ONR GUIDE			
CIVIL ENGINEERING - CONSTRUCTION ASSURANCE			
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LIST OF ABBREVIATIONS

ACI	American Concrete Institute
BS	British Standards
BS EN	Eurocode Standards
CDM	Construction (Design and Management) Regulations
EIMT	Examination, Inspection, Maintenance and Testing
ENSREG	European Nuclear Safety Regulators Group
HSE	Health & Safety Executive
IAEA	International Atomic Energy Agency
ISO	International Standards Organisation
LC(s)	Licence Condition(s)
ONR	Office for Nuclear Regulation
PCSR	pre-construction safety report
RGP	Relevant Good Practice
SAP	Safety Assessment Principle(s)
SQEP	Suitably qualified and experienced person
SSC	Structure, System and Component
TAG	Technical Assessment Guide(s) (ONR)
WENRA	Western European Nuclear Regulators' Association

GLOSSARY

Term	Description	Definition from
Ageing	General process in which characteristics of a structure, system or component gradually change with time or use.	WENRA Decommissioning Safety Reference Levels: (DSRL)
Care and Maintenance	A phase within the decommissioning stage of a facility, for which the deferral of further decommissioning has been substantiated, and for which safety is maintained by passively safe means and an appropriate examination, inspection, maintenance and testing programme.	derived
'Civil works and structures'	See Appendix A of TAG 17 head document	derived
Containment / Confinement	IAEA guidance refer to confinement (rather than containment) of nuclear material. IAEA define the containment as the physical structure that confines the nuclear material. Methods or physical structures designed to prevent the dispersion of radioactive material	IAEA Safety Glossary
Construction	"construction work" means the carrying out of any building, civil engineering or engineering construction work and includes— (a) the construction, alteration, conversion, fitting out, commissioning, renovation, repair, upkeep, redecoration or other maintenance (including cleaning which involves the use of water or an abrasive at high pressure, or the use of corrosive or toxic substances), de-commissioning, demolition or dismantling of a structure; (b) the preparation for an intended structure, including site clearance, exploration, investigation (but not site survey) and excavation (but not pre-construction archaeological investigations), and the clearance or preparation of the site or structure for use or occupation at its conclusion; (c) the assembly on site of prefabricated elements to form a structure or the disassembly on site of the prefabricated elements which, immediately before such disassembly, formed a structure; (d) the removal of a structure, or of any product or waste resulting from demolition or dismantling of a structure, or from disassembly of prefabricated elements which immediately before such disassembly formed such a structure; (e) the installation, commissioning, maintenance, repair or removal of mechanical, electrical, gas, compressed air, hydraulic, telecommunications, computer or similar services which are normally fixed within or to a structure, but does not include the exploration for, or extraction of, mineral resources, or preparatory activities carried out at a place where such exploration or extraction is carried out	CDM2015
	The activities related to installation or building, modifying, testing, remediating, repairing, renovating, repurposing, alteration, refurbishment, replacement, maintaining, decommissioning, decontamination, dismantling or demolishing a civil engineering structure, system or component. 'Construction' can happen at any stage in the lifecycle of the site, including earthworks, site preparation, enabling works, ground investigations, geotechnical or ground engineering, foundations and superstructure construction works, mock-ups and trials, and temporary works to support the same. Construction may also include civil engineering works associated with examination, inspection, testing and maintenance.	For the purposes of this TAG and the associated annexes
Contractors	All references to 'contractors' include proportionate consideration of the whole contracting and supply chain, whether for the provision of goods and services to the dutyholder or on the licensed site. This includes designers, vendors, suppliers, manufacturers etc. as appropriate.	SAPs definition
Decommissioning	Administrative and physical actions taken to allow removal of some or all of the regulatory controls from a nuclear facility.	SAPs definition

Decontamination	The complete or partial removal of contamination by a deliberate physical, chemical or biological process.	WENRA DSRL
Demolition	Removal of the buildings, structures and plant and disposal of the arising materials.	derived
Design	The definition of design for this civil engineering annex applies equally across all stages of a nuclear facility's lifecycle, including generic and/or concept design, licensing, site identification, site specific design, construction and installation, operation, modifications, post-operation, decommissioning and demolition, 'care and maintenance' phase etc. 'Design' can also include, the safety case documentation, supporting references, justification and substantiation of claims, modelling or other analysis tools, the process(es) and records of design decision making, and independent reviews of the above. It should be recognised, within the life cycle of 'civil engineering works', that the assumptions made by the designer and incorporated within the justification of the design within a safety case, must be properly carried through the construction stage and through to modifications, demolition and site clearance. All associated construction activities throughout the life cycle are much a part of the safety case as the design.	
	"design" includes drawings, design details, specifications and bills of quantities (including specification of articles or substances) relating to a structure, and calculations prepared for the purpose of a design;	CDM2015
Design Life	The period of time during which a facility or component is expected to perform according to the technical specifications to which it was produced.	IAEA Safety Glossary
Design intent	The fundamental criteria and characteristics (including reliability levels) that need to be realised in a facility, plant or SSC in order that it achieves its operational and safety functional requirements.	SAPs definition
Dutyholder	For the purpose of this annex, the dutyholder is any organisation or person that holds duties under legislation that ONR regulates. 'Dutyholder' includes Licensees, Requesting Parties, Potential Future Licensees, Operational Licence Dutyholders, Decommissioning Site Licensees, New Build Site Licensees, budget holders, vendors and supply chain members.	For the purposes of this TAG and the associated annexes
Ground Model	Outline of the understanding of the disposition and character of soil, rock and groundwater under and around the site	BS5930:2015
Management system	A set of interrelated or interacting elements (system) for establishing policies and objectives and enabling the objectives to be achieved in an efficient and effective manner. The management system integrates all elements of an organization into one coherent system to enable all the organization's objectives to be achieved. These elements include the organizational structure, resources and processes. Personnel, equipment and organizational culture as well as the documented policies and processes are parts of the management system. The organization's processes have to address the totality of the requirements on the organization as established in, for example, IAEA safety standards and other international codes and standards.	WENRA DSRL
Nuclear Facility	A facility and its associated land, buildings and equipment in which nuclear materials are produced, processed, used, handled, stored or disposed of on such a scale that consideration of safety is required.	WENRA DSRL
Nuclear Safety	The achievement of proper operating conditions, prevention of accidents or mitigation of accident consequences, resulting in protection of workers the public and the environment from undue radiation hazards	WENRA DSRL
Operation	All activities performed to achieve the purpose for which an authorized facility was constructed.	WENRA DSRL
Quality Management	Co-ordinated activities to direct and control an organisation with regard to quality (i.e. ensuring that requirements are fulfilled). Direction and control with regard to quality generally includes quality policy, quality objectives, quality planning, quality control, quality assurance and quality	SAPs definition

	improvement. Licence Condition 17 requires adequate quality management arrangements in respect of all matters which may affect safety. Such matters include those derived from the safety case, facility design and licence conditions.	
Quality Management System	Quality management system A management system to direct a unit and control an organisation with regard to quality; a combination of resources and means with which quality is realised (ISO 9000).	SAPs definition
Risk	The chance that someone or something is adversely affected in a particular manner by a hazard (R2P2).	SAPs definition
Safety Assessment	Assessment of all aspects of the site, design, operation and decommissioning of an authorized facility that are relevant to protection and safety.	WENRA DSRL
Safety Case	A collection of arguments and evidence in support of the safety of a facility or activity. This will normally include the findings of a safety assessment and a statement of confidence in these findings. 'safety case' refers to the totality of a licensee's (or dutyholder's) documentation to demonstrate safety, and any sub-set of this documentation that is submitted to ONR. Note: Licence Condition 1 defines 'safety case' as the document or documents produced by the dutyholder in accordance with Licence Condition 14.	WENRA DSRL SAPs definition:
Safety function	A specific purpose that must be accomplished for safety	IAEA Safety Glossary
Structure	"structure" means— (a) any building, timber, masonry, metal or reinforced concrete structure, railway line or siding, tramway line, dock, harbour, inland navigation, tunnel, shaft, bridge, viaduct, waterworks, reservoir, pipe or pipeline, cable, aqueduct, sewer, sewage works, gasholder, road, airfield, sea defence works, river works, drainage works, earthworks, lagoon, dam, wall, caisson, mast, tower, pylon, underground tank, earth retaining structure or structure designed to preserve or alter any natural feature and fixed plant; (b) any structure similar to anything specified in paragraph (a); (c) any formwork, falsework, scaffold or other structure designed or used to provide support or means of access during construction work, and any reference to a structure includes part of a structure;	CDM2015
Structures Systems and Components (SSCs)	Definition from WENRA Decommissioning Reference Levels: A general term encompassing all of the elements (items) of a facility or activity which contribute to protection and safety, except human factors. - **Structures** are the passive elements: buildings, vessels, shielding, etc. - A **system** comprises several **components**, assembled in such a way as to perform a specific (active) function. - A **component** is a discrete element of a **system**.	WENRA DSRL

1 INTRODUCTION

1. This annex to Technical Assessment Guide 17 (TAG 17) provides guidance on the main aspects of ONR's approach to the assessment of construction arrangements and processes in relation to nuclear facilities. It includes general guidance and advice to ONR inspectors on aspects of civil engineering construction management and related assurance. This TAG annex is not intended to provide detailed guidance on the construction process: its main purpose is to highlight certain salient areas for inspectors to consider as part of their regulatory assessment. It aims to highlight the application of the Safety Assessment Principles (SAPs) [1] to aid the assessment of civil engineering works and structures (see Appendix 1 of TAG 17), for activities during the construction phase.

2. Civil engineering construction assurance encompasses the processes, arrangements and cultural aspects necessary to provide the level of confidence that the works are constructed in accordance with the design intent as required by the safety case. The materials used and construction methodologies adopted must not undermine the design assumptions made. The Inspector should be aware of the importance of assumptions made by the designer being carried through the construction stage. The construction is thus as much a part of the safety case as the design.

3. This TAG annex applies equally during the pre-construction and construction stages of a new nuclear facility as to modification, refurbishment or demolition (for residual safety functions) of existing facilities. It also considers the proportionate oversight of related verification tests undertaken in order to demonstrate acceptability for ongoing use. It should be noted that there are often significant interfaces and overlaps of the guidance between the various stages of a site lifecycle.

1.1 Structure of this annex

4. This annex covers the following topics as part of civil engineering nuclear safety assessment of construction assurance:

- Design Authority and Intelligent Customer Functions,
- 'As Low as Reasonably Practicable' Principles (ALARP),
- safety culture,
- Construction (Design and Management) Regulations 2015,
- Generic Design Assessment and site licensing phases,
- codes and standards,
- Building Information Management and other computer tools,
- categorisation and classification,
- security,
- construction readiness,
- pre-construction stage,
- construction stage,
- OPEX and lessons learnt.

1.2 Applicable SAPs to this annex

5. The ONR's Safety Assessment Principles (SAPs) [1] and Security Assessment Principles (SyAPs) [2] have been reviewed to ascertain which are relevant to construction phase, together with other relevant technical assessment guides (TAGs) when assessing construction processes and arrangements.

6. The most relevant SAPs for construction related activities are the civil engineering principles:

- ECE.3: It should be demonstrated that structures important to safety are sufficiently free of defects so that their safety functions are not compromised, that

identified defects can be tolerated, and that the existence of defects that could compromise safety functions can be established through their lifecycle.
- ECE.15 provides assessment principles in relation to verification activities,
- ECE.16 Civil construction materials should be compliant with the design methodologies used and shown to be suitable for the purpose of enabling the design to be constructed, operated, inspected and maintained throughout the life of the facility.
- ECE.17 The construction should use appropriate materials, proven techniques and approved procedures to minimise the occurrence of defects that might affect the required integrity of structures.
- ECE.18 Provision should be made for inspection during construction to demonstrate that the required standard of workmanship has been achieved.
- ECE.19 Where construction non-conformances are judged to have a detrimental effect on integrity or significant defects are detected, remedial measures should achieve the original design intent.
- ECE.24 There should be arrangements to monitor civil engineering structures during and after construction to check the validity of predictions of performance made during the design and for feedback into design reviews.

7. Other ECE SAPs relating to civil engineering principles; investigations; design; structural analysis and model testing; in service inspection; testing and monitoring may all have relevance to construction activities.

8. Other relevant SAP's include but are not limited to:

- MS.1-4 for Leadership and Management for Safety,
- ECS.1-3 for Safety Classification and Standards,
- DC.1 establishes the expectation that the selection of the materials to consider replacement in design, shown to be appropriate for the required design life,
- DC.6 establishes the expectation for documents to be kept for the whole life cycle
- ECV.1-3 for containment and Ventilation,
- EMC.5 and EMC.6 advises as to the identification and management of defects to metal components and structures,
- EMC.19 for non-conformities or significant defects on metal components and structures to be remediated.
- When assessing high integrity metal civil structures, the Inspector may similarly need to consider appropriate principles in the sub-section on Integrity of metal components and structures, in particular SAPs EMC.13, EMC.14, EMC.20, EMC.27 and EMC.30 for assessing supply chain especially when offsite operations are involved in manufacturing metal components,
- EQU.1 establishes the expectation that qualification process and procedures are required to ensure structures will perform their safety functions in line with the design intent,
- EHF.1, EHF.5 and EHF.6 consideration of constructability and construction tasks and activities on site, regarding construction sequencing and access
- Where a structural component also forms part of containment, the principles in SAP paragraph 519 ff. will also be relevant (see ONR-NS-TAST-GD-020 'Containment').

1.3 Exclusions

9. This annex refers to construction assurance. For design of earthworks and underground structure design and construction, see:

- TAG 17 Annex 3 'Civil Engineering – Ground investigations, Geotechnics and underground structure design'.

10. This annex refers to conventional health and safety. For more guidance on conventional health and safety, see:

- ONR-NS-INSP-GD-051 'The Regulation of Conventional Health and Safety on GB Nuclear Sites'.

11. The commencement of construction works whilst design is being undertaken can mean inspectors who are assessing the design have additional aspects for consideration, and an additional interface with the site. For more information regarding design with construction activities in parallel, see:

- TAG17 Annex 1 'Civil Engineering – Design'.

2 CONSTRUCTION ASSURANCE

12. This section provides inspectors with general advice and information relevant to construction management and assurance. Guidance on specific areas associated with different project stages is provided, initially in relation to the pre-construction stage (e.g. briefing and design), and subsequently to the construction stage.

2.1 Design maturity

13. For major projects, such as construction of a new nuclear facility, it is likely that some aspects of design will be undertaken in parallel with the construction activities. This section focuses on considerations for the Inspector who is assessing the construction activities in this scenario.

14. The design activities prior to construction usually achieve a level of maturity that is sufficient for a design to be 'fit for construction' (or similar) or 'frozen' prior to the date for construction start. There are several factors which can impact on the availability of design information before construction start, including (but not limited to):

- a routine project, where only the construction detailing and addressing late design changes remains outstanding at the start of construction, post design freeze,
- a project where the design programme has been compressed or when construction is being incrementally awarded, resulting in different aspects of the structure being at a different level of design development, ranging from fully designed to designed in outline only,
- a major project, such as a nuclear new build, where significant design elements are likely to remain outstanding and only design principles have been established at the start of construction.

15. As construction progresses, the inspector(s) assessing the construction activities are encouraged to liaise with those undertaking other regulatory activities on the design, to allow those assessing the design to understand the potential changes that the site construction activities can impose on the design, and to avoid potential gaps in the regulation of construction. The Inspector is reminded that the communication of risks is a key consideration in Construction (Design and Management) Regulations 2015 (CDM2015)

16. This annex refers to CDM 2015, for more guidance on CDM2015, see

- L153 'Managing health and safety in construction' [3].

17. For the scope of the civil engineering regulatory activities undertaken for design in parallel with construction on site, please see:

- TAG 17 Annex 1, 'Civil Engineering – Design'.

2.2 Design Authority and Intelligent Customer functions

18. It is recognised that the dutyholder may appoint external design and / or construction organisations to carry out specific functions at various times. The dutyholder retains overall responsibility for both the design and the construction process as an Intelligent Customer (IC).

19. For considering construction assurance Design Authority (DA) and Intelligent Customer arrangements, the Inspector may wish to consider:

- identification and implementation of organisational arrangements and core competencies to understand and manage the design of its plant and the safety functions that need to be provided,
- the use of contractors as 'Responsible Designers' to provide authoritative advice to the DA,
- the retention of design knowledge in a form that is practically and easily available to the dutyholder over the full lifetime of the facility,
- if suitably qualified and experienced personnel (SQEP) resource is available with sufficient time to adequately undertake the DA and IC function.

20. For guidance on Intelligent Customer and Design Authority functions, see:

- TAG17 Annex 1 'Civil Engineering – Design'; Section 5 'Key assessment principles for civil engineering design undertaken in parallel with construction activities',
- ONR-NS-TAST-GD-049 'Licensee Core Safety and Intelligent Customer Capabilities',
- ONR-NS-TAST-GD-079 'Licensee Design Authority Capability'.

21. SAP ECS.1 establishes the expectation that, for construction of a nuclear facility, the standards employed are commensurate with the magnitude and nature of the hazard presented by the facility and are higher than for general industrial and construction works. SAP ECS.3 (paras 169-171) establishes the expectation that suitable safety categorisation and classification by the dutyholder should set the requirements for the extent of control and assurance that the construction of a facility is subject to.

22. The Inspector should expect the pre-construction safety report (PCSR) to document how operational and safety functional requirements (SFRs) have been derived and communicated to the civil engineering constructor in a clear manner. The construction assurance assessment assumes the design has adequately demonstrated that items and components can be manufactured, constructed, assembled, installed and erected. The Inspector may wish to seek assurance that this is in accordance with established processes and techniques that ensure the achievement of the design specifications and the required level of nuclear safety. The Inspector may wish to seek assurance that the construction details, processes and arrangements in place ensure that these design requirements are achieved via the construction process.

23. In line with the requirements of IAEA SSG-38 [4] if the full suite of design documentation is not at an approved status and available for construction at the start of construction work, the Inspector may seek assurance that an action plan is developed by the design organisation. The Inspector may wish to consider whether this action plan facilitates a process by which the outstanding design documentation is completed in a timely fashion to reduce the risks to construction quality. The Inspector should appreciate the processes that happen on site regarding how much time is required for design to be provided to site in advance of the works. The Inspector may wish to seek assurance that sufficient time has been allocated in the dutyholders programme to ensure the quality of instructions, procedures and drawings and to provide sufficient time for the contractor(s) to make appropriate preparation for the works.

2.3 Demonstration of As Low as Reasonably Practicable (ALARP)

24. To demonstrate that risks are reduced to a level that is considered in line with the ALARP principles, continuous improvement is required in relation to construction assurance and management. The Inspector should expect that construction reviews, including lessons learnt, will be undertaken at both pre-construction and during the construction stages.

25. For guidance on the ALARP principles, see:

- ONR-NS-TAST-GD-005 'Demonstration of ALARP (As Low as Reasonably Practicable)'.

2.4 Safety culture

26. SAPs MS.1-4 set clear regulatory expectations for effective leadership and management for safety and discuss the importance of safety culture.

27. The International Nuclear Safety Advisory Group (INSAG) [5] defines safety culture as:

"…that assembly of characteristics and attitudes in organisations and individuals which establishes that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance."

28. The Inspector is reminded that INSAG-15 'Key Practical Issues in Strengthening safety culture' [6] complements [4].

29. Establishing and maintaining an appropriate safety culture is a priority for nuclear site dutyholders. The Inspector may wish to consider the changes in the safety culture regularly throughout the construction phase.

30. For further information about safety culture see:

- ONR-NS-TAST-GD-080 'Challenge Culture Capability (including an Internal Regulation function), and the provision of Nuclear Safety Advice',
- Engineering the Future, Nuclear Construction Lessons Learned, Guidance on best practice: nuclear safety culture [7].

2.5 Construction (Design and Management) Regulations 2015

31. The sharing of appropriate information between dutyholders throughout the different stages of a construction project is a key consideration in reducing the risk of harm to those who have to construct, use and maintain civil engineering structures. The CDM Regulations place specific legal requirements on organisations and individuals at different project stages (e.g. pre-construction, design, construction stages etc.). The Inspector is reminded of the role and duties of Principal Designer for design coordination.

32. For more guidance on CDM2015, see:

- L153 'Managing health and safety in construction' [3].

2.6 Design

33. SAP DC.1 and ECE. 26 state the expectation that decommissioning and demolition of structures (including possible Care and Maintenance periods) will be considered during the planning, design, construction and operational stages. This is also in line with the expectations of Licence Condition LC 35 and CDM2015 [3]**Error! Reference source not found.**.

34. There are varying levels of design in line with UK Government Policy, with a design progressing through two stages prior to assessment of the construction phase, namely these are the phases of Generic Design Assessment and Site Licensing.

2.6.1 Early Design and Site Licensing

35. GDA is the process stipulated by UK Government Policy [8] and regulated by ONR and the relevant environment regulator to assess the safety, security and environmental implications of reactor designs for construction in the UK. The GDA is a step wise approach with the assessment becoming more detailed at each step. ONR publish their findings in a set of reports at the end of each step. When this is the case, the Inspector should be aware that there may be previous design ONR findings related to the construction works.

36. For guidance on the civil engineering aspects of the GDA and site licensing process, see:

- TAG 17 Annex 1, 'Civil Engineering – Design'.

37. Whilst full construction detailing will not initially be available at the GDA stage, ONR expects that the presented design is demonstrated to be viable; sufficiently mature to enable construction and based on relevant good practice. This includes, but is not limited to:

- recognition that construction materials in the UK are predominately in accordance with European (EN) specifications,
- identification of novel forms of construction / techniques not typical to the UK industry and the methodology for their use e.g. how they will be proven,
- consideration of construction loads and temporary states,
- consideration of hazards arising from the design,
- consideration of aspects of the proposed construction techniques that could affect the permanent structures,
- consideration of how the construction techniques adopted may influence decontamination and subsequent decommissioning of the civil structures.

38. Some early site preparation activities such as, geological investigation, mass excavations, site preparations and procurement of long-lead items may be carried out before a licence has been granted. The Inspector assessing site licensing will consider the arrangements in place to ensure that, if the results of these activities are to be incorporated into the permanent works or can have an influence on them, they are planned, executed, monitored and documented to standards equivalent to activities that would later be carried out under the licence, specifically to reduce risks to a level in line with the ALARP principle (ECE.24). At the point of construction, the Inspector may wish to check the assumptions made during decision making in earlier phases of the project remain valid (ECE.15).

39. The Inspector should be aware that assumptions are made during the early design and ground information data collection. The ground models that are developed based on such early information are often averages across a site that are informed by boreholes at intervals across the site. When the construction begins on site, the information that is collected within early excavations can be used to verify and validate the ground model that has been used in the design (ECE.15 and ECE.24). The Inspector may wish to assess whether verification and validation exercises are undertaken when the actual ground conditions are apparent. The Inspector may wish to consider how effective the communication between site and design are at this stage.

40. For more information on validation of assumptions in the ground model, see:

- TAG17 Annex 3, ‘Ground investigations, geotechnics and underground structure design’

2.6.2 Design codes and standards

41. Whilst British Standard (BS) and Euro norm (EN) codes, (including nationally determined annexes) may not be specifically written with nuclear facility designs in mind, it is noted that they may form the base understanding of construction in terms of control of materials, workmanship, durability, tolerances, testing and inspection regimes.

42. In the UK nuclear industry, designers may utilise other international codes as part of the design process. These may also be supplemented or replaced entirely by the dutyholder’s own standards. The Inspector should be aware that special measures may be required when imperial designs are ‘converted’ into metric construction details and the use of non-UK specifications, for quality, testing and materials.

43. The Inspector should recognise that codes may set standards and requirements for construction details, workmanship, concrete mix design, reinforcement standards and fixing details, material specifications. The Inspector should be aware that in the case of the EN codes, the codes may set options for control of construction which may be less familiar to a UK construction work force, especially if they have limited experience of nuclear construction.

44. The Inspector should be aware that international codes may base the design on differing forms of test results and requirements pertaining to construction materials, such as American Institute of Steel Construction (ANSI/AISC) ‘Specification for structural steel buildings’ [9], [10] and [11], or American Concrete Institute (ACI) ‘Code requirements for nuclear safety related concrete structures’ [12].

45. The Inspector should be aware that international codes may base design on materials available within the country of origin. These materials may not be the standard, or readily accepted or readily available norms in the UK. The Inspector should be aware of the useful information from relevant industry bodies such as:

- UK Certification Authority for Reinforcing Steels (CARES) for reinforcement bars [13],
- British Construction Steelwork Association (BCSA) for steel construction [14],
- International Masonry Society (IMS) for masonry [15] etc.

2.7 Building Information Modelling

46. The UK Government have established a centre of excellence, ‘the Centre for Digital Built Britain’ (CDBB). This is a partnership between Business, Energy and Industrial Strategy and the University of Cambridge to understand how the construction and infrastructure sectors could use a digital approach to better design and build projects. The CDBB have developed guidelines for utilising Building Information Models (BIM) in construction projects [16].

47. In construction, BIM is currently adopted to a limited extent when considering the potential uses that will likely develop in the construction industry in the future. The most frequently used models for construction are reinforcement 3-D models, where anti-clash programmes can move each bar within the tolerance and avoid clashes on site. The Inspector may seek assurance that the site construction team understand the use of these tools and the way they link to hardcopy 2-D drawings.

48. The Inspector may wish to seek assurance in the adequacy of the quality arrangements for approval of site construction documents, any hierarchy associated with different

systems showing the same information, and the process for checking reinforcement locations. This applies for use of any 3-D models on site as part of the construction activities.

49. 3-D models can be a useful tool for discussions with early contractor engagement regarding methodology and / or inclusion of screenshots in method statements to explain the space constraints associated with particular construction activities. The Inspector should be aware if such technology is available when discussing activities and whether this tool is being used to its most benefit.

50. The Inspector should be aware of the validation and verification (ECE.15 and ECE.24) of such tools when assessing nuclear safety significant activities that are reliant on automatically processed outputs.

51. For guidance on civil engineering assessment of Building Information Modelling (BIM), see:

- TAG17 Annex 2 – 'Building Information Modelling'.

52. For information on security of information, see:

- ONR-CNS-TAST-GD-7.1 'Effective Cyber & Information Risk Management',
- ONR-CNS-TAST-GD-7.2 'Information Security',
- ONR-CNS-TAST-GD-7.4 'Physical Protection of Information'.

2.8 Categorisation and classification

53. SAP ECS.1 establishes the expectation that the safety functions to be delivered (by civil engineering SSCs) should be categorised based on their significance to safety. The IAEA Safety Glossary refers to a 'graded approach' when referring to the categorisation and classification of items on site, related to their nuclear safety significance. The Inspector should expect the graded approach to extend to activities undertaken by the supply chain e.g. contractors that are manufacturing and assembling items important to safety.

54. The Inspector should expect a graded approach to the application of the assurance requirements, based on the relative importance to safety of each item, service or process, for all construction activities. Such an approach should reflect a planned and recognised difference in the application of specific management system requirements, for example, those relating to quality assurance of construction.

55. The Inspector should be aware that the graded approach can be unfamiliar to some construction sites, despite the importance that it is observed correctly during the works. The Inspector should be aware that this is a fundamental requirement that merits time and effort be given to getting it right. The Inspector should use the expectations as set out in SAP ECS.1 and ECS.2 regarding categorisation and classification as well as ECE.1 and ECE.2 regarding functional performance and the safety case claims made on civil engineering SSCs.

56. The Inspector may wish to consider the consequences of categorisation and classification when assessing the application of the graded approach to construction assurance, including categorisation of non-conformances and associated design changes.

57. The Inspector may wish to seek assurance in the adequacy of the decision-making processes on site, regarding how categorisation and classification are taken into consideration when making decisions.

2.9 Nuclear security aspects

58. In addition to ensuring that works are constructed in accordance with the design intent as required by the safety case, nuclear security aspects will be considered by inspectors who specialise in nuclear security. These will be evaluated during both the pre-construction and construction stages. The civil engineering inspector may be on site more often than a security specialist inspector, so should raise any security issues they identify whilst on site with the appropriate Inspector(s).

59. When assessing construction assurance, the Inspector should be aware of nuclear security arrangements on sites with existing nuclear facilities, or when new build construction has one unit operational whilst continuing the construction of other unit(s).

60. Nuclear Industries Security Regulations 2003 (NISR) [17] places obligations on the operators of civil licensed nuclear sites with regard to physical security measures for facilities, nuclear material and the security of sensitive nuclear information (SNI). NISR also covers the vetting of permanent staff and contractors. This legislation requires all civil nuclear operators to produce and implement robust nuclear site security plans (NSSP). There are specific security requirements which are concerned with nuclear construction sites apply during the design and construction stages. For further information relating to security aspects on a nuclear construction site refer to:

- Security Assessment Principles (SyAPs) [2],
- ONR-CNS-TAST-GD-6.6 ‘Nuclear Construction Sites’,
- ONR-CNS-TAST-GD-5.2 ‘Examination, Inspection, Maintenance and Testing of Physical Protection Systems,
- ONR-CNS-TAST-GD-4.3 ‘Oversight of Suppliers of Items or Services of Nuclear Security Significance’,
- ONR-CNS-TAST-GD-7.1 ‘Effective Cyber & Information Risk Management’,
- ONR-CNS-TAST-GD-7.2 ‘Information Security’,
- ONR-CNS-TAST-GD-7.4 ‘Physical Protection of Information’.

2.10 Construction readiness reviews

61. The Inspector may wish to seek assurance in the readiness of major construction activities by observing a dutyholder’s construction readiness review, including consideration of the construction progress and readiness for subsequent project stages (e.g. first of a kind, handover(s), commissioning).

62. The Inspector should be aware of the IAEA Construction Readiness Review (CORR) guidelines[18] with respect to preparing and conducting regulatory readiness reviews. The guidelines set out the following objectives of a review of construction assurance for readiness of an activity:

- assess strategy, organisation, leadership, management vision, goals, methods and processes,
- identify project management, engineering, procurement, quality management, human resources, construction readiness, and construction completion assurance related issues or concerns related to the project under review,
- identify issues, make observations, and identify good practices related to the project under review,
- facilitate personal exchanges of experience.

63. The Inspector should apply experience and judgement when determining specific intervention scopes and ensure proportionality of approach. When deciding on scope of the assessment, the Inspector may wish to consider the interfaces with other disciplines in the site construction activities being assessed, which could include physical interfaces, structural integrity, mechanical and electrical or control & instrumentation engineering.

64. The IAEA CORR guidelines [18] refers to the following nine themes:

- project management,
- engineering readiness (Engineering deliverables required to support construction),
- procurement / material / supply chain readiness (material available to support construction activities,
- quality management and records,
- human resources and training,
- construction readiness,
- construction installation completion assurance/system turnover process,
- targeted area reviews (including project delays and corrective actions),
- technical visits.

65. In order to assess adequacy with respect to the above themes, Appendix II of the CORR guidelines comprise checklist tables of subjects that may be considered by an Inspector [18]. The Inspector should note the "specific references" column should be adjusted to include ONR specific guidance documents e.g. SAPs, TIGs and TAGs.

66. Although the nine themes can be considered at different project stages (i.e. pre-construction stage or construction stage) the applicability of certain areas and the nature of their application may vary. Theme 7, 'Construction installation completion assurance / system turnover process' is an example of this, as at pre-construction stages the focus would be on whether the required processes are in place, whilst during the construction stage, the emphasis would be on reviewing performance against the process in place. The Inspector should be aware that where relevant, the IAEA CORR guidelines [18] indicate this, referring to pre-construction and construction as Phase 1 and Phase 2 respectively.

67. The checklists included at Appendix II of the IAEA CORR guidelines [18] provide useful prompts for the Inspector when seeking assurance for the adequacy against the nine themes as necessary, at both the pre-construction and construction phases.

2.11 Pre-construction phase

68. Prior to the construction or modification of an existing nuclear facility, the Inspector is reminded of the particular importance that certain tasks and activities have been completed. The Inspector may wish to consider the relevant arrangements, procedures and quality assurance programmes for implementing or modifying the design in place and consider whether the arrangements are at a sufficient level of maturity to control the works. This may not be the case for smaller projects, where alternative safety case documentation may be available.

69. The Inspector should expect an adequate and buildable design solution developed by the design organisation as a prerequisite for the start of construction of a nuclear facility. The design organisation is responsible for preparation of the detailed design. The design process comprises many elements; for guidance, see:

- TAG 17 Annex 1 'Civil Engineering – Design',
- ONR-NS-TAST-GD-057 Design Safety Assurance.

70. When the early construction 'earthworks'/'preparatory works' begin on site, the Inspector should be aware that the information available within early excavations can be used to verify and validate the ground model used in the design. The Inspector may wish to assess whether verification and validation exercises are undertaken when the actual ground conditions are exposed. The Inspector may also wish to consider how effective the communication between site and design are at this stage.

71. For more information on earthworks and validation of assumptions in the ground model, see:

- TAG17 Annex 3 'Ground investigations, geotechnics and underground structure design'.

72. For more information on working in excavations, see:

- L101 Safe work in confined spaces. Confined Spaces Regulations 1997 Approved Code of Practice, Regulations and guidance [19].

2.11.1 Scope and Sample for pre-construction phase

73. As part of the sample, the Inspector may proportionately select certain activities on site to enable observance or testing of aspects of the construction, especially before irreversible steps of safety significance are taken. The Inspector may seek assurance that preparations by the construction organisation to progress to the next stage are adequate.

2.11.2 Quality Management

74. SAP ECE.17 establishes the expectation that, since construction work has significant impact on the future safety of a nuclear facility, an integrated management system covering construction should be implemented. The Inspector should expect the management system to ensure that defects are minimised (ECE.3, ECE.19), and that safety matters relating to construction are not dealt with in isolation but are considered within the context of all construction activities and in relation to facility lifetime requirements.

75. The Inspector may seek assurance that, between the safety case claims, the civil engineering design substantiation, the specification of the design details and the construction competency of the contractors the dutyholder chooses to employ, there is a consistency of purpose.

76. The Inspector may wish to seek assurance regarding quality management and the adequacy of arrangements and processes that are targeted at achieving the required quality, so far as can be established during the development and pre-construction stage of the project. The Inspector may seek assurance that the civil engineering designers' intentions are specified in a manner that can be realised by competent contractors who employ suitably qualified and experienced personnel (SQEP).

2.11.3 Early contractor involvement (ECI)

77. As there is potential for the contractors' construction methods to undermine design assumptions, the Inspector should expect the designer and contractor(s) to engage in early dialogue regarding the methods to be used, the design intent and possible contractor 'optioneering', residual risks and areas of novel or unusual design. This is considered an important stage in the early communication of both the design and the assumptions made during the design to fulfil the safety case justification.

78. The Inspector should expect contract drawings, schedules and construction specification will include all design, workmanship, inspection and testing requirements to be fulfilled during the construction process. The Inspector may wish to seek assurance that the designer highlights risks arising from the design, as well as areas that might not represent 'normal' practice, in order to establish the practicality of the design proposal as early as possible. This is to ensure that the contractor understands the full requirements.

79. Early construction meetings between the designer and contractor are encouraged to discuss these issues. These could lead to the requirements for early test panels and mock-up requirements.

2.11.4 Pre-Construction Safety Report (where applicable)

80. Prior to the submission of the Pre-Construction Safety Report (PCSR), the Inspector should focus assessment on standards and principles being employed. The Inspector may wish to include the visibility of optioneering to demonstrate risks are reduced in line with the ALARP principles and the adequacy of the proposed construction assurance processes and associated arrangements in the assessment scope.

81. Following submission of the PCSR but prior to permissioning, the Inspector may wish to seek assurance in the adequacy of construction assurance processes, by reviewing documentation of proposed activities. In addition, activities subject to a permission or hold point by ONR should be fully defined. The Inspector may wish to seek assurance at this stage, with a demonstration that processes and arrangements are capable of delivering the requirements of the design and safety case, using examples and evidence of procedural adherence.

2.11.5 Design changes

82. The Inspector should expect design needs to be specified in a manner that is both understandable and achievable for the contractor. Failure to communicate and agree with the contractor these requirements will lead to formal design change requests later.

83. The Inspector should expect changes in design or materials subsequent to the completion of the design to be kept to a minimum, as determining the implications for the holistic design can require multi- disciplinary specialist knowledge and numerous design changes risk losing awareness by change aggregation.

84. For more discussion on design changes, see:

- TAG 17 Annex 1, 'Civil Engineering – Design',
- TAG 17 head document Section 5.9.5 'Modification'.

2.11.6 Competent contractors and Intelligent Customer

85. The Inspector should be aware of specific civil engineering nuclear safety training that is required for contractors. The Inspector should expect the key message to be clear, that future nuclear safety is related to the quality of work carried out on site. Training is often procured, and therefore should have an input from the Intelligent Customer function.

86. The Inspector should expect the Intelligent Customer to understand the importance of communication from the designer to the contractor regarding construction workmanship and quality, and their bearing on nuclear safety. The Inspector should expect the dutyholder to make arrangements for the contractor (or if not yet appointed, the Intelligent Customer) to attend design reviews during the pre-construction phase.

87. Further to this, the commencement of construction works whilst design is being undertaken can mean there is a change in the IC function. For more information, see:

- TAG 17 Annex 1, 'Civil Engineering - Design' Section 5 for the aspects where design is not wholly complete prior to the construction start.

88. For guidance on procurement of services and Intelligent Customer capabilities, see:

- ONR-NS-TAST-GD-49, 'Licensee Core Safety and Intelligent Customer Capabilities',
- ONR-NS-TAST-GD-077, 'Supply Chain Management Arrangements for the Procurement of Nuclear Safety Related Items or Services'.

89. For guidance on assessment of competence of SQEP contractors, see:

- ONR-NS-TAST-GD-027 'Training and Assuring Personnel Competence',
- ONR-NS-INSP-GD-010 'LC10 – Training'.

2.12 Construction Stage

90. Construction is the process of manufacturing and assembling the components of a facility, the carrying out of civil works, the installation of components and equipment and the performance of associated tests, either as part of new build construction or modification to existing civil engineering SSCs. The associated tests are those carried out to ensure that the structures, systems and components (SSCs) have been constructed, manufactured and installed in accordance with the design specifications.

2.12.1 Scope and sample area for construction stage

91. Major nuclear related construction projects are anticipated to include regulatory hold points. Following permissioning and commencement of construction, the Inspector may wish to focus on the arrangements in place for management and technical control, to seek demonstration that the completed construction works conform to the specified requirements:

- Firstly, to confirm the suitability and sufficiency of all that has been documented as the input to an assured construction process.
- Secondly, to ascertain those organisations responsible for construction activities fully understand the documented construction information.
- Thirdly, to confirm that construction is proceeding in a controlled, proven and validated manner.
- Fourthly, to seek assurance that appropriate action is taken in the event of non-conformance.
- Lastly to seek assurance that the civil engineering structures are being constructed as specified without undermining any design assumptions.

92. The Inspector is reminded to focus on-site inspections of construction activities on areas of highest nuclear safety significance where proportionately higher standards are required and / or on any novel or innovative techniques being employed in accordance with the 'graded approach'.

93. The Inspector should implement a proportionate oversight programme that is consistent with the construction plan / programme detailed by the dutyholder as part of its application for construction. The Inspector should regularly cross-check the intervention plan with the construction programme to ensure compatibility of timings, as the timescales for the construction programme may change.

2.12.2 Safety culture

94. Even if the design and commissioning are fully compliant with all safety requirements, a high level of safety can only be achieved when the construction is carried out with quality and nuclear safety in mind, since commissioning cannot test all aspects of the construction. The Inspector may wish to seek assurance that the dutyholder appreciates that all construction activities ultimately can have a potential impact on nuclear safety, even though there may be no nuclear material present during the construction.

95. The Inspector may wish to seek assurance regarding the adequacy of the site safety culture, as this can impact on quality of construction. The Inspector may wish to consider whether the culture is such that contractors are positively encouraged to report openly any potential non-conformances, no matter how they have arisen. The Inspector may wish to assess whether generally, a 'questioning attitude' and 'no blame culture' is adopted within the construction team.

96. For guidance on assessment of safety culture, see:

- ONR-NS-TAST-GD-080 ‘Challenge Culture Capability (including an Internal Regulation function), and the provision of Nuclear Safety Advice’.

97. The Inspector should consider the quality management systems and use of the dutyholder’s supply chain should be included in the scope of assessment, sampling areas across a range of construction activities. The Inspector should not assume that the same level of quality is achieved across all the contractors in the supply chain (and their sub-contractors). The Inspector should be aware that quality can differ between contractors, and quality can differ between the same contractor working in different areas across the site or under different contracts. As commercial arrangements can have an impact on quality, the Inspector may wish to seek assurance regarding contracts used on site and whether these may impact on quality, especially where contracts impose limits or restrictions on the work undertaken.

98. The Inspector should expect that appropriate quality systems are applied as necessary throughout all levels of a project supply chain in accordance with the requirements of licence condition LC 6 and LC 17. The Inspector may seek assurance that there is site wide procedural adherence from all parties involved in the quality assurance process.

99. For guidance on Licence conditions 6 and 17, see:

- ONR-NS-INSP-GD-006 ‘LC 6 – Documents, records, authorities and certificates’,
- ONR-NS-INSP-GD-017 ‘LC 17 – Management systems’.

2.12.3 Nuclear safety claims

100. As part of the assessment scope, the Inspector may wish to seek assurance that the contractors and subcontractors are sufficiently aware of the safety significance of the work that they have been contracted to do. Such awareness of safety should be ensured for all tasks, including more conventional construction tasks, since contractors may not have experience of working in the nuclear industry.

101. The Inspector should expect that a suitable contractor-proposed material approval system is implemented. When assessing this, the Inspector may wish to check how the material selection by the construction team within the specification is verified by the original designer against the original design intent (as translated into the specification). The objective of the check is to confirm the specification meets the original design intent and therefore also meets any claims on the safety case.

102. It is recognised that developments occur due to advances or innovation in construction (e.g. technology, research and experience). Whilst not discouraged, first-of-a-kind, novel or new methods / technologies could lead to an increase in non-conformances and rework and should therefore be subject to proportionate additional substantiation and adequate controls. The Inspector should expect activities to be undertaken to prove that a concept or new technology will not increase errors. Such activities may include; mock-ups, tests, trials etc. prior to the use for permanent nuclear safety significant civil engineering SSCs to demonstrate that the SFRs are achievable.

2.12.4 Confirmation of quality

103. The Inspector should consider observing contractor defined witness points in the surveillance or inspection of quality for significant construction works (ECE.18). The Inspector should expect testing requirements and acceptance criteria to be clearly stated in the specification and should incorporate standards appropriate to the categorisation and classification of the SSC in a ‘graded manner’. The Inspector may wish to consider whether requirements are incorporated into agreed quality management systems, including Inspection Test Plans or Quality Management Plans. The Inspector may wish

to review witness point control plans, and whether these are integrated within any overarching risk management processes. The Inspector should be aware that the use of approved contractor method statements may also act as a witness point and detail control over works on site.

104. As an example, when assessing site checking activities, the Inspector is reminded of the details in IAEA NS-G-3.6 'Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power plants' [20] specifically:

- Section 2, site investigation,
- Section 4, consideration for foundations,
- Section 7, monitoring of geotechnical parameters, for further details relating specifically to site investigation.

105. Under a 'graded approach', the Inspector should expect self-certification by the work originator of design and construct civil engineering SSCs whose failure would have no nuclear consequence. This can give adequate assurance of structural safety, provided there are appropriate systems in place for ensuring competence.

106. For safety critical items of plant, SSCs or nuclear related construction processes whose failure would have high consequences, the Inspector should expect third party independent certification should be used to give added assurance of quality and therefore nuclear safety (ECE.15 and ECE.24 can apply). The Inspector may wish to assess, at appropriate levels, throughout a supply chain, whether checks and certification are found between these two extremes, following the 'graded approach'.

107. There are a number of activities that take place during the final stages of construction that are closely linked with the commissioning stage. The Inspector may wish to seek assurance regarding the adequacy of the engagement with and input of SQEP responsible designers, dutyholder design teams and / or the construction organisation.

108. For information relating to specific functions and responsibilities in commissioning related to construction, the Inspector should refer to:

- IAEA SSG-28 'Commissioning for Nuclear Power Plants' [4].

2.12.5 Temporary Works

109. The Inspector may wish to seek assurance that the temporary works arrangements for civil engineering SSCs are adequate, specifically when the temporary works has the potential to impact the permanent construction of civil engineering SSCs with nuclear safety significance. The Inspector is reminded to liaise with the relevant Inspector from the conventional health and safety discipline regarding the interface between the two disciplines.

110. Temporary works should be coordinated on site in accordance with the most up to date version of the CDM Regulations, currently CDM2015 [3]. CDM2015 requires specific roles to be allocated, the Inspector may wish to seek assurance that these roles are filled, and the associated responsibilities are being fulfilled adequately with a process or procedure to describe the nature of the role. The dutyholders use of a Temporary Works register can provide assurance to the Inspector of the management of temporary works; where the register provides information on the categories and subsequent requirements for temporary works design checks which relate to the complexity of the temporary works proposed, in line with the requirements of BS5975:2019 [21].

111. A function of the CDM2015 regulations is to encourage co-operation between the permanent and temporary works teams. The Inspector may wish to seek assurance in the arrangements that manage the interface where permanent works support loadings from temporary works. The Inspector may wish to consider the potential impact the

temporary works could have on the permanent structure, if ill-conceived or executed. The integrity of temporary structures often relies on propping. The Inspector may wish to consider the arrangements in place to ensure the level and plan position of props; either in excavations or supporting works for adjacent structures. This is to give the Inspector confidence that the temporary works and temporary loading scenarios will not have an impact on the permanent structures; either the adjacent civil SSCs already in place or the civil SSCs being constructed.

112. The Inspector should note that other temporary structures can be in place to facilitate construction activities e.g. temporary retaining structures are often used in excavations to protect adjacent structures and services.

113. The Inspector is reminded of the potential implications of the propping arrangements in terms of access / egress and working areas and conditions and the potential impact these may have on the contractor achieving the required quality of the work (EHF.1, EHF.5 and EHF.6).

114. The Inspector should note the removal of temporary structures can need as much consideration as their installation, regarding potential impact on the permanent structure.

115. For other considerations for foundation or sub-surface structure construction, see:

- TAG 17 – Annex 3 ‘Ground investigations, geotechnics and underground structure design’.

2.12.6 Reinforcement and embedded items

116. Early contractor involvement in the design may be a key consideration of constructability. The constructability considerations of CDM2015 suggest these considerations are recorded in Designers Risk Assessments or a similar equivalent document. For embedded items or other metals cast into concrete, the Inspector may seek further assurance (through demonstration in mock-ups, site trials or otherwise) that the adequately accurate positioning of cast-in items can be achieved.

117. The same is true for highly congested areas of reinforcement, where mock-ups or site trials can confirm that the required levels of quality for the concrete pour are achievable. As discussed, the areas of high reinforcement for concrete foundations and underground structures are often not inspectable once the site is operational. In such a case, the construction records identifying construction quality is assured contribute to the safety case justification that the structure will meet the design requirements the full design life.

118. The Inspector may seek assurance that the processes in place for achieving the reinforcement placement and kicker levels are appropriate and that detailing of the use of lapping reinforcement or use of couplers is clear to the contractor. The Inspector should be aware that aggregation of individual tolerance can lead to a situation where the top levels are out of tolerance and may seek assurance that the dutyholder has arrangements in place to avoid this scenario.

119. The Inspector may wish to seek assurance that the contractor’s achievement of reinforcement levels and the dutyholders surveillance arrangements ensure the reinforcement is placed in line with the original design intent. This can include phased surveillance for very deep foundations where surveillance checks accuracy of sections of the foundation reinforcement, during the reinforcement installation. Without a parallel installation and surveillance process in place, the Inspector should note that some errors in reinforcement placement may be identified too late to be resolved, if several other layers of reinforcement have been laid on top, and so it is key for this to be considered early.

120. The Inspector should be aware that reinforcement placement may require reference to 3D models where de-clashing modelling has been undertaken as part of the design. In this scenario, the 2D drawings are drawn with average centres, but the 3D model after having 'de-clashed' the reinforcement may have slightly different spacing measurements to be used, which should be within the allowable tolerance of the reinforcement design. The use of de-clashing modelling can reduce the need for lapping or couplers and can make construction of embedded items easier. The Inspector should be aware this requires consistent understanding across the site regarding the processes to follow and in which sequence the drawings or 3D model takes precedent.

- Related to this, the Inspector may wish to consider which of these sources of data are 'the single source of the truth', and seek assurance of whether the appropriate levels of review, approval and verification have been adequately applied,
- The Inspector may wish to consider how the dutyholder controls versions of 2D drawings and 3D models, and how changes on site are captured e.g. spacings to accommodate clashes,
- The Inspector may wish to consider how the as-built data will be confirmed for foundations, especially concerning the use of couplers or other means to avoid clashes,
- As part of this clarification between two sources of information, the Inspector may wish to seek assurance in the adequacy of the process(es) in place to raise queries regarding the design, as well as how minor design changes will be approved and accepted prior to their implementation. This may have an interface with the organisational capability inspectors regarding procedural adherence, and conventional health and safety inspectors when considering the role of and duties of the Principal Designer as per CDM2015.

121. For more information on the use of computer tools to aid design, see:

- TAG 17 Annex 2 'Building Information Modelling'.

122. For information on the role and duties of the Principal Designer and other roles, see:

- L153 'Managing health and safety in construction' [3].

123. The Inspector may wish to seek assurance in the adequacy of arrangements in place to manage surveillance and other inspections that confirm quality has been achieved and accept the works as complete (ECE.18). The Inspector may wish to check that these processes produce clear indication of where inspections have been undertaken and where errors have been found and resolved. The Inspector may seek assurance that the inputs to this process i.e. drawings, clearly identify which levels of reinforcement are being inspected and which reinforcement layers are omitted for purposes of clarity of illustration.

124. The Inspector should be aware of the availability and adequacy of storage areas for materials on site, specifically reinforcement or other items that should not be cyclically wet and dry, such as insulation for membranes. The Inspector should also be aware of civil structures, systems or components (SSCs) that are manufactured off-site, including reinforcement bars. Where reinforcement bars are produced for a site, the Inspector may wish to consider the benefit of undertaking a supply chain inspection. Where civil SSCs are delivered to site, the Inspector should be aware of the process of supply chain and dutyholder inspection and acceptance of items, appreciating what happens if an item arrives at the site and does not have the required level of quality. During earthworks, although the site may be large, there may be few areas designated as storage, so the dutyholder might use the approach of 'just in time delivery'. The Inspector may wish to consider the risks associated with such an approach and seek assurance in how the dutyholder is mitigating these risks.

125. The Inspector may wish to consider the arrangements that are in place for lifting prefabricated reinforcement cages or other pre-welded or part installed and the potential this has for damaging the cage. The Inspector may choose to seek assurance the arrangements adequately consider the method of lifting through engineered lifting points, the welding of reinforcement, and minimising the distances lifted. The operational experience on dropped reinforcement cages should be referred to.

126. For further guidance, see:

- L113 ‘Approved Code of Practice for Lifting Operations and Lifting Equipment Regulations’ 1998 (LOLER) [22],
- ‘Stability of reinforcement cages prior to concreting’ TWF [23].

2.12.7 Concrete production and site readiness

127. As foundations and sub-surface structures are often the first elements to be constructed on a site, the Inspector should be aware of the ‘first of a kind’ nature of the works may be used (in part) to validate processes, procedures and/or methodology on first use. For other aspects of foundation or sub surface structures, see:

- TAG 17 Annex 3 – ‘Ground investigations, geotechnics and underground structure design’.

128. Due to the reliance on quality for structures that are underground and cannot be inspected again for the design life, the Inspector may wish to focus on the methods of construction, including extensive use of mock-ups and site trials to demonstrate increased and developed construction assurance is achieved.

129. The Inspector may seek assurance of the dutyholder’s ability to produce and quality assure the concrete mixes that are required by the site. There are likely to be several concrete mix types for different applications, but also to accommodate variations in different suppliers of the constituents of the concrete to achieve the requirements in the design specification. At the early stages of first concrete pours, the Inspector should note that the full suite of approved concrete mixes may not be available, but may seek assurance that sufficient testing and trials have been undertaken to prove the concrete mixes required at that time are adequate and consistent.

130. The Inspector may wish to seek assurance of the adequacy of the management arrangements in place regarding concrete pours, including that the workmanship quality is clearly articulated and understood by all parties. The specification requirements and quality should be achieved on the first nuclear safety significant pour. In order to achieve this, the Inspector should be aware that mock-ups and / or trials can be used on site to demonstrate quality. Other, non-nuclear safety significant structures can be constructed using the nuclear safety significant-grade concrete mix to afford some experience to the contractors to practice the workmanship and curing techniques without impacting on nuclear safety.

131. The Inspector may wish to seek assurance in the adequacy of the site readiness for concrete pours of structures that are significant to safety. There are specific considerations regarding contingency supplies for larger pours, and the Inspector may wish to assess the measures and arrangements in place to ensure continuity of production and adequate and consistent quality of the finished structure. The Inspector may pay more attention to (smaller) first-of-a-kind pours, as these may test the site processes and procedures for the first time. If the Inspector has awareness of other (smaller or non-nuclear significant) pours that have been undertaken with the same concrete mix, and has sight of the issues and resolutions of the same, this can add to Inspector confidence that the first concrete pour will be undertaken without resulting in significant defects, in line with the expectations of ECE.17.

132. For information on concrete for nuclear construction, see:

- 'Nuclear Construction Lessons Learned: best practice: concrete' [24].

2.12.8 Non-conformances and changes

133. The Inspector should be aware of activities that review the 'as-built' civil engineering SSCs against the original design parameters during construction and commissioning. The Inspector should expect adequate arrangements are established to address non-conformities in design, manufacturing, construction and operation. SAP ECE.19 establishes the expectation that the dutyholder's arrangements and processes should investigate and correct (or accept) non-conformances to explicitly adopt a graded approach including, where appropriate, categorisation and classification. The Inspector should expect resolutions to correct differences from the initial design to be documented as design changes, such that those made to the civil engineering SSC safety functional requirements during construction. The Inspector may wish to assess whether such changes are accurately recorded and whether their impacts are assessed in accordance with quality assurance and management requirements.

134. The Inspector should expect design changes that could have an impact on safety to be minimised after construction starts. The Inspector should expect any design changes that occur to be recorded by means of a well-defined change process. The Inspector should recognise that changes to the design and possible non-conformances may arise from various sources and for a variety of reasons during the construction process. The Inspector should expect that the dutyholder has a coordinated approach between the design and construction teams, to operate rigorous systems to capture, record, justify and implement any proposed changes or non-conformances, however they are initiated.

135. The Inspector may wish to seek assurance in the adequacy of arrangements and processes in place that cover the investigation of any non-conformances identified, whether they establish the root cause(s), with the aim of preventing recurrence. Non-conformances of safety significance should be resolved by means of a corrective and preventive action programme using the 'graded approach'. The Inspector should be aware of whether the aggregation of a number of more minor non-conformances leads to unforeseen consequential safety significant changes.

136. The Inspector may wish to seek assurance in the decision-making processes following the identification of a non-conformance, including the efficacy and adequacy of any delegated authorities from the design authority. The Inspector may wish to consider whether the processes and arrangements in place allow a suitably qualified and experienced personnel (SQEP) resource sufficient time and information to decide on the implications of each non-conformance proposal. The Inspector may wish to consider whether the process permits the decision to be fed-back to the relevant members of the design team for consideration and agreement (or challenge) to the change, as necessary, updating any design documentation as appropriate. The Inspector may wish to consider the formal and informal communication routes between the site and design teams and whether examples of non-conformances or design changes follow due process for the categorisation and classification of changes. The Inspector may wish to seek assurance that decisions made for non-conformance or design change proposal acceptance have undergone sufficient challenge according to their categorisation and classification.

137. The Inspector should be aware that processes in place to manage the design prior to construction may have changed as construction activities progressed. This may include processes requesting information from the design house, or for clarification purposes. The Inspector may wish to seek assurance as to whether these processes, originating from the design phase, are appropriate for the construction phase.

138. The Inspector should be aware of the differences between the terms ‘non-conformity’ and ‘non-conformance’; the first is a Quality Management term explicitly defined in the BS ISO 9000 series of Standards, whilst the second is a more general term that could relate to any construction defect.

2.12.9 Contractor Handover

139. The Inspector should be aware that the handover requires dutyholder oversight and acceptance through the Intelligent Customer function. The Inspector may seek assurance that the handover functions are supported by the dutyholder Intelligent Customer and other Design Authority surveillance activities that confirm the quality of completed areas meets the requirements of the works information or technical specification. For example, once the earthworks contractors have completed their scope of works, there is a handover between contractors, for the earthworks contractor to prove their works are completed as required and for the structural contractor to accept the area to begin their foundation or sub-surface structure construction. There may be other handovers between contractors where preparation works are handed to the construction team, or between structural completion to mechanical or electrical fit-out.

140. There may be occasions where there is a partial handover of a contractor-managed area, where a portion of the work areas can be handed over to another party, whilst there is ongoing construction in the remaining area. The Inspector may wish to sample the handover plans or other arrangements to manage multi-party work access to a contractor-managed area (EHF.1, EHF.5 and EHF.6).

141. The Inspector may wish to seek assurance of the adequacy of the processes in place for handover once construction is completed, including aspects of ‘commissioning’ the construction, which should include as built records, defect and non-conformance resolution etc. The Inspector should consider the other aspects of handover related to the area being a contractor-managed area to an operating facility, this will often happen once the inactive commissioning has been completed.

142. For earthworks contractor and early construction considerations, where handover arrangements may be immature, see:

- TAG 17 Annex 3 – ‘Ground investigations, geotechnics and underground structure design’.

2.12.10 Records

143. IAEA SSG-38 [4] states:

> “Comprehensive photographic records and, where appropriate, video records and computer simulations should be compiled, particularly for areas that will later be inaccessible or will be subject to high levels of radiation. Such information will facilitate the planning of work in these areas during commissioning, operation and decommissioning. Such visual records of as built conditions made during construction should show identification marks and should be comprehensively catalogued with descriptive captions. This will ensure that visual records made during subsequent inspections or maintenance work can be easily compared, and will help in any preparation for work”.

144. The Inspector may wish to seek assurance in the adequacy of the processes that are in place for records to be produced at the end of the construction project, to form the ‘as-constructed’ or ‘as-built’ records. The Inspector should be aware that records management and retention is often found to be an area for poor practice or sometimes records are not available due to the time delays in their production. The Inspector should expect that as-constructed records provide a fully referenced account of the work constructed. They should be produced in a timely manner as the information becomes

available throughout the contract, in line with the expectations of SAPs EMC.20 and DC.6.

145. SAP ECE.1 establishes the expectation that safety functions and structural performance of civil engineering SSCs will be specified. The Inspector may wish to consider the traceability of evidence of quality for items important to safety to extend through all civil engineering SSCs, including records evidencing materials, procedures, and other quality management documents, to evidence that items important to safety are constructed to the appropriate quality level for their safety required.

146. The Inspector should be aware of the expectations of SAPs MS.2, ECE.20, EQU.1 and DC.6 when assessing accurate record keeping and storage for future use of the documents, in line with Licence condition 6. The Inspector may wish to consider the records may be used as a record when considering future modifications to civil engineering SSCs, or for use as part of a safety justification for continued use after identification of ageing effects or damage. As such, the Inspector may wish to seek assurance that the records are sufficiently detailed for use in future by a party who has no involvement in the construction phase, and are stored appropriately to preserve the documents.

147. For more information on record keeping, see:

- ONR-NS-TAST-GD-033 ‘Dutyholder Management of Records’,
- ONR-NS-INSP-GD-010 ‘LC6 – Documents, Records, Authorities and Certificates’.

148. For more information on ageing effects and damage, see:

- TAG 17 Annex 5, ‘Ageing management and damaged structures’.

2.12.11 Asset Management

149. During the construction stage, the Inspector may wish to seek assurance in the adequacy of the asset management arrangements during construction to protect and maintain nuclear safety significant constructed items. The Inspector may wish to consider whether appropriate preventive or corrective maintenance is undertaken under a plan in order to maintain their functionality as required by the original design intent. The Inspector may seek assurance that the plan continues into commissioning and feeds into the maintenance programmes for operation.

2.12.12 Emergency preparedness

150. For sites with existing nuclear facilities, the Inspector should expect arrangements to be in place for emergency preparedness and response in accordance with Licence Condition (LC) 11, to ensure the safety of workers and the public in the case of an accident occurring at or affecting the construction site. The Inspector may wish to consider the adequacy of these arrangements in light of any new construction.

151. For information on emergency arrangements under LC 11, see:

- ONR-NS-INSP-GD-011 ‘LC 11 and REPPIR – Operators Emergency Arrangements’.

2.13 Operating experience and lessons learnt

152. For the purposes of this annex, lessons learnt ranges from formal workshops and operational experience, through to smaller scale on-site decisions relating to prevention of recurrence of non-conformances.

153. SAP MS.4 establishes the expectation for lessons to be learned from internal and external sources. There are numerous sources of relevant operational experience and lessons learnt that relate to construction, within and outside the nuclear industry. ONR's goal-setting regulatory framework and the requirement for dutyholder's to reduce risks in line with the ALARP principles, necessitates dutyholder's to demonstrate continuous improvement.

154. The Inspector should expect that construction reviews including lessons learnt will be undertaken, often after significant milestones in the project, following mock-ups or trails to capture learning, and regularly as part of normal business to facilitate continual improvement.

155. The Inspector should expect that learning processes incorporate the review of all relevant events and information, including factors which had a direct influence on the outcome and peripheral factors which may have had an influence.

156. The Inspector should expect lessons learnt exercises to be undertaken after any significant non-conformances, defects or other such unplanned outcomes to prevent reoccurrence (MS.4). The Inspector may wish to seek assurance that lessons learnt activities adequately capture the root cause of issues, identifying whether there were indications or near-misses that were not captured as warnings of an event.

3 RELEVANT STANDARDS AND GOOD PRACTICE

157. This section provides a summary of the relevant guidance for inspectors to be aware of, along with sources for further information that provide useful background.

158. The Inspector is advised to ensure these guides are the most up to date, given the review period of the TAG.

159. Note the lists provided are not full and comprehensive lists. The Inspector should only use the guidance that is relevant to the scenario being assessed and seek other appropriate guidance to suit the circumstances.

3.1 ONR Technical Assessment Guides (TAGs) and Technical Inspection Guides (TIGs)

160. Quality assurance and design assurance are inextricably linked to the issues surrounding construction assurance. A number of existing TAGs are relevant to these specific topic areas and the management thereof.

161. This annex should be read in conjunction with other relevant TAGs including, but not limited to, the following:

- ONR-NS-TAST-GD-057 'Design Safety Assurance',
- ONR-NS-TAST-GD-016 'Integrity of Metal Structures, Systems and Components'
- ONR-NS-TAST-GD-077 'Supply Chain Management Arrangements for the Procurement of Nuclear Safety Related Items or Services',
- ONR-NS-TAST-GD-049 'Licensee Core Safety and Intelligent Customer Capabilities',
- ONR-NS-TAST-GD-005 'Demonstration of ALARP (As Low as Reasonably Practicable)',
- ONR-NS-TAST-GD-009 'Examination Inspection Maintenance and Testing of Items Important to Safety',
- ONR-NS-TAST-GD-020 'Civil Engineering Containments for Reactor Plants',
- ONR-NS-TAST-GD-067 'Pressure Systems Safety',
- ONR-NS-TAST-GD-026 'Decommissioning',
- ONR-NS-TAST-GD-027 'Training and Assuring Personnel Competence',
- ONR-NS-TAST-GD-048 'Organisational Change',

- ONR-NS-TAST-GD-051 ‘The Purpose, Scope and Content of Safety Cases’,
- ONR-NS-TAST-GD-060 ‘Procedure Design and Administration Controls’,
- ONR-NS-TAST-GD-061 ‘Staffing Levels and Task Organisation’,
- ONR-NS-TAST-GD-065 ‘Function and Content of the Nuclear Baseline’,
- ONR-NS-TAST-GD-079 ‘Licensee Design Authority Capability’,
- ONR-NS-TAST-GD-080 ‘Challenge Culture Capability (including an Internal Regulation function), and the provision of Nuclear Safety Advice’,
- ONR-NS-TAST-GD-094 ‘Categorisation of Safety Functions and Classification of Structures Systems and Components (SSCs)’,
- ONR-NS-TAST-GD-098 ‘Asset Management’,
- ONR-NS-TAST-GD-033 ‘Dutyholder Management of Records’.

162. Whilst general reference is made within this Annex to issues relating to both quality and design assurance during the design and construction stages, more detailed information may be found within the following:

- ONR-NS-INSP-GD-010 ‘LC6 – Documents, Records, Authorities and Certificates’
- ONR-NS-INSP-GD-010 ‘LC10 - Training’,
- ONR-NS-INSP-GD-011 ‘LC11 – Emergency Arrangements and REPPIR’
- ONR-NS-INSP-GD-014 ‘LC14 – Safety Documentation’,
- ONR-NS-INSP-GD-017 ‘LC17 - Management systems’,
- ONR-NS-INSP-GD-019 ‘LC19 - Construction and installation of New Plant’,
- ONR-NS-INSP-GD-020 ‘LC20 – Modification to Design of Plant Under Construction’,
- ONR-NS-INSP-GD-021 ‘LC21 - Commissioning’,
- ONR-NS-INSP-GD-022 ‘LC22 – Modification or Experiment on Existing Plant’,
- ONR-NS-INSP-GD-025 ‘LC25 – Operational Records’,
- ONR-NS-INSP-GD-026 ‘LC26 – ‘Control and Supervision of Operations’,
- ONR-NS-INSP-GD-028 ‘LC28 – Examination, Inspection, Maintenance and Testing EIMT’,
- ONR-NS-INSP-GD-035 ‘LC35 Decommissioning’,
- ONR-NS-INSP-GD-051 ‘The Regulation of Conventional Health and Safety on GB Nuclear Sites’,
- ONR-NS-INSP-GD-011 ‘LC 11 and REPPIR – Operators Emergency Arrangements’.

3.2 UK Regulations

- Construction (Design and Management) Regulations 2015 (CDM2015),
- Section 34 of the Environmental Protection Act 1990,
- UK Building Act 1984 and Building Regulations 2010,
- The Electricity at Work Regulations 1989,
- Control of Substances Hazardous to Health Regulations (as amended) (COSHH 2002),
- Working at Height Regulations 2005,
- The Confined Spaces Regulations 1997,
- The Waste (England and Wales) Regulations 2011 (as amended), the Hazardous Waste Regulations 2005 and the Controlled Waste Regulations 2012 and the Special Waste Regulations 1996 (for Scotland, SEPA).

3.3 Licence Conditions

163. This TAG does not specifically address a single licence condition or group of Safety Assessment Principles but concerns an area of activity which is of regulatory interest.

164. It should be noted that the Nuclear Installations Act 1965 [25] makes specific reference to construction and modification as activities which may be subject to licence conditions and places duties on a dutyholder to ensure that the conditions of the site licence are complied with.

- Licence conditions 14; 17; 19; 20; 22 are the most relevant licence conditions requiring the dutyholder to make and implement adequate arrangements.
- Licence condition 14, relating to safety documentation, requires that the dutyholder “shall make and implement adequate arrangements for the production and assessment of safety cases consisting of documentation to justify safety during the design, construction, manufacture, commissioning, operation and decommissioning stages of the installation.”
- Licence condition 17, relating to management systems, requires the dutyholder to “make and implement adequate quality management arrangements in respect of all matters which may affect safety”.
- Licence condition 19, relating to construction or installation of new plant, requires that where the dutyholder “proposes to construct or install any new plant which may affect safety”, the dutyholder “shall make and implement adequate arrangements to control the construction or installation.”
- Licence condition 20, relating to modification to design of plant under construction, requires that the dutyholder “shall ensure that no modification to the design which may affect safety is made to any plant during the period of construction except in accordance with adequate arrangements made and implemented.”
- Licence condition 22, relating to modification or experiment on existing plant, requires that the dutyholder “shall make and implement adequate arrangements to control any modification or experiment carried out on any part of the existing plant or processes which may affect safety.”
- By the very nature of the subject and potential effect on safety there are many other possible relevant licence conditions including LC 26 - control and supervision of operations; LC 25 operational records; LC 12 duly authorised and other suitably qualified and experienced (SQEP) persons and LC 11 emergency arrangements.

3.4 UK Policy

- UK National Policy for siting of nuclear power plants e.g. Department of Energy and Climate Change, National Policy Statement for Nuclear Power Generation (EN-6) [8].

3.5 Associated UK HSE Guidance (L Series, HSG, INDG and RR Series)

Legal (L) Series

- L153 Managing Health and Safety in Construction Approved Code of practice for CDM 2015 [3],
- L101 Safe work in confined spaces. Confined Spaces Regulations 1997 Approved Code of Practice, Regulations and guidance [19].

Health and Safety Guide (HSG) Series

- HSG65 Managing for Health and Safety 2013,
- HSG 159 Managing Contractors,
- HSG268 The health and safety toolbox: how to control risks at work 2014.

Industry Guidance (INDG) Series

- INDG411 A quick guide for clients on CDM 2015.

Research Report (RR) Series

- HSE RR319 - Safer foundations by design (buildability).

3.6 International Guidance (IAEA, WENRA and NUREG)

165. IAEA guidance including, but not limited to:

- The IAEA Safety Standards GSR Part 2 'Leadership and Management for Safety'.
- GS-G-3.1 'Application of the Management Systems for Nuclear Power Plants'.
- GS-G-3.5 'Management System for Nuclear Installations' Appendix V.

provide guidance on quality management, assurance aspects and management systems guidance applicable to construction activities.

166. Other relevant guidance can be found within:

- SSR-2/1 'Safety for Nuclear Power Plant (NPP) Design'.
- SSR-1 'Site evaluation for nuclear installations', section 6 on quality control.

Specific Safety Guides:

- SSG-38 'Construction for Nuclear Installations' [4],
- SSG-28 'Commissioning for Nuclear Power Plants'.

167. Western European Nuclear Regulators Association (WENRA):

- Safety Reference Levels for Existing Reactors, 24th September 2014.

168. United States Nuclear Regulatory Commission guidance including, but not limited to:

- Regulatory Guide 4.7, 'General Site Suitability Criteria for Nuclear Power Plants',
- Regulatory Guide 1.132, 'Site Investigations for Foundations of Nuclear Power Plants',
- Regulatory Guide 1.138, 'Laboratory Investigations of Soils and Rocks for Engineering Analysis and Design of Nuclear Power Plants',
- Review of Safety Analysis Reports for Nuclear Power Plants NUREG-0800.

3.7 Design standards and industrial guidance

3.7.1 Temporary works

- BSI, BS 5975:2019 Code of practice for temporary works procedures and the permissible stress design of falsework, London, BSI, 2019,
- Peter Pallett's article "a viewpoint on temporary works procedures" is published in the CONCRETE magazine for February 2019 Volume 31 Issue 01 This article, with clear colour diagrams, gives readers a summary of the terms and procedures adopted by BS5975:2019 [26],
- Eurocode 0: Basis of Structural Design,
- ICE Forensic Engineering Volume 167 Issue FE2, 'Revisiting Bragg to keep UK's temporary works safe under EuroNorms' [27],
- HSE – Sector Information Minute (SIM) 02/2010/04 - The management of temporary works in the construction industry [28].

3.7.2 Reinforcement

- BS 4449:2005 +A3:2016 - Steel for the reinforcement of concrete - Weldable reinforcing steel - Bar, coil and decoiled product – Specification,
- BS 7973–1:2001 - Spacers and chairs for steel reinforcement and their specification. Part 1 - Product performance requirements. Part 2 - Fixing and application of spacers and chairs and tying of reinforcement,
- BS8000-2.2 - workmanship on building sites – in-situ and pre-cast concrete,
- BS8666:2005 - Scheduling, dimensioning, bending and cutting of steel reinforcement for concrete – Specification,

- BS EN ISO 17660:2006 Welding of Reinforcing Steel: Part 1- Load-bearing welded joints; Part 2 - Non load-bearing welded joints,
- CIRIA SP118 (1995) - Steel Reinforcement – a handbook for young construction professionals [27],
- Stability of reinforcement cages prior to concreting Temporary Works Forum [23],
- Concrete Society - Concrete on site 2 – Reinforcement http://www.concrete.org.uk/publications-concrete-on-site.asp [29],
- IStructE - Standard method of detailing structural concrete (Third Edition) June 2006 and associated Technical Guidance Notes.

3.7.3 Operational experience

169. The below list is illustrative only and not exhaustive but incorporates some useful prompts for inspectors with respect to relevant OPEX events and lessons learnt.

- First Construction Experience Synthesis Report: https://www.oecd-nea.org/nsd/docs/2012/cnra-r2012-2.pdf ,
- Second Construction Experience Synthesis Report: https://www.oecd-nea.org/nsd/docs/2015/cnra-r2015-4.pdf ,
- Guidance on best practice: concrete [24],
- Engineering the Future, Nuclear Lessons Learned, Overarching lessons learnt report [30],
- Engineering the Future, Nuclear Lessons Learned, Guidance on best practice: nuclear safety culture [7],
- Engineering the Future, Nuclear Construction Lessons Learned, Guidance on best practice: concrete [24],
- Guidance on Best Practice: Welding [31],
- Project Management in Nuclear Power Plant Construction: Guidelines and Experience [32],
- Construction Technologies for Nuclear Power Plant Construction [3333].

4 REFERENCES

1. ONR, 'Safety Assessment Principles for Nuclear Facilities', 2014 Edition, Rev 0, November 2014, www.onr.org.uk/saps/saps2014.pdf.

2. ONR Security Assessment Principles for the Civil Nuclear Industry (SyAPs) 2017 Rev. 0 www.onr.org.uk/syaps (last accessed November 2020).

3. Construction (Design and Management) Regulations 2015 (CDM2015) www.legislation.gov.uk (last accessed November 2020).

   See also HSE guidance L153 'Managing health and safety in construction' 2015 www.hse.gov.uk (last accessed November 2020).

4. IAEA Safety Guide SSG-38 "Construction for Nuclear Installations" www.iaea.org (last accessed November 2020).

5. International Nuclear Safety Advisory Group (INSAG), IAEA Safety Series 75-INSAG-4, 1991 Safety Culture www.iaea.org (last accessed November 2020).

6. International Nuclear Safety Advisory Group (INSAG), IAEA Safety Series INSAG-15 2002 www.iaea.org (last accessed November 2020).

7. ISBN: 1-903496-75-6, Engineering the Future, Nuclear Construction Lessons Learned, Guidance on best practice: nuclear safety culture 2012 (CM9 2020/314991).

8. Department of Energy and Climate Change (DECC) National Policy Statement for Nuclear Power Generation (EN-6) Volume 1 & 2 Planning for new energy infrastructure 2011 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/47859/2009-nps-for-nuclear-volumeI.pdf (last accessed November 2020).

   https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/47860/1943-nps-nuclear-power-annex-volII.pdf (last accessed November 2020).

9. ANSI/AISC 360-16, American Institute of Steel Construction, Specification for Structural Steel Buildings.

10. ANSI/AISC 341-16, American Institute of Steel Construction, Seismic Provisions for Structural Steel Buildings.

11. ANSI/AISC N690-12, American Institute of Steel Construction, Specification for Safety-Related Steel Structures for Nuclear Facilities.

12. ACI 349/13, American Concrete Institute Code requirements for Nuclear Safety-Related Concrete Structures.

13. UK CARES; www.ukcares.com (last accessed November 2020).

14. British Construction Steelwork Association, BCSA, www.steelconstruction.org (last accessed November 2020).

15. International Masonry Society, IMS, www.masonry.org.uk (last accessed November 2020)

16. 'the Centre for Digital Built Britain' (CDBB) https://www.cdbb.cam.ac.uk/ (last accessed November 2020).

17. Nuclear Industries Security Regulations 2003 NISR www.legislation.gov.uk (last accessed November 2020).

18. Service Series No. 24, IAEA CORR Guidelines, Preparing and Conducting Review Missions of Construction Project Readiness for Nuclear Power Plants.

19. HSE guidance L101 Safe work in confined spaces. Confined Spaces Regulations 1997 Approved Code of Practice, Regulations and guidance. www.hse.gov.uk (last accessed November 2020).

20. IAEA NS-G-3.6 'Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power plants' https://www.iaea.org (last accessed November 2020).
21. BS5975:2019 Code of Practice for Temporary Works procedures and the permissible stress design of falsework.
22. Lifting Operations and Lifting Equipment Regulations (LOLER).
23. 'Stability of reinforcement cages prior to concreting' Temporary Works Forum Oct 2013 TWf2013:01 (2020/314995).
24. 'Nuclear Construction Lessons Learned: Guidance on best practice: concrete' (2020/314996).
25. Nuclear Installations Act 1965.
26. CONCRETE magazine - Peter Pallett "A viewpoint on temporary works procedures" February 2019 Volume 31 Issue 01 (2020/314998).
27. ICE Forensic Engineering Volume 167 Issue FE2, 'Revisiting Bragg to keep UK's temporary works safe under EuroNorms' - Re-visiting Bragg to keep UK's temporary works safe under EuroNorms (ice.org.uk) (last accessed November 2020) CM9 2020/315000
28. HSE – Sector Information Minute (SIM) 02/2010/04 - The management of temporary works in the construction industry (2020/315024) https://www.hse.gov.uk/foi/internalops/sims/constrct/2_10_04.htm. (last accessed November 2020).
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30. Engineering the Future, Nuclear Lessons Learned, Overarching lessons learnt report (2020/315002).
31. Engineering the Future, Nuclear Construction Lessons Learned: Guidance on Best Practice: Welding 2012 (2020/315003).
32. Nuclear Energy Series NP-T.7, IAEA Project Management in Nuclear Power Plant Construction: Guidelines and Experience www.iaea.org (last accessed November 2020)
33. Nuclear Energy Series NP-T-2.5, IAEA Construction Technologies for Nuclear Power Plants www.iaea.org (last accessed November 2020)