear Energy Ltd., 5 Jul 2017. TRIM Ref: 2017/267599

Ref 50. RCCV Liner Design Report, DD-GD-0020, Rev 1, Hitachi-GE Nuclear Energy Ltd., 30 Apr 2017. TRIM Ref: 2017/167704

Ref 51. MC Components of Reinforced Concrete Containment Vessel Structural Design Report, DD-GD-0004, Rev 5, Hitachi-GE Nuclear Energy Ltd., 30 Mar 2017. TRIM Ref: 2017/128398

Ref 52. Drywell Head Design Report, DD-GD-0022, Rev 2, Hitachi-GE Nuclear Energy Ltd., 30 Apr 2017. TRIM Ref: 2017/165651

Ref 53. Personnel Airlocks Design Report, DD-GD-0013, Rev 2, Hitachi-GE Nuclear Energy Ltd., 30 Apr 2017. TRIM Ref: 2017/173450

Ref 54. Equipment Hatch Design Report, DD-GD-0014, Rev 2, Hitachi-GE Nuclear Energy Ltd., 30 Apr 2017. TRIM Ref: 2017/173475

Ref 55. Containment Penetrations Design Report, DD-GD-0015, Rev 1, Hitachi-GE Nuclear Energy Ltd., 30 Apr 2017. TRIM Ref: 2017/291531

Ref 56. Internal Structures of Reinforced Concrete Containment Vessel Structural Design Report, DD-GD-0005, Rev 5, Hitachi-GE Nuclear Energy Ltd., 30 Mar 2017. TRIM Ref: 2017/131508

Ref 57. RPV Pedestal Design Report, DD-GD-0016, Rev 1, Hitachi-GE Nuclear Energy Ltd., 30 Apr 2017. TRIM Ref: 2017/173486

Ref 58. Diaphragm Floor Design Report, DD-GD-0017, Rev 1, Hitachi-GE Nuclear Energy Ltd., 30 Apr 2017. TRIM Ref: 2017/173454

Ref 59. Access Tunnel Design Report, DD-GD-0018, Rev 1, Hitachi-GE Nuclear Energy Ltd., 30 Apr 2017. TRIM Ref: 2017/168005

Ref 60. Reactor Shield Wall Design Report, DD-GD-0023, Rev 1, Hitachi-GE Nuclear Energy Ltd., 30 Apr 2017. TRIM Ref: 2017/167404

Ref 61. Civil Engineering Supporting Report Control Building Seismic Analysis Report, JE-GD-0026, Rev 6, Hitachi-GE Nuclear Energy Ltd., 15 May 2017. TRIM Ref: 2017/249091

Ref 62. Civil Engineering Supporting Report Control Building Structural Design Report, LE-GD-0026, Rev 5, Hitachi-GE Nuclear Energy Ltd., 15 May 2017. TRIM Ref: 2017/256224

Ref 63. Civil Engineering Supporting Report Control Building Structural Design Report (SNI), LE-GD-0306, Rev 2, Hitachi-GE Nuclear Energy Ltd., 29 Jun 2017. TRIM Ref: 2017/257768

Ref 64. Civil Engineering Supporting Report Heat Exchanger Building Seismic Analysis Report, JE-GD-0069, Rev 4, Hitachi-GE Nuclear Energy Ltd., 31 May 2017. TRIM Ref: 2017/211356

Ref 65. Civil Engineering Supporting Report Heat Exchanger Building Structural Design Report, LE-GD-0060, Rev 3, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/249128

Ref 66. Civil Engineering Supporting Report Heat Exchanger Building Structural Design Report (SNI), LE-GD-0307, Rev 1, Hitachi-GE Nuclear Energy Ltd., 28 Jun 2017. TRIM Ref: 2017/257772

Ref 67. Civil Engineering Supporting Report, Turbine Building Seismic Analysis Report, JE-GD-0057, Rev 4, Hitachi-GE Nuclear Energy Ltd., 31 May 2017. TRIM Ref: 2017/212726

Ref 68. Civil Engineering Supporting Report Turbine Building Structural Design Report, LE-GD-0061, Rev 3, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/253817

Ref 69. Civil Engineering Supporting Report Turbine Building Structural Design Report (SNI), LE-GD-0308, Rev 1, Hitachi-GE Nuclear Energy Ltd., 29 Jun 2017. TRIM Ref: 2017/257770

Ref 70. Civil Engineering Supporting Report Radwaste Building Seismic Analysis Report, JE-GD-0058, Rev 4, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/254694

Ref 71. Civil Engineering Supporting Report Radwaste Building Structural Design Report, LE-GD-0062, Rev 3, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/256834

Ref 72. Civil Engineering Supporting Report Radwaste Building Structural Design Report (SNI), LE-GD-0309, Rev 2, Hitachi-GE Nuclear Energy Ltd., 3 Jul 2017. TRIM Ref: 2017/267605

Ref 73. Civil Engineering Supporting Report Backup Building Seismic Analysis Report, JE-GD-0059, Rev 4, Hitachi-GE Nuclear Energy Ltd., 31 May 2017. TRIM Ref: 2017/211521

Ref 74. Civil Engineering Supporting Report Backup Building Structural Design Report, LE-GD-0063, Rev 3, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/253950

Ref 75. Civil Engineering Supporting Report Backup Building Structural Design Report (SNI), LE-GD-0310, Rev 1, Hitachi-GE Nuclear Energy Ltd., 28 Jun 2017. TRIM Ref: 2017/257783

Ref 76. Civil Engineering Supporting Report Service Building Seismic Analysis Report, JE-GD-0214, Rev 1, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/254711

Ref 77. Civil Engineering Supporting Report Service Building Structural Design Report, LE-GD-0167, Rev 1, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/255142

Ref 78. Civil Engineering Supporting Report Service Building Structural Design Report (SNI), LE-GD-0311, Rev 1, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/257782

Ref 79. Civil Engineering Supporting Report Stack Structural Seismic Report, JE-GD-0060, Rev 4, Hitachi-GE Nuclear Energy Ltd., 7 Mar 2016. TRIM Ref: 2017/95740

Ref 80. Civil Engineering Supporting Report Stack Structural Design Report, LE-GD-0064, Rev 3, Hitachi-GE Nuclear Energy Ltd., 30 Apr 2017. TRIM Ref: 2017/253958

Ref 81. Civil Engineering Supporting Report Filter Vent Building Seismic Analysis Report, JE-GD-0080, Rev 4, Hitachi-GE Nuclear Energy Ltd., 30 Apr 2017. TRIM Ref: 2017/249118

Ref 82. Civil Engineering Supporting Report Filter Vent Building Structural Design Report, LE-GD-0084, Rev 3, Hitachi-GE Nuclear Energy Ltd., 15 May 2016. TRIM Ref: 2017/256205

Ref 83. Civil Engineering Supporting Report Filter Vent Building Structural Design Report (SNI), LE-GD-0313, Rev 2, Hitachi-GE Nuclear Energy Ltd., 28 Jun 2017. TRIM Ref: 2017/257760

Ref 84. Civil Engineering Supporting Report Emergency Diesel Generator Building Seismic Analysis Report, JE-GD-0075, Rev 4, Hitachi-GE Nuclear Energy Ltd., 31 May 2017. TRIM Ref: 2017/211347

Ref 85. Civil Engineering Supporting Report Emergency Diesel Generator Building Structural Design Report, LE-GD-0059, Rev 3, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/249108

Ref 86. Civil Engineering Supporting Report Emergency Diesel Generator Building Structural Design Report (SNI), LE-GD-0314, Rev 1, Hitachi-GE Nuclear Energy Ltd., 28 Jun 2017. TRIM Ref: 2017/257765

Ref 87. Light Oil Storage Tank Basement and Connecting Service Tunnel Seismic Analysis, JE-GD-0061, Rev 4, Hitachi-GE Nuclear Energy Ltd., 23 May 2017. TRIM Ref: 2017/200733

Ref 88. Light Oil Storage Tank Basement and Connecting Service Tunnel Structural Design Report, LE-GD-0065, Rev 4, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/256820

Ref 89. Condensate Storage Tank Basement and Connecting Service Tunnel Seismic Analysis Report, JE-GD-0062, Rev 4, Hitachi-GE Nuclear Energy Ltd., 16 Jun 2017. TRIM Ref: 2017/253979

Ref 90. Condensate Storage Tank Basement and Connecting Service Tunnel Structural Design Report, LE-GD-0066, Rev 3, Hitachi-GE Nuclear Energy Ltd., 16 Jun 2017. TRIM Ref: 2017/253824

Ref 91. Civil Engineering Supporting Report RCW Tunnel Seismic Analysis Report, JE-GD-0043, Rev 4, Hitachi-GE Nuclear Energy Ltd., 31 Mar 2017. TRIM Ref: 2017/137226

Ref 92. Civil Engineering Supporting Report RCW Tunnel Structural Design Report, LE-GD-0045, Rev 3, Hitachi-GE Nuclear Energy Ltd., 31 Mar 2017. TRIM Ref: 2017/256804

Ref 93. Civil Engineering Supporting Report RCW Tunnel Structural Design Report (SNI), LE-GD-0317, Rev 2, Hitachi-GE Nuclear Energy Ltd., 29 Jun 2016. TRIM Ref: 2017/257788

Ref 94. Civil Engineering Supporting Report R/B-B/B Connecting Service Tunnel Seismic Analysis Report, JE-GD-0063, Rev 4, Hitachi-GE Nuclear Energy Ltd., 20 Apr 2017. TRIM Ref: 2017/158706

Ref 95. Civil Engineering Supporting Report R/B-B/B Connecting Service Tunnel Structural Design Report, LE-GD-0067, Rev 3, Hitachi-GE Nuclear Energy Ltd., 14 Apr 2017. TRIM Ref: 2017/253873

Ref 96. Civil Engineering Supporting Report R/B-B/B Connecting Service Tunnel Structural Design Report (SNI), LE-GD-0318, Rev 1, Hitachi-GE Nuclear Energy Ltd., 14 Apr 2017. TRIM Ref: 2017/257800

Ref 97. Civil Engineering Supporting Report R/B - EDG/B Connecting Service Tunnel Seismic Analysis Report, JE-GD-0074, Rev 4, Hitachi-GE Nuclear Energy Ltd., 20 Apr 2017. TRIM Ref: 2017/158709

Ref 98. Civil Engineering Supporting Report R/B-EDG/B Connecting Service Tunnel Structural Design Report, LE-GD-0068, Rev 3, Hitachi-GE Nuclear Energy Ltd., 14 Apr 2017. TRIM Ref: 2017/253967

Ref 99. Civil Engineering Supporting Report R/B-EDG/B Connecting Service Tunnel Structural Design Report (SNI), LE-GD-0319, Rev 2, Hitachi-GE Nuclear Energy Ltd., 29 Jun 2017. TRIM Ref: 2017/257806

Ref 100. Civil Engineering Supporting Report FLSS Water Storage Tank Basement and Connecting Service Tunnel Seismic Analysis Report, JE-GD-0126, Rev 1, Hitachi-GE Nuclear Energy Ltd., 16 Jun 2017. TRIM Ref: 2017/235443

Ref 101. Civil Engineering Supporting Report FLSS Water Storage Tank Basement and Connecting Service Tunnel Structural Design Report, LE-GD-0169, Rev 1, Hitachi-GE Nuclear Energy Ltd., 16 Jun 2017. TRIM Ref: 2017/253853

Ref 102. Civil Engineering Supporting Report Reactor Building Hydrodynamic Vibration Analysis Report, JE-GD-0117, Rev 4, Hitachi-GE Nuclear Energy Ltd., 22 Jun 2017. TRIM Ref: 2017/239635

Ref 103. Civil Engineering Assumptions for Site Conditions, LE-GD-0344, Rev 0, Hitachi-GE Nuclear Energy Ltd., 28 Feb 2017. TRIM Ref: 2017/83783

Ref 104. Accidental AIA Strategy Document, AE-GD-0176, Rev 2, Hitachi-GE Nuclear Energy Ltd., 12 Jul 2016. TRIM Ref: 2016/280243

Ref 105. Malicious AIA Strategy Document, AE-GD-0177, Rev 2, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2016. TRIM Ref: 2016/280253

Ref 106. Physical Damage Protection Policy, LE-GD-0071, Rev 4, Hitachi-GE Nuclear Energy Ltd., 30 April 2017. TRIM Ref: 2017/186426

Ref 107. Civil Engineering Supporting Report Reactor Building Aircraft Impact Assessment Physical Damage Evaluation Report, LE-GD-0025, Rev 4, Hitachi-GE Nuclear Energy Ltd., 15 May 2017. TRIM Ref: 2017/195094

Ref 108. Civil Engineering Supporting Report Reactor Building Aircraft Impact Assessment Shock Damage Evaluation Report, JE-GD-0081, Rev 3, Hitachi-GE Nuclear Energy Ltd., 30 Apr 2017. TRIM Ref: 2017/186412

Ref 109. Fire damage methodology document for AIA, BKE-GD-0026, Rev 0, Hitachi-GE Nuclear Energy Ltd., 27 May 2015. TRIM Ref: 2015/197615

Ref 110. Preliminary Aircraft Impact Assessment Document, AE-GD-0252, Rev 0, Hitachi-GE Nuclear Energy Ltd., 29 May 2015. TRIM Ref: 2015/205980

Ref 111. Aircraft Impact Assessment Document, AE-GD-0665, Rev 2, Hitachi-GE Nuclear Energy Ltd., 30 April 2017. TRIM Ref: 2017/186434

Ref 112. Civil Engineering Supporting Report Examination, Maintenance, Inspection and Testing for Civil Engineering, LE-GD-0325, Rev 1, Hitachi-GE Nuclear Energy Ltd., 31 May 2017. TRIM Ref: 2017/211266

Ref 113. Validation Test Report for SSDP-2D, LE-GD-0096, Rev 1, Hitachi-GE Nuclear Energy Ltd., 27 Jun 2017. TRIM Ref: 2017/321366

Ref 114. Validation Test Report for SSDP-ST, LE-GD-0111, Rev 1, Hitachi-GE Nuclear Energy Ltd., 27 Jun 2017. TRIM Ref: 2017/247502

Ref 115. SSI Analysis Model Approach, Deliverables Plan and Schedule Plan in GDA, JE-GD-0155, Rev 1, Hitachi-GE Nuclear Energy Ltd., 1 Sept 2016. TRIM Ref: 2016/339700

Ref 116. Explanation of differences of drawings for R/B, FV/B, and S/B for Civil Engineering Design, LE-GD-0397, Rev 0, Hitachi-GE Nuclear Energy Ltd., 30 Jun 2017. TRIM Ref: 2017/256983

Ref 117. List of Safety Category and Class for UK ABWR, AE-GD-0224, Rev 3, Hitachi-GE Nuclear Energy Ltd., 11 Apr 2016. TRIM Ref: 2017/336173

Ref 118. Codes and Standards Full Comparison matrix Report, LE-GD-0126, Rev 0, Hitachi-GE Nuclear Energy Ltd., 28 May 2015. TRIM Ref: 2017/200236

Ref 119. Verification and Validation Plan for Design and Analysis Software used in Civil Engineering, LE-GD-0072, Rev 0, Hitachi-GE Nuclear Energy Ltd., 9 December 2014. TRIM Ref: 2014/464378

Ref 120. Verification and Validation of NASTRAN for FE analysis of RCCV components, DD-GD-0011, Rev 1, Hitachi-GE Nuclear Energy Ltd., 27 May 2015. TRIM Ref: 2015/197558

Ref 121. ONR/TSC Comment Response (Underground & Foundation) RQ-ABWR-1419 UK ABWR Step 4 Geotechnical Assessment, LE-GD-0371, Rev 0, Hitachi-GE Nuclear Energy Ltd., 20 Apr 2017. TRIM Ref: 2017/308980

Ref 122. ONR/TSC Comment Response (Underground & Foundation) RQ-ABWR-1406 UK ABWR Step 4 Civil Design Assessment, LE-GD-0370, Rev 0, Hitachi-GE Nuclear Energy Ltd., 20 April 2017. TRIM Ref: 2017/308967

Ref 123. Seismic Evaluation Methodology of Cliff-edge Effect on Civil Structures, JE-GD-0114, Rev 2, Hitachi-GE Nuclear Energy Ltd., 12 May 2017. TRIM Ref: 2017/187673

Ref 124. UK ABWR Ultimate Capacity Evaluation for RCCV Concrete Structure, DE-GD-0123, Rev 0, Hitachi-GE Nuclear Energy Ltd., 12 May 2017. TRIM Ref: 2017/187646

Ref 125. RCCV Concrete Structure Ultimate Pressure Capacity Evaluation Report, DE-GD-0119, Rev 0, Hitachi-GE Nuclear Energy Ltd., 30 June 2017. TRIM Ref: 2017/255126

Ref 126. Verification and Validation Report for Ultimate Capacity Evaluation of RCCV Concrete Structure, DE-GD-0125, Rev 0, Hitachi-GE Nuclear Energy Ltd., 30 June 2017 TRIM Ref: 2017/198713

Ref 127. UK ABWR Ultimate Capacity Evaluation for RCCV Concrete Structure Update #2, DE-GD-0128, Revision 0, Hitachi-GE Nuclear Energy Ltd., 31 July 2017. TRIM Ref: 2017/295907

Ref 128. Internal Hazards Barrier Substantiation Report, BKE-GD-0019, Rev 5, Hitachi-GE Nuclear Energy Ltd., 02 August 2017. TRIM Ref: 2017/298164

Ref 129. Topic Report on Dropped and Collapsed Loads, LE-GD-0082, Rev 4, Hitachi-GE Nuclear Energy Ltd., 01 August 2017. TRIM Ref: 2017/295829

Ref 130. Civil Structure Evaluation Report for Barrier Substantiation, LE-GD-0322, Rev 1, Hitachi-GE Nuclear Energy Ltd., 01 August 2017. TRIM Ref: 2017/295865

Ref 131. Topic Report on Combined Internal Hazards, SE-GD-0217, Rev 4, Hitachi-GE Nuclear Energy Ltd., 03 August 2017, TRIM 2017/299956

Ref 132. ABWR GDA Step 4 ARUP Civil Engineering Technical Assessment - Step 3 Comment Register, ARUP, TRIM Ref: 2017/374458

Ref 133. ABWR GDA Step 4 ARUP Civil Engineering Technical Assessment - Step 4 Comment Register, ARUP, TRIM Ref: 2017/374459

Ref 134. ABWR GDA Step 4 ARUP (ABS) Seismic Analysis Technical Assessment - Step 3 Comment Register Civil Engineering, ARUP (supported by ABS), TRIM Ref: 2017/374771

Ref 135. ABWR GDA Step 4 ARUP (ABS) Seismic Analysis Technical Assessment - Step 4 Comment Register Civil Engineering, ARUP (supported by ABS), TRIM Ref: 2017/374773

Ref 136. Reactor Building construction method statement, RQ-ABWR-0898, 16th May 2016.TRIM Ref: 2016/312921

Ref 137. Civil Engineering Queries on Impacts of Construction Techniques on Decommissioning, RQ-ABWR-1125, 13 October 2016. TRIM Ref: 2016/442468

Ref 138. UK ABWR Review of Cliff Edge Effects on Civil Structures, RQ-ABWR-1387, 23 March 2017. TRIM Ref: 2017/167705

Ref 139. UK ABWR Civil Engineering Supporting Report Examination, Maintenance, Inspection and Testing for Civil Engineering, RQ-ABWR-1402, 30th March 2017. TRIM Ref: 2017/196726

Ref 140. UK ABWR Step 4 Seismic Assessment, RQ-ABWR-1405, 4th April 2017. TRIM Ref: 2017/173961

Ref 141. UK ABWR Step 4 Civil Design Assessment, RQ-ABWR-1406, 4th April 2017. TRIM Ref: 2017/182360

Ref 142. UK ABWR Ultimate Capacity Evaluation for RCCV Concrete Structure, RQ-ABWR-1411, 6th April 2017. TRIM Ref: 2017/141367

Ref 143. UK ABWR Step 4 Geotechnical Assessment, RQ-ABWR-1419, 12th April 2017. TRIM Ref: 2017/180796

Ref 144. UK ABWR Ultimate Capacity Evaluation for RCCV Concrete Structure Update #2, RQ-ABWR-1488, 16th June 2017. TRIM Ref: 2017/295905

Ref 145. PSA Supporting Information Regarding SFP Structural Analysis, AE-GD-0709, Revision 0, Hitachi-GE Nuclear Energy Ltd., TRIM Ref. 2016/202260

Ref 146. SSI Analysis Model Approach, Deliverables Plan and Schedule Plan in GDA, JE-GD-0155 Rev 1, 01 September 2016. TRIM Ref: 2016/339700

Ref 147. Generic PCSR Chapter 5: General Design Aspects, XE-GD-0645, DR11, Hitachi-GE Nuclear Energy Ltd., 24 March 2017. TRIM Ref: 2017/132629

Ref 148. Response to UK ABWR Review of Cliff Edge Effects on Civil Structures (Response to RQ-ABWR-1387), JE-GD-0231, Rev 2 , Hitachi-GE Nuclear Energy Ltd., 20 June 2017. TRIM Ref: 2017/237678

Ref 149. Generic PCSR Chapter 7: Internal Hazards, SE-GD-0127, Rev C, Hitachi-GE Nuclear Energy Ltd., 30 August 2017. TRIM Ref: 2017/335032

Ref 150. Safety Design Report for the Spent Fuel Storage Pool, the Steam Dryer/Separator Pit and the Reactor Well as a Large Volume of Water, FSE-GD-0011, Rev.0, Hitachi-GE Nuclear Energy Ltd. TRIM Ref: 2016/471704

Ref 151. Safety Design Report for the Suppression Pool within the Reinforced Concrete Containment Vessel as a Large Volume of Water, DE-GD-0088, Rev.0, Hitachi-GE Nuclear Energy Ltd. TRIM Ref: 2016/469398

Ref 152. Topic Report of CDM2015 Compliance (Response to RQ-ABWR-1184 and 1413), XE-GD-0706, Rev 1, Hitachi-GE Nuclear Energy Ltd., 31 May 2017. TRIM Ref: 2017/211434

Ref 153. UK ABWR GDA Containment Performance Analysis Report in UK ABWR, AE-GD-0561, Rev 3, Hitachi-GE Nuclear Energy Ltd., 30 June 2017.TRIM Ref: 2017/256271

Ref 154. GDA, Step 4: Civil Engineering Assessment to Support the PSA Level 2 Containment Analysis. TRIM Ref: 2017/228708

Ref 155. Step 4 Assessment of PSA for the UK ABWR, Generic Design Assessment – New Reactors Division, ONR-NR-AR-17-014. TRIM Ref: 2017/98147

Ref 156. Step 4 Assessment of Fault Studies for the UK ABWR, Generic Design Assessment – New Reactors Division, ONR-NR-AR-17-016. TRIM Ref: 2017/98169

Ref 157. Step 4 Assessment of Severe Accident Analysis for the UK ABWR, Generic Design Assessment – New Reactors Programme, ONR-NR-AR-17-015. TRIM Ref: 2017/98159

Ref 158. Step 4 Assessment of Decommissioning for the UK ABWR, Generic Design Assessment – New Reactor Division, ONR-NR-AR-17-034. TRIM Ref: 2017/234730

Ref 159. Influence of Construction Technique on decommissioning (Response to RQ-ABWR-1125), DCE-GD-0093, Rev 0, Hitachi-GE Nuclear Energy Ltd., 14 November 2016. TRIM Ref: 2016/442475

Ref 160. Topic Report on Decommissioning: Impact of Construction Techniques on Decommissioning, DCE-GD-0068, Rev 1, Hitachi-GE Nuclear Energy Ltd., 30 March 2017. TRIM Ref: 2017/131478

Ref 161. Guidance to Requesting Parties, ONR-GDA-GD-001 Revision 3, Office for Nuclear Regulation, September 2016. http://www.onr.org.uk/new-reactors/ngn03.pdf

Ref 162. Response to UK ABWR review of cliff edge effects on civil structures (response to RQ-ABWR-1387) JE-GD-0231, Rev 2, Hitachi-GE Nuclear Energy Ltd., 19 June 2017. TRIM Ref: 2017/237678

Annex 1

Safety Assessment Principles

SAP No	SAP Title	Description
SC.1	The regulatory assessment of safety cases. Safety case production process.	The process for producing safety cases should be designed and operated commensurate with the hazard, using concepts applied to high reliability engineered systems.
SC.4	The regulatory assessment of safety cases. Safety case characteristics.	A safety case should be accurate, objective and demonstrably complete for its intended purpose.
ELO.4	Engineering principles: layout. Minimisation of the effects of incidents	The design and layout of the site, its facilities (including enclosed plant), support facilities and services should be such that the effects of faults and accidents are minimised.
EMT.1	Engineering principles: maintenance, inspection and testing. Identification of requirements	Safety requirements for in-service testing, inspection and other maintenance procedures and frequencies should be identified in the safety case.
ECS.1	Engineering principles: safety classification and standards. Safety categorisation.	The safety functions to be delivered within the facility, both during normal operation and in the event of a fault or accident, should be identified and then categorised based on their significance with regard to safety.
ECS.2	Engineering principles: safety classification and standards. Safety classification of structures, systems and components.	Structures, systems and components that have to deliver safety functions should be identified and classified on the basis of those functions and their significance to safety.
ECS.3	Engineering principles: safety classification and standards. Codes and standards.	Structures, systems and components that are important to safety should be designed, manufactured, constructed, installed, commissioned, quality assured, maintained, tested and inspected to the appropriate codes and standards.
ECE.1	Engineering principles: civil engineering. Functional performance.	The required safety functions and structural performance of the civil engineering structures under normal operating, fault and accident conditions should be specified.
ECE.2	Engineering principles: civil engineering. Independent arguments.	For structures requiring the highest levels of reliability, multiple independent and diverse arguments should be provided in the safety case.
ECE.4	Engineering principles: civil engineering: investigations. Natural site materials.	Investigations should be carried out to determine the suitability of the natural site materials to support the foundation loadings specified for normal operation and fault conditions.

ECE.5	Engineering principles: civil engineering: investigations. Geotechnical investigation.	The design of foundations and sub-surface structures should utilise information derived from geotechnical site investigation.
ECE.6	Engineering principles: civil engineering: design. Loadings.	Load development and a schedule of load combinations, together with their frequencies, should be used as the basis for structural design. Loadings during normal operating, testing, design basis fault and accident conditions should be included.
ECE.7	Engineering principles: civil engineering: design. Foundations.	The foundations and sub-surface structures should be designed to meet their safety functional requirements specified for normal operation and fault conditions with an absence of cliff edge effects beyond the design basis.
ECE.8	Engineering principles: civil engineering: design. Inspectability.	Designs should allow key load-bearing elements to be inspected and, where necessary, maintained.
ECE.10	Engineering principles: civil engineering: design. Groundwater.	The design should be such that the facility remains stable against possible changes in the groundwater conditions.
ECE.12	Engineering principles: civil engineering: structural analysis and model testing. Structural analysis and model testing.	Structural analysis and/or model testing should be carried out to support the design and should demonstrate that the structure can fulfil its safety functional requirements over the full range of loading for the lifetime of the facility.
ECE.13	Engineering principles: civil engineering: structural analysis and model testing. Use of data.	The data used in structural analysis should be selected or applied so that the analysis is demonstrably conservative.
ECE.14	Engineering principles: civil engineering: structural analysis and model testing. Sensitivity studies.	Studies should be carried out to determine the sensitivity of analytical results to the assumptions made, the data used, and the methods of calculation.
ECE.15	Engineering principles: civil engineering: structural analysis and model testing. Validation of methods.	Where analyses have been carried out on civil structures to derive static and dynamic structural loadings for the design, the methods used should be adequately validated and the data verified.
ECE.16	Engineering principles: civil engineering: construction. Materials.	The construction materials used should comply with the design methodologies employed, and be shown to be suitable for enabling the design to be constructed and then operated, inspected and maintained throughout the life of the facility.
ECE.17	Engineering principles: civil engineering: construction. Prevention of defects.	The construction should use appropriate materials, proven techniques and a quality management system to minimise defects that might affect the required integrity of structures.
ECE.18	Engineering principles: civil engineering: construction. Inspection during construction.	Provision should be made for inspection and testing during construction to demonstrate that appropriate standards of workmanship etc have been achieved.
ECE.20	Engineering principles: civil engineering: in-service inspection and testing. Inspection, testing and monitoring.	Provision should be made for inspection, testing and monitoring during normal operations aimed at demonstrating that the structure continues to meet its safety functional requirements. Due account should be taken of the periodicity of the activities.

ECE.21	Engineering principles: civil engineering: in-service inspection and testing. Proof pressure tests.	Pre-stressed concrete pressure vessels and containment structures should be subjected to a proof pressure test, which may be repeated during the life of the facility.
ECE.25	Engineering principles: civil engineering: design. Provision for construction.	Items important to safety should be designed so that they can be manufactured, constructed, assembled, installed and erected in accordance with established processes that ensure the achievement of the design specifications and the required level of safety. The effects of construction hazards on any nearby safety related SSCs should be taken into account.
ECE.26	Engineering principles: civil engineering: design. Provision for decommissioning.	Special consideration should be given at the design stage to the incorporation of features to facilitate radioactive waste management and the future decommissioning and dismantling of the facility.
EHA.7	Engineering principles: external and internal hazards. 'Cliff-edge' effects.	A small change in design basis fault or event assumptions should not lead to a disproportionate increase in radiological consequences.
EHA.18	Engineering principles: external and internal hazards. Beyond design basis events.	Fault sequences initiated by internal and external hazards beyond the design basis should be analysed applying an appropriate combination of engineering, deterministic and probabilistic assessments.
ECV.1	Engineering principles: containment and ventilation: containment design. Prevention of leakage.	Radioactive material should be contained and the generation of radioactive waste through the spread of contamination by leakage should be prevented.
ECV.2	Engineering principles: containment and ventilation: containment design. Minimisation of releases.	Containment and associated systems should be designed to minimise radioactive releases to the environment in normal operation, fault and accident conditions.
ECV.4	Engineering principles: containment and ventilation: containment design. Provision of further containment barriers.	Where the radiological challenge dictates, waste storage vessels, process vessels, piping, ducting and drains (including those that may serve as routes for escape or leakage from containment) and other plant items that act as containment for radioactive material, should be provided with further containment barrier(s) that have sufficient capacity to deal safely with the leakage resulting from any design basis fault.
ECV.7	Engineering principles: containment and ventilation: containment monitoring. Leakage monitoring.	Appropriate sampling and monitoring systems should be provided outside the containment to detect, locate, quantify and monitor for leakages or escapes of radioactive material from the containment boundaries.
EDR.1	Engineering principles: design for reliability. Failure to safety.	Due account should be taken of the need for structures, systems and components to be designed to be inherently safe, or to fail in a safe manner, and potential failure modes should be identified, using a formal analysis where appropriate.
ERL.1	Engineering principles: reliability claims. Form of claims.	The reliability claimed for any structure, system or component should take into account its novelty, experience relevant to its proposed environment, and uncertainties in operating and fault conditions, physical data and design methods.

ERL.2	Engineering principles: reliability claims. Measures to achieve reliability	The measures whereby the claimed reliability of systems and components will be achieved in practice should be stated.

Annex 2

Technical Assessment Guides

TAG Ref	TAG Title
NS-TAST-GD-017 Revision 3	Civil Engineering
NS-TAST-GD-020 Revision 3	Civil Engineering Containment for Reactor Plants
NS-TAST-GD-005 Revision 8	Guidance on the demonstration of ALARP (As Low As Reasonably Practicable)
NS-TAST-GD-051 Revision 4	The purpose, scope and content of safety cases
NS-TAST-GD-009 Revision 3	Examination, Inspection, Maintenance and Testing of Items Important to Safety, Nuclear Safety Technical Assessment Guide

Annex 3

National and International Standards and Guidance

National and International Standards and Guidance
British Standard Institute, BS 6229:2003, Flat roofs with continuously supported coverings – Code of practice, 2003
The Concrete Society, Friction between materials, Concrete Advice No. 54, Oct 2015.
ASCE 4-98, Standard for Seismic Analysis of Safety-Related Nuclear Structures and Commentary.
ASCI 4-15 (Draft), Standard for Seismic Analysis of Safety-Related Nuclear Structures and Commentary.
ASCE 7-05, Standard for Minimum Design Loads for Buildings and Other Structures. 2005.
ASCE 7-10, Standard for Minimum Design Loads for Buildings and Other Structures. 2010.
ASCE 7-16, Standard for Minimum Design Loads for Buildings and Other Structures. 2016.
British Standard Institute, BS 8102:2009, Code of practice for protection of below ground structures against water from the ground. 2009.
British Standard Institute, BS 8500-1:2015, Concrete – complementary
American Institute of Steel Construction, AISC N690-12, Specification for safety-related steel structures for nuclear facilities. 2012.
American Institute of Steel Construction, AISC 360-10, Specification for structural steel buildings. 2010.
American Institute of Steel Construction, AISC 360-16, Specification for structural steel buildings. 2016.
American Concrete Institute, ACI 349-13, Code Requirements for Nuclear Safety-Related Concrete Structures. 2013.
American Concrete Institute, ACI 349.1R-07, Reinforced Concrete Design for Thermal Effects on Nuclear Power Plant Structures. 2007.
American Concrete Institute, ACI 318-14, Building Code Requirements for Structural Concrete. 2014.
British Standard Institute, BS 9999:2008, Fire safety in the design, management and use of buildings. 2008.

British Standard Institute, BS 9999:2008, Fire safety in the design, management and use of buildings. 2017.

British Standard Institute, BS EN 206-1:2013, Concrete. Specification, performance, production and conformity. 2013.

British Standard Institute, BS EN 10080:2005, Steel for the reinforcement of concrete. 2015.

British Standard Institute, BS 4449:2005, Steel for the reinforcement of concrete. 2005

British Standard Institute, BS EN 10025-1:2004, Hot rolled products of structural steel. 2004

CIRIA, CIRIA C660, Early-age thermal crack control in concrete. 2007.

British Standard Institute, BS EN 1993-1-1:2005, Eurocode 3: Design of steel structures – Part 1-1: General rules and rules for buildings. 2005.

British Standard Institute, BS EN 1992-1-1:2004, Eurocode 2: Design of Concrete structures – Part 1-1: General rules and rules for buildings. 2004.

G. Gurfinkel, Thermal effects in walls of nuclear containment elastic and inelastic behaviour, SMIRT, J3/7, 1971.

American Society of Civil Engineers 43-05: Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities

EUR Volume 2:General Nuclear Island Requirements, Chapter4 Design Basis, Revision D

BE Generation, R3 assessment procedure , 2008

IAEA Fundamental Safety Principles Series No. SF-1, 2006. ISBN:92-0-110706-4

IAEA Specific Safety Requirements Series No. SSR-2/1 Safety of Nuclear Power Plants: Design, 2012. ISBN:978-92-0-121510-9

IAEA Safety Guide Safety Standards Series No. NS-G-1.5- External Events Excluding Earthquakes in the Design of Nuclear Power Plants

IAEA Safety Guide Safety Standards Series No. NS-G-1.6 - Seismic Design and Qualification for Nuclear Power Plants Safety Guide

Safety of Nuclear Power Plants: Design. Safety Requirements. International Atomic Energy Agency (IAEA). Safety Standards Series No. NS-R-1. IAEA. Vienna. 2000. www.iaea.org.

American Society of Mechanical Engineers - International Boiler and Pressure Vessel Code. Section II and Section III. Rules for Construction of

Nuclear Facility Components

WENRA references:

Statement on Safety Objectives for New Nuclear Power Plants (March 2013) and Safety of New NPP Designs (March 2013)

Annex 4

Assessment Findings

Assessment Finding Number	Assessment Finding	Report Section Reference	Related Civil engineering comments
AF-ABWR-CE-01	The Requesting Party has mixed metric and imperial civil engineering design codes, therefore the licensee shall apply a consistent approach to the application of design standards and justify the impact that updated code versions have on the civil engineering design. Future licensee to refer to section 4.3.3 of Civil Engineering GDA Step 4 report for further information.	Design Codes and Standards - 4.3.3	01-RB04 01-RB07 01-LOT13
AF-ABWR-CE-02	As the civil engineering design is at different stages of maturity and a number of misalignments between buildings and tunnels have been identified, the licensee shall consider the interfaces at buildings and tunnels and provide a design that facilitates constructible interface details. The Licensee to refer to section 4.3.5 of Civil Engineering GDA Step 4 report for further information.	Site Layout - 4.3.4	01-RW13 01-CST01 01-RB38 01-RCW04 01-RB35 01-RCW05 01-RCW03 01-CB14 (3)
AF-ABWR-CE-03	Due to the assumptions made during GDA on geotechnical properties, the licensee shall re-visit the geotechnical design of the civil engineering structures using site specific geotechnical parameters, groundwater levels and suitable fill properties to demonstrate these assumptions are applicable and in line with UK relevant good practice. Future Licensee to refer to section 4.3.6 of the Civil Engineering GDA Step 4 report for further information.	Ground conditions and site envelope - 4.3.6	A4 (Step 3) 02-020 A8 (Step 3) 02-025 A9 (Step 3) 02-028 A10 (Step 3), 01-RCW02 A11 (Step 3) 02-009, 02-016 02-021 02-019 02-013 02-010 02-026, 02-002 02-027 02-003 B4 (all E.11 buildings) 02-004
AF-ABWR-CE-04	In the absence of detailed design loading information during GDA, Hitachi-GE has made a number of assumptions and simplifications in order to design the civil engineering structures. The licensee shall undertake an evaluation of future loadings and combinations for use in site specific design. Future licensee to refer to section 4.3.8 of Civil Engineering GDA Step 4 report for further information.	Loads & Load Combinations - 4.3.8	01-G04 01-RB18 01-RB16 01-HX02 01-ST01, 01- 01-RB22 RB10 01-RW01 01-CB01 01-CB04 01-LOT16 02-011 01-RB11 02-023 01-LOT06 02-012 01-RW04 02-024

			01-HX01
AF-ABWR-CE-05	To provide confidence on the hydrodynamic load analysis performed for the Reactor Building and Heat Exchanging Building design, the licensee shall provide a justification of the damping ratios used in the calculation of hydrodynamic loads.	Loads & Load Combinations - 4.3.8	01-HV02
AF-ABWR-CE-06	The use of European civil engineering materials against the performance requirements of the plant has not been justified during GDA. The licensee shall justify the use of European materials in line with performance requirements and the use of European material properties beyond American code limits. The effects of bimetallic corrosion in civil engineering structures/components shall also be checked for the longevity of the plant. Future licensee to refer to section 4.3.9 of Civil Engineering GDA Step 4 report for further information.	Materials - 4.3.9	01-RB31 01-CB06 part 3 01-RB13
AF-ABWR-CE-07	In the analysis of a number of civil engineering structures, there are cases of modelling simplifications that need further justification. The licensee shall justify key modelling simplifications in nuclear safety significant civil engineering structures, with particular attention to finite element mesh quality and the omissions of secondary structures from the model. Future licensee to refer to Section 4.3.10 of Civil Engineering GDA Step 4 report for further information.	Analysis - 4.3.10	01-CB13 01-EDG02 01-CB20 01-TB04 01-RW14 01-RB27 01-RB23 01-RB39 01-CB18
AF-ABWR-CE-08	In the civil engineering design, a limited number of structural checks have been carried out on structural members. To address this limitation, the licensee shall ensure that a robust process for the detailed design of members and connections of reinforced concrete elements is in place. The licensee to refer to section 4.3.11 of Civil Engineering GDA Step 4 report for further information.	Member and connections design - 4.3.11	01-CB08 01-RW12 (4) 01-CB09 01-CST09 01-RB37 01-FLSS02 01-TB02 01-CB14 (1) 01-RW07 01-CB15 01-RW09 01-CB16 01-RW10 01-CB19 01-RW11
AF-ABWR-CE-09	As the information on the civil engineering Metallic Containment Components was limited, the licensee shall justify the design and construction details, including connections, of the Reactor Pressure Vessel pedestal, access tunnel, diaphragm floor, reactor shield wall and Reactor Pressure Vessel stabiliser. Future licensee to refer to section 4.3.11 of Civil Engineering GDA Step 4 report for further information.	Member and connections design - 4.3.11	01-MC03 01-MC06 01-MC07 01-MC11 01-MC08 01-MC14 01-MC09 01-MC16 01-MC13 01-MC19 01-MC15 01-MC21 01-MC18 01-MC24 01-MC23 01-MC02 01-MC25 01-MC12 01-MC26 01-MC10
AF-ABWR-CE-010	Due to the simplified range of loadings and structural checks carried out	Member and	01-ST04 04-007

	during Generic Design Assessment, the licensee shall undertake a detailed design of the Reactor Building stack. This shall include impact, fatigue and thermal loads, accidental torsion loads and connection design. Future licensee to refer to section 4.3.11 of Civil Engineering GDA Step 4 report for further information.	connections design - 4.3.11	01-ST06 01-ST02 01-ST03 04-006	04-008 04-010 04-011
AF-ABWR-CE-011	To address limitations on the level of detail and justification provided in the GDA seismic models of the civil engineering structures, the licensee shall validate the seismic analysis modelling with site specific soil properties, accurate representation of plant items, further crane loading combinations and include the lower dry well access tunnel in the seismic model. Future licensee to refer to section 4.3.12.2 of Civil Engineering GDA Step 4 report for further information.	Seismic assessment - 4.3.12	E.1 E.4 E.19 E.21 04-003 04-023 04-32 04-38 04-042 04-043	04-056 04-058 04-051 04-055 04-012 04-022 04-045 04-065 04-066
AF-ABWR-CE-012	Due to simplifications and assumptions on the seismic analysis of the civil engineering structures, the licensee shall justify that the effects of embedment, fill material and SSSI on the design of nuclear safety significant buildings and tunnels is fully accounted for. Future licensee to refer to section 4.3.12.3 and 4.3.12.4 of Civil Engineering GDA Step 4 report for further information.	Seismic assessment - 4.3.12	E.70 04-032 04-002 04-032 04-038	04-058 04-061 04-024 04-048 04-062
AF-ABWR-CE-013	The reduced scope of GDA for the Radwaste Building, Service Building, Heat Exchanger Building, Turbine Building, Back-up Building and Emergency Diesel Generator Buildings meant that a reduced seismic and structural assessment was performed for these buildings during GDA. The licensee shall complete the seismic analysis of the above buildings in line with relevant good practice. Future licensee to refer to section 4.3.12.5 of Civil Engineering GDA Step 4 report for further information.	Seismic assessment - 4.3.12	04-028 04-032 04-039 04-042 04-043 04-056 24-058 04-061	04-040 04-042 04-043 04-056 04-059 04-061 01-RW06
AF-ABWR-CE-014	Some aspects of the seismic analysis models and procedures require further validation and verification. The licensee shall undertake suitable verification and validation methods for the Reactor Building, Control Building, Filter Vent Building, Turbine Building, Emergency Diesel Generator Buildings, Backup Building and Radwaste Building and connecting tunnels. Future licensee to refer to section 4.3.12.6 of Civil Engineering GDA Step 4 report for further information.	Seismic assessment - 4.3.12	04-020 04-022 04-045 04-065 04-066 04-023	04-032 04-038 04-042 04-043 04-058
AF-ABWR-CE-015	To address simplifications outside relevant civil engineering codes of practice for seismic analysis, the licensee shall justify its approach against relevant good practice with particular focus in the following areas:	Seismic assessment - 4.3.12	E.4 E.7	E.10 04-063

	derivation of time histories, treatment of the operating basis earthquake and the approach to concrete cracking. Future licensee to refer to section 4.3.12.7 of Civil Engineering GDA Step 4 report for further information.		
AF-ABWR-CE-016	The safety function requirements of the waterproofing systems are not currently linked to internal systems and equipment. Hence the licensee shall detail suitable waterproofing arrangements for the civil engineering structures, considering their safety function requirements, the interactions between structures and the effect on the coefficient of friction to resist sliding. Future licensee to refer to section 4.3.14 of Civil Engineering GDA Step 4 report for further information.	Serviceability and fire - 4.3.14	01-RCW09 01-LOT08 01-RCW11 01-G02
AF-ABWR-CE-017	The Requesting Party has not provided sufficient evidence of the assurance process associated with the custom software used in GDA to design the civil engineering structures and it has not justified the treatment of thermal strains associated with the Reactor Building design. The licensee shall demonstrate and validate the reliability of the data generated from the custom software. Future licensee to refer to section 4.3.15 of Civil Engineering GDA Step 4 report for further information.	Custom software - 4.3.15	01-001 01-003 01-SSDP01
AF-ABWR-CE-018	The Suppression Pool design submitted under GDA does not incorporate a liner leak detection system. The licensee shall either justify this design choice or incorporate a system to monitor leakages or escapes of radioactive material from the containment boundary. Future licensee to refer to section 4.3.18 of Civil Engineering GDA Step 4 report for further information.	Leak Detection System - 4.3.19	
AF-ABWR-CE-019	During GDA only a limited number of civil engineering elements have been checked for internal hazards loads. The licensee shall take account of the final Internal Hazards loads and update/perform the structural designs of the civil engineering structures that provide claimed barriers and assess the effect that this could have on the rest of the structure.	Cross Cutting Topics - 4.3.21	

Annex 5

Minor Shortfalls

Minor Shortfall Number	Minor Shortfall Finding	Report Section Reference	Related Civil engineering comments
MS-ABWR-CE-01	The licensee should include a clarification on torsion and the torsional stiffness approach for steel member design.	steel members (excluding MC components) - 4.3.11.2	01-CTS03 01-RB21
MS-ABWR-CE-02	The licensee should determine if the tunnel joints can accommodate the differential displacements from seismic loadings.	Seismic assessment - 4.3.12	04-021 04-065 04-022 04-066 04-045
MS-ABWR-CE-03	The licensee should ensure that the effects of seismic loading in the longitudinal direction and inertial loading are taken into account in the Reactor Cooling Water tunnel design.	Seismic assessment - 4.3.12	04-018 04-065 04-022 04-066 04-045
MS-ABWR-CE-04	The licensee should specify fire resistance periods for all the civil engineering structures.	Serviceability and Fire Protection - 4.3.14.2	01-LOT15
MS-ABWR-CE-05	The licensee should update the civil engineering design reports and technical drawings to reflect the comments within section 4.3.17 of the Civil Engineering GDA Step 4 report.	Accuracy of RP's Safety Case - 4.3.17	01-RB26 01-RW02 01-RB21 01-LOT08 01-CB02 01-RCW01 01-CB18 01-LOT01 01-G05
MS-ABWR-CE-06	The licensee should consider the effects that possible modifications to the venting system may have in the civil engineering structures.	Fault analysis - 4.3.21.6	

Annex 6

Safety Property Claims Table

No.	SPC	Safety Properties Claim (SPC) Contents
1	CE SPC 01	CE structures have been classified in accordance with the safety functional category of the equipment housed within them or supported by them.
2	CE SPC 02	Civil structures are seismically categorised to ensure either the SSCs contained within them can operate safely following a seismic event or such that a failure of a structure dies not have a detrimental impact on adjacent structures containing SSCs.
3	CE SPC 03	The analysis and design of CE structures has been carried out using conservative methods and input parameters to ensure they are robust and thus achieve the required reliability to meet all relevant accident conditions, including suitable resilience to DBA, BDBA and SA events.
4	CE SPC 04	CE structures are designed to be tolerant of external hazards and provide the protection to the SSCs housed within or supported by the structures. The magnitude of normal operational and design basis external hazards is given in PCSR Chapter 2, Generic Site Envelope.
5	CE SPC 05	CE structures designed to Seismic Category 1 requirements have no cliff edge effects for beyond design basis seismic events.
6	CE SPC 06	CE structures are designed to be tolerant of variations in the ground conditions, since GDA is not based on a specific site. This includes variations in seismic soil parameters and the assumption that the ground water level is at ground level.
7	CE SPC 07	CE structures are designed to be tolerant of internal hazards and provide the required barrier functions as specified in PCSR Chapter 7 Internal Hazards.
8	CE SPC 08	CE structures are designed using relevant good practice and complies with the appropriate internationally, recognised codes and standards.
9	CE SPC 09	Finite element analysis models used in the CE structures' analyses have been sufficiently validated to provide confidence in the results. The various computer codes have been sufficiently verified to prove they are used within the limits of applicability.
10	CE SPC 10	CE structures have a design life of 100 years to ensure they are robustly detailed so that they can be maintained appropriately throughout the 60 years operational life, and also for the safe decommissioning of the site.
11	CE SPC 11	The internal layouts of the CE structures and buildings provide suitable space and access in respect of safety requirements during normal operations and emergency response considerations. The layouts are derived from the Japanese reference plant and are established with relevant operator experience..
12	CE SPC 12	The materials and details used for civil structures are appropriate to reduce the hazard from contamination and activation at the time of decommissioning
13	CE SPC 13	The generic design of CE structures has included designers' hazard logs for recording risks for consideration by the future licensee (contractor)

Annex 7

Load Combinations, Load Factors and Acceptance Criteria

Table 5.3.1-1 Load Combinations, Load Factors and Acceptance Criteria for Reinforced Concrete Containment Vessel

Description	No.	Load Conditions[*1]																	Acceptance Criteria[*2]
		D	L	Pt	SRV	Pa	Tt	To	Ta	Ess	W	Wt	Ro	Ra	Rr	Pv	Ha	LOCA	
Service Test	CV-1	1.0	1.0	1.0			1.0												S
Construction	CV-2	1.0	1.0					1.0			1.0								S
Normal	CV-3	1.0	1.0		1.0			1.0					1.0			1.0			S
Factored Severe Environmental	CV-4	1.0	1.3		1.3			1.0			1.5		1.0			1.0			U
Extreme Environmental	CV-5	1.0	1.0		1.0			1.0		1.0			1.0			1.0			U
	CV-6	1.0	1.0		1.0			1.0				1.0	1.0			1.0			U
Abnormal	CV-7	1.0	1.0		1.25	1.5			1.0					1.0				1.5	U
	CV-8	1.0	1.0		1.0	1.0			1.0					1.25				1.0	U
	CV-9	1.0	1.0		1.25	1.25			1.0					1.0				1.25	U
Abnormal/Severe	CV-10	1.0	1.0		1.0	1.25			1.0		1.25			1.0				1.25	U
Environmental	CV-11	1.0	1.0		1.0			1.0			1.0						1.0		U
Abnormal/Extreme Environmental	CV-12	1.0	1.0		1.0	1.0			1.0	1.0				1.0	1.0			1.0	U

Note: Based on ASME BPVC Sec. III Division 2, 2013 and SRP 3.8.1 Appendix A 2.A. (The load combination cases related to OBE were deleted. LOCA was added to take into account for CO, CHUG and PS loads.)

*1: D = Dead loads, including hydrostatic and permanent equipment loads
L = Live loads, including any movable equipment loads and other loads which vary with intensity and occurrence, such as soil pressures
Pt = Pressure during the structural integrity and leak rate tests
SRV = Loads resulting from relief valve or other high energy device actuation
Pa = Design Pressure load within the containment generated by the DBA, based upon the calculated peak pressure with an appropriate margin
Tt = Thermal effects and loads during the test
To = Thermal effects and loads during normal conditions or shutdown conditions, based on the most critical transient or steady state condition
Ta = Thermal effects and loads generated by the DBA including To
Ess = Loads generated by the DBE.
W =Loads generated by the design wind specified for the plant site
Wt = Tornado loading including the effects of missile impact.
Ro = Pipe reactions during normal conditions or shutdown conditions, based on the most critical transient or steady state condition
Ra = Pipe reaction from thermal conditions generated by the DBA including Ro
Rr = The local effects on the containment due to the DBA
Pv = external pressure loads resulting from pressure variation either inside or outside the containment.
Ha =Load on the containment resulting from internal flooding, if such an occurrence is defined in the Design Specification as a design basis event
LOCA = Pressure loads including CO, CHUG, and PS. The load factor for LOCA shall be the same as the corresponding pressure load Pa.

*2: S = Allowable Stress as in ASME Section III, Div. 2, Subsection CC-3430 for Service Load Combination.
U = Allowable Stress as in ASME Section III, Div. 2, Subsection CC-3420 for Factored Load Combination.

Table 5.3.3-1 Load Combinations, Load Factors and Acceptance Criteria for Safety-Related Reinforced Concrete Structures

Category	No.*1	Load *2														Acceptance Criteria*3
		D	F	L	H	Pa	To	Ta	Ess	W	Wt	Ro	Ra	Y	C_{cr}	
Normal	RB-1	1.4	1.4	1.7	1.7							1.7			1.4	U
	RB-9	1.05	1.05	1.3	1.3		1.2					1.3				U
Severe Environmental	RB-3	1.4	1.4	1.7	1.7					1.7		1.7				U
	RB-11	1.05	1.05	1.3	1.3		1.2			1.3		1.3				U
Extreme Environmental	RB-4	1.0	1.0	1.0	1.0		1.0		1.0			1.0			1.0	U
	RB-5	1.0	1.0	1.0	1.0		1.0				1.0	1.0				U
Abnormal	RB-6	1.0	1.0	1.0	1.0	1.4		1.0					1.0		1.0	U
Abnormal/Extreme Environmental	RB-8	1.0	1.0	1.0	1.0	1.0		1.0	1.0				1.0	1.0		U

Note : According to ACI 349-13 Appendix C and USNRC RG1.142.

*1: No. is based on ACI 349. (The load combination cases including OBE were deleted.)

*2: D = Dead loads

F = Hydrostatic pressure loads

L = Live loads (For the roof, Roof Live loads or Snow loads or Rain loads each acting independently.)

H = Lateral soil pressure loads

Pa = Pressure loads generated by a postulated pipe break

To = Thermal loads during the normal condition

Ta = Thermal loads generated by a postulated pipe break

Ess = Seismic loads (DBE)

W = Wind loads (basic wind)

Wt = Wind loads (tornado wind) - – read as extreme wind consistent with definition of W that is 10^{-4} pa wind load.

Ro = Pipe reaction loads during the normal condition

Ra = Pipe reaction loads generated by a postulated pipe break

Y = Yj + Ym + Yr

Yj = Jet impingement load on the structure generated by a postulated pipe break

Ym = Missile impact load on the structure generated by a postulated pipe break

Yr =Load on the structure generated by a postulated pipe break

C_{cr} = Crane load-rated capacity

*3: U = Required section strength based on the strength design method per ACI 349-13.

Table 5.3.4-1 Load Combinations, Load Factors and Acceptance Criteria for Safety-Related Steel Structures

		D	L	Lr or S or R	Pa	To	Ta	Es	W*1	Wt	Ro	Ra	Y	C	Acceptance Criteria*2
Normal	NB-2-1	1.4				1.0					1.4			1.0	U
	NB-2-2	1.2	1.6	0.5		1.0					1.2			1.4	U
	NB-2-3	1.2	0.8	1.6		1.0					1.2			1.4	U
Severe Environmental	NB-2-4	1.2	0.8	0.5		1.0			1.6		1.2			1.0	U
	NB-2-5	1.2	0.8	0.2		1.0					1.2			1.0	U
Extreme Environmental and Abnormal	NB-2-6	1.0	0.8			1.0		1.0			1.0			1.0	U
	NB-2-7	1.0	0.8							1.0	1.0				U
	NB-2-8	1.0	0.8		1.2		1.0					1.0		1.0	U
	NB-2-9	1.0	0.8		1.0		1.0	0.7				1.0	1.0		U

Note : According to ANSI/AISC N690-12 (The load combination cases related to OBE were deleted.)

*1: D = Dead loads due to the weight of the structural elements, fixed-position equipment, and other permanent appurtenant items; weight of crane trolley and bridge
L = Live load due to occupancy and moveable equipment, including impact
Lr = Roof live load
R = Rain load
C = Rated capacity of crane (shall include the maximum wheel loads of the crane and the vertical, lateral and longitudinal forces induced by the moving crane)
S = Snow load as stipulated in Minimum Design Loads for Buildings and Other Structures (SEI/ASCE 7) for Category IV facilities
Pa = Maximum differential pressure load generated by the postulated accident
To = Thermal effects and loads during normal condition, start-up, or shutdown conditions, based on the most critical transient or steady-state condition
Ta = Thermal loads generated by the postulated accident, including To
Es = Seismic loads (DBE)
W = Wind loads (basic wind) Because the basic wind is defined based on ASCE 7-05, the factor 1.6 is used based on AISC N690-06.
Wt = Wind loads (tornado wind) – read as extreme wind consistent with definition of W that is 10^{-4} pa wind load.
Ro = Pipe reactions during normal condition, start-up, or shutdown conditions, based on the most critical transient or steady-state condition
Ra = Pipe and equipment reactions generated by the postulated accident
Y = Yj + Ym + Yr
Yj = Jet impingement load generated by the postulated accident
Ym = Missile impact load, such as pipe whipping generated by or during the postulated accident
Yr = Loads on the structure generated by the reaction of the broken high-energy pipe during the postulated accident

*2: U = Required section strength based on the LRFD design method per AISC N690-12.