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Title

E3S Case Chapter 9B: Civil Engineering Works & Structures

Executive Summary

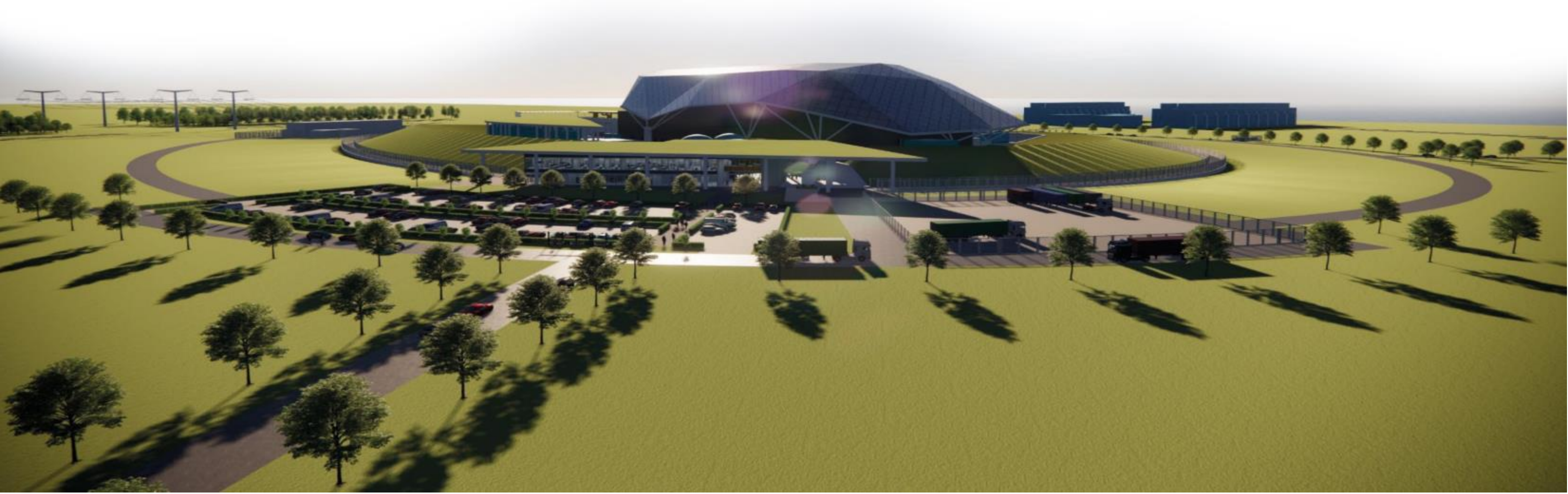
This chapter of the Environment, Safety, Security, and Safeguards (E3S) Case presents the Civil Engineering Works & Structures of the Rolls-Royce Small Modular Reactor (RR SMR). The chapter outlines the arguments and preliminary evidence available at the Preliminary Concept Definition (PCD) design stage to underpin the high-level Claim that the RR SMR Civil Structures are designed and substantiated to achieve functional and non-functional E3S requirements and reduce risks to As Low As Reasonably Practicable (ALARP).

The civil structures covered in the scope of the E3S Case include all Reactor Island structures [U01], the Essential Services Water System (ESWS) structures [UPJ], and the back-up generation structures [UBM].

At PCD, concept solutions are still in development, therefore a high-level overview of each civil structure is provided. High-level, generic safety requirements for all civil structures are also defined.

The civil structures design includes a Hazard Shield that will provide protection of Structures, Systems and Components (SSCs) against external hazards in the Containment, Safeguards Building, and the Fuelling Building. A base isolation system is also being developed to support standardisation of the RR SMR concept, to protect the supported structure above it from the damaging effects of horizontal earthquake motion.

Further evidence to support the derivation and substantiation of requirements on the civil structures will be developed as the design programme progresses, including derivation of safety categorised functional requirements and non-functional system requirements for civil structures based on E3S assessments and principles, down-selection of concept design solutions to meet requirements and demonstrate risks are reduced to ALARP, and verification that the final design solution can meet requirements.



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9B.0 Introduction

9B.0.1 Introduction

Chapter 9B of the Rolls-Royce Small Modular Reactor (RR SMR) Environment, Safety, Security and Safeguards (E3S) Case forms part of the Pre-Construction Safety Report (PCSR), as defined in E3S Case Chapter 1: Introduction, Reference [1].

Chapter 9B presents the overarching summary and entry point to the design and safety information for the civil structures of the Rolls-Royce Small Modular Reactor (RR SMR), as defined at Reference Design (RD) 5 level of design maturity.

9B.0.2 Scope

The list of structures that are covered in the scope of the Civil, Structural and Architecture (CS&A) [CIV] aspects is provided in Section 9B.0, Appendix B, including those that are within scope but excluded from this revision due to design immaturity. This includes:

1. Reactor Island structures [U01], comprising:
    a. Hazard Shield
    b. Raft Foundation and Retaining Walls
    c. Base Isolation System
    d. Containment Support Structure
    e. Safeguards Building
    f. Fuelling Building (including Spent Fuel Pool)
    g. Ancillary Building
    h. Auxiliary Building
    i. Access Building
    j. Containment Internal Structures
2. Essential Service Water System (ESWS) structures [UPJ], including;
    a. Foundations to the ESWS cooling towers (incorporating blowdown pond)
    b. Foundations to the ESWS make-up water storage tanks
    c. Service culverts housing ESWS pipework
3. Back-up Generation structures [UBM], including;

a. Structures supporting and housing the back-up generation system and associated fuel store

b. Service culverts housing back-up generation electrical cables

4. Structures which may impede the function of Class 1 and Class 2 Structures, Systems and Components (SSCs) if subject to failure

The location and layout of these civil structures are illustrated indicatively in Figure 9B.0-1 and Figure 9B.0-2, taken from the Site Layout Report [2].

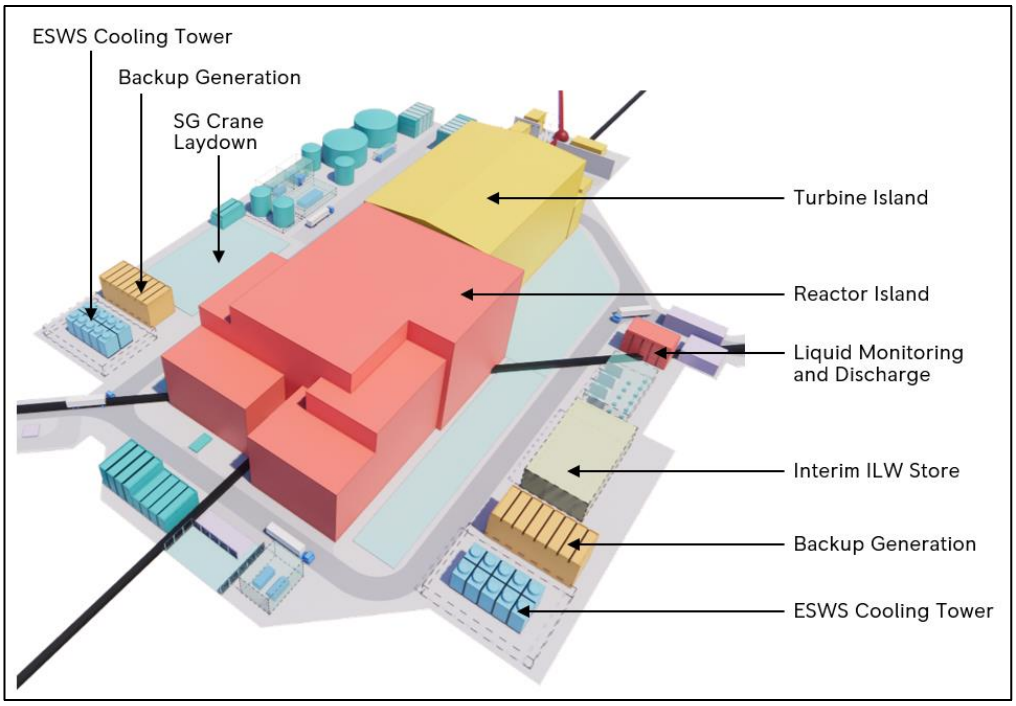

Figure 9B.0-1: Civil Structure Locations

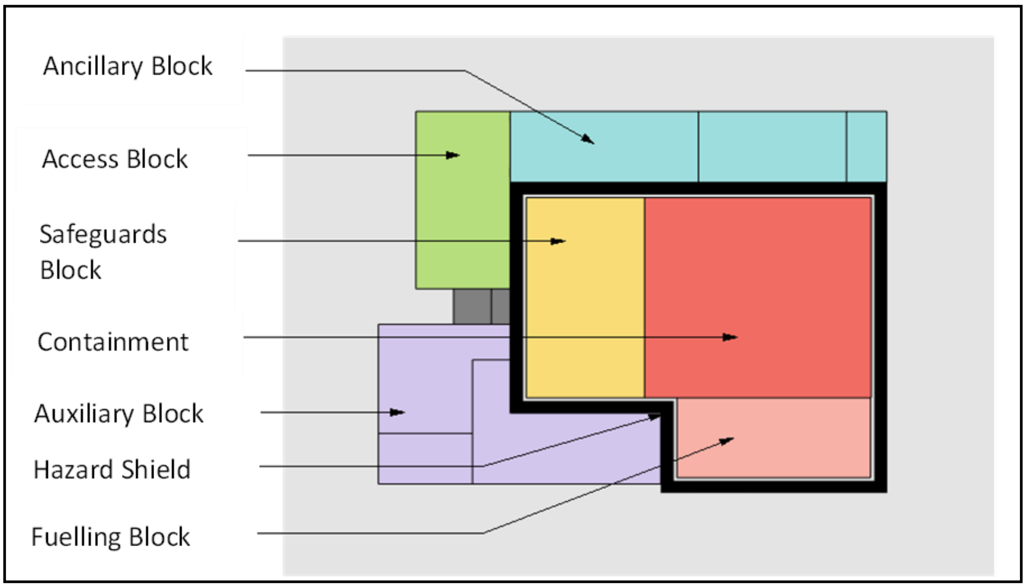

Figure 9B.0-2: Reactor Island Structures

The following structures are excluded from the scope at this stage:

1. Turbine Island structures
2. Cooling Water Island structures (other than ESWS structures [UPJ])
3. Balance of Plant structures (other than Back-Up Generation structures [UBM])

The Containment Vessel is covered in E3S Case Chapter 6: Engineered Safety Features [3], and is not described in this report.

Design/Programme Maturity

RR SMR design information presented in this revision of the PCSR is largely based on the design definition at the end of Preliminary Concept Definition (PCD), which is an interim design stage representing RD5 level of design maturity.

For CS&A [CIV], a description of the preliminary design of the Reactor Island structures including base isolation system (including seismic isolation system, basemat, and foundation), containment support structure, and Hazard Shield is provided. A brief description of other structures is also provided. Further detail of these structures and will be provided as the design matures (see Section 9B.0).

9B.0.3 Claims, Arguments, Evidence Route Map

The Chapter level Claim for E3S Case Chapter 9B: Civil Engineering Works & Structures is:

Claim 9B: The RR SMR Civil Structures are designed and substantiated to achieve functional and non-functional E3S requirements, and reduce risks to As Low As Reasonably Practicable (ALARP)

A decomposition of this Claim into Sub-Claims, Arguments, and link to the relevant Tier 2 Evidence is provided in Appendix A. For each lowest level Sub-Claim, the sections of this report providing the Evidence summary are also identified.

The complete suite of evidence to underpin the Claims in the E3S Case will be generated through the RR SMR design and E3S Case programme and documented in the Claims, Arguments, Evidence (CAE) Route Map [4], described further in E3S Case Chapter 1: Introduction, Reference [1].

9B.0.4 Applicable Regulations, Codes & Standards

The civil structures summarised in this report are designed in accordance with the codes and standards outlined in in Table 9B.0-1, as identified in Reference [5].

Table 9B.0-1: Civil & Structural Codes & Standards

Description	Code
Eurocode 1: actions on structures	European Standard adopted as a British Standard (BS EN) 1991: 2002

Description	Code
Code requirements for nuclear safety-related concrete structures	American Concrete Institute (ACI) 349M-13
Building code requirements for structural concrete	ACI 318M-08
Reinforced concrete design for thermal effects on nuclear power plant structures	ACI 349.1R-07
Seismic design of liquid-containing concrete structures	ACI 350.3-06
Specification for the design, fabrication, and erection of steel safety-related structures for nuclear facilities	American National Standards Institute (ANSI)/American Institute for Steel Construction (AISC) N690-18
Specification for structural steel buildings	ANSI/AISC 360-16
Seismic provisions for structural steel buildings	ANSI/AISC 341-16
Seismic analysis of safety-related nuclear structures	American Society of Civil Engineers (ASCE) / Structural Engineering Institute (SEI) 4-16
Seismic design criteria for structures, systems, and components in nuclear facilities	ASCE/SEI 43-19
Structural bearings	BS EN 1337-1: 2000
Anti-seismic devices	BS EN 15129: 2018

The civil codes and standards which remain to be confirmed include those in the design of geotechnical and foundation solutions, the design of roads and highways, including networks (e.g., surface water drainage, foul water, and potable water) and tunnels.

9B.0.5 Safety Design Bases

Safety Functional Requirements

At PCD, generic safety categorised functional requirements are placed on the CS&A [CIV] design, these are managed in the requirements management system ('Dynamic Object-Oriented Requirements System (DOORS)), in the Civils DOORS Requirements Module and summarised in Table 9B.0-2. These are applicable to all structures in Reactor Island [R01] described throughout Section 9B.0.

Table 9B.0-2: Safety Categorised Functional Requirements for Civil Structures

DOORS ID	Safety Categorised Functional Requirements
CIV-R-1266	CIV shall support, protect, and restrain the SMR in normal and faulted operation
CIV-R-1267	CIV shall support applicable SMR Structures, Systems and Components for design basis external hazards and design basis threats

CIV-R-1268	CIV shall protect applicable SMR Structures, Systems and Components for design basis external hazards and design basis threats
CIV-R-1269	CIV shall restrain applicable SMR Structures, Systems and Components for design basis external hazards and design basis threats
CIV-R-1270	CIV shall support applicable SMR Structures, Systems and Components for design basis internal hazards and design basis threats
CIV-R-1271	CIV shall protect applicable SMR Structures, Systems and Components for design basis internal hazards and design basis threats
CIV-R-1272	CIV shall restrain applicable SMR Structures, Systems and Components for design basis internal hazards and design basis threats

More specific safety categorised functional requirements for civil structures will be derived through the Fault Schedule, presented in E3S Case Chapter 15: Safety Analysis, Reference [6], based on the outputs of internal and external hazards assessments that will be developed in line with the CAE route map.

Non-Functional System Requirements

At PCD, a generic non-functional system requirement is placed on civil structures to be compliant with the E3S Design Principles, Reference [7]. Specific non-functional system requirements for civil structures based on the E3S Design Principles are still to be developed.

Classification

Preliminary SSC and Seismic Performance Classification (SPC) has assigned all Reactor Island structures [U01], ESWS structures [UPJ], and Back-Up Generation structures [UBM] with a preliminary SPC of 1 or 2. These are to be formalised in accordance with the E3S Categorisation and Classification methodology and Seismic Classification Methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [8].

Verification Activities

At PCD, verification strategies for CS&A [CIV] to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements are in development and stored in DOORS, including:

1. Structural analysis (finite element models or hand calculations) and subsequent design of all structures to the applicable codes and standards, considering all life-cycle stages and operational modes of the station and plant. Sensitivity studies and analysis model validation carried out where necessary

2. Proof of concept demonstration testing of novel components

3. Rig testing of novel components to provide data for substantiating claims for code acceptance. This is primarily for novel concrete solutions and would be targeted at mature design geometry when the final concept solutions are chosen

4. Structural analysis of novel components

5. Concrete material test programme

These preliminary verification strategies and associated activities will be developed further alongside the development of specific safety categorised functional requirements and non-functional performance requirements.

9B.1 Reactor Island Structures

9B.1.1 Overview

Reactor Island comprises a number of concrete structures providing support, and protection, to mechanical and electrical services housed within an arrangement of steel support modules.

The Reactor Island is approximately 90m long, 75m wide, and extends 40m above ground level. The Hazard Shield structure provides aircraft impact protection and is illustrated on **Error! Reference source not found.**Figure 9B.1-1 as the thick black line surrounding the Containment, Safeguards Building, and the Fuelling Building. Within the Hazard Shield, the structures are supported on a base isolated 'basemat' slab. A description of the base isolation system is included in Section 9B.0. A section through the Reactor Island is presented in Figure 9B.1-2.

Outside of the Hazard Shield, the Auxiliary, Access, and Ancillary Buildings are supported directly from the raft foundation slab.

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Figure 9B.1-1: Reactor Island Layout showing Hazard Shield

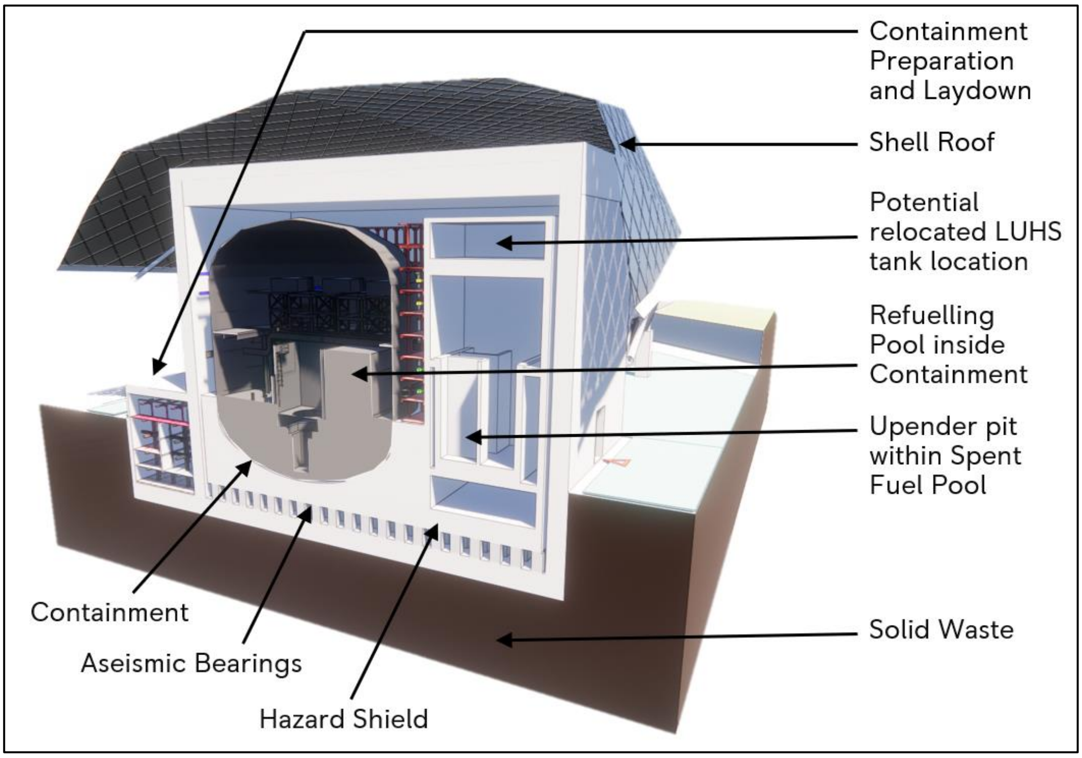

Figure 9B.1-2: Cross-section through Containment, Interspace & Fuelling Building

Lateral stability of the Hazard Shield and Fuelling Building is provided by diaphragm action of the roof slabs and in-plane shear in the perimeter walls. Stability of the steel module arrangements is provided by bracing within the modules.

9B.1.2 Base Isolation

Structural Role

Base isolation is an application of seismic isolation that reduces the response of a structure to horizontal ground motion through the installation of horizontally flexible and vertically stiff seismic isolators between the superstructure and the substructure.

The base isolation serves two key functions, to support the gravity loads and protect the supported structure from the damaging effects of horizontal earthquake motion. The decoupling of the superstructure from ground motion, reduces the response in the structure that would otherwise occur in buildings with non-base isolated raft foundations.

Safety Design Bases

From the codes and standards defined in Section 9B.0, the design of the base isolation system will use:

1. Seismic Analysis of Safety-Related Nuclear Structures, ASCE/SEI 4-16
2. Structural Bearings, BS EN 1337-1
3. Anti-Seismic Devices, BS EN 15129

The civil modules for the Aseismic Bearing pedestal design shall conform to:

1. Code requirements for nuclear safety-related concrete structures, ACI 349M-13
2. Eurocode 2: Design of concrete structures and United Kingdom (UK) national annex, BS EN 1992

The base isolation system is being designed to withstand a design basis earthquake seismic spectra anchored to a Peak Ground Acceleration (PGA) of 0.3g for both vertical and horizontal spectra, and enveloping hard, medium, and soft sites making allowances for uncertainties in the ground model. European Utility Requirements (EUR) standard shaped response spectra have been adopted. The beyond design basis spectra proposed is assumed to be 150% of the design basis values. These parameters are described in E3S Case Chapter 2: Generic Site Characteristics, Reference [9].

It is intended to provide base isolation to areas that contribute to the safe operation of the reactor and therefore require post-earthquake functionality, primarily Class 1 and Class 2 SSCs within Reactor Island [R01]. At PCD, the areas located on the base isolation include the Containment, the Safeguards Building, and the Fuelling Building, as shown in Figure 9B.1-1.

Structural Description

The base isolation system is comprised of three main components:

1. Reinforced Concrete (RC) Raft Foundation
2. RC Pedestals and Aseismic Bearings

3. RC Basemat

The system is supported on concrete pedestals founded on a raft foundation. Pedestals are used to facilitate inspection and possible replacement of the seismic isolators. The Aseismic Bearings provide the decoupling between the ground and the superstructure, with a gap (labelled as moat in Figure 9B.1-3) around the perimeter to allow for horizontal displacements, shown conceptually in Figure 9B.1-3, noting this is for illustration purposes only.

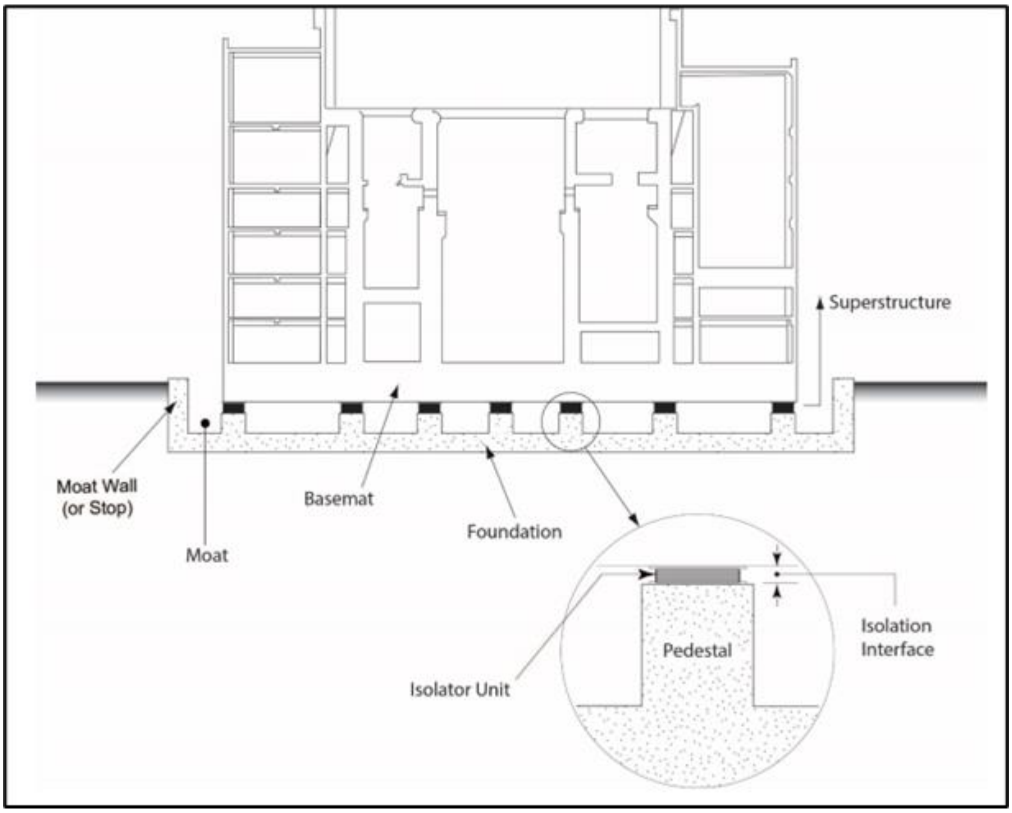

Figure 9B.1-3: Cross-section of a Base Isolation System

<u>RC Raft Foundation & Basemat</u>

The raft foundation and basemat comprise thick RC slabs. The slabs are expected to be approximately 3m in depth and contain multiple layers of reinforcement.

<u>RC Pedestals</u>

RC Pedestals ensure that the Aseismic Bearings can be accessed for maintenance and replacement. At PCD, a Pre-Cast Concrete (PCC) solution in the construction of Aseismic Bearing pedestal modules is being explored, utilising vertical starter bars that allow the assembly to be cast in place with the Raft Foundation.

Optimisation of the PCC concept solution is being progressed, in particular for reinforcement detailing and key interfaces. This will be reported in a future revision of this report as evidence in the CAE route map is developed.

Materials

The elastomeric bearings will be manufactured using natural rubber that usually goes through a vulcanisation process to improve its rigidity and durability. The mechanical properties and requirements for the elastomeric bearings will be reported in a future revision of this chapter.

Control and Instrumentation

Modern three-component digital seismic monitoring equipment will be placed at a minimum of three locations around the perimeter of the basemat to capture the acceleration response of the isolated superstructure. In the case of a seismic event, the seismic monitoring equipment would provide valuable information on the dynamic response of the isolation system and the superstructure that can be compared with the expected behaviour.

Examination, Maintenance, Inspection & Testing

A maintenance strategy is still to be developed for the base isolation system, including inspection arrangements and replacement strategy through the lifetime of the facility in line with relevant codes and standards.

Radiological Aspects

Radiation exposure of the base isolation system is expected to be low as isolators will be housed and shielded in a seismic vault away from the radiation sources, with high thicknesses of concrete in between.

Preliminary Substantiation

Verification activities to substantiate safety categorised functional requirements and non-functional system requirements are still to be determined as the requirements are developed.

ALARP in Design Development

The design of the base isolation system is being developed in accordance with the systems engineering design process, which includes alignment to Relevant Good Practice (RGP) & Operating Experience (OPEX), design to codes and standards according to the safety classification, and a systematic optioneering process with down-selection of design options based on assessment against relevant safety criteria (as described in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [8]).

The selection of base isolation over a non-base isolated design is supported by optioneering studies, which have concluded that a base isolated foundation has advantages of reducing the effects of horizontal seismic movements on both the structure and the equipment and fittings inside the structure, and significant improvements to the buildability of the design due to standardisation.

Whilst a relative novel design feature for traditional nuclear power plants, six existing Pressurised Water Reactors (PWRs), with a further two under construction, utilise a form of seismic isolation. RGP and OPEX from these plants is being incorporated into the design of the RR SMR base isolation, such as recommendations to no longer use synthetic rubber (neoprene) for the bearings due to reported long-term changes in the mechanical properties of the elastomer, which has led to the selection of elastomeric low damping rubber bearings as part of the concept design solution.

9B.1.3 Retaining Walls

Overview

The Reactor Island structures [U01] share the same raft foundation. There is a perimetral retaining wall [UWC] marking the boundary of the Reactor Island [R01]. At PCD, a PCC cellular solution is being explored, utilising reinforced in-situ piers through the cells, connected to the Raft Foundation.

Optimisation of the PCC concept solution is being progressed, in particular for reinforcement detailing and key interfaces. This will be reported in a future revision of this report as evidence in the CAE route map is developed.

9B.1.4 Containment Support Structure

Overview

The RR SMR is developing a steel containment vessel solution. It is intended that the vertical and lateral loads on the containment vessel and internal structures are transferred to the basemat below the vessel by friction and bearing on the containment support structure. Shear studs or any other means to provide shear resistance may be required to be incorporated to provide additional margin for beyond design basis events.

The containment support structure comprises:

1. Inner pedestal – concrete central plinth
2. Outer pedestal – concrete perimetral strip columns
3. Steel construction supports
4. Weld line access corridor
5. Grout interface between the concrete and steel containment

The bottom of the containment vessel is formed of two pieces, an external ring and internal dish. The two pieces are welded together through a circumferential weld. The containment support structure is illustrated in Figure 9B.1-4.

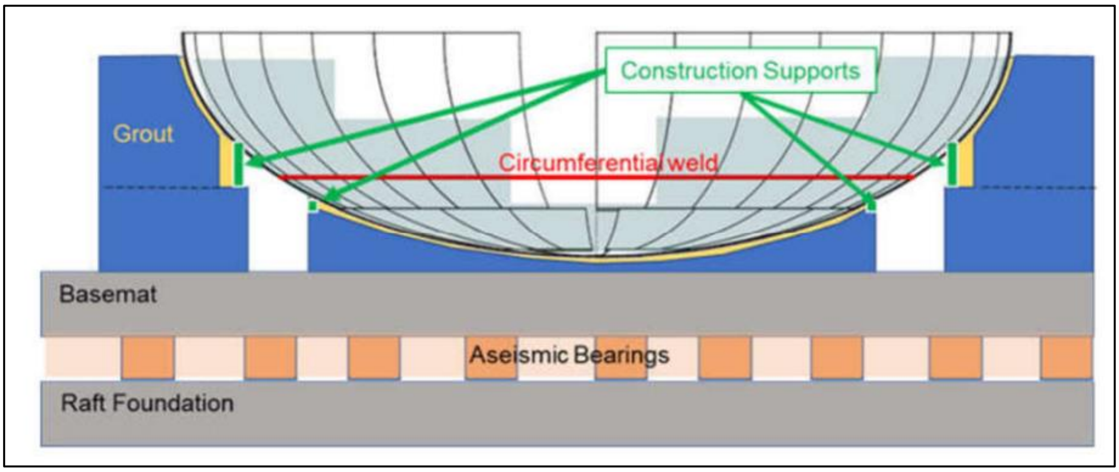

Figure 9B.1-4: Containment Support Structure (Elevation View)

9B.1.5 Hazard Shield

Overview

The purpose of the Hazard Shield is to protect SSCs that deliver safety functions from external hazards, ensuring that radiological consequences are not unacceptably affected by an initiating event or by any consequential hazards such as fire, explosions, or steam release.

The Hazard Shield is being developed based on an accidental aircraft impact hazard, with design parameters presented in E3S Case Chapter 2: Generic Site Characteristics, Reference [9].

The concept design of the Hazard Shield walls and roof is ongoing. The concept will be reported in a future revision of this report.

Preliminary Safety Analysis

Sensitivity studies have been undertaken to understand the behaviour of the Hazard Shield walls and roof to variations in thickness, reinforcement quantities and span. Preliminary analysis of an aircraft crash, based on IAEA guidance, has been undertaken to determine its effects and the steps necessary to limit consequences to an acceptable level. Detailed analysis of the Hazard Shield structure is still required.

9B.1.6 Fuelling Building

Overview

The Fuelling Building provides the route for the handling and storage of new and spent fuel. The Fuelling Building houses SSCs performing Category A and Category B safety functions, including the Spent Fuel Pool (SFP) [FAB10], Cask Handling Facility and New Fuel Receipt and Inspection Areas [FAA]. It is located to the 'south-east' of Reactor Island [R01], within the Hazard Shield and supported off the base isolated basemat slab.

The design of the civil structures will be reported in a future revision of the E3S Case, as evidence in the CAE route map is developed.

9B.1.7 Safeguards Building

Overview

The Safeguards Building houses SSCs performing Category A and Category B safety functions, such as the Cold Shutdown Cooling System (CSCS) [JNA], Spent Fuel Pool Cooling System [FAK], and Class 1 and 2 Electrical, Control and Instrumentation (EC&I) systems. It is located within the Hazard Shield and supported off the base isolated basemat slab.

The Safeguards Building accommodates a module stack that is 6 modules by 11 modules on plan, with a height of 13 modules, including 2 module levels located below ground with 11 module levels above ground level.

The lower-level modules house the fluid systems, with EC&I and Heating Ventilation and Air Conditioning (HVAC) units located on levels above allowing for reduced cable length and complexity between EC&I and fluid systems, and a lower risk of flood hazards to EC&I areas. The Main Control Room (MCR) and adjacent support functions are located at the top of the Safeguards Building.

The design of the civil structures will be reported in a future revision of the E3S Case, as evidence in the CAE route map is developed.

9B.1.8 Auxiliary Building

Overview

The Auxiliary Building is located to the 'south-west' of Reactor Island and houses the SSCs required for the collection, storage, treatment, processing and disposal of solid, liquid and gaseous radioactive waste, including both Intermediate-Level Waste (ILW) and Low-Level Waste (LLW).

The design of the civil structures will be reported in a future revision of the E3S Case, as evidence in the CAE route map is developed.

9B.1.9 Ancillary Building

Overview

The Ancillary Building is located to the 'north' of Reactor Island [R01]. It primarily houses the non-classified duty EC&I Systems that are not required to be within the Hazard Shield or on the Aseismic Base Isolation. The Ancillary Building also houses the Containment Preparation and Laydown area to provide an area outside the Hazard Shield but with ease of access to the Containment Vessel and Interspace to facilitate efficient sequencing of activities to enable short/optimised Outage timescales.

The design of the civil structures will be reported in a future revision of the E3S Case, as evidence in the CAE route map is developed.

9B.1.10 Access Building

Overview

The Access Building is located to the 'north-west' of Reactor Island [R01]. It provides the main personnel access point into Reactor Island [R01], from which access is gained to both the 'clean' (unclassified supervised) areas and the radiological controlled areas through the Health Physics area, located within the Radwaste Building.

The Access Building houses the key 'personnel' functions that are required to be within Reactor Island {REDACTED FOR PUBLICATION} that are not required to be within the Hazard Shield. Where possible personnel have been located outside Reactor Island [R01] and within the Administration Building.

The design of the civil structures will be reported in a future revision of the E3S Case, as evidence in the CAE route map is developed.

9B.1.11 Containment Internal Structures

Overview

The Containment Internal Structures provide support to major components within Containment (for example the Steam Generators, Refuelling Pool, and mechanical handling systems).

The design of the structures will be reported in a future revision of the E3S Case, as evidence in the CAE route map is developed.

9B.2 Other Structures

9B.2.1 Essential Services Water System Structures

The ESWS [PB] is comprised of two trains of Mechanical Draft Cooling Towers (MDCTs) working with a two-loop system of heat exchangers, resulting in the requirement for two sets of cooling towers. It is a Safety Class 2 system.

The two trains of ESWS [PB] are located to provide maximum separation between them. The towers sit with one train to the 'north' of Reactor Island [R01] and the second train to the 'south'.

Each train of ESWS is approximately 14m x 22m in plan, 10m high, and comprises 4 MDCTs. The MDCTs are supported on a series of concrete pedestals and perimeter walls. The full design of the civil structures will be reported in a future revision of the E3S Case, as evidence in the CAE route map is developed.

9B.2.2 Back-Up Generation Structures

Two Back-up Generators and associated Fuel Stores are located to the 'north' and 'south' sides of Reactor Island [R01]. Each Back-up Generator and Fuel Store is approximately 11.2m x 26m in plan and 10m high. One train of ESWS and Back-up Generation is indicated on Figure 9B.2-1.

The design of the civil structures will be reported in a future revision of the E3S Case, as evidence in the CAE route map is developed.

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Figure 9B.2-1: Approximate Sizes of ESWS and Back-up Generation Structures

9B.3 Conclusions

9B.3.1 Conclusions

Preliminary evidence is presented to support the overall claim that 'The RR SMR Civil Structures are designed and substantiated to achieve functional and non-functional E3S requirements and reduce risks to ALARP', which contributes to the overall E3S objective to protect people and the environment from harm, and the demonstration that risks are reduced ALARP.

At PCD, concept solutions are still in development for civil structures, therefore a high-level overview of each structure is provided. Only high-level, generic safety requirements for all civil structures are defined, with further derivation of safety categorised functional requirements still to be specified for each structure as external and internal hazards assessment are undertaken. Specification of non-functional system requirements is also still to be developed based on the E3S Design Principles. Evidence of the down-selection of concept design solutions to meet requirements and demonstrate risks are reduced to ALARP will be reported as the case is developed.

The RR SMR incorporates a Hazard Shield that is being developed to withstand an accidental aircraft impact, providing protection of SSCs in the Containment, Safeguards Building, and the Fuelling Building. The design of the Hazard Shield is ongoing and will be reported in more detail as the case and supporting evidence is developed.

Base isolation is chosen as a preferred solution to support standardisation of the RR SMR concept to protect the supported structure above it from the damaging effects of horizontal earthquake motion. Learning and RGP from six existing nuclear power plants, and two ongoing nuclear construction projects, that utilise base isolation is being incorporated into the design of the RR SMR to support the overall demonstration that the RR SMR can reduce risks to ALARP.

The full suite of evidence to underpin the claim will be developed in line with the CAE Route Map and reported in future revisions of the E3S Case, including definition of the requirements for all Reactor Island structures [U01], as well as the Back-Up Generation structures [UBM] and ESWS structures [UPJ], and ongoing development of the design solution to meet those requirements, ultimately substantiation of safety requirements.

9B.3.2 Assumptions & Commitments on Future Dutyholder/ Licensee

None identified at this revision.

9B.4 References

[1] RR SMR Report, SMR0004294/001, “E3S Case Chapter 1: Introduction,” March 2023.

[2] RR SMR Report, SMR0001186/001, “Site Layout Report,” September 2022.

[3] RR SMR Report; SMR0003771/001, “E3S Case Chapter 6: Engineered Safety Features,” March 2023.

[4] RR SMR Report, SMR0002155/001, “E3S Case CAE Route Map,” March 2023.

[5] RR SMR Report, SMR0003023/001, “Reactor Codes and Standards,” October 2022.

[6] RR SMR Report, SMR0003977/001, “E3S Case Chapter 15: Safety Analysis,” March 2023.

[7] RR SMR Report, SMR0001603/001, “Environment, Safety, Security and Safeguards Design Principles,” August 2022.

[8] RR SMR Report, SMR0004589/001, “E3S Case Chapter 3: E3S Objectives & Design Rules,” March 2023.

[9] RR SMR Report, SMR0004542/001, “E3S Case Chapter 2: Generic Site Characteristics,” March 2023.

9B.5 Appendix A: CAE Route Map

9B.5.1 Chapter 9B Route Map

A preliminary Claims decomposition from the overall Chapter 9B Claim is summarised in Table 9B.5-1, including the Tier 2 Evidence underpinning the Claims at PCD (i.e., summarised in Revision 1 of this report) and further Tier 2 Evidence still to be developed.

Table 9B.5-1: CAE Route Map

Level 1 Claims	**Level 2 Claims**	**Level 3 Claims**	**Arguments**	**Evidence Summary within Chapter 9B**	**Underpinning Tier 2 Evidence** ***at PCD**	**Underpinning Tier 2 Evidence** ***to be developed**
Safety Categorised Functional & Non-Functional System Requirements are derived and justified based on sound safety	-	-	General requirements are specified for the design of the base isolation system, including relevant codes and standards	Section 9B.1.2	Not applicable (n/a)	Design Basis for Reactor Island Structures Design Basis for Back-up Generation Structures Design Basis for Essential Services

Level 1 Claims	Level 2 Claims	Level 3 Claims	Arguments	Evidence Summary within Chapter 9B	Underpinning Tier 2 Evidence ***at PCD**	Underpinning Tier 2 Evidence ***to be developed**
principles and methods	-	-	General requirements are specified for the CS&A [CIV] design, applicable to Reactor Island structures, ESWS structures, and Backup Generation Structures	Section 9B.0.5	CS&A [CIV] DOORS Requirements Module	Water System (ESWS) Structures Civil & Structural Codes & Standards Policy Material Code Compliance
Architecture is designed to achieve safety	-	-	The preferred design solution has been	Sections 9B.1,9B.2	n/a	Design Descriptions for: Raft Foundation,

Level 1 Claims	**Level 2 Claims**	**Level 3 Claims**	**Arguments**	**Evidence Summary within Chapter 9B**	**Underpinning Tier 2 Evidence** ***at PCD**	**Underpinning Tier 2 Evidence** ***to be developed**
requirements, considering RGP & OPEX to reduce risks to ALARP			developed following a structured systems engineering approach with evaluation against safety criteria supporting the decision-making process		n/a	Seismic Isolation System, Containment Support Structure, Fuelling Block, Safeguards Block, Auxiliary Block, Ancillary and Access Block, Hazard Shield, Back-up Generation Structures, Essential Services Water System (ESWS) Structures Structural Design Method Statement

Level 1 Claims	**Level 2 Claims**	**Level 3 Claims**	**Arguments**	**Evidence Summary within Chapter 9B**	**Underpinning Tier 2 Evidence** ***at PCD**	**Underpinning Tier 2 Evidence** ***to be developed**
The design has been substantiated to achieve its safety requirements through the lifecycle	-	-	Verification activities to demonstrate safety requirements can be achieved have been developed based on sound engineering judgement and methods	Section 9B.0.5	DOORS Verification Modules	Design Substantiation Reports for Reactor Island Structures, Backup Generation Structures, and ESWS Structures

9B.6 Appendix B: SSCs in Scope of Chapter 9B

Table 9B.6-1 lists those SSCs that are within the scope of Chapter 9B, and the section of the report they are addressed.

Table 9B.6-1: SSCs in Scope of PCSR

RDS-PP	SSC	Section in PCSR
U	Structures and Areas for Systems Inside of the Power Plant Process	Covered by [U01] Sections
U01	Reactor Island Structures and Areas	Section 9B.1.1
UW	Structures for Common Systems	
UWA	Seismic Isolation System	Section 9B.1.2
UWB	Foundation & Basemat	
UWC	Retaining Wall	Section 9B.1.3
UWD	Hazard Shield	Section 9B.1.5
UF	Structures for the Handling of Nuclear Equipment	Section 9B.1.6 (section placeholder only in this revision)
UFA	Structure for Internal Storage of Fuel Assemblies (if separate from reactor building *UJA*)	
UJ	Structures for Reactor Plant	Section 9B.1.11 (section placeholder only in this revision)
UJA	Reactor Building Interior	
UK	Structures for Reactor Auxiliary Systems	Section 9B.1.7 / Section 9B.1.8 (section placeholder only in this revision)
UKA	Reactor Auxiliary Building	
UKB	Reactor Ancillary Building	Section 9B.1.9 (section placeholder only in this revision)
UPJ	Structures for Cooling Towers (Auxiliary and Secondary processes)	Section 9B.2.1 (section placeholder only in this revision)
UPJ10	ESWS Cooling Tower 1	

RDS-PP	**SSC**	**Section in PCSR**
UPJ20	ESWS Cooling Tower 2	
UBM	Structures for Power Generation for Safety Services	Section 9B.2.2 (section placeholder only in this revision)
UBM01	Backup Generation 1 and Fuel Store	
UBM02	Backup Generation 2 and Fuel store	

9B.7 Acronyms and Abbreviations

ACI	American Concrete Institute
AISC	American Institute of Steel Construction
ALARP	As Low As Reasonably Practicable
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
BS EN	European Standard adopted as a British Standard
CAE	Claims, Arguments, Evidence
CS&A	Civil, Structural and Architecture
CSCS	Cold Shutdown Cooling System
DOORS	Dynamic Object-Oriented Requirements System
EC&I	Electrical Control and Instrumentation
E3S	Environmental, Safety, Security and Safeguards
ESWS	Essential Service Water System
EUR	European Utility Requirements
HVAC	Heating, Ventilation and Air Conditioning
ILW	Intermediate-Level Waste
LLW	Low-Level Waste
MCR	Main Control Room
MDCT	Mechanical Draft Cooling Towers
n/a	Not Applicable
OPEX	Operational Experience
PCC	Pre-Cast Concrete

PCD	Preliminary Concept Definition
PCSR	Pre-Construction Safety Report
PGA	Peak Ground Acceleration
PWR	Pressurised Water Reactor
RC	Reinforced Concrete
RD	Reference Design
RDS-PP	Reference Designation System for Power Plants
RGP	Relevant Good Practice
RR	Rolls-Royce
SEI	Structural Engineering Institute
SFP	Spent Fuel Pool
SMR	Small Modular Reactor
SPC	Seismic Performance Classification
SSC	Structure, System and Component
UK	United Kingdom