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No. 86

Guidelines on Training Syllabi in Non-destructive Testing for Civil Engineering (NDT-CE)

GUIDELINES ON TRAINING SYLLABI IN NON-DESTRUCTIVE TESTING FOR CIVIL ENGINEERING (NDT-CE)

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GUIDELINES ON TRAINING SYLLABI IN NON-DESTRUCTIVE TESTING FOR CIVIL ENGINEERING (NDT-CE)

INTERNATIONAL ATOMIC ENERGY AGENCY
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FOREWORD

The IAEA has consistently taken a proactive role in advancing the adoption and application of non-destructive testing technology. This commitment is exemplified through various initiatives, including national and regional technical cooperation projects. Through this cooperation, Member States have initiated national programmes for the training and certification of non-destructive testing personnel based on ISO standards. As part of these efforts, the IAEA has been actively involved in developing training materials and guidelines which have been instrumental in developing significant institutional and human capacity and technical infrastructure in Member States.

In response to the expressed needs of Member States, the IAEA has promoted the development of non-destructive testing capabilities for civil engineering, during maintenance and before and after a catastrophic event. Under the framework of several technical cooperation projects, the IAEA has been training non-destructive testing professionals to build up a team capable of assessing the condition of civil structures. The IAEA is assisting them in establishing networks in Asia and the Pacific, Latin America and Europe to share experience, expertise and equipment when a catastrophic event occurs.

To ensure uniformity and harmonization in training related to non-destructive testing for civil engineering, this publication has been developed as a reference on training syllabi for methods and techniques used in civil structures inspection. It will not only be used as a guideline for IAEA experts in conducting training courses to provide consistency and uniformity in the training provided but will also serve as a reference for Member States in developing materials for training programmes for the competency of personnel in non-destructive testing for civil engineering. This publication, as previous publications related to non-destructive testing published by the IAEA, will continue to play an important role in international harmonization of non-destructive testing training and certification.

The IAEA officers responsible for this publication were H.A. Affum and G. Maghella-Seminario of the Division of Physical and Chemical Sciences.

CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

Civil structures, including buildings, bridges, dams, tunnels and infrastructure, are critical components of public safety and national infrastructure. The inspection of these civil structures becomes more relevant due to the ageing process and the occurrence of natural disasters. Non-Destructive Testing (NDT) techniques are essential in the inspection of civil structures to detect and identify defects, cracks, voids, reinforcement corrosion, and other structural issues to assess the integrity, safety, and durability of various structural components such as foundations, columns, beams, slabs, and other concrete elements without causing damage [1–2]. These NDT techniques help engineers and inspectors to evaluate the structural health of civil structures, ensuring their reliability and preventing potential failures. In the nuclear power industry for example, the application of NDT is particularly vital due to the stringent safety standards and the potential consequences of failures. NDT provides essential means for determining structural properties and assessing concrete conditions, as well as evaluating material properties of hardened concrete in existing structures and repairs. Often in practice, the most effective approach is to use a combination of NDT methods and techniques (radiation and non-radiation), as no single testing technique can detect all potential degradation factors. By employing a comprehensive array of NDT methods, nuclear power plants can maintain high levels of safety, efficiency, and compliance with regulatory standards. This comprehensive approach is also applicable to other related industries that rely on NDT to ensure safety and reliability.

Training in NDT inspection methodologies and procedures is fundamental for fulfilling the compulsory requirements for qualification examinations that lead to third-party certification in accordance with recognized standards. Having qualified and certified personnel is vital for establishing a comprehensive and sustainable national infrastructure for structural and public safety, which is essential for protecting people from the harmful effects of failures or catastrophes. Especially important to the effectiveness of such an infrastructure is the high-level education and training of inspection personnel, regulators, future decision makers, as well as key personnel from relevant national bodies such as technical support organizations. NDT training at Level 1 provides basic instruction for personnel to perform specific NDT methods under supervision. Trainees learn the principles of NDT, proper use and maintenance of equipment, execution of tests according to instructions, and safety protocols, focusing on detecting discontinuities or defects and accurately reporting results without being responsible for choosing methods or interpreting results. At Level 2, training advances personnel’s skills, enabling them to set up and calibrate equipment, conduct and supervise tests, interpret and evaluate results, and document findings. These personnel develop and apply NDT instructions, guide Level 1 personnel, and ensure compliance with standards. Training at Level 3 prepares trainee to establish and direct NDT programs, develop and approve procedures, and interpret codes and standards. These personnel possess comprehensive knowledge of NDT methods, solve complex problems, and play a critical role in quality assurance and regulatory compliance within an organization [4].

1.2. OBJECTIVE

This publication provides requirements and information on training syllabuses for methods and techniques in NDT for civil engineering (NDT-CE). It was developed as a reference for NDT trainers, training organizations, and certification bodies, detailing the subject matter and the content for each level of certification. The format of the content is consistent with ISO/TS 25107:2019 [5].

1.3. SCOPE

All information for training syllabuses described in this publication covers both theory and practical, and with the intention of harmonizing and maintaining the general standard of training of NDT personnel for civil structure inspection. It also establishes the minimum requirements for effective structured training for NDT-CE personnel to ensure eligibility for qualification examinations leading to third-party certification according to recognized standards.

1.4. STRUCTURE

As the evaluation of civil structures and its applications are distinct and sufficiently different, training on the general knowledge of concrete should be addressed separately. Consequently, training on the general knowledge of concrete is a mandatory requirement for each level of competency in NDT-CE, and therefore is included as a separate section.

Since there are many methods and techniques of inspection in NDT-CE, they are grouped based on the fundamental principles of their application as follows:

- Mechanical and measurement;
- Electrical and magnetic;
- Acoustics;
- Radiation.

A table prior to detail description of syllabus for each method and technique provides the training percentage for each level, from the proposed total hours for every area of knowledge.

All training should be followed by an examination and could lead to a certification. Examination and certification processes are not covered by this publication, but detailed information about this can be found in ISO 9712 standard [4].

2. GENERAL KNOWLEDGE ON CONCRETE

General knowledge and understanding of concrete are essential for NDT practitioners conducting inspections on civil structures. Without the foundational knowledge in concrete, the primary constituent of many civil structures, jeopardizes the precision and reliability of NDT inspections [6]. Additionally, the inability to accurately interpret inspection findings within the context of concrete's behaviour can lead to erroneous conclusions regarding structural stability and safety.

Proficiency in concrete properties aids in the optimal selection of NDT methods, enhancing accuracy and minimizing unnecessary maintenance interventions. It bridges the gap between theoretical understanding and practical application, enabling NDT practitioners to accurately evaluate structural integrity, make informed recommendations, and contribute significantly to the resilience and safety of civil structures. Therefore, training on the general knowledge of concrete is a mandatory requirement before a candidate is allowed to take part in training on any methods and techniques in NDT-CE.

Ultimately, the knowledge enables NDT practitioners to contribute significantly to the safety, resilience, and overall health of civil structures.

The general knowledge on concrete training only covers the theoretical aspects of concrete technology and needs to correspond with Tables 1 and 2.

TABLE 1. GENERAL CONTENT FOR GENERAL KNOWLEDGE ON CONCRETE

	Content	Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
1.1	Properties of concrete	33	33	33
1.2	Structural concepts of concrete	33	33	33
1.3	Defects and damages of concrete	34	34	34
	Total Hours	**24**	**36**	**20**

TABLE 2. GENERAL KNOWLEDGE ON CONCRETE — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
2.1 Properties of concrete	Basic knowledge	Reinforced concrete structure	X	X	X
		Basic components	X	X	X
		History and evolution	X	X	X
		Interaction between components		X	X
		Stress and strain in concrete material	X		X
		Stress-strain diagram		X	X
		Structural behaviour under compression loads	X	X	X
		Structural behaviour under bending and tensile loads	X	X	X
		Structural properties	X	X	X
		Concrete classification	X	X	X
		Textures and finishing	X	X	X
	Concrete materials	Cement		X	X
		Coarse aggregates	X	X	X
		Fine aggregates	X	X	X
		Water	X	X	X
		Additives		X	X
		Causes of concrete anisotropy and variability of properties	X	X	X
	Concrete mix proportioning, mixing and placing	Chemical principles	X	X	X
		Cement hydration		X	X
		Importance of water / cement (W/C) ratio	X	X	X
		Preparation of new concrete	X	X	X
	Reinforcement	Steel reinforcements	X	X	X
		Reinforcement uses	X	X	X

TABLE 2. GENERAL KNOWLEDGE ON CONCRETE — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Steel properties and strength	X	X	X
		Fibre reinforcements		X	X
	Main constructions	Types of construction	X	X	X
	Main elements of constructions structural behaviour	Typical functioning	X	X	X
		Forms		X	X
		Role of reinforcement		X	X
		Changes of behaviour		X	X
2.2 Structural concepts of concrete	Construction methods	Types of methods	X	X	X
	Geometrical sizes and tolerances	Nominal dimensions, deviations, and tolerances	X	X	X
	Structural behaviour	Variability in dimensions of structural elements	X	X	X
		Cast in place and precast concretes	X	X	X
		Rebars separators and positioners	X	X	X
	Construction methods	Movements and deformations of forms during concreting	X	X	X
2.3 Defects and damages of concrete	Geometrical sizes and tolerances	Loads and project loads		X	X
		Nominal dimensions and change of shapes		X	X
		Cambers and form deformations		X	X
		How loads changes in case of construction change shape		X	X
		How changes in shape can affect serviceability of the structure		X	X
		Changes in shape by loads		X	X
		Change in shapes by concrete volumetric changes		X	X
		Change in shapes with time		X	X
		Rheologic performance		X	X
		Cracks in concrete	X	X	X
		Joints		X	X
		Corrosion		X	X
		Type of damages		X	X

3. MECHANICAL AND MEASUREMENT

3.1. REBOUND HAMMER

Rebound hammer is a handheld, NDT device used for inspecting and assessing the quality of concrete structures. This portable tool helps engineers, construction professionals, and inspectors evaluate the compressive strength and overall integrity of concrete surfaces.

The test method operates on the principle of measuring the rebound of a hardened steel hammer mass when it impacts the concrete surface under a standardized force. This rebound value is then correlated to the compressive strength of the concrete, allowing inspectors to estimate the concrete's structural health and durability.

Rebound hammer testing is particularly valuable for assessing concrete in-situ, such as walls, columns, and pavements. It offers a quick and convenient method for evaluating concrete without causing damage. However, it's important to note that while rebound hammer results provide a useful indication of concrete strength, they are not as precise as laboratory testing methods like compression testing. Therefore, rebound hammer measurements are often used as a preliminary assessment to identify areas that may require further investigation or more comprehensive testing.

Rebound hammer training which covers theory and practical sessions needs to correspond with Tables 3 and 4.

TABLE 3. GENERAL CONTENT FOR REBOUND HAMMER

	Content	**Level 1 (% of total duration)**	**Level 2 (% of total duration)**	**Level 3 (% of total duration)**
3.1	Introduction to rebound hammer	9	3	3
3.2	Physical principles of the method and associated knowledge	6	6	6
3.3	Product knowledge and capabilities of the method and its derived techniques	3	3	3
3.4	Equipment	6	6	5
3.5	Information prior to testing	6	6	7
3.6	Testing	21	6	6
3.7	Evaluation and reporting	33	42	42
3.8	Assessment	0	6	6
3.9	Quality aspects	6	12	10
3.10	Developments	10	10	12
	Total Hours	**12**	**12**	**12**

TABLE 4. REBOUND HAMMER — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
4.1 Introduction to rebound hammer	History	Measurement of concrete strength	X		
		On site sampling	X		
	Purpose of NDT	Definition of (NDT)	X		
		Partially destructive test (PDT)	X		
		Application of NDT	X		

TABLE 4. REBOUND HAMMER — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
		The importance of NDT	X		
		NDT personnel	X		
		Main NDT methods	X		
	Purpose of rebound hammer test	Definition	X		
		Applicability and limitations	X		
	Relevant standards	Standards and regulations	X	X	X
4.2 Physical principles of the method and associated knowledge	Basic physical principles	Rebound number	X		
		Rebound hammer test objective	X		
	Advanced physical principles	Limitations of the test method	X	X	X
		Correlation between rebound number to other property of concrete		X	X
		Influence of concrete age	X	X	X
		Influence of carbonation of concrete surface		X	X
4.3 Product knowledge and capabilities of the method and its derived techniques	Related capability of the method and derived techniques	Strength of concrete related to surface hardness.	X	X	X
		Strength of mortar in masonry	X	X	X
		Variability of the strength within a structure	X	X	X
		Strength of the stone in stone works	X	X	X
4.4 Equipment	Description of basic equipment	Description of the rebound hammer	X		
		Types of rebound hammers	X		
		Description of the steel reference anvil	X		
		Verification of rebound hammer	X		
		Abrasive stone	X		
		Vision of the instrument and of the other devices	X		
	Other types or alternative equipment	Use of other hammer		X	X
		Principles of functioning of non-standard hammers		X	X

TABLE 4. REBOUND HAMMER — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Vision of alternative instrument and of the other devices		X	X
4.5 Information prior to testing	Operating principles	Analyze the internal procedures / Manufacturer's instructions to use the device	X		
		Test location	X	X	X
		Representability of the test		X	X
		Number of measurements of testing		X	X
		Minimum number of impacts per test location	X	X	
4.6 Testing	Preparation	Selection of a rebound hammer		X	X
		Initial verification	X		
		Selection of test location		X	X
		Preparation of the area	X		
	Execution	Operating according to the instruction	X		
	Reading the results	Faulting and repetition of test, in cases where rebound hammer readings are invalids	X		
		Correlation between rebound number and concrete strength		X	X
	Factors influencing the results	Proper choice of the operative area in compliance with the structural requirements		X	X
		Analysis of factors that influence the selection of test locations		X	X
	Verification / Calibration	Specifications according to every equipment	X		
		Periodic verification / calibration of equipment		X	X
	Operating procedure	Standard operating procedure (SOP)	X	X	X
	Advanced practice	Dismantling and maintenance of		X	X

TABLE 4. REBOUND HAMMER — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
		equipment according to instruction			
4.7 Evaluation and reporting	Reporting	Data quality assessment	X		
		Record on worksheet	X		
		Practical writing of a test report	X		
	Evaluation	Practical interpretation of a test report		X	X
		Correlation of the test results with concrete strength		X	X
		General survey and evaluation of the test and data quality		X	X
4.8 Assessment	Conformity assessment of test report	Accuracy of measurement		X	X
		Assessing the reliability of the records		X	X
		Assessment according to the technical specification		X	X
4.9 Quality aspects	Documents	National and international standards			X
		Issue of testing procedures			X
	Procedures and its contents	Concept		X	X
		Application		X	X
		Development/ creation		X	X
		Essential components of procedures		X	X
		System verification		X	X
		Data quality		X	X
		Coverage of inspection area		X	X
	Personnel qualification	ISO 9712		X	X
		Other NDT qualification and certification systems		X	X
	Factors affecting results	Quality and cleaning of the surface	X		
		Characteristics of the concrete	X	X	X
		Thickness of concrete section related with impact energy	X		
		Presence or low cover of rebars		X	
		Carbonation		X	
		Age of concrete		X	

TABLE 4. REBOUND HAMMER — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Mis-calibration of device	X		
		Superficial humidity		X	
		Hits on rebars, coarse aggregate or holes	X		
		Misalignment of the impact (device not at 90°)	X		
		Concrete sample not rigid		X	
	Other aspects	Supplementary inspections			X
		Further quality assurance measures			X
	Supplementary investigations	Other NDTs		X	X
4.10 Developments	Advancement	Automated recording of results			X
		Combined method (sonic vs penetration)			X

3.2. PENETRATION RESISTANCE TEST

Penetration resistance test is an NDT method used in civil engineering to assess the surface hardness and strength of concrete structures. This method involves applying a known force to a specialized penetrometer or penetration resistance tester, which is pressed against the concrete surface.

As the penetrometer's tip penetrates the concrete, the resistance encountered is measured. This resistance is an indicator of the concrete's compressive strength and durability at the surface level. The depth of penetration and the force required to achieve it are used to estimate the concrete's quality.

The is commonly used on concrete floors, pavements, and structures to quickly evaluate surface hardness and integrity. It provides valuable information for quality control and can help identify potential variations in concrete consistency and strength. However, it is important to note that this test provides an indirect assessment of concrete strength and should be complemented with other testing methods for a comprehensive evaluation. It's a practical tool for on-site inspections due to its speed and minimal disruption to the tested surface.

Penetration resistance test training which covers theory and practical sessions needs to correspond with Tables 5 and 6.

TABLE 5. GENERAL CONTENT FOR PENETRATION RESISTANCE TEST

	Content	Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
5.1	Introduction to penetration resistance test	9	3	0

TABLE 5. GENERAL CONTENT FOR PENETRATION RESISTANCE TEST

	Content	**Level 1 (% of total duration)**	**Level 2 (% of total duration)**	**Level 3 (% of total duration)**
5.2	Physical principles of the method and associated knowledge	6	6	6
5.3	Product knowledge and capabilities of the method and its derived techniques	3	3	3
5.4	Equipment	6	6	0
5.5	Information prior to testing	10	10	6
5.6	Testing	26	15	9
5.7	Evaluation and reporting	28	34	40
5.8	Assessment	6	14	15
5.9	Quality aspects	6	9	10
5.10	Developments	0	0	11
	Total Hours	**12**	**12**	**12**

TABLE 6. PENETRATION RESISTANCE TEST — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
6.1 Introduction to penetration resistance test	History	Concrete strength (standard cube or cylinder and core specimens)	X		
		On site samples (coring)	X		
	Purpose of NDT	Application of NDT	X		
		The importance of NDT	X		
		NDT personnel	X		
		Tasks of the inspection personnel	X		
	Purpose of testing	Definition	X		
		Applicability and limitations	X		
	Relevant standards	Standards and regulations	X	X	X
6.2 Physical principles of the method and associated knowledge	Basic physical principles	Penetration resistance test	X		
		Test objective	X		
	Advanced physical principles	Limitations of the method	X	X	X
		Correlation between testing and other characteristics of the element		X	X
		Influence of concrete age		X	X
		Influence of carbonation of concrete surface		X	X

TABLE 6. PENETRATION RESISTANCE TEST — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
6.3 Product knowledge and capabilities of the method and its derived techniques	Related capability of the method and derived techniques	Strength of concrete related to penetration of the probe	X	X	X
		Variability of the strength within a structure		X	X
6.4 Equipment	Description of basis equipment	Description of the resistance penetration test system	X	X	
		Driver unit	X		
		Powder charge: energy released	X		
		Probes or pins	X		
		Positioning device	X		
		Measuring apparatus	X		
6.5 Information prior to testing	Operating principles	Analyse the internal procedures / Manufacturer's instructions to use the device	X		
		Test location	X	X	X
		Representability of the test		X	X
		Number of measurements of testing		X	X
		Evaluation the level of damages produced by the test		X	X
6.6 Testing	Preparation	Selection of powder and actuated device applicable to the type of concrete	X	X	X
		Initial verification	X		
		Selection of test location	X	X	
		Preparation of the area	X		
	Execution	Operating according to instruction	X	X	
	Reading the results	Faulting and repetition of test in cases where exposed length of steel probe/ pin are invalids	X	X	
		Correlation between exposed probe length and concrete strength		X	X
	Factors influencing the results	Proper choice of the operative area in compliance with the structural requirements		X	X

TABLE 6. PENETRATION RESISTANCE TEST — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
		Analysis of factors that influence the selection of test locations		X	X
	Verification / calibration	Specifications according to every equipment	X		
		Periodic verification / calibration of equipment		X	X
	Operating procedure	Standard operating procedure (SOP)	X	X	X
	Advanced practice	Dismantling and maintenance of equipment according to instruction		X	X
6.7 Evaluation and reporting	Reporting	Data quality assessment	X		
		Record on worksheet	X		
		Practical writing of a test report	X		
	Evaluation	Practical interpretation of a test report	X	X	X
		Correlation of the test results with concrete strength		X	X
		General survey and evaluation of the test and data quality		X	X
6.8 Assessment	Conformity assessment of test report	Accuracy of measurement		X	X
		Assessing the reliability of the measurement records		X	X
		Assessment according to the technical specification		X	X
6.9 Quality aspects	Documents	National and international standards		X	X
		Issue of testing procedures		X	X
	Procedures and its contents	Concept		X	X
		Application		X	X
		Development/ creation		X	X
		Essential components of procedures		X	X
		System verification		X	X
		Data quality		X	X
		Coverage of inspection area		X	X
		ISO 9712	X	X	X

TABLE 6. PENETRATION RESISTANCE TEST — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
	Personnel qualification	Other NDT qualification and certification systems		X	X
	Other aspects	Supplementary inspections			X
		Further quality assurance measures			X
	Factors affecting results	Quality and cleaning of the surface	X		
		Characteristics of the concrete	X	X	X
		Thickness of concrete section related with impact energy	X		
		Presence or low cover of rebars		X	
		Carbonation		X	
		Age of concrete		X	
		Mis-calibration of device	X		
		Hits on rebars, coarse aggregate or holes	X		
		Misalignment of driven steel probes	X		
		Superficial humidity		X	
		Concrete sample not fixed		X	
	Supplementary investigations	Other NDTs		X	X
6.10 Developments	Advancement	Automated recording of results			X
		Combined method (sonic vs penetration)			X

3.3. PULL OUT TEST

Pull out test is an NDT method used to evaluate the bond strength between concrete and embedded reinforcement, such as rebar or anchors. This test involves applying a gradually increasing axial force to the embedded reinforcement until it either pulls out from the concrete or reaches a specified limit.

The tests method provides valuable information about the bond quality between the concrete and the reinforcement by measuring the maximum force required to pull out the reinforcement. This information is essential for assessing the structural integrity and load-bearing capacity of concrete elements.

The pull out test is commonly employed in construction projects to ensure that the reinforcement is properly anchored within the concrete. It helps identify potential issues such as poor adhesion, inadequate embedment depth, or subpar concrete quality. This test is relatively quick and can be performed on-site, making it a practical tool for quality control and assurance during construction and inspection processes. However, it is important to consider that the test represents localized bond strength and might not reflect the entire structural behaviour, therefore it is often used in conjunction with other testing methods for a comprehensive assessment.

Pull out test training which covers theory and practical sessions needs to correspond with Tables 7 and 8.

TABLE 7. GENERAL CONTENT FOR PULL OUT TEST

	Content	Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
7.1	Introduction to pull out test	10	8	3
7.2	Physical principles of the method and associated knowledge	10	6	6
7.3	Product knowledge and capabilities of the method and its derived techniques	5	3	3
7.4	Equipment	6	3	0
7.5	Information prior to testing	10	10	6
7.6	Testing	25	14	8
7.7	Evaluation and reporting	28	38	40
7.8	Assessment	0	12	12
7.9	Quality aspects	6	6	10
7.10	Developments	0	0	12
	Total Hours	**12**	**12**	**12**

TABLE 8. PULL OUT TEST — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
8.1 Introduction to pull out test	History	Concrete strength (standard cube or cylinder and core specimens)	X		
		On site samples (coring)	X		
	Purpose of NDT	Partially destructive test (PDT)	X		
		Application of NDT	X		
		The importance of NDT	X		
		NDT personnel	X		
		Tasks of the inspection personnel	X		
	Purpose of testing	Definition	X		
		Applicability and limitations	X		
	Relevant standards	Standards and regulations	X	X	X
8.2 Physical principles of the method and	Basic physical principles	Pull out test	X		
		Test objective	X		
		Limitations of the method	X	X	X

TABLE 8. PULL OUT TEST — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
associated knowledge	Advanced physical principles	Correlation between testing and other characteristics of the element		X	X
		Influence of concrete age		X	X
		Influence of carbonation of concrete surface		X	X
8.3 Product knowledge and capabilities of the method and its derived techniques	Related capability of the method and derived techniques	Strength of concrete related to penetration of the probe	X	X	X
		Variability of the strength within a structure		X	X
8.4 Equipment	Description of basic equipment	Description of the loading test system	X		
		Pressure gauge	X		
		Different types of hydraulic and commercially available pull out tester	X		
		Reaction frame	X		
		Embeds/inserts/ Dolly/ fixtures for attachment to test specimen	X		
8.5 Information prior to testing	Operating principles	Analyze the internal procedures / Manufacturer's instructions to use the device	X		
		Test location	X	X	X
		Representability of the test		X	X
		Number of measurements of testing		X	X
		Evaluation the level of damages produced by the test		X	X
8.6 Testing	Preparation	Selection of suitable range of load capacity of the equipment according to the type of concrete and the instruction	X	X	X
		Initial verification	X		
		Selection of test location	X	X	
		Preparation of the area	X		

TABLE 8. PULL OUT TEST — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
	Execution	Operation of the instrument	X	X	
	Reading the results	Faulting and repetition of test in cases where the results of test are invalids	X	X	
		Correlation between test results and concrete strength		X	X
	Factors influencing the results	Proper choice of the operative area in compliance with the structural requirements		X	X
		Analysis of factors that influence the selection of test locations		X	X
	Verification / calibration	Specifications according to every equipment	X		
		Periodic verification / calibration of equipment		X	X
	Operating procedure	Standard operating procedure (SOP)	X	X	X
	Advanced practice	Dismantling and maintenance of equipment procedure		X	X
8.7 Evaluation and reporting	Reporting	Data quality assessment	X		
		Record on worksheet	X		
		Practical writing of a test report	X		
	Evaluating a report	Practical interpretation of a test report	X	X	X
		Correlation of the test results with concrete strength		X	X
		General survey and evaluation of the test and data quality		X	X
8.8 Assessment	Conformity assessment of test report	Accuracy of measurement		X	X
		Assessing the reliability of the measurement records		X	X
		Assessment according to the technical specification		X	X
8.9 Quality aspects	Documents	National and international standards		X	X

TABLE 8. PULL OUT TEST — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Issue of testing procedures		X	X
	Procedures and its contents	Concept		X	X
		Application		X	X
		Development / creation		X	X
		Essential components of procedures		X	X
		System verification		X	X
		Data quality		X	X
		Coverage of inspection area		X	X
	Personnel qualification	ISO 9712		X	X
		Other NDT qualification and certification systems		X	X
	Other aspects	Supplementary inspections			X
		Further quality assurance measures			X
	Factors affecting results	Quality of the surface	X		
		Characteristics of the concrete	X	X	X
		Thickness of concrete section	X		
		Presence or low cover of rebars		X	
		Carbonation		X	
		Age of concrete		X	
		Mis-calibration of device	X		
		Presence of rebars, coarse aggregate or holes	X		
		Misalignment of the testing equipment (device not at 90°)	X		
		Concrete sample not rigid	X		
8.10 Developments	Advancement	Automated recording of results			X
		Combined method (sonic vs pull out test)			X

3.4. FLAT JACK TEST

Flat jack test is an NDT method used for assessing the structural integrity and load-bearing capacity of concrete structures. This method involves placing a flat, inflatable jack between the surface of a concrete element and a load distribution plate. As the jack expands, it induces stress within the concrete, simulating the effect of an external load. The resulting strain and deformation of the concrete are measured, providing valuable information about its response to stress and the distribution of forces within the structure.

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The test is particularly useful for evaluating the in-situ behaviour of concrete elements, such as slabs, beams, and columns. It can help identify potential weaknesses, such as voids, delamination, or insufficiently bonded areas. By analysing the stress-strain relationship, engineers can gain insights into the structural health and load-carrying capacity of the concrete.

This testing method is advantageous because it offers a way to assess concrete structures without causing significant damage. It provides valuable data for decision-making in terms of repair, maintenance, or reinforcement strategies. However, it's important to note that the flat jack test requires expertise in its application and interpretation, and it is often used in combination with other testing techniques to obtain a comprehensive understanding of the concrete's condition.

Flat jack test training which covers theory and practical sessions needs to correspond with Tables 9 and 10.

TABLE 9. GENERAL CONTENT FOR FLAT JACK TEST

	Content	**Level 1 (% of total duration)**	**Level 2 (% of total duration)**	**Level 3 (% of total duration)**
9.1	Introduction to flat jack test	12	5	0
9.2	Physical principles of the method and associated knowledge	10	8	6
9.3	Product knowledge and capabilities of the method and its derived techniques	6	6	3
9.4	Equipment	12	9	9
9.5	Information prior to testing	9	9	9
9.6	Testing	33	12	9
9.7	Evaluation and reporting	12	30	33
9.8	Assessment	0	12	12
9.9	Quality aspects	6	9	9
9.10	Developments	0	0	10
	Total Hours	**20**	**20**	**10**

TABLE 10. FLAT JACK TEST — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
10.1 Introduction to flat jack test	History	Mechanical characteristics and strength of masonry	X	X	
		Characteristics of a masonry wall	X	X	
	Purpose of NDT	NDT application	X		
		The importance of NDT	X		
		NDT personnel	X		

TABLE 10. FLAT JACK TEST — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Tasks of the inspection personnel	X		
	Purpose of testing	Definition	X		
		Applicability and limitations	X		
	Relevant standards	Standards and regulations	X		
10.2 Physical principles of the method and associated knowledge	Basic physical principles	Standard operation	X		
		Single flat jack test	X	X	X
		Two parallel flat jack tests	X	X	X
	Advanced physical principles	Limitations	X	X	X
		Correlation between testing and other characteristics of the element		X	X
10.3 Product knowledge and capabilities of the method and its derived techniques	Related capability of the method and derived techniques	Different texture of masonry	X	X	X
		Mechanical characteristics of masonry	X	X	X
		Estimation the strength of masonry	X	X	X
10.4 Equipment	Description of basis equipment	Flat jack	X		
		Displacement gauge	X		
		Hydraulic system and pressure gauge	X		
		Vision of the full instrument	X		
	Other types or alternative equipment	Different types of flat jack		X	X
		Different possibilities of displacement measurement		X	X
		Vision of alternative types of devices		X	X
10.5 Information prior to testing	Basic operating principles	Analyze the internal procedures / Manufacturer's instructions to use the device	X		
		Test location and position	X	X	X
		Representability of the test		X	X
		Number of measurements		X	X
		Level of damages evaluation		X	X

TABLE 10. FLAT JACK TEST — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
	Advanced operating principles	General principle of single and parallel flat jack test		X	X
10.6 Testing	Preparation	Dimension of flat jack and actuated device	X	X	X
		Initial verification	X		
		Selection of test location and position	X	X	
		Preparation of the area	X		
	Execution	Operation of single and parallel flat jack test	X		
	Reading the results	Faulting and repetition of test	X	X	
		Correlation between test results and masonry stresses and / or strength		X	X
	Factors influencing the results	Influence of texture of masonry		X	X
		Dimension of flat jack vs masonry elements		X	X
		Dimension of the elements related to the dimension of the sample		X	X
		Representability of the test in the case of multilayer masonry or in the case of out of center loads		X	X
		Out of representability cases		X	X
		Alternative test method		X	X
	Verification and calibration	Specifications	X		
		Periodic verification / calibration of equipment		X	X
	Operating procedure	Standard operating procedure (SOP)	X	X	X
	Advanced practice	Dismantling and maintenance of equipment procedure		X	X
10.7 Evaluation and reporting	Reporting	Data quality assessment	X		
		Record on worksheet	X		
		Practical writing of a test report	X		
	Evaluation	Practical interpretation of a test report	X	X	X

TABLE 10. FLAT JACK TEST — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Correlation of test results with masonry stresses and / or strength		X	X
		General survey and evaluation of the test and data quality		X	X
10.8 Assessment	Conformity assessment of test report	Accuracy of measurement		X	X
		Assessing the reliability of the measurement records		X	X
		Assessment according to the technical specification		X	X
10.9 Quality aspects	Documents	National and international standards		X	X
		Issue of testing procedures		X	X
	Procedures and its contents	Concept		X	X
		Application		X	X
		Development / creation		X	X
		Essential components of procedures		X	X
		System verification		X	X
		Data quality		X	X
		Coverage of inspection area		X	X
	Personnel qualification	ISO 9712		X	X
		Other NDT qualification and certification systems		X	X
	Other aspects	Supplementary inspections			X
		Further quality assurance measures			X
	Supplementary investigations	Other NDTs		X	X
10.10 Developments	Advancement	Correlation with destructive testing methods			X
		Automated recording of results			X

3.5. CARBONATION AND CHLORIDE TESTS

The carbonation and chloride tests are essential methods for evaluating the durability and potential corrosion risk of concrete structures.

Carbonation is a natural process in which atmospheric carbon dioxide reacts with calcium hydroxide in hydrated cement paste, forming calcium carbonate. This can decrease the concrete's alkalinity and potentially lead to embedded steel reinforcement corrosion. To assess carbonation, a surface of the concrete is exposed, and phenolphthalein indicator is applied. The indicator changes colour as the concrete's pH drops due to carbonation. Measuring the depth of carbonation provides insight into potential corrosion risks and overall structural durability.

Chloride ions, often introduced by de-icing salts, marine environments, or industrial processes, can cause corrosion of embedded steel in concrete. Chloride tests help assess the concentration of chloride ions in concrete. The "Rapid Chloride Ion Penetration Test" applies a voltage to a specimen, causing chloride ions to migrate; the conductivity of the solution on the other side indicates penetration. Alternatively, the "Chemical Test" involves extracting chlorides from crushed concrete samples. Understanding chloride ion levels assists in gauging corrosion risks and making informed construction and maintenance decisions to ensure the longevity and safety of concrete structures.

Both tests contribute significantly to evaluating concrete structure conditions, potential durability issues, and safeguarding against corrosion-related concerns.

Carbonation and chloride tests training which covers theory and practical sessions needs to correspond with Tables 11 and 12.

TABLE 11. GENERAL CONTENT FOR CARBONATION AND CHLORIDE TESTS

	Content	**Level 1 (% of total duration)**	**Level 2 (% of total duration)**	**Level 3 (% of total duration)**
11.1	Introduction to carbonation and chloride tests	15	10	3
11.2	Physical principles of the method and associated knowledge	6	6	3
11.3	Product knowledge and capabilities of the method and its derived techniques	3	3	0
11.4	Equipment	10	6	0
11.5	Information prior to testing	6	6	15
11.6	Testing	21	15	15
11.7	Evaluation and reporting	33	39	30
11.8	Assessment	0	6	14
11.9	Quality aspects	6	9	10
11.10	Developments	0	0	10
	Total Hours	**12**	**12**	**10**

TABLE 12. CARBONATION AND CHLORIDE TESTS — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
12.1 Introduction to carbonation and chloride tests	History	Meaning of the carbonation and how it affects to concrete	X		
		Chloride content effects on behavior of reinforced concrete	X		
	Purpose of NDT	Partially destructive test (PDT)	X		
		Application of NDT	X		

TABLE 12. CARBONATION AND CHLORIDE TESTS — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
		The importance of NDT	X		
		NDT personnel	X		
		Tasks of the inspection personnel	X		
	Purpose of testing	Definition	X		
		Applicability and limitations	X		
	Relevant standards	Standards and regulations	X	X	X
12.2 Physical principles of the method and associated knowledge	Basic physical principles	Determination of carbonation depth by using phenolphthalein method	X	X	
		Determination of chloride content. chloride chemical test kit (non-standard)	X	X	
	Advanced physical principles	Limitations of the method	X	X	X
		Propose alternative test methods		X	X
12.3 Product knowledge and capabilities of the method and its derived techniques	Related capability of the method and derived techniques	Depth of penetration of carbonation	X	X	
		Overall chloride contents	X	X	
		Depth of chloride penetration in aggressive environmental	X	X	
12.4 Equipment	Description of basic equipment	Description of the testing equipment	X	X	
		Device for concrete core drilling or to take concrete dust	X	X	
		Specified chemicals for field test determination	X	X	
	Description of advanced equipment	Any necessary additional equipment / Chemicals as per specified standards		X	X
12.5 Information prior to testing	Operating principles	Analyse the internal procedures / Manufacturer's instructions to use the device	X		
		Test location	X	X	X
		Representability of the test		X	X

TABLE 12. CARBONATION AND CHLORIDE TESTS — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Number of measurements of testing		X	X
		Evaluation the level of damages produced by the test		X	X
12.6 Testing	Preparation	Selection of test location	X	X	
		Preparation of the area	X		
	Execution	According to instruction	X	X	
	Reading the results	Faulting and repetition of test in cases where the results of test are invalids	X	X	
		For chloride content test	X	X	X
		For carbonation test	X	X	X
	Factors influencing the results	Proper choice of the operative area		X	X
		Analysis of factors that influence the selection of test locations		X	X
	Verification and calibration	Periodic verification of chemicals and kits		X	X
	Operating procedure	Standard operating procedure (SOP)	X	X	X
	Advanced practice	Make determinations at different depths		X	X
12.7 Evaluation and reporting	Reporting	Data quality assessment	X		
		Record on worksheet	X		
		Practical writing of a test report	X		
	Evaluating a report	Practical interpretation of a test report	X	X	X
		General survey and evaluation of the test and data quality		X	X
12.8 Assessment	Assessment of the results	Accuracy of measurement		X	X
		Assessing the reliability of the measurement records		X	X
		Assessment according to the technical specification		X	X
12.9 Quality aspects	Documents	National and international standards		X	X

TABLE 12. CARBONATION AND CHLORIDE TESTS — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Issue of testing procedures		X	X
	Procedures and its contents	Application		X	X
		Development		X	X
		Essential components		X	X
		System verification		X	X
		Data quality		X	X
	Personnel qualification	ISO 9712		X	X
		Other NDT qualification and certification systems		X	X
	Other aspects	Supplementary inspections			X
		Further quality assurance measures			X
	Factors that can influence the results	Surface contaminants		X	X
12.10 Developments	Advancement	Fluorescence technique (pFRX)			X
		Automated recording methods			X

3.6. VISUAL TESTING (VT)

Visual testing (VT) is a fundamental and initial approach employed in concrete testing to evaluate the visible condition and surface quality of concrete structures. This non-destructive method relies on direct visual observation to identify visible defects, irregularities, and potential issues in the concrete.

During visual testing, trained inspectors carefully examine the concrete surface for signs of cracks, spalling, discoloration, honeycombing, and other visible abnormalities. This method provides immediate insights into the concrete's health and can help identify issues that might compromise its structural integrity or aesthetics.

Visual testing is used throughout the lifecycle of concrete structures. It serves as an essential quality control tool during construction to ensure proper workmanship and identify surface imperfections. In existing structures, it aids in routine inspections, helping to detect early signs of deterioration, assess damage, and plan maintenance. This method is widely applied in assessing bridges, buildings, pavements, and other concrete components. While limited to surface-level evaluations, visual testing remains a critical initial step in identifying potential problems and ensuring the safety and durability of concrete structures.

Visual testing training which covers theory and practical sessions needs to correspond with Tables 13 and 14.

TABLE 13. GENERAL CONTENT FOR VISUAL TESTING

	Content	Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
13.1	Introduction to visual testing (VT)	9	3	3
13.2	Physical principles of the method and associated knowledge	12	12	3
13.3	Product knowledge and capabilities of the method and its derived techniques	3	3	0
13.4	Equipment	12	12	8
13.5	Information prior to testing	12	12	12
13.6	Testing	24	22	20
13.7	Evaluation and reporting	19	21	30
13.8	Assessment	0	6	10
13.9	Quality aspects	9	9	10
13.10	Developments	0	0	4
	Total Hours	**24**	**24**	**16**

TABLE 14. VISUAL TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
14.1 Introduction to visual testing (VT)	History	VT as an NDT method	X	X	
		Differences between VT and survey	X	X	
		VT as preliminary method for other NDT analysis	X	X	
	Purpose of NDT	Partially destructive test (PDT)	X		
		Application of NDT	X		
		The importance of NDT	X		
		NDT personnel	X		
		Tasks of the inspection personnel	X		
	Purpose of testing	Definition	X		
		Applicability and limitations	X		
	Relevant standards	Standards and regulations	X	X	X
14.2 Physical principles of the method and associated knowledge	Basic physical principles	Characteristics of light	X	X	
		Physical concepts as reflection, refraction, etc.	X	X	
		Emissivity and reflectance	X	X	
	Advanced physical principles	Limitations of the method	X	X	X
		Human limitations	X	X	X
14.3 Product knowledge and capabilities of	Related capability of the method and	Preliminary method necessary for implementing NDT	X	X	

TABLE 14. VISUAL TESTING — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
the method and its derived techniques	derived techniques	campaign and other NDT methods			
		Detection of defects in compliance with standard reference	X	X	
		Detection of crack and deformation pattern in compliance with standard reference	X	X	
14.4 Equipment	Description of basic equipment	Direct, indirect, and remote visual testing equipment and accessories	X	X	X
14.5 Information prior to testing	Operating principles	Analyse the internal procedures / Manufacturer's instructions to use the equipment	X		
		Test location	X	X	X
		Representability of the test		X	X
		Inspection area	X	X	X
14.6 Testing	Preparation	Selection of method and equipment according to the type of area to be inspected	X	X	X
		Initial verification	X		
		Selection of test location	X	X	
		Preparation of the area	X		
	Execution	How to proceed with the inspection	X	X	
	Recording the results	Recording of the test, including measurements according to the instruction	X	X	X
		Faulting and repetition of test in cases where the results of test are insufficient	X	X	X
	Factors influencing the results	VT for reception of CE		X	
		VT for survey and assessment of CE		X	
		VT for emergency cases		X	
	Verification/ calibration	Specifications according to every equipment	X		

TABLE 14. VISUAL TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Periodic verification / calibration of equipment		X	X
	Operating procedure	Standard operating procedure (SOP)	X	X	X
	Advanced practice	Dismantling and maintenance of equipment according to procedure		X	X
14.7 Evaluation and reporting	Reporting	Data quality assessment	X		
		Record on worksheet	X		
		Practical writing of a test report	X		
	Evaluating a report	Practical interpretation of a test report	X	X	X
		General survey and evaluation of the test and data quality		X	X
14.8 Assessment	Conformity assessment of test report	Accuracy of measurement		X	X
		Assessing the reliability of the measurement records		X	X
		Assessment according to the technical specification		X	X
14.9 Quality aspects	Documents	National and international standards		X	X
		Issue of testing procedures		X	X
	Procedures and its contents	Concept		X	X
		Application		X	X
		Development		X	X
		Essential components		X	X
		System verification		X	X
		Data quality		X	X
	Personnel qualification	ISO 9712		X	X
		Other NDT qualification and certification systems		X	X
	Other aspects	Supplementary inspections			X
		Further quality assurance measures			X
	Factors affecting results	Lack of detailed instructions	X	X	
		Inadequate illumination	X	X	

TABLE 14. VISUAL TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Less information of civil structures to be tested		X	
		Safety concerns	X	X	
		Subjective causes: error of identification, visual fatigue, faulting records	X	X	
		Unsafe or inadequate environment conditions	X	X	
		Lack of accessing media for reach the inspection site	X	X	
14.10 Developments	Advancement	Automatized methods			X
		Artificial intelligence			X

3.7. STRAIN GAUGE TESTING (ST)

Strain gauge testing (ST) is a method used in concrete testing to measure the deformation or strain experienced by concrete structures under various loads. It involves the application of strain gauges, which are specialized sensors, to the surface of a concrete element. These gauges detect changes in length or deformation by converting mechanical strain into electrical resistance changes.

The principles behind ST are rooted in the piezoresistive effect, where the electrical resistance of certain materials changes when subjected to mechanical strain. Strain gauges consist of a thin wire or foil grid attached to a flexible backing. As the concrete deforms under load, the strain gauge experiences a proportional change in resistance, which is then measured using a Wheatstone bridge circuit. This allows for precise quantification of strain, which provides insights into the structural behaviour of the concrete under different conditions.

The applications of ST in concrete testing are extensive. Engineers use this method to assess the structural performance of concrete components, monitor stress distribution, evaluate load-bearing capacities, and determine the effects of temperature changes and environmental factors. ST is especially valuable in research and quality control, helping to ensure the safety, durability, and optimal functioning of concrete structures, such as bridges, dams, buildings, and more. It offers detailed data that aids in making informed design and maintenance decisions, ultimately contributing to the longevity and reliability of concrete infrastructure.

Strain gauge testing training which covers theory and practical sessions needs to correspond with Tables 15 and 16.

TABLE 15. GENERAL CONTENT FOR STRAIN GAUGE TESTING

	Content	Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
15.1	Introduction to strain gauge testing (ST)	9	3	3

TABLE 15. GENERAL CONTENT FOR STRAIN GAUGE TESTING

	Content	Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
15.2	Physical principles of the method and associated knowledge	13	13	3
15.3	Product knowledge and capabilities of the method and its derived techniques	3	3	3
15.4	Equipment	9	6	10
15.5	Information prior to testing	9	9	10
15.6	Testing	33	21	21
15.7	Evaluation and reporting	18	33	33
15.8	Assessment	0	6	6
15.9	Quality aspects	6	6	6
15.10	Developments	0	0	5
	Total Hours	**20**	**20**	**10**

TABLE 16. STRAIN GAUGE TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
16.1 Introduction to strain gauge testing (ST)	History	Requirement for measurements	X	X	
		Importance of strain gauging	X	X	
	Purpose of NDT	Partially destructive test (PDT)	X		
		Application of NDT	X		
		The importance of NDT	X		
		NDT personnel	X		
		Tasks of the inspection personnel	X		
	Purpose of testing	Definition	X		
		Applicability and limitations	X		
	Relevant standards	Standards and regulations	X	X	X
16.2 Physical principles of the method and associated knowledge	Basic physical principles	Concept of strain and stresses		X	
		Experimental strain measurement techniques		X	
		Amperage and voltage	X	X	
		Ohm’s Law and resistance	X	X	
		Conductivity and resistivity		X	
		Gauge as electrical resistance	X		
		Change in resistance by change in length of gauge	X	X	

TABLE 16. STRAIN GAUGE TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Stress-strain relation in general (Hooke's Law)	X	X	
		Stress-strain relation of steel and concrete	X	X	
	Advanced physical principles	Limitations of the method	X	X	X
16.3 Product knowledge and capabilities of the method and its derived techniques	Related capability of the method and derived techniques	Measurement of strain in structural components	X	X	
16.4 Equipment	Description of basic equipment	Gauges	X	X	
		Transducers	X	X	
		Connecting wires	X	X	
		Adhesive	X	X	
		Tapes	X	X	
		Data acquisition system	X	X	X
		PC with measurement software by data logger manufacturer	X	X	X
16.5 Information prior to testing	Operating principles	Analyse the internal procedures / Manufacturer's instructions to use the device	X		
		Test location	X	X	X
		Representability of the test		X	X
		Number of measurements of testing		X	X
		Evaluation the level of damages produced by the test		X	X
16.6 Testing	Preparation	Select suitable strain gauge according to the type of concrete and the instruction	X	X	X
		Initial verification	X		
		Selection of test location	X	X	
		Preparation of the area	X		
	Execution	How to operate with the instrument	X		
	Reading the results	Faulting and repetition of test in cases where	X	X	

TABLE 16. STRAIN GAUGE TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		the results of test are invalids			
		Correlation between test results and concrete stress		X	X
	Factors influencing the results	Proper choice of the operative area in compliance with the structural requirements		X	X
		Analysis of factors that influence the selection of test locations		X	X
	Verification/ calibration	Specifications according to every equipment	X		
		Periodic verification / calibration of equipment		X	X
	Operating procedure	Standard operating procedure (SOP)	X	X	X
	Advanced practice	Maintenance of equipment procedure		X	X
16.7 Evaluation and reporting	Reporting	Data quality assessment	X		
		Record on worksheet	X		
		Practical writing of a test report	X		
	Evaluating a report	Practical interpretation of a test report	X	X	X
		Correlation of the test results		X	X
		General survey and evaluation of the test and data quality		X	X
16.8 Assessment	Conformity assessment of test reports	Accuracy of measurement		X	X
		Assessing the reliability of the measurement records		X	X
		Assessment according to the technical specification		X	X
16.9 Quality aspects	Documents	National and international standards		X	X
		Issue of testing procedures		X	X
	Procedures and its contents	Concept		X	X
		Application		X	X
		Development/ creation		X	X

TABLE 16. STRAIN GAUGE TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Essential components of procedures		X	X
		System verification		X	X
		Data quality		X	X
		Coverage of inspection area		X	X
	Personnel qualification	ISO 9712		X	X
		Other NDT qualification and certification systems		X	X
	Other aspects	Supplementary inspections			X
		Further quality assurance measures			X
	Factors affecting results	Environmental conditions		X	
		Concrete surface condition		X	X
		Effect of temperature in measurements		X	X
		Disconnection of gauges		X	X
		Improper sampling frequency		X	X
		Gauge de-bonding		X	X
16.10 Developments	Advancement	Continuous structural monitoring			X
		Measurement of multi-directional stresses			X
		Combined methods			X

3.8. LEAK TESTING (LT)

Leak testing (LT) is an NDT method used in civil engineering to evaluate the water tightness and integrity of concrete structures. It plays a crucial role in assessing whether the concrete effectively resists water penetration and prevents leaks that could compromise its durability and functionality.

The test typically involves creating a pressure differential across the concrete structure, simulating real-world conditions. A controlled amount of water or air pressure is applied to one side of the concrete while the other side is observed for any signs of leakage. If water or air escapes through the concrete, it indicates potential vulnerabilities in its composition or construction.

Leak testing finds wide-ranging applications in various concrete structures. It is essential for assessing the water resistance of structures such as reservoirs, water tanks, swimming pools, tunnels, and basements. Leak tests are also used in assessing containment structures for hazardous materials and preventing environmental pollution. By pinpointing areas prone to leaks or seepage, engineers and contractors can make informed decisions about repair, maintenance, or the need for additional waterproofing measures. The leak test is a vital tool in ensuring the longevity and effectiveness of concrete structures, particularly those exposed to water or other liquids.

Leak testing training which covers theory and practical sessions needs to correspond with Tables 17 and 18.

TABLE 17. GENERAL CONTENT FOR LEAK TESTING

	Content	Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
17.1	Introduction to leak testing (LT)	9	3	3
17.2	Physical principles of the method and associated knowledge	13	13	0
17.3	Product knowledge and capabilities of the method and its derived techniques	3	3	0
17.4	Equipment	12	9	0
17.5	Information prior to testing	9	9	18
17.6	Testing	33	18	18
17.7	Evaluation and reporting	15	33	35
17.8	Assessment	0	6	10
17.9	Quality aspects	6	6	10
17.10	Developments	0	0	6
	Total Hours	**12**	**12**	**10**

TABLE 18. LEAK TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
18.1 Introduction to leak testing (LT)	History	Requirement for measurements	X		
		Leak testing in buildings	X		
		Evaluation of air tightness of rooms and close environments	X		
	Purpose of NDT	Partially destructive test (PDT)	X		
		NDT application	X		
		The importance of NDT	X		
		NDT personnel	X		
		Tasks of the inspection personnel	X		
	Purpose of testing	Definition	X		
		Applicability and limitations	X		
	Relevant standards	Standards and regulations	X	X	X
18.2	Basic physical principles	Leak test	X		
		Test objective	X		

TABLE 18. LEAK TESTING — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
Physical principles of the method and associated knowledge	Advanced physical principles	Quantitative, semi-quantitative and qualitative analysis		X	
		Pressure measurement testing	X	X	
		Vacuum box testing	X	X	
18.3 Product knowledge and capabilities of the method and its derived techniques	Related capability of the method and derived techniques	Typology of structural elements affected by air penetration	X	X	
		Properties of construction materials	X	X	
		Constructive joints	X	X	
18.4 Equipment	Description of basic equipment	Hermetic surfaces	X	X	
		Differential manometer	X	X	
		Pressurising or vacuum equipment	X	X	
		Air flow meter	X	X	
		Other accessories	X	X	
	Leakage detection techniques	Smoke generator		X	
		Infrared camera		X	
18.5 Information prior to testing	Operating principles	Analyse the internal procedures / Manufacturer's instructions to use the device	X		
		Test location	X	X	X
		Representability of the test		X	X
		Number of measurements		X	X
18.6 Testing	Preparation	Selection of testing equipment	X	X	X
		Operation and installation of blow door	X	X	
		Test location	X	X	
		Preparation of the area	X		
		Initial verification	X		
	Execution	Testing implementation	X		
	Reading the results	Faulting and repetition of test	X	X	
		Visual testing inspection		X	X
	Factors influencing the results	Proper choice of the operative area in compliance with the requirements		X	X

TABLE 18. LEAK TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Environmental conditions	X	X	
		Difficulty of implant the testing system	X	X	
		Incompatibility	X	X	
	Verification / calibration	Specifications	X		X
		Periodic verification / calibration of equipment		X	X
	Operating procedure	Standard operating procedure (SOP)	X	X	X
	Advanced practice	Dismantling and maintenance of equipment procedure		X	X
18.7 Evaluation and reporting	Reporting	Data quality assessment	X		
		Record on worksheet	X		
		Practical writing of a test report	X		
	Evaluating a report	Practical interpretation	X	X	X
		General survey and evaluation		X	X
18.8 Assessment	Conformity assessment of test report	Accuracy of measurement		X	X
		Reliability of the measurement records		X	X
		Assessment according to the technical specification		X	X
18.9 Quality aspects	Documents	National and international standards		X	X
		Issue of testing procedures		X	X
	Procedures and its contents	Concept		X	X
		Application		X	X
		Development / creation		X	X
		Essential components		X	X
		System verification		X	X
		Data quality		X	X
		Coverage of inspection area		X	X
	Personnel qualification	ISO 9712		X	X
		Other NDT qualification and certification systems		X	X
	Faults possibility	Weather considerations:	X	X	
		Difficulty in placing the equipment	X	X	
		Electrical plant	X	X	

TABLE 18. LEAK TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Air conditioning systems	X	X	
	Other aspects	Supplementary inspections			X
		Further quality assurance measures			X
	Factors affecting results	Capacity of the equipment		X	X
		Overall dimension of the building and close environments		X	X
		Accessibility	X	X	
18.10 Developments	Advancement	Thermal performance and air permeability			X

4. ELECTRICAL AND MAGNETIC

4.1. GROUND PENETRATING RADAR (GPR)

Ground penetrating radar (GPR) is an NDT method used in concrete testing to assess the internal structure of concrete elements. It utilizes electromagnetic waves to penetrate the concrete and provides valuable insights into the composition, thickness, and presence of voids, rebar, and other embedded features.

The principle of GPR application is based on emitting short pulses of electromagnetic energy into the concrete surface. These waves bounce back when they encounter changes in material properties, such as from air voids or reinforcement bars. By analysing the time it takes for the waves to return, and their amplitude, GPR creates a detailed cross-sectional image of the subsurface features.

GPR is extensively applied in various concrete testing scenarios. It helps identify the location and depth of rebar and other reinforcements, which is crucial for structural assessments. GPR can also detect voids, delamination, and cracks that are not visible on the surface, aiding in assessing the concrete's quality and potential deterioration. This technique is often used in assessing bridges, tunnels, buildings, and pavements, offering valuable data for repair, maintenance, and retrofitting decisions. GPR's ability to provide non-invasive insights into concrete's internal condition makes it an essential tool for ensuring the safety and longevity of concrete structures.

Ground penetrating radar training which covers theory and practical sessions needs to correspond with Tables 19 and 20.

TABLE 19. GENERAL CONTENT FOR GROUND PENETRATING RADAR

	Content	Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
19.1	Introduction to ground penetrating radar (GPR)	5	0	0
19.2	Physical principles of the method and associated knowledge	10	5	5

TABLE 19. GENERAL CONTENT FOR GROUND PENETRATING RADAR

	Content	Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
19.3	Product knowledge and capabilities of the method and its derived techniques	10	5	0
19.4	Equipment	15	10	5
19.5	Information prior to testing	15	10	5
19.6	Testing	30	20	20
19.7	Evaluation and reporting	10	20	20
19.8	Assessment	5	10	20
19.9	Quality aspects	0	10	15
19.10	Developments	0	10	10
	Total Hours	**40**	**40**	**20**

TABLE 20. GROUND PENETRATING RADAR — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
20.1 Introduction to ground penetrating radar (GPR)	History	Development of GPR	X		
	Introduction	Purpose of NDT	X		
		NDT application	X		
		The importance of NDT	X		
		NDT personnel	X		
		Tasks of the inspection personnel	X		
	Purpose of testing	Definition	X		
		Applicability and limitations	X		
	Relevant standards	Standards and regulations	X		
20.2 Physical principles of the method and associated knowledge	Theory and properties of electromagnetic waves	Impulses	X	X	
		Electromagnetic waves	X	X	
		Propagation	X	X	X
		Wave types	X	X	
		Electromagnetic generation	X		
		Frequency	X	X	
		Wave speed	X		
		Wavelength	X	X	
		Wave types	X		
		Electromagnetic radiation	X		
	Antennas	Resolution	X	X	X
		Bandwidth	X	X	
		Transmitter/ Receiver	X	X	
		Polarization	X	X	X
	Basic GPR principle	Transit time	X	X	
		Reflection coefficient	X	X	X
		Signal representation	X	X	X
		Reflection	X	X	
		Attenuation	X	X	

TABLE 20. GROUND PENETRATING RADAR — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Scattering	X	X	
		Dielectric properties	X	X	X
		Permittivity	X	X	
		Conductivity	X	X	
20.3 Product knowledge and capabilities of the method and its derived techniques	Object properties	Material properties	X	X	
		Fixtures	X		
		Defect types	X	X	
		Geometry	X	X	
	Reference to GPR	Transit time measurement	X	X	
		Dielectric differences	X	X	
		Total reflection	X	X	
		Reflection coefficient	X	X	
	Influencing variables	Moisture	X	X	
		Reinforcement content	X	X	
		Steel fiber reinforcement	X	X	
		Effect on detection	X	X	
		Effect of coating	X	X	
		Effect on penetration	X	X	
		Effect on resolution	X	X	
20.4 Equipment	Equipment for data acquisition	Main unit	X		
		Antennas	X	X	X
		Cables	X		
		Software	X	X	
		Automation	X	X	X
	Equipment for data evaluation	Main unit	X	X	
		Software	X	X	X
		Automation	X	X	X
20.5 Information prior to testing	Information about testing object	Objective of the inspection	X		
		Surface condition	X	X	
		Access	X		
		Coordinate system	X		
		Measuring arrangement	X	X	
		Concrete age	X	X	
		Moisture	X	X	
		Line scan	X		
		Area scan	X		
		Preparation of the result presentation	X	X	X
	Instructions	Preparation of written procedures			X
		Preparation of written instructions		X	
		Performing inspection in accordance with written instruction	X		
		Documentation			X

TABLE 20. GROUND PENETRATING RADAR — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
		Presentation of the procedures, codes, and standards			X
20.6 Testing	Measuring grid	Space distance	X	X	
		Line distance	X	X	
		Polarization	X	X	
		Time-controlled	X	X	
		Way-controlled	X	X	
	Filters	High pass	X	X	
		Low pass	X	X	
		Band-pass	X	X	
		Background removal	X	X	
		Averaging	X	X	
	Gain and adjustment	Device change	X	X	
		Depth scaling	X	X	
		Zero point	X	X	
		Calibration checks	X	X	
		Reference checks in and out	X	X	
		Maximum penetration depth	X	X	
		Signal-to-noise-ratio	X	X	
		Coverage of the inspection area	X	X	
	Examples for data acquisition	Inspection tasks	X	X	X
		Laboratory examples	X	X	X
		On-site measurements	X	X	X
		Alternative methods		X	X
20.7 Evaluation and reporting	Preparation	Data quality assessment	X	X	X
		Elimination of systematic errors		X	X
		Filtering		X	X
		Calibration in terms of a subsequent depth scaling			X
		Zero-point correction			X
		Migration			X
		Hilbert transform			X
	Evaluation	Signal analysis for detection		X	X
		Indication interpretation		X	X
		Display of results (A-Scan, B-Scan, C-Scan)	X	X	
		Marking of component / structure	X	X	
	Examples for data evaluation	Inspection tasks	X	X	X
		Laboratory examples	X	X	X
		On-site evaluations	X	X	X

TABLE 20. GROUND PENETRATING RADAR — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Alternative methods			X
	Reporting	Compile all results and readings	X	X	X
		Report writing		X	X
20.8 Assessment	Conformity assessment of test report	Accuracy of measurement		X	X
		Assessing the reliability of the measurement records		X	X
		Assessment according to the technical specification		X	X
20.9 Quality aspects	Documents	National and international standards			X
		Issue of testing procedures			X
	Procedures and its contents	Concept		X	X
		Application		X	X
		Development / creation		X	X
		Essential components of procedures		X	X
		System verification		X	X
		Data quality		X	X
		Coverage of inspection area		X	X
		Coupling		X	X
	Personnel qualification	ISO 9712	X	X	X
		Other NDT qualification and certification systems		X	X
	Other aspects	Supplementary inspections			X
		Further quality assurance measures			X
20.10 Developments	Advancement	Stepped frequency		X	X
		Automation		X	X
		Arrays		X	X

4.2. THERMOGRAPHIC TESTING (TT)

Thermographic testing (TT) offers non-contact and non-destructive insights into the thermal behaviour and condition of concrete structures. By capturing temperature variations on the surface, it unveils hidden flaws, moisture penetration, and areas of concern that may not be evident through conventional methods.

The method relies on the principle that materials emit infrared radiation in response to temperature variations. When applied to concrete, this technique detects differences in surface temperatures that are indicative of subsurface anomalies. By utilizing specialized cameras, the heat distribution on concrete surfaces is visualized in real-time, facilitating the identification of areas with potential defects or irregularities.

Thermographic testing method finds wide-ranging applications in civil engineering. It effectively detects delamination, cracks, voids, and moisture infiltration, all of which can compromise the structural integrity of civil structures. This method is invaluable in assessing the condition of building envelopes, pavements, and concrete foundations, enabling proactive maintenance and targeted repairs. Furthermore, TT assists in monitoring the efficacy of insulation and energy efficiency within concrete structures. By swiftly identifying problematic areas without invasive measures, this technology plays a pivotal role in optimizing maintenance strategies and safeguarding the longevity of concrete infrastructure.

Thermographic testing training which covers theory and practical sessions needs to correspond with Tables 21 and 22.

TABLE 21. GENERAL CONTENT FOR THERMOGRAPHIC TESTING

	Content	**Level 1 (% of total duration)**	**Level 2 (% of total duration)**	**Level 3 (% of total duration)**
21.1	Introduction to thermographic testing (TT)	5	3	0
21.2	Physical principles of the method and associated knowledge	25	23	5
21.3	Product knowledge and capabilities of the method and its derived techniques	25	20	15
21.4	Equipment	15	10	10
21.5	Information prior to testing	3	10	10
21.6	Testing	20	15	10
21.7	Evaluation and reporting	6	10	15
21.8	Assessment	0	5	15
21.9	Quality aspects	1	4	15
21.10	Developments	0	0	5
	Total Hours	**40**	**48**	**20**

TABLE 22. THERMOGRAPHIC TESTING — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
22.1 Introduction to thermographic testing (TT)	History	Importance of thermographic testing in evaluation of civil structures	X	X	
		Terminology	X	X	
	Purpose of NDT	Introduction	X	X	
		NDT application	X	X	
		The importance of NDT	X	X	
		NDT personnel	X	X	
	Purpose of the thermographic testing method	Definition	X	X	
		Applicability and limitations	X	X	
22.2 Physical principles of the method and	Heat transfer	Heat / temperature / energy	X	X	
		Material properties	X	X	

TABLE 22. THERMOGRAPHIC TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
associated knowledge		Heat conductivity and head capacity			
		1st and 2nd law of thermodynamics	X	X	
		Stages of matter	X	X	
		Temperature scales	X		
		Fundamentals of Heat Conduction	X	X	
		Fundamentals of Heat Convection	X	X	
		Fundamentals of thermal radiation	X	X	
		Thermal properties of materials	X		
		Steady and transitional regime	X	X	
		Thermal diffusivity		X	
	Infrared theory	Electromagnetic spectrum	X		
		Emissivity	X		
		Black body/grey body	X		
		Dependency of emission coefficient from view angle	X		
		Non-grey bodies	X		
		Kirchhoff's law	X		
		Atmospheric window	X		
		Absorption		X	X
	Temperature measurement methods	Measurement of emissivity of real bodies	X	X	X
22.3 Product knowledge and capabilities of the method and its derived techniques	Principles of thermography	Passive technique	X	X	
		Active techniques		X	
		Use of sun radiation and temperature change (day/night)		X	
		Qualitative thermography	X	X	
		Quantitative thermography		X	
	Inspection conditions	Temperature difference	X	X	X
		Temperature change in time	X	X	X
		Exposure to sun radiations	X	X	X
		Distance	X	X	X
		Wind speed	X	X	X
		Pressure difference	X	X	X
		Humidity	X	X	X
		Adhesion defects	X	X	X

TABLE 22. THERMOGRAPHIC TESTING — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
	Types of defects that can be found	Discontinuities	X	X	X
		Dis-bonding	X	X	X
		Cracks	X	X	X
		Construction and cold joints	X	X	X
		Infiltration	X	X	X
		Leakage	X	X	X
		Thermal bridges	X	X	X
		Moisture	X	X	X
	Applicable codes	Thermal insulation	X	X	X
22.4 Equipment	Infrared cameras	Characteristics of sensors		X	X
		Minimum Detectable Dimension (MDD)	X	X	X
		Noise Equivalent Temperature Difference (NETD)		X	X
		Length range measurement wave		X	X
	Condition monitoring tools	Thermometers	X		
		Hygrometers	X		
		Differential monometers	X		
		Laser rulers	X		
	Accessories	Filters		X	X
		Optical lenses		X	X
		Blower		X	X
	Heat input devices (active thermography)	Types of heating	X	X	X
		Criteria for the selection of the heat input device		X	X
		Safety	X	X	X
22.5 Information prior to testing	Information about the object to be inspected	General knowledge	X	X	
	Test conditions and application of standards	Measurement planning		X	X
		Accessibility		X	X
		Surface preparation	X	X	X
		Special test conditions		X	X
		Relevant standards		X	X
		Preparation of written instructions		X	X
	Guidelines	Measurement	X		
22.6 Testing	Test conditions	Focus adjustment	X		
	Infrared instrument operations	Correction of atmospheric absorption and reflected radiation		X	
		Setting up emissivity		X	X

TABLE 22. THERMOGRAPHIC TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Spatial resolution assessment		X	X
		Distance	X	X	
		Humidity	X	X	
		Measurement of the angle of incidence		X	X
		Temperature scale range	X	X	
		Setting the frame rate (sample rate)	X	X	
		Data logging	X		
		Performing the inspection in accordance with the written instructions	X	X	
	Execution	Color palettes	X		
22.7 Evaluation and reporting	Image processing	Use of isotherms		X	X
		Use of graphical tools for temperature measurement	X	X	X
		Operations on images	X	X	X
		Visualization of the temperature trend over time		X	X
		Trend processing Temperature / time		X	X
		Relevant information about the test	X	X	
	Reporting	Interpretation and evaluation of results		X	X
		Acceptance and rejection criteria		X	X
22.8 Assessment	Conformity assessment of test report	Accuracy of measurement		X	X
		Assessing the reliability of the measurement records		X	X
		Assessment according to the technical specification		X	X
22.9 Quality aspects	Personnel qualification	ISO 9712 Certification	X	X	X
		Other NDT qualifications and certification schemes		X	X
	Documentation	Controlling the application of written instructions		X	X
		Measurement reliability		X	X
		Document traceability		X	X

TABLE 22. THERMOGRAPHIC TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Documentation management		X	X
	Knowledge of NDT application and product standards	Selecting the NDT method		X	X
		Correct selection of the technique		X	X
		Using the correct test parameters		X	X
		Training	X	X	X
		Equipment verification	X	X	X
		Faults possibility	X	X	X
	Factors that can affect the results	Sun radiation	X	X	X
		Improper view angle	X	X	X
		Improper emission coefficient and reflected temperature	X	X	X
		Hot objects near inspected construction	X	X	X
		Incorrect settings of equipment	X	X	X
22.10 Developments	Innovative applications	Automated inspection			X
		Automated analysis			X
		Pulse phased thermography			X
		Image fusion			X

4.3. MAGNETIC DETECTION

Magnetic detection is commonly used as an NDT approach to identify and assess the location and distribution of reinforcement bars (rebars) within concrete structures. By leveraging magnetic principles, this technique provides crucial insights into the structural integrity and composition of the concrete.

The principles in magnetic detection involve using specialized instruments that generate a magnetic field. When applied to a concrete surface, these devices can detect variations in the magnetic field caused by the presence of ferrous materials like rebars. As the instrument is moved over the surface, it registers fluctuations in the magnetic field strength, allowing the operator to pinpoint the location and alignment of reinforcement within the concrete.

Magnetic detection is widely applied in concrete testing and construction quality control. It ensures accurate placement and alignment of rebars during construction, helping prevent structural deficiencies and weaknesses. In existing structures, it aids in assessing the as-built condition of reinforcement, identifying corrosion, and evaluating potential areas of concern. This technique is especially valuable for evaluating bridges, columns, and other load-bearing components. By providing rapid and non-invasive insights into reinforcement distribution, magnetic detection contributes to maintaining the structural integrity and safety of concrete structures.

Magnetic detection training which covers theory and practical sessions needs to correspond with Tables 23 and 24.

TABLE 23. GENERAL CONTENT FOR MAGNETIC DETECTION

	Content	Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
23.1	Introduction to magnetic detection	4	4	2
23.2	Physical principles of the method and associated knowledge	16	16	8
23.3	Product knowledge and capabilities of the method and its derived techniques	16	12	6
23.4	Equipment	12	10	8
23.5	Information prior to testing	6	14	10
23.6	Testing	20	10	10
23.7	Evaluation and reporting	10	18	30
23.8	Assessment	8	8	10
23.9	Quality aspects	8	8	10
23.10	Developments	0	0	6
	Total Hours	**12**	**12**	**8**

TABLE 24. MAGNETIC DETECTION — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
24.1 Introduction to magnetic detection	History	Requirement for measurements	X	X	
		Importance of rebar detection, diameter estimation, and cover measurement	X	X	
		Historical development	X		
	Purpose of NDT	Introduction	X		
		NDT application	X		
		The performance of NDT	X		
		NDT personnel	X		
		Tasks of the inspection personnel	X		
		Main NDT methods	X	X	
	Purpose of survey	Definition	X	X	
		Applicability and limitations	X	X	X
	Relevant standards	Terminology	X	X	
		National or international concrete structures standards	X	X	X
24.2 Physical principles of the method and associated knowledge	Electricity	Direct current	X	X	
		Alternating current	X	X	
	Magnetism	Introduction	X	X	
		Magnetic fields	X	X	
		Magnetic permeability	X	X	
		Iron and steel magnetization	X	X	

TABLE 24. MAGNETIC DETECTION — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
	Electromagnetism	Correlation between electric and magnetic fields	X	X	X
		Current induced by a magnetic field	X	X	X
		Transformers. Primary and secondary circuits and currents	X	X	X
		Lenz's law		X	X
24.3 Product knowledge and capabilities of the method and its derived techniques	Cover of reinforcement	Necessity of covering	X	X	
		Minimum usual coverings accord relevant standards	X	X	
		Anchor of reinforcements in concrete		X	X
		Durability aspects of covers		X	X
		Increasing of minimum covers		X	X
		Covers of strands and tendons		X	X
	Types of reinforcement	Longitudinal and transversal	X	X	
		Welded and fabric panels	X	X	
		Prestressing strands and tendons	X	X	X
		Rebar bundles		X	X
		Tendon ducts in prestressed structures		X	X
		Steel fibres reinforced structures		X	X
24.4 Equipment	Instruments	Use of magnetic field	X	X	
		Eddy current devices	X	X	
		Reluctance (Magnetic induction) devices	X	X	
		Accessories	X	X	
		Influence of electric conductor materials		X	X
		Accuracy of measurement		X	X
		Limitation of detection		X	X
24.5 Information prior to testing	Information about testing object	Available documents	X	X	
		Instruction and templates	X	X	X
		Writing instructions and templates		X	X
	Test condition and application of standards	Planning of measurement		X	X

TABLE 24. MAGNETIC DETECTION — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
	Example of on-site application	Typical walls, columns, slabs and beams reinforcement arrangement, both in concrete and masonry structures	X	X	
24.6 Testing	Previous test preparations	Surface preparation and cleaning	X		
		Repetitive test		X	X
	Procedure including calibration	Practice with probes of adequate rebar diameter for cover determination, or special geometry if necessary		X	X
		Rebar location, including field marks		X	X
		Concrete cover measurement		X	X
		Rebar size estimation		X	X
		Influence of other re-bars and reinforcement meshes		X	X
		Embedded ferromagnetic objects investigation and its influence on measurement		X	X
		Minimum detectable spacing of rebar		X	X
24.7 Evaluation and reporting	Report writing	Recording of the test	X	X	
		Recording and saving of measurement data	X	X	
		Marking of component / structure	X	X	
		Compile all results and readings		X	X
	Interpretation	Analysis of records of the test, and reporting		X	X
		Interpretation of results		X	X
	Evaluation	Concrete cover conformity and number and arrangement of rebars as required by design		X	X
		Diameter estimation		X	X
	Factors influencing the test	Concrete surface condition		X	X
		How longitudinal and transversal rebars		X	X

TABLE 24. MAGNETIC DETECTION — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
		affects the measurement			
		Surface curvature		X	X
		Others		X	X
24.8 Assessment	Conformity assessment of test reports	Accuracy of measurement		X	X
		Assessing the reliability of the measurement records		X	X
		Assessment according to the technical specification		X	X
24.9 Quality aspects	Documents	National and international standards			X
		Issue of testing procedures			X
	Procedures and its contents	Concept		X	X
		Application		X	X
		Development/ creation		X	X
		Essential components of procedures		X	X
		System verification		X	X
		Data quality		X	X
		Coverage of inspection area		X	X
		Coupling		X	X
	Personnel qualification	ISO 9712	X	X	X
		Other NDT qualification and certification systems		X	X
	Other aspects	Supplementary inspections			X
		Further quality assurance measures			X
24.10 Developments	Other methods	Ground penetrating radar (GPR)			X
		Automatic methods			X
		Pulsed eddy current (PEC) technique			X

4.4. POTENTIAL MAPPING

Potential mapping is employed in concrete testing to assess the likelihood of corrosion in reinforced concrete structures. It involves measuring and analysing electrical potentials on the concrete surface to evaluate the condition of embedded reinforcement.

In potential mapping, reference electrodes are strategically positioned on the concrete surface. Through the measurement of the electrical potential differences between these electrodes and the reinforcement, engineers can determine the electrochemical activity and potential for corrosion. By comparing these readings to established benchmarks, the corrosion risk of the reinforcement can be inferred.

Potential mapping is pivotal for assessing the durability of reinforced concrete structures. It is particularly useful in identifying areas prone to corrosion due to factors like proximity of reinforcement to the surface or exposure to corrosive agents. Engineers employ this method in bridges, marine structures, and environments with harsh conditions. By identifying high-risk areas, necessary preventive measures can be implemented to mitigate corrosion, prolonging the lifespan of the concrete structure. Potential mapping is a valuable tool in ensuring the integrity and longevity of reinforced concrete infrastructure.

Potential mapping training which covers theory and practical sessions needs to correspond with Tables 25 and 26.

TABLE 25. GENERAL CONTENT FOR POTENTIAL MAPPING

	Content	**Level 1 (% of total duration)**	**Level 2 (% of total duration)**	**Level 3 (% of total duration)**
25.1	Introduction to potential mapping	4	4	2
25.2	Physical principles of the method and associated knowledge	18	16	2
25.3	Product knowledge and capabilities of the method and its derived techniques	16	12	12
25.4	Equipment	10	8	2
25.5	Information prior to testing	10	16	16
25.6	Testing	20	14	10
25.7	Evaluation and reporting	10	18	30
25.8	Assessment	6	6	10
25.9	Quality aspects	6	6	10
25.10	Developments	0	0	6
	Total Hours	**12**	**12**	**8**

TABLE 26. POTENTIAL MAPPING — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
26.1 Introduction to potential mapping	History	Requirement for measurements	X	X	
		Importance of potential mapping	X	X	
	Purpose of NDT	Introduction	X		
		NDT application	X		
		The performance of NDT	X		
		NDT personnel	X		
		Main NDT methods	X	X	
	Purpose of potential mapping survey	Definition	X	X	
		Applicability and limitations	X	X	X
	Relevant standards	National or international	X	X	X
26.2	Electricity and electrolytes	Direct current	X	X	
		Faraday’s law	X	X	

TABLE 26. POTENTIAL MAPPING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
Physical principles of the method and associated knowledge		Electrical potential of elements	X		
		Electric potential and galvanic currents	X		
		Electrolytic cell	X	X	
		Electric potential	X	X	
	Corrosion principles	Definition of corrosion	X		
		Electric potential and galvanic currents	X		
		Polarization		X	
26.3 Product knowledge and capabilities of the method and its derived techniques	Corrosion of steel in concrete	Iron in nature	X	X	
		Steel manufacturing	X	X	
		Protection against steel corrosion	X	X	X
		Carbonation process	X	X	X
		Chloride concentration	X	X	X
		Localized corrosion		X	X
		Tutti diagram		X	X
		Half cell types	X	X	X
26.4 Equipment	Instruments	High impedance voltmeter	X		
		Specific devices	X		
		Half cell	X		
		Wet sponge	X		
		Cables, clamps	X		
		Proper connection of cables and clamps	X		
		Thermometer	X		
		Accessories	X		
26.5 Information prior to testing	Information about testing element	Available documents	X	X	
		Writing instructions		X	X
		Instruction and templates	X	X	X
	Test condition and application of standards	Planning of measurement		X	X
26.6 Testing	Previous work	Surface preparation	X		
		Rebar access to connect positive clamp.	X		
		Rebar location with other NDT techniques		X	
		Control of electric continuity of rebars	X		
		Preparing an electrical contact solution	X	X	X
	Procedure including calibration	Initial calibration of half cell with hydrogen electrode	X	X	

TABLE 26. POTENTIAL MAPPING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Verification of the porous plug of the half cell	X		
		Measurement points	X		
		Initial device preparation for testing	X		
		Record of measurements	X		
		Number of points of testing according to measured potential		X	X
	Example of on-site application	Condition monitoring related with potential corrosion		X	X
26.7 Evaluation and reporting	Report writing	Recording of the test	X		
		Recording and saving of measurement data	X	X	
		Marking of component / structure	X	X	
		Compile all results and readings	X	X	
		Temperature correction		X	X
	Interpretation	Analysis of records of the test and reporting		X	X
		Obtaining equipotential diagrams		X	X
		Cumulative frequency distribution		X	X
		Interpretation of results		X	X
26.8 Assessment	Conformity assessment of test reports	Accuracy of measurement		X	X
		Reliability of the measurement records		X	X
		Assessment according to the technical specification		X	X
26.9 Quality aspects	Documents	National and international standards			X
		Issue of testing procedures			X
	Procedures and its contents	Concept		X	X
		Application		X	X
		Development / creation		X	X
		Essential components		X	X
		System verification		X	X
		Data quality		X	X
		Coverage of inspection area		X	X

TABLE 26. POTENTIAL MAPPING — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
	Personnel qualification	EN ISO 9712	X	X	X
		Other NDT qualification and certification systems		X	X
	Other aspects	Supplementary inspections			X
		Quality assurance measures			X
26.10 Developments	Other methods	Corrosion rate			X
		Automatized monitoring corrosion measurement			X

4.5. RESISTIVITY MEASUREMENT

Resistivity measurement is employed in concrete testing to assess the electrical properties of concrete. By measuring the resistance of a concrete sample to the flow of electrical current, it offers insights into the material's quality, composition, and potential durability.

The principles of resistivity measurement involve applying a known electrical current to a concrete sample and measuring the resulting voltage drop. The resistance to the current flow is then calculated, providing the resistivity value. This value is influenced by factors such as moisture content, porosity, and the presence of ions or contaminants within the concrete.

Resistivity measurement finds diverse applications in concrete testing. It assists in evaluating the quality of fresh concrete, monitoring the curing process, and assessing the impact of supplementary materials like fly ash or silica fume. Additionally, resistivity values can indicate the potential for chloride ion penetration and the risk of reinforcement corrosion. This technique aids in optimizing concrete mix designs for specific applications, enhancing concrete durability, and supporting informed decision-making in construction and maintenance practices. Resilient and informative, resistivity measurement contributes significantly to ensuring the longevity and performance of concrete structures.

Resistivity measurement training which covers theory and practical sessions needs to correspond with Tables 27 and 28.

TABLE 27. GENERAL CONTENT FOR RESISTIVITY MEASUREMENT

	Content	**Level 1 (% of total duration)**	**Level 2 (% of total duration)**	**Level 3 (% of total duration)**
27.1	Introduction to resistivity measurement	5	5	5
27.2	Physical principles of the method and associated knowledge	15	12	10
27.3	Product knowledge and capabilities of the method and its derived techniques	15	15	15
27.4	Equipment	15	10	10
27.5	Information prior to testing	10	15	15
27.6	Testing	20	10	10
27.7	Evaluation and reporting	10	20	20
27.8	Assessment	5	5	5

TABLE 27. GENERAL CONTENT FOR RESISTIVITY MEASUREMENT

	Content	Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
27.9	Quality aspects	5	5	5
27.10	Developments	0	3	5
	Total Hours	**12**	**12**	**8**

TABLE 28. RESISTIVITY MEASUREMENT — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
28.1 Introduction to resistivity measurement	History	Importance of the technique	X	X	X
	Purpose of NDT	Introduction	X	X	X
		NDT application	X	X	X
		The performance of NDT	X	X	X
		NDT personnel	X	X	X
		Main NDT methods	X	X	X
	Purpose of resistivity measurement	Definition	X		
		Applicability and limitations	X		
28.2 Physical principles of the method and associated knowledge	Electricity	Current	X	X	X
		Voltage	X	X	X
		Resistance	X	X	X
		Ohm's Law	X	X	X
		Conductivity	X	X	X
		Resistivity	X	X	X
	Electrical properties of concrete	Moisture content	X	X	X
		Dielectric properties	X	X	X
		Resistance	X	X	X
		Capacitance	X	X	X
	Factors affecting concrete resistivity	Microstructure		X	X
		Temperature		X	X
		Moisture content		X	X
		Geometry of specimen		X	X
28.3 Product knowledge and capabilities of the method and its derived techniques	Defectology	Discontinuities and defects		X	X
		Material properties		X	X
		Correlation with performance characteristics		X	X
	Applications of resistivity measurement	Chloride permeability	X	X	X
		Diffusion coefficient	X	X	X
		Corrosion	X	X	X
		Crack detection	X	X	X
		Setting time measurement	X	X	X
		Moisture content	X	X	X
	Capabilities	Bulk resistivity	X	X	X
		Surface resistivity	X	X	X
	Techniques	Two-point technique	X	X	X

TABLE 28. RESISTIVITY MEASUREMENT — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
		Four-point technique	X	X	X
	Code and standards	Applicable codes applied		X	X
	Test conditions and application of standard	Moisture	X	X	X
		Salts content		X	X
		Steel fiber reinforcement	X	X	X
		Temperature	X	X	X
		Water / cement ratio		X	X
		Mix proportions		X	X
		Application standard		X	X
		Requirement of test personnel		X	X
		Acceptance criteria		X	X
28.4 Equipment	Resistivity measurement system	Instrument (resistivity meters)	X	X	X
		Electrodes	X	X	X
	Output	Measured resistivity	X	X	X
28.5 Information prior to testing	Information about the test object	Written instruction	X		
		Identification or designation material:	X	X	X
		— Type of concrete structures;	X	X	X
		— Process of manufacture;	X	X	X
		— Catalogue of defects;		X	X
		— Extent of test coverage.		X	X
	Technique and sequence of performing test	Surface condition	X	X	X
		Surface preparation	X	X	X
		Post-test documentation		X	X
		Equipment to be used		X	X
		Requirement for recording	X	X	X
	Instructions	Preparation of written procedures		X	X
		Preparation of written instructions		X	
		Performing inspection	X		
		Documentation		X	X
		Procedures, codes, and standards		X	X
28.6 Testing	Probe selection	Product		X	X
		Grade		X	X
		Metallurgical condition		X	X
		Shape		X	X

TABLE 28. RESISTIVITY MEASUREMENT — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
		Type of discontinuity sought		X	X
		Location		X	X
		Extent of examination		X	X
	Operating conditions	Moisture		X	X
		Salt content		X	X
		Temperature		X	X
		Water/cement ratio		X	X
		Mix proportions		X	X
	Parameters setting	Spacing	X	X	X
		Surface coupling	X	X	X
		Frequency	X	X	X
		Data acquisition	X	X	X
		Written procedure		X	X
		Written instruction	X	X	
28.7 Evaluation and reporting	Reporting	Reporting level		X	X
		Examination report	X	X	X
	Evaluation	Characterization of the indications		X	X
		Two-point technique analysis		X	X
		Four-point technique analysis		X	X
		Data analysis		X	X
28.8 Assessment	Evaluation and confirmation of test reports	Acceptance criteria		X	X
		Training of Level 1 and Level 2 of the acceptance criteria			X
28.9 Quality aspects	Factors affecting the quality of testing	Personnel qualification	X	X	X
		ISO 9712	X	X	X
		Other NDT qualification and certification systems			X
		Format and scope of working procedures			X
		Qualification of NDT procedures			X
		Authorization			X
		Developing written instruction		X	
		Working correctly to written instruction	X		
		Traceability of documents		X	X
		Reliability of measurements		X	X
	Knowledge of applicable NDT application and	Correct technique selection		X	
		Use of correct test parameters		X	

TABLE 28. RESISTIVITY MEASUREMENT — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
	product standards	NDT method selection		X	X
		Job specific training	X	X	X
		Equipment verification	X	X	X
28.10 Developments	General information	Surface disc test			X
		Four probe square array			X
		Imaging			X
		Nano carbon materials		X	X

5. ACOUSTICS

5.1. ULTRASONIC AND SONIC TESTING

Ultrasonic and sonic testing are widely used in concrete inspection to assess the internal condition and integrity of structures. These methods rely on the transmission of high-frequency sound waves (ultrasonic) or audible sound waves (sonic) through the concrete.

In ultrasonic testing (UT), high-frequency waves are transmitted into the concrete, and their reflections are recorded. By analysing the time it takes for the waves to bounce back and their energy patterns, engineers can determine the depth, size, and nature of defects such as cracks, voids, and delamination within the concrete. This method is highly sensitive and provides detailed information about subsurface anomalies.

On the other hand, sonic testing employs relatively lower audible sound waves to evaluate concrete properties. A sound source is applied to the surface, and the time taken for the sound to travel through the concrete and return to a receiver is measured. Sonic waves are effective in assessing the quality of concrete, detecting voids, and estimating concrete strength and elasticity.

Both ultrasonic and sonic testing offer valuable insights into concrete's internal condition, helping engineers make informed decisions about repairs, maintenance, and structural soundness. They play a crucial role in ensuring the longevity and safety of concrete structures by detecting issues that might not be visible on the surface.

Ultrasonic and sonic testing training which covers theory and practical sessions needs to correspond with Tables 29 and 30.

TABLE 29. GENERAL CONTENT FOR ULTRASONIC AND SONIC TESTING

	Content	**Level 1 (% of total duration)**	**Level 2 (% of total duration)**	**Level 3 (% of total duration)**
29.1	Introduction to ultrasonic and sonic testing	3	3	3
29.2	Physical principles of the method and associated knowledge	18	18	16
29.3	Product knowledge and capabilities of the method and its derived techniques	16	14	2
29.4	Equipment	15	8	11
29.5	Information prior to testing	2	12	14
29.6	Testing	36	30	20

TABLE 29. GENERAL CONTENT FOR ULTRASONIC AND SONIC TESTING

	Content	**Level 1 (% of total duration)**	**Level 2 (% of total duration)**	**Level 3 (% of total duration)**
29.7	Evaluation and reporting	8	8	13
29.8	Assessment	0	4	6
29.9	Quality aspects	2	3	10
29.10	Developments	0	0	5
	Total Hours	**40**	**60**	**30**

TABLE 30. ULTRASONIC AND SONIC TESTING — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
30.1 Introduction to ultrasonic and sonic testing	Non-destructive testing (NDT)	Basic knowledge to NDT	X	X	
		Main NDT methods and applications	X	X	
	Ultrasonic and sonic testing	Basic knowledge	X	X	
		Applicability and limitations	X	X	
	Terminology	Sound attenuation	X	X	
		Acoustic noise	X	X	
		Piezo electric materials	X	X	
		Wave modes	X	X	
		Other relevant terminology	X	X	
	Relevant standard and specification	ISO standards		X	X
		EN standards		X	X
		ASTM standards		X	X
		ASME standards		X	X
		Other applicable standards and specification		X	X
30.2 Physical principles of the method and associated knowledge	Basic mathematics	Trigonometric function	X		
		Logarithmic	X		
	Physical definitions and characteristics	Sinusoidal movement	X	X	
		Amplitude	X	X	
		Wavelength	X	X	
		Velocity	X	X	
		Period	X	X	
		Frequency	X	X	
		Acoustic impedance	X	X	
	Waves mode	Longitudinal	X	X	
		Transverse	X	X	
		Rayleigh (Surface)	X	X	
		Guided waves		X	X
	Generation of ultrasonic signal	Basics of transducers	X	X	
		Piezo – electric effects	X	X	
		Sound beam characteristics	X	X	X
		Pulse characteristics	X	X	

TABLE 30. ULTRASONIC AND SONIC TESTING — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
	Propagation of waves in elastic bodies	Near fields (Fresnel zone)	X	X	
		Far fields (Fraunhofer zone)	X	X	
		Beam divergence	X	X	
		Influence of transducer frequency and diameter to signal	X	X	X
		Relation between velocity and elastic properties			X
	Reflection / transmission of waves in elastic bodies	Effects at interfaces at normal incidence	X	X	X
30.3 Product knowledge and capabilities of the method and its derived techniques	General defects in concrete materials	Honeycombing	X	X	
		Debonding	X	X	
		Shaft (pile) defects	X	X	
		Air voids	X	X	
		Cracks	X	X	
		Deviations from the specification of physic-mechanical characteristics	X	X	X
	Implementation of the techniques	According to product	X	X	
		According to expected discontinuities	X	X	
		Codes, standards, and specifications		X	X
	Influence of surface and geometry on acoustics signal	Surface roughness	X	X	
		Dimension of contact surface (curvature/ irregular shape)	X	X	
		Part geometry	X	X	
	Influence of material properties	Sound attenuation	X	X	
		Acoustic noise	X	X	
		Signal to noise ratio (SNR)	X	X	
		Simulation of beam propagation			X
30.4 Equipment	Ultrasonic instruments (design and function)	Types	X	X	
		Difference between digital and analog			X
		Impact echo and Pile integrity testing (PIT) equipment	X	X	
		Ultrasonic pulse velocity system	X	X	
		Pulse-echo equipment	X	X	
		Automated and semi-automated systems		X	X

TABLE 30. ULTRASONIC AND SONIC TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
	Probes (design and application)	Probe types	X	X	
		Probe characteristics			
		Frequency bandwidth			X
		Measurement of pulse length			X
		Measurement of beam direction			X
		Dynamic range			X
	Impactor (design and application	Impactor types	X	X	
		Impactor characteristics	X	X	
	Couplant (as applicable)	Types of couplant	X	X	
		Contact techniques	X	X	
	Cables and connectors	Type of cables and connectors	X	X	
		Length of cables and impedance		X	X
	Calibration / Reference blocks	Zero-point setting	X	X	X
		Velocity in the field	X	X	X
		Equipment functional check	X	X	X
		Artificial reflector in reference block	X	X	X
30.5 Information prior to testing	Object to be tested	Geometry	X	X	X
		Surface	X	X	X
		Rebar location	X	X	X
		Structure	X	X	X
	Kind of manufacture	Composition	X	X	X
		Properties of concrete	X	X	X
	Extend of test coverage	Void	X	X	
		Crack	X	X	
		Debonding	X	X	
		Honeycombing	X	X	
		Heat damaged	X	X	
	Test conditions and application of standards	Accessibility		X	X
		Applicable standards			X
		Technical specifications			X
		Testing stage			X
		Requirements of test personnel		X	X
		Acceptance criteria		X	X
	Written instructions and procedures	Preparation of written instruction		X	
		Preparation of written procedure			X
		Performing inspection in accordance to written instruction	X		

TABLE 30. ULTRASONIC AND SONIC TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
30.6 Testing	Preparation	Variation of artificial reflectors	X	X	X
		Range setting	X	X	
		Sensitivity setting	X	X	
		Functional tests	X	X	X
		Verify the settings	X	X	X
	Techniques	Pulse – echo	X	X	
		Through transmission	X	X	
		Ultrasonic thickness measurement	X	X	
		Ultrasonic pulsed velocity measurement	X	X	
		Impact echo	X	X	
		Pile integrity testing (PIT)		X	
		Impulse response		X	
		Multiple probe arrays		X	X
		Other techniques	X	X	X
		Verification of procedures and instructions			X
30.7 Evaluation and reporting	Interpretation	Referencing standards, specifications, and manuals		X	X
		Conventional or computer aided methods	X	X	X
		Impact echo, pile integrity testing (PIT) and impulse response results	X	X	X
		Displays (images)	X	X	X
		Acceptance criteria: Standards, specification, and other documents		X	X
	Detecting, locating, and sizing techniques	Testing reporting	X	X	X
		Storage of data-file and generated report	X	X	X
		Detecting true/false display indication	X	X	X
		Sizing techniques	X	X	
		Position and depth of defects	X	X	
30.8 Assessment	Application of the acceptance criteria according to standards, codes, and procedures	Type of defect		X	X
		Size of defect		X	X
		Localization		X	X
		Regularity		X	X
		Influence of material origin		X	X

TABLE 30. ULTRASONIC AND SONIC TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
30.9 Quality aspects	Construction concept	Safety consideration	X	X	X
		Damage tolerance	X	X	X
	Reliability of measurements	Limits of ultrasonic and sonic testing		X	
		Detectable flaw size	X	X	
		Factors influencing the test	X	X	X
		Quality of images		X	X
	Documents	Traceability of documents		X	X
		Equipment verification		X	X
		Format of working procedure			X
	Personnel qualification	ISO 9712		X	X
		Other NDT qualification and certification systems		X	X
30.10 Developments	Other techniques	Dynamic vibration technique			X
		Ultrasonic pulsed compression			X
		Computer modelling			X

5.2. ULTRASONIC AND SONIC ARRAY TESTING

Ultrasonic and sonic array testing are employed in concrete inspection to comprehensively assess the internal composition and structural integrity of materials. These techniques involve the deployment of arrays—multiple sensors—to achieve more detailed and accurate results.

In ultrasonic array testing, also known as phased array ultrasonic testing (PAUT), an array of high-frequency transducers emits ultrasonic waves into the concrete. These waves propagate through the material and are received by sensors, creating a detailed image of the internal structure. By analysing the wave patterns and their interactions, engineers can identify defects, such as cracks, voids, and rebar corrosion, with high precision. Ultrasonic arrays provide a more complete understanding of a structure's condition compared to traditional single-point testing.

Sonic array testing functions similarly, utilizing audible sound waves. Array sensors emit sound waves that travel through the concrete, with receiving sensors capturing the transmitted signals. The collected data is then processed to create a comprehensive image of the material's internal state. Sonic array testing is particularly effective in assessing the uniformity of concrete and detecting areas of potential weakness or anomalies.

Both ultrasonic and sonic array testing significantly enhance the quality and accuracy of concrete inspection. By providing detailed subsurface information, these techniques enable engineers to make well-informed decisions about maintenance, repair, and structural assessments. The array-based approach amplifies the capabilities of these methods, ensuring the safety, durability, and longevity of concrete structures.

Ultrasonic and sonic array testing training which covers theory and practical sessions needs to correspond with Tables 31 and 32.

TABLE 31. GENERAL CONTENT FOR ULTRASONIC AND SONIC ARRAY TESTING

	Content	Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
31.1	Introduction to ultrasonic and sonic array testing	4	7	5
31.2	Physical principles of the method and associated knowledge	14	12	7
31.3	Product knowledge and capabilities of the method and its derived techniques	14	12	10
31.4	Equipment	14	12	12
31.5	Information prior to testing	7	7	12
31.6	Testing	25	17	12
31.7	Evaluation and reporting	22	17	14
31.8	Assessment	0	5	14
31.9	Quality aspects	0	11	14
31.10	Developments	0	0	0
	Total Hours	**24**	**40**	**24**

TABLE 32. ULTRASONIC AND SONIC ARRAY TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
32.1 Introduction to ultrasonic and sonic array testing	Ultrasonic and sonic array testing	Basic knowledge	X	X	
		Applicability and limitation	X	X	
		Difference with conventional method	X	X	
	Terminology	Active aperture	X	X	
		Linear scan	X	X	
		Array probes	X	X	
		Other relevant terminologies	X	X	
	Relevant standards and specifications	ISO standards		X	X
		EN standards		X	X
		ASTM standards		X	X
		ASME standards		X	X
		Others		X	X
32.2 Physical principles of the method and associated knowledge	Mathematical and physical basics	Basic of sound beam	X	X	
		Waves	X	X	
		Influence of sound bandwidth	X	X	
		Terms relating to sound	X	X	
		Terms relating to arrays	X	X	
		Influence of band width	X	X	
	Generation of signal	Basics of transducers	X	X	
		Sound beam characteristics	X	X	
		Impulse characteristics	X	X	
		Near fields (Fresnel zone)	X	X	

TABLE 32. ULTRASONIC AND SONIC ARRAY TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
	Propagation of waves in elastic bodies	Far fields (Fraunhofer zone)	X	X	
		Beam divergence	X	X	X
		Influence of transducer frequency and active aperture	X	X	X
32.3 Product knowledge and capabilities of the method and its derived techniques	General defects in concrete composite materials	Delamination	X	X	
		Honeycombing	X	X	
		Debonding	X	X	
		Air voids	X	X	
		Cracks	X	X	
		Deviations from the specification of physic-mechanical characteristics	X	X	X
	Implementation of the techniques	According to product		X	X
		According to expected discontinuities	X	X	X
		Codes, standards, and specifications		X	X
	Influence of surface and geometry	Surface roughness	X	X	
		Dimension of contact surface	X	X	
		Part geometry	X	X	
	Influence of material properties	Sound attenuation	X	X	
		Acoustic noise	X	X	
		Signal to noise ratio (SNR) and their improvement	X	X	X
		Simulation of beam propagation			X
32.4 Equipment	Instruments (design and function)	Array probe	X	X	X
		Full matrix capture (FMC) / Total focusing method (TFM)	X	X	X
		Amplitude balancing	X	X	
		Multi group capability	X	X	
		Number of active apertures	X	X	
	Array probes	Linear array	X	X	
		Matrix (2D) array	X	X	
		Multi group capability	X	X	
	Encoders	Different type of scanners	X	X	
	Couplant	Types of couplant	X	X	
		Contact techniques	X	X	
		Zero-point setting	X	X	
		Velocity in the fields	X	X	

TABLE 32. ULTRASONIC AND SONIC ARRAY TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
	Calibration / Reference blocks	Artificial reflector in reference block	X	X	X
32.5 Information prior to testing	Applied codes, standards, and specifications	Related codes, standards and specifications	X	X	X
		Requirements for procedure		X	X
		Developing written procedure			X
32.6 Testing	Techniques for testing	Linear scanning	X	X	
		Multi group scanning	X	X	
	Test setting	Sensitivity setting	X	X	
		Range setting		X	
		Typical application of array techniques	X	X	X
		Typical application of FMC/TFM techniques	X	X	X
32.7 Evaluation and reporting	Interpretation	Distinction between defect and geometry	X	X	X
		Type of defect	X	X	
		Location and sizing of defect	X	X	
		Interpretation and evaluation of indication		X	X
		Sizing of defect	X	X	
		A-, B-, and C- scan interpretation	X	X	X
	Generation of test report	Recording	X	X	
		Classification of results according to the written procedure		X	X
		Location and sizing of defect	X	X	
		Storage of data	X	X	
32.8 Assessment	Application the acceptance criteria to standards, code, procedure, or specification	Type of defect		X	X
		Size of defect		X	X
		Localization		X	X
		Regularity		X	X
		Influence of material origin		X	X
32.9 Quality aspects	Reliability of measurements	Limits of the techniques		X	X
		Detectable flaw size		X	X
		Factors influencing the test		X	X
		Quality of evaluated images		X	X
	Documents	National and international standards		X	X

TABLE 32. ULTRASONIC AND SONIC ARRAY TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Format of working procedures		X	X
	Personnel qualification	EN ISO 9712		X	X
		Other NDT qualification and certification systems		X	X
32.10 Developments	N/A				

5.3. ACOUSTIC EMISSION TESTING (AT)

Acoustic emission testing (AT) is a cutting-edge technique method for concrete testing, offering insights into the internal behaviour of concrete structures. By capturing and analysing acoustic signals generated during material deformation, AT provides valuable information about structural integrity and potential defects.

The application of AT involves strategically placing sensors on the concrete surface or embedding them within the structure. As the concrete undergoes stress, loading, or environmental changes, it emits acoustic waves that are detected by these sensors. These waves are translated into data that can reveal the initiation, growth, and propagation of cracks, as well as other internal structural changes.

AT is particularly valuable for detecting cracks, microcracking, and other defects that might not be visible on the surface. It is used in assessing various concrete structures, from buildings to infrastructure like bridges and tunnels, helping to identify potential issues early on. The real-time monitoring aspect of AT enables timely intervention and targeted maintenance, ultimately enhancing the safety and durability of concrete elements. As an NDT method, AT contributes significantly to the understanding and management of concrete's structural health.

Acoustic emission testing training which covers theory and practical sessions needs to correspond with Tables 33 and 34.

TABLE 33. GENERAL CONTENT FOR ACOUSTIC EMISSION TESTING

	Content	Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
33.1	Introduction to acoustic emission testing	2	2	3
33.2	Physical principles of the method and associated knowledge	12	12	10
33.3	Product knowledge and capabilities of the method and its derived techniques	30	22	10
33.4	Equipment	12	10	0
33.5	Information prior to testing	2	10	6
33.6	Testing	30	28	10
33.7	Evaluation and reporting	10	9	12
33.8	Assessment	0	4	12
33.9	Quality aspects	2	3	12
33.10	Developments	0	0	25
	Total Hours	**40**	**80**	**30**

TABLE 34. ACOUSTIC EMISSION TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
34.1 Introduction to acoustic emission testing	Background	History	X	X	
		Purpose of NDT	X	X	
	Purpose of acoustic emission testing (AT)	Definition	X	X	
		Applicability and limitations	X	X	X
	Relevant standards and guidelines	ISO 12716, ACI, DGZfP	X	X	X
34.2 Physical principles of the method and associated knowledge	Physical principles	Relevant standards	X	X	X
		General principle	X		
		Overview	X		
		Visual demonstration	X		
		Frequency range		X	
		Source characteristics		X	
	Characteristics of AT	Transient emission	X		
		Continuous emission	X		
		Amplitude	X		
		Frequency range	X		
		Effect of source dimension		X	
		Effect of source dimension		X	
		Source propagation		X	
		Loading		X	
		Kaiser effect	X	X	
		Overview	X		
		In different material		X	X
	Sources of acoustic emission	Metals	X	X	
		Composites	X	X	
		Other materials	X	X	
		Dislocation	X	X	
		Cold Joint	X	X	
		Inclusion	X	X	
		Crack growth	X	X	
		critical and sub-critical crack growth	X	X	
		Fatigue crack	X	X	
		Crack surface friction	X	X	
		Corrosion	X	X	
		Stress corrosion cracking	X	X	
		Leak	X	X	
		Mechanical friction	X	X	
		Lose parts	X	X	
		Non-detectible source	X	X	
	Wave propagation	Type of elastic waves	X		
		Longitudinal waves	X		
		Transverse waves	X		

TABLE 34. ACOUSTIC EMISSION TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Rayleigh waves	X		
		Lamb waves	X	X	
		Wave parameters	X		
		Wave motion and velocity		X	X
		Mode conversion	X	X	X
		Reflection and refraction	X	X	
		Wave attenuation	X	X	X
		Wave dispersion		X	X
		Geometric effects		X	
		Shadowing effects		X	
	Source location	One sensor location	X		
		Linear location with delta – t	X		
		Planar location with delta – t	X		
		Continuous emission		X	
		Zone location		X	X
		Thin-walled and thick-walled structure		X	
		Location uncertainty		X	
		Guard sensor	X	X	
34.3 Product knowledge and capabilities of the method and its derived techniques	General defects in composite materials	Defects in cement matrix composite	X	X	
		Initial imperfections	X	X	
		Degradation due to aging	X	X	
	Implementation of the AT techniques	According to product		X	X
		According to expected discontinuities	X	X	X
		Standards, specifications and codes		X	X
	Influence of testing parts	influence of surface and geometry	X	X	
		Influence of material properties	X	X	
34.4 Equipment	Sensors	Piezoelectricity	X		
		Construction	X		
		Frequency response	X		
		Wide – band and resonance sensors	X		
		Coupling and sensitivity	X		
		Integral electronics / differential	X		
		Connectors	X		
		Cables	X		
		Adjustment methods		X	

TABLE 34. ACOUSTIC EMISSION TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Sensor selection		X	
		Ground – loop		X	
		Temperature effect		X	
		Acoustic impedance	X	X	
		Wave guide		X	
	Preamplifiers	Single ended / differential	X		
		Unit of gain (dB scale)	X		
		Electronic noise	X		
		Filters	X		
		Frequency filter selection		X	
		Cable length effect		X	
		Common mode rejection		X	
		Signal saturation		X	
	Signal processing	Acoustic emission testing parameters (ISO 12716)		X	
		Energy (true, MARSE, alternative)		X	
		Continuous signal	X		
		Transient signal	X		
		Background noise	X		
		ALS	X		
		RMS	X		
		Amplitude	X		
		Threshold	X		
		Single vs multichannel system	X		
		Acquisition rate		X	
		Waveform digitization		X	
		Waveform recording		X	
	Source location processing	Algorithm	X	X	
		Overview	X		
		Knowledge		X	
		Selection		X	
		Linear location	X		
		Zone location	X		
		Hit – sequence location	X		
		Planar location	X		
		Three – dimension location		X	
		Location uncertainty		X	
		Guard channel		X	
	Advanced signal processing	External parameters	X		
		Distribution plots	X		
		Correlation plots	X		
		FFT		X	

TABLE 34. ACOUSTIC EMISSION TESTING — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
		Waveform future extraction		X	
		Timing consideration		X	
	Equipment adjustments	Sensor verification in lab	X		
		Sensor adjustment in lab		X	
		Acoustic Emission testing verification	X		
		Acoustic Emission testing adjustment		X	
		Applicable standards		X	
	Fundamentals of informatics	Knowledge and use of computers	X	X	
		Knowledge of software		X	X
34.5 Information prior to testing	Information about testing object	Object to be tested	X	X	
		Kind of manufacture	X	X	
		Catalogue of defects		X	X
		Extent of test coverage	X	X	
	Test condition and application of standards	Accessibility		X	
		Particular test condition		X	
		Application standard		X	
		Standards assigned to the test object		X	X
		Requirements of test personnel		X	X
		Acceptance criteria		X	X
	Technique and sequence of performing test	Surface condition		X	
		Surface preparation		X	
		Post – test documentation		X	X
	Instructions	Preparation of written instruction		X	X
		Performing inspection in accordance to written instruction	X		
34.6 Testing	Equipment set-up	Sensor placement	X		
		Equipment verification	X		
		Noise identification and elimination	X		
		Velocity and attenuation measurement	X		
		Location and simulated source	X		
		Factors affecting the selection of the test equipment		X	X
		Loading procedure	X	X	

TABLE 34. ACOUSTIC EMISSION TESTING — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
	Test performance	Actions during the test	X	X	
	Data acquisition and data display during the test	Data acquisition	X		
		Significance of the plots for the data display (time-based, load-based, location, correlation)	X		
		Comparison with the verification	X		
		Comparison with location of simulated source	X		
		Establishing of accepting criteria		X	X
		Selection of plots, correlation and distribution		X	
	Necessary action during the test	Stop criteria	X		
		Verification of on-line detected Acoustic emission testing sources by other NDT method		X	X
34.7 Evaluation and reporting	Data display	Time display	X		
		Load-based plots	X		
		Parameter-based plots	X		
		Location plots	X		
		Distribution plots	X		
		Correlation plots	X		
		Acoustic testing source correlation		X	
	Data interpretation	Noise and other non-relevant identification	X		
		Acoustic Emission testing source correlation	X		
		Post processing noise identification and filtering		X	
		Source activity		X	
	Data evaluation	Source severity		X	X
		Source criticality		X	X
		Advanced evaluation process		X	X
	Documentation and reporting	Documentation of results	X	X	X
		Report according to the relevant standard		X	X

TABLE 34. ACOUSTIC EMISSION TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
34.8 Assessment	Evaluation and confirmation of test reports	Application of the acceptance criteria to standards, code, procedure or specification (quality of concrete)		X	X
34.9 Quality aspects	Construction concept	Safe Life	X	X	
		Damage tolerance	X	X	X
	Reliability of measurements	Limits of AT		X	X
		Detectable flaw size		X	X
		Factors influencing the test		X	X
	Documents	National and international standards		X	X
		Issue of testing procedures		X	X
	Personnel qualification	ISO 9712	X	X	X
		Other NDT qualification and certification systems		X	X
34.10 Developments	Advanced imaging	TR method			X
	Combination with other monitoring methods, e. g. ultrasonic	Use of data from other methods, e. g. changing wave velocities			X
	Simulation of Acoustic Emission Testing	Simulation of wave propagation in concrete			X
	Integration into decision making	Thresholds, alarm systems			X

6. RADIATION

6.1. RADIOGRAPHIC TESTING (RT)

Radiographic testing (RT) is a valuable NDT method used in concrete inspection to reveal the internal structure and identify potential defects within the material. This method involves the use of X-rays or gamma rays to create images that provide insights into the composition, integrity, and potential anomalies within concrete structures.

During RT, a radiation source is placed on one side of the concrete, and a film is positioned on the opposite side. As the radiation passes through the concrete, it gets attenuated differently based on the density and thickness of the material. This results in a radiographic image that highlights variations in density, such as cracks, voids, delamination, and the presence of reinforcing materials like rebar.

RT is particularly effective for assessing the depth and size of defects that might be hidden from the surface view. The technique provides detailed images that aid engineers in evaluating the overall condition of concrete structures, identifying areas of concern, and making informed decisions about repairs or maintenance.

While RT offers valuable insights, it requires safety measures due to the use of radiation. Trained personnel and strict procedures ensure that the testing is conducted safely and effectively. Overall, RT serves as a crucial tool in concrete inspection, contributing to the structural integrity, safety, and longevity of various civil engineering projects.

Radiographic testing training which covers theory and practical sessions needs to correspond with Tables 35 and 36.

TABLE 35. GENERAL CONTENT FOR RADIOGRAPHIC TESTING

	Content	**Level 1 (% of total duration)**	**Level 2 (% of total duration)**	**Level 3 (% of total duration)**
35.1	Introduction to radiographic testing	6	5	3
35.2	Physical principles of the method and associated knowledge	15	15	5
35.3	Product knowledge and capabilities of the method and its derived techniques	18	10	10
35.4	Equipment	20	10	5
35.5	Information prior to testing	10	5	10
35.6	Testing	18	20	18
35.7	Evaluation and reporting	7	10	10
35.8	Assessment	0	10	18
35.9	Quality aspects	6	10	18
35.10	Developments	0	4	6
	Total Hours	**40**	**80**	**40**

TABLE 36. RADIOGRAPHIC TESTING — LEVELS 1, 2 AND 3

<table>
<tr><th>Content</th><th colspan="2"></th><th>Level 1</th><th>Level 2</th><th>Level 3</th></tr>
<tr><td rowspan="17">36.1 Introduction to radiographic testing (RT)</td><td rowspan="2">Non-destructive testing (NDT)</td><td>Basic knowledge to NDT</td><td>X</td><td>X</td><td></td></tr>
<tr><td>Main NDT methods</td><td>X</td><td>X</td><td></td></tr>
<tr><td rowspan="2">Radiographic testing (RT)</td><td>Basic knowledge to RT</td><td>X</td><td>X</td><td></td></tr>
<tr><td>Applicability and limitations</td><td>X</td><td>X</td><td></td></tr>
<tr><td rowspan="9">Terminology</td><td>Ionizing radiation</td><td>X</td><td>X</td><td></td></tr>
<tr><td>Energy</td><td>X</td><td>X</td><td></td></tr>
<tr><td>Dose and dose rate</td><td>X</td><td>X</td><td></td></tr>
<tr><td>Dose rate constant</td><td>X</td><td>X</td><td></td></tr>
<tr><td>Activity</td><td>X</td><td>X</td><td></td></tr>
<tr><td>Intensity</td><td>X</td><td>X</td><td></td></tr>
<tr><td>Ionization</td><td>X</td><td>X</td><td></td></tr>
<tr><td>Radiographic sensitivity</td><td>X</td><td>X</td><td></td></tr>
<tr><td>Radiographic contrast</td><td>X</td><td>X</td><td></td></tr>
<tr><td rowspan="2">Relevant standards</td><td>ISO Standards</td><td></td><td>X</td><td>X</td></tr>
<tr><td>European standards</td><td></td><td>X</td><td>X</td></tr>
</table>

TABLE 36. RADIOGRAPHIC TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		ASTM standards		X	X
		ASME standards		X	X
		Other applicable standards		X	X
36.2 Physical principles of the method and associated knowledge	General	Structure of atom	X	X	
		Electromagnetic spectrum	X	X	
		Sources of radiation in RT applications	X	X	
		Essential radiographic parameters (kV, mA, activity)	X	X	
		Radiation filters		X	
		Focal spot	X	X	
	Attenuation of radiation	General mechanism of interaction:			
		— Photoelectric effect;	X	X	
		— Compton effect;	X	X	
		— Pair production;	X	X	
		— HVL, TVL and attenuation law;	X	X	
		— Hardening of radiation;	X	X	
		— Scattered radiation and build up factor;	X	X	
		— Filtering and collimation;	X	X	
		— X-ray fluorescence;	X	X	
		— Attenuation of neutrons and electrons.			X
	Radiographic sensitivity	Radiographic contrast	X	X	
		Specific contrast		X	
		Scatter radiation	X	X	
		Un-sharpness	X	X	
	Optimization of image quality	Radiation scattering	X	X	X
		Source energy		X	X
		Physical arrangement		X	X
	Geometrical projection conditions	Geometrical Un-sharpness	X	X	X
		Image magnification		X	X
		Inverse Square Law	X	X	X
	Image quality indicators	Wire type	X	X	X
		Step hole type	X	X	X
		Plate hole type	X	X	X
		Duplex wire type	X	X	X
36.3		Initial defect	X	X	X

TABLE 36. RADIOGRAPHIC TESTING — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
Product knowledge and capabilities of the method and its derived techniques	General defects in concrete materials	Degradation due to aging	X	X	X
	Application of radiographic testing	Pre-service	X	X	X
		In-service	X	X	X
		Post disaster/ incident	X	X	X
	Influence of detectability	Type of defect	X	X	X
		Size of defect	X	X	X
		Orientation	X	X	X
		Number of exposures		X	X
		Beam direction	X	X	X
		Increase in wall thickness		X	X
		Thickness ranges for X-ray and gamma ray		X	X
	Influence of testing part	Types of concrete basic structures:			
		— Slab;	X	X	X
		— Column;	X	X	X
		— Beam;	X	X	X
		— Wall;	X	X	X
		— Thickness and geometry;		X	X
		— Concrete properties.		X	X
36.4 Equipment	X-ray	Construction and function of X-ray tubes	X	X	
		X-ray generation	X	X	
		X-Ray beam	X	X	
		Parameters	X	X	
	Gamma	Gamma Container:			
		— Shielding;	X	X	
		— Transportation;	X	X	
		— Source assembly;		X	
		— Handling and projection;	X	X	
		— Special design;		X	
		— Collimation;	X	X	
		— Classes of containers.		X	X
		Parameters:			
		— Source type;	X	X	
		— Spectrum;	X	X	
		— Energy;	X	X	
		— Activity;	X	X	
		— Source size;	X	X	
		— Half life.	X	X	

TABLE 36. RADIOGRAPHIC TESTING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
	Film	Radiographic image development	X	X	
		Film characteristics:			
		— Film properties;	X	X	
		— Characteristic curve;	X	X	
		— Development time;	X	X	
		— Film granularity;	X	X	
		— Film classification;	X	X	
		— Film quality assurance.		X	
		Film screens	X	X	
	Darkroom facilities and practice	Darkroom design	X	X	X
		Film chemicals	X	X	
		Film development process	X	X	
	Accessories	Work setup:			
		— Lead letters and tape;	X	X	
		— Holding magnets;	X	X	
		— Rubber bands.	X	X	
		Safety:			
		— Lead shielding;	X	X	X
		— Collimator;	X	X	X
		— Radiation protection equipment;	X	X	X
		— Emergency equipment.	X	X	X
36.5 Information prior to testing	Information about the test object	Technical documents	X	X	X
		Identification or designation of material	X	X	X
		Type of concrete structures	X	X	X
		Catalogue of defects		X	X
		Extent of test coverage		X	X
	Test conditions and application of standard	Accessibility		X	X
		Related standards		X	X
		Requirements of test personnel		X	X
		Acceptance criteria		X	X
	Technique and sequence of performing test	Surface condition		X	X
		Equipment to be used		X	X
		Test setup		X	X
		Requirement for recording		X	X
		Post-test documentation		X	X
		Preparation of written instructions		X	

TABLE 36. RADIOGRAPHIC TESTING — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
	Written instructions and procedures	Preparation of written procedures.			X
		Testing preparation in accordance with written instruction	X	X	
		Presentation of the procedures, codes and standards			X
36.6 Testing	Standard practice and evaluation standards	Performing inspection in accordance with written instruction / procedure	X	X	
		Selection of technique		X	X
		Different exposure settings		X	X
		Interpretation of images		X	X
		Evaluation of flaws		X	X
36.7 Evaluation and reporting	Basic of evaluation	Viewing conditions:			
		— Room condition;	X	X	X
		— Viewing time;	X	X	
		— Lapsed time after dazzling;	X	X	
		— Luminance;		X	
		— Density measurement;	X	X	
		— Mach effect.		X	
		Film viewer:			
		— Introduction;	X	X	
		— Minimum luminance;		X	
		— Homogeneity factor.		X	
	Physical factors	Eyesight		X	
		Adaption prior viewing		X	
	Evaluation of radiographs	Verification of the image quality	X	X	X
		Report of imperfections		X	X
	Test report	Complies with examination standard		X	X
		Conformed to test quality		X	X
36.8 Assessment	Evaluation of defect	Type of defect		X	X
		Size of defect		X	X
		Localization		X	X
		Regularity		X	X
		Influence of material origin		X	X

TABLE 36. RADIOGRAPHIC TESTING — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
36.9 Quality aspects	Personnel qualification	ISO 9712		X	X
		Other NDT qualification and certification systems		X	X
	Documentation	Format and scope of working procedures			X
		Qualification of NDT procedures			X
		Authorization of NDT instructions, procedures, and personnel			X
		Developing written instruction		X	X
		Working correctly to written instruction	X	X	
		Traceability of documents		X	X
		Reliability of measurements		X	X
	Knowledge of applicable NDT application and product standards	Correct technique selection		X	X
		Use of correct test parameters		X	X
		NDT method selection			X
		Job specific training		X	X
		Equipment verification		X	X
36.10 Developments	Other techniques	Radiographic testing – digital (RT-D)		X	X
		Computed tomography (CT)		X	X
		Stereo radiography		X	X
		Laminography		X	X

6.2. RADIOGRAPHIC TESTING–DIGITAL (RT–D)

Radiographic testing–digital (RT–D) is an advanced NDT technique used in civil engineering to reveal the internal structure and detect potential defects within concrete structures. This technique employs digital detectors instead of traditional film to capture X-ray or gamma-ray images, providing detailed insights into the composition, integrity, and possible anomalies within concrete structures.

During RT–D inspection, a radiation source is positioned on one side of the concrete, while a digital detector is placed on the opposite side. As radiation passes through the concrete, the digital detector captures the attenuated rays, converting them into high-resolution images displayed on a computer screen. These images offer a clear view of density variations, such as cracks, voids, delamination, and the presence of reinforcing materials like rebar.

RT–D enhances efficiency and accuracy in concrete inspection. The digital format allows for immediate image analysis, manipulation, and sharing, aiding engineers in making swift and informed decisions about structural condition, repairs, or maintenance.

While RT–D offers exceptional insights, it is important to follow safety guidelines due to the use of radiation. Qualified personnel and stringent protocols ensure the safety of testing procedures. In summary, RT–D plays a pivotal role in concrete inspection, contributing to the assessment, safety, and longevity of diverse civil engineering projects.

Radiographic testing–digital training which covers theory and practical sessions needs to correspond with Tables 37 and 38.

TABLE 37. GENERAL CONTENT FOR RADIOGRAPHIC TESTING–DIGITAL

	Content	**Level 1 (% of total duration)**	**Level 2 (% of total duration)**	**Level 3 (% of total duration)**
37.1	Introduction to radiographic testing–digital	6	5	3
37.2	Physical principles of the method and associated knowledge	15	15	5
37.3	Product knowledge and capabilities of the method and its derived techniques	18	10	10
37.4	Equipment	20	10	5
37.5	Information prior to testing	10	5	10
37.6	Testing	18	20	18
37.7	Evaluation and reporting	7	10	10
37.8	Assessment	0	10	18
37.9	Quality aspects	6	10	18
37.10	Developments	0	4	6
	Total Hours	**40**	**80**	**40**

TABLE 38. RADIOGRAPHIC TESTING–DIGITAL — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
38.1 Introduction to radiographic testing–digital (RT–D)	Non-destructive testing (NDT)	Basic knowledge to NDT	X	X	
		Main NDT methods	X	X	
	Radiographic testing–digital (RT–D)	Basic knowledge to RT–D	X	X	
		Applicability and limitations	X	X	
	Terminology	Ionizing radiation	X	X	
		Digital detector array (DDA)	X	X	X
		Computed radiography (CR)	X	X	X
		Grey value	X	X	X
		Contrast to noise ratio (CNR)		X	X
		Basic spatial resolution (SR_b)	X	X	X
		Signal to noise ratio (SNR)	X	X	X
		ISO standards		X	X

TABLE 38. RADIOGRAPHIC TESTING–DIGITAL — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
	Relevant standards	European standards		X	X
		ASTM standards		X	X
		ASME standards		X	X
		Other applicable standards		X	X
38.2 Physical principles of the method and associated knowledge	General	Structure of atom	X	X	
		Electromagnetic spectrum	X	X	
		Sources of radiation in RT-D applications	X	X	
		Essential radiographic parameters	X	X	
	Attenuation of radiation	General mechanism of interaction:			
		— Photoelectric effect;	X	X	
		— Compton effect;	X	X	
		— Pair production;		X	
		— HVL, TVL and attenuation law;	X	X	
		— Hardening of radiation;		X	
		— Build-up factor;		X	
		— Filtering and collimation;		X	
		— X-ray fluorescence;		X	
		— Attenuation of neutrons and electrons.			X
	Radiographic sensitivity	Radiographic contrast	X	X	
		Radiographic definition	X	X	
		Specific contrast		X	
		Scatter radiation	X	X	
		Signal-to-noise ratio (SNR)	X	X	X
		Contrast-to-noise ratio		X	X
		Radiographic un-sharpness	X	X	
		Basic spatial resolution (SR_b)	X	X	X
		Pixel size	X	X	X
		Normalized SNR (SNR_N)	X	X	X
	Optimization of image quality	Compensation principles:			
		— Contrast vs SNR;		X	X
		— SR_b vs SNR;		X	X
		— Local un-sharpness vs SNR;		X	X

TABLE 38. RADIOGRAPHIC TESTING–DIGITAL — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
		Radiation scattering;	X	X	
		Source of energy;		X	
		Physical arrangement.		X	
	Geometrical projection conditions	Geometrical Un-sharpness		X	X
		Image magnification	X	X	X
		Inverse Square Law	X	X	X
	Image quality indicators	Wire type	X	X	X
		Step hole type	X	X	X
		Plate hole type	X	X	X
		Duplex wire type	X	X	X
		Measurement of SRb		X	X
		Converging line pairs		X	X
		Line pair gauges (MTF)			X
38.3 Product knowledge and capabilities of the method and its derived techniques	General defects in concrete materials:	Initial defect	X	X	X
		Degradation due to aging	X	X	X
	Application of radiographic testing–digital	Pre-service	X	X	X
		In-service	X	X	X
		Post disaster/ incident	X	X	X
	Influence of detectability	Type of defect	X	X	X
		Size of defect	X	X	X
		Defect orientation	X	X	X
		Number of exposures		X	X
		Beam direction	X	X	X
		Increase in wall thickness		X	X
		Thickness ranges for X-ray and gamma ray		X	X
	Influence of testing part	Types of concrete basic structures:			
		— Slab;	X	X	X
		— Column;	X	X	X
		— Beam;	X	X	X
		— Wall;	X	X	X
		— Thickness and geometry;		X	X
		— Concrete properties.		X	X
38.4 Equipment	X-ray	Construction and function of X-ray tubes	X	X	
		X-ray generation	X	X	
		X-Ray beam	X	X	
		Parameters	X	X	
	Gamma	Gamma container:			
		— Shielding;	X	X	
		— Transportation;	X	X	

TABLE 38. RADIOGRAPHIC TESTING–DIGITAL — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
		— Source assembly;		X	
		— Handling and projection;	X	X	
		— Special design;		X	
		— Collimator;	X	X	
		— Classes of containers.		X	X
		Parameters	X	X	
	Computed radiography (CR) and imaging plates	Phosphor imaging plates:			
		— Introduction;	X	X	
		— Design;	X	X	X
		— Imaging plate and CR scanner;	X	X	
		— CR image classification;		X	
		— Quality assurance (phantom);		X	X
		— Exposure conditions;	X	X	X
		— Working with exposure charts;	X	X	
		— Handling of CR and imaging plate;	X	X	X
		— System selection.		X	X
	Digital detector array (DDA)	Introduction	X	X	
		Design	X	X	X
		Indirect converting		X	X
		Direct converting		X	X
		CCD, CMOS, Amorphous, Silica		X	X
		Detector adjustment		X	X
		Quality assurance		X	X
		Exposure conditions		X	X
		Handling	X	X	X
		System selection			X
	Line detector array (LDA)	Introduction	X	X	X
		Design		X	X
		Application areas		X	X
		LDA vs DDA		X	X
		Quality assurance (phantom)		X	X
		Exposure conditions and diagrams		X	X
		Handling of LDA	X	X	X
		System selection			X
	Film digitization	Scanner design:			
		— Laser scanners;			X
		— Quality assurance (phantom);			X

TABLE 38. RADIOGRAPHIC TESTING–DIGITAL — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		— Handling, archiving;			X
		— Classification.		X	X
	Accessories	Work setup:			
		— Lead letters and tape;	X	X	
		— Holding magnets;	X	X	
		— Rubber bands.	X	X	
		Safety:			
		— Lead shielding;	X	X	X
		— Collimator;	X	X	X
		— Radiation protection equipment;	X	X	X
		— Emergency equipment.	X	X	X
	Data acquisition, detector adjustment	A/D interface	X	X	X
		Computer structure		X	X
		Image integration		X	X
38.5 Information prior to testing	Information about the test object	Written instruction	X	X	
		Identification or designation of material	X	X	X
		Type of concrete structures	X	X	X
		Catalogue of defects		X	X
	Test conditions and application of standard	Accessibility		X	X
		Related standards		X	X
		Requirements of test personnel		X	X
		Acceptance criteria		X	X
	Technique and sequence of performing test	Surface condition		X	X
		Equipment to be used		X	X
		Test setup		X	X
		Requirement for recording		X	X
		Post-test documentation		X	X
	Written instructions and procedure	Preparation of written instructions		X	
		Preparation of written procedure			X
		Presentations of the procedures, codes, and standards			X
38.6 Testing	Standard practice and evaluation standards	Performing test inspection in accordance with written instruction / procedure	X	X	X

TABLE 38. RADIOGRAPHIC TESTING–DIGITAL — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Selection of technique		X	X
		Different exposure settings		X	X
		Interpretation of images		X	X
		Evaluation of flaws		X	X
38.7 Evaluation and reporting	Basic of evaluation	Viewing conditions:			
		— Room condition;	X	X	
		— Viewing time;	X	X	
		— Luminance;		X	
	Physical factors	Eyesight		X	
	Evaluation of radiographs	Verification of the image quality		X	X
		Report of imperfections		X	X
	Test report	Complies with examination standard		X	X
		Conformed to test quality		X	X
	Digital image processing	Image structure, quantization (bits and bytes)		X	X
		Basic operation		X	X
		Point operations		X	X
		Matrix operation, filters		X	X
		Measurement tools:			
		— Adjustment;		X	X
		— Line profile;		X	X
		— Measurement of flaw length;		X	X
		— Measurement of areas;		X	X
		— Measurement of depth.		X	X
		Correction of raw data:			
		— Introduction;		X	X
		— Linearization, LUT;			X
		— Bad pixel interpolation.			X
	Automated image interpretation	Principles		X	X
		Binarization			X
		Measurement of dimensions		X	X
38.8 Assessment	Evaluation of defect	Type of defect		X	X
		Size of defect		X	X
		Localization		X	X

TABLE 38. RADIOGRAPHIC TESTING–DIGITAL — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		Regularity		X	X
		Influence of material origin		X	X
38.9 Quality aspects	Personnel qualification	ISO 9712		X	X
		Other NDT qualification and certification systems		X	X
	Documentation	Format and scope of working procedures			X
		Qualification of NDT procedures			X
		Authorizations			X
		Developing written instruction		X	
		Working correctly to written Instruction	X	X	
		Traceability of documents		X	X
		Reliability of measurements		X	X
	Knowledge of applicable NDT application and product standards	Correct technique selection		X	X
		Use of correct test parameters		X	X
		NDT method selection		X	X
		Job specific training		X	X
		Equipment verification		X	X
38.10 Developments	Other techniques	Computed tomography (CT)		X	X
		Stereo radiography		X	X
		Laminography		X	X

6.3. COMPUTED TOMOGRAPHY (CT)

Computed tomography (CT) is employed in concrete inspection to provide comprehensive insights into the internal structure and condition of materials. This technique utilizes X-rays to capture a series of cross-sectional images, allowing for a detailed three-dimensional reconstruction of the concrete's interior.

During CT scanning, X-ray beams are projected through the concrete from various angles, and detectors capture the attenuated X-rays on the other side. By compiling these cross-sectional images, a computer generates a 3D model that highlights variations in density, defects, voids, and reinforcing materials like rebar. This detailed visualization offers engineers a clear understanding of the concrete's internal features.

CT scanning is particularly effective for locating hidden defects and assessing structural integrity. It reveals information that might be difficult to discern using other methods. The technique is versatile, making it valuable for a wide range of applications, from characterizing concrete properties to diagnosing structural issues.

Despite its comprehensive insights, CT scanning involves a higher level of complexity and resource requirement compared to other methods. However, its ability to provide detailed information about the internal condition of concrete structures makes it a valuable tool for engineers and inspectors working to ensure the safety, durability, and efficiency of various civil engineering projects.

Computed tomography training which covers theory and practical sessions needs to correspond with Tables 39 and 40.

TABLE 39. GENERAL CONTENT FOR COMPUTED TOMOGRAPHY

	Content	Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
39.1	Introduction to computed tomography	6	5	3
39.2	Physical principles of the method and associated knowledge	15	15	5
39.3	Product knowledge and capabilities of the method and its derived techniques	18	10	10
39.4	Equipment	20	10	5
39.5	Information prior to testing	10	5	10
39.6	Testing	18	20	18
39.7	Evaluation and reporting	7	10	10
39.8	Assessment	0	10	18
39.9	Quality aspects	6	10	18
39.10	Developments	0	4	6
	Total Hours	**40**	**80**	**40**

TABLE 40. COMPUTED TOMOGRAPHY — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
40.1 Introduction to computed tomography (CT)	Purpose of NDT	Introduction	X	X	
		NDT application	X	X	
		The performance of NDT	X	X	
		NDT personnel	X	X	
		Main NDT methods	X	X	
	Purpose of CT	Definition	X	X	
		Applicability and limitations	X	X	
		Radiography vs tomography	X	X	
	Development of CT	Generation of CT	X	X	
	Terminology	Electromagnetic radiation	X	X	
		Energy	X	X	
		Dose	X	X	
		Dose rate	X	X	
		Dose rate constant	X	X	
		Intensity	X	X	
		Activity	X	X	
	Relevant standards	ISO standards	X	X	X
		European standards	X	X	X

TABLE 40. COMPUTED TOMOGRAPHY — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		ASTM standards	X	X	X
		ASME standards	X	X	X
		Other Standards	X	X	X
40.2 Physical principles of the method and associated knowledge	General	Structure of the atom	X	X	
		Electromagnetic spectrum	X	X	
		Sources of radiation and its properties:			
		— X-rays;	X	X	
		— Gamma rays;	X	X	
		— Neutrons;			X
		— X-ray and gamma ray spectrum.	X	X	
		Essential radiographic parameters	X	X	
	Attenuation of radiation	General mechanism of interaction:			
		— Photoelectric effect;	X	X	
		— Compton effect;	X	X	
		— Pair production;	X	X	
		— HVL, TVL and attenuation law;	X	X	
		— Hardening of radiation;	X	X	
		— Scattered radiation and build up factor;	X	X	
		— Filtering and collimation;	X	X	
		— X-ray fluorescence;	X	X	
		— Attenuation of neutrons and electrons.			X
	Radiographic sensitivity	Contrast, noise, granularity	X	X	
		Specific contrast		X	
		Scatter influence	X	X	
		Unsharpness	X	X	
	Optimization of image quality	Radiation scattering	X	X	X
		Source energy		X	X
		Physical arrangement		X	X
	Geometrical projection conditions	Geometrical unsharpness	X	X	X
		Optimum image magnification		X	X
		Inverse Square Law	X	X	X
		Wire type	X	X	X
		Step hole type	X	X	X

TABLE 40. COMPUTED TOMOGRAPHY — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
	Image quality indicators or Parameters	Plate hole type	X	X	X
		Duplex wire type	X	X	X
40.3 Product knowledge and capabilities of the method and its derived techniques	General defects in concrete materials	Initial defect	X	X	X
		Degradation due to aging	X	X	X
	Application of computed tomography testing	Pre-service	X	X	X
		In-service	X	X	X
		Post disaster/ incident	X	X	X
	Influence of detectability	Type of defect	X	X	X
		Size	X	X	X
		Orientation	X	X	X
		Number of exposures		X	X
		Beam direction	X	X	X
		Increase in wall thickness		X	X
		Thickness ranges for X- and gamma rays		X	X
	Influence of testing part	Types of concrete basic structures:			
		— Column;	X	X	X
		— Open Beam;	X	X	X
		— Thickness and geometry;		X	X
		— Concrete properties.		X	X
40.4 Equipment	CT imaging system and hardware design	Construction and function of CT imaging system and detector	X	X	
		Source selection.		X	
		Scanning geometry, collimation and filtration		X	X
		Electronics control data acquisition system		X	X
	X-ray equipment	X-ray generation	X	X	
		X-Ray beam	X	X	
		Parameters	X	X	
	Gamma equipment	Gamma container:			
		— Shielding;	X	X	
		— Transportation;	X	X	
		— Source assembly;		X	
		— Handling and projection	X	X	
		— Special design;		X	
		— Collimation;	X	X	

TABLE 40. COMPUTED TOMOGRAPHY — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
		— Classes of containers.		X	X
		Parameters:			
		— Source type;	X	X	
		— Spectrum;	X	X	
		— Energy;	X	X	
		— Activity;	X	X	
		— Source size;	X	X	
		— Half life.	X	X	
	Accessories	Work setup:			
		— Lead letters and tape;	X	X	
		— Holding magnets;	X	X	
		— Rubber bands.	X	X	
		Safety:			
		— Lead shielding;	X	X	X
		— Collimator;	X	X	X
		— Radiation protection equipment;	X	X	X
		— Emergency equipment.	X	X	X
40.5 Information prior to testing	Information about the test object	Written instruction	X		
		Identification	X	X	X
		Type of concrete structures	X	X	X
		Process of manufacture	X	X	X
		Catalogue of defects		X	X
		Extent of test coverage		X	X
	Test conditions and application of standard	Accessibility		X	X
		Related standards		X	X
		Requirements of test personnel		X	X
		Acceptance criteria		X	X
	Technique and sequence of performing test	Surface condition		X	
		Equipment to be used		X	
		Test setup		X	
		Requirement for recording		X	
		Post-test documentation		X	X
	Instructions	Preparation of written procedures			X
		Preparation of written instructions		X	
		Performing inspection in accordance with written instruction	X	X	

TABLE 40. COMPUTED TOMOGRAPHY — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
		Presentations of the procedures, codes, and standards			X
40.6 Testing	Data acquisition	CT equipment set-up	X	X	X
		Accomplishing a measurement	X	X	X
		Optimum magnification and unsharpness	X	X	X
		Noise and artefacts	X	X	X
		Image reconstruction algorithms and processing		X	X
		Contrast sensitivity		X	X
		Image resolution		X	X
		Errors in image reconstruction		X	X
		CT image quality		X	X
		CT simulator software		X	X
40.7 Evaluation and reporting	Visualization and evaluation	Viewing conditions:			
		— Room condition;	X	X	
		— Viewing time;	X	X	
		— Lapsed time after dazzling;	X	X	
		— Luminance;		X	
		— Density measurement;	X	X	
		— Homogeneity factor.		X	
	Physical factors	Eyesight		X	
		Adaption prior viewing		X	
	Evaluation of tomographs	Verification of the image quality parameters	X	X	X
		Report of imperfections		X	X
	Test report	Complies with examination standard		X	X
		Conformed to test quality		X	X
		Achieved test class	X	X	X
		Achieved diagnostic coverage of test object	X	X	X
40.8 Assessment	Evaluation of discontinuities	Type		X	X
		Size		X	X
		Localization		X	X
		Regularity		X	X
		Influence of manufacture and material		X	X

TABLE 40. COMPUTED TOMOGRAPHY — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
40.9 Quality aspects	Personnel qualification	ISO 9712		X	X
		Other NDT qualification and certification systems			X
	Documentation	Format and scope of working procedures			X
		Qualification of NDT procedures			X
		Authorizations (NDT instruction, procedures, and personnel)			X
		Developing written instruction		X	X
		Working correctly to written instruction	X	X	
		Traceability of documents		X	X
		Reliability of measurements		X	X
	Knowledge of applicable NDT application and product standards	Correct technique selection		X	X
		Use of correct test parameters		X	X
		NDT method selection			X
		Job specific training		X	X
		Equipment verification		X	X
40.10 Developments	Other techniques	Radiographic testing–digital (RT–D)		X	X
		Stereo radiography		X	X
		Laminography		X	X

6.4. NUCLEONIC GAUGING

Nucleonic gauging is employed in concrete testing to measure properties like density and thickness using radioactive sources. This non-destructive method provides valuable insights into the composition and quality of concrete structures.

Nucleonic gauging involves the use of a radioactive source that emits gamma or beta radiation. This radiation passes through the concrete and interacts with its atoms. A detector measures the amount of radiation that interacts with the material, which is then used to calculate properties like density and thickness.

In concrete testing, nucleonic gauging finds application in assessing the density of fresh concrete during construction, helping ensure proper compaction and quality. It's also utilized to measure the thickness of concrete layers, such as slabs or walls. Nucleonic gauging offers a non-destructive means of gathering critical data for quality control, ensuring compliance with specifications, and making informed decisions about construction and maintenance of concrete structures.

Nucleonic gauging training which covers theory and practical sessions needs to correspond with Tables 41 and 42.

TABLE 41. GENERAL CONTENT FOR NUCLEONIC GAUGING

	Content	Level 1 (% of total duration)	Level 2 (% of total duration)	Level 3 (% of total duration)
41.1	Introduction to nucleonic gauging	4	3	5
41.2	Physical principles of the method and associated knowledge	6	9	5
41.3	Product knowledge and capabilities of the method and its derived techniques	4	6	0
41.4	Equipment	6	6	0
41.5	Information prior to testing	17	12	18
41.6	Testing	25	19	18
41.7	Evaluation and reporting	8	19	18
41.8	Assessment	8	6	12
41.9	Quality aspects	4	6	12
41.10	Developments	17	12	12
	Total Hours	**24**	**32**	**16**

TABLE 42. NUCLEONIC GAUGING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
42.1 Introduction to nucleonic gauging	History	Requirement for measurements	X	X	
		Importance of gauging	X	X	
	Purpose of NDT	Introduction	X	X	
		NDT application	X	X	
		The importance of NDT	X	X	
		NDT personnel	X	X	
		Main NDT methods	X	X	
	Purpose of nucleonic gauging in civil engineering	Definition	X	X	
		Applicability and limitations	X	X	
	Development of nucleonic gauging	Evolution of the technology	X	X	
	Terminology	Ionizing radiation	X	X	
		Fast neutron	X	X	
		Resonance neutron	X	X	
		Thermal neutron	X	X	
		Energy	X	X	
		Dose rate constant	X	X	
		Neutron activation	X	X	
	Relevant standards	Density measurement using nuclear techniques	X	X	X
		Moisture measurement using nuclear techniques	X	X	X

TABLE 42. NUCLEONIC GAUGING — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
42.2 Physical principles of the method and associated knowledge	Radiation theory	Introduction	X	X	
		Interactions with matter	X	X	
		Gamma attenuation	X	X	
		Neutron moderation and slowdown	X	X	
	Radiation sources	Gamma sources	X	X	
		Neutron sources	X	X	
	Detector	Gamma detection	X	X	
		Neutron detection	X	X	
	Methodology	Gamma technique:	X	X	
		Neutron back scattering (NBS) technique	X	X	
	Density gauging using gamma sources in civil engineering	Density measurement of construction materials	X	X	X
		Density determination in soil, soil-stone materials in layers of 4 inches or greater	X	X	X
		Density determination in asphalt or hardened layers of 4 inches or greater	X	X	X
		Density determination in asphalt layers of less than 4 inches	X	X	X
	Applications of the NBS technique in civil engineering (moisture measurement)	Neutron thermalization to monitor the moisture content of a material	X	X	X
		Moisture determination in soil, soil-stone materials in layers of 4 inches or greater	X	X	X
		Measurement of the humidity, the space between a bottom plate of a tank and the base foundation and detection of water / vacuum inside slabs	X	X	X
42.3 Product knowledge and capabilities of the method and its derived techniques	Asphalt	Introduction	X	X	
		Different types of asphalt	X	X	
		Types of asphalt pavement	X	X	
		Different asphalt layers	X	X	

TABLE 42. NUCLEONIC GAUGING — LEVELS 1, 2 AND 3

Content			Level 1	Level 2	Level 3
	Bitumen	Introduction	X	X	
		Different types of bitumen	X	X	
		Properties of bitumen	X	X	
		Grade of bitumen (60/70)	X	X	
	Hydrogenous materials	Cement, gypsum, coal, mica, lime etc.	X	X	
	Neutron absorbers materials	Boron, cadmium etc.	X	X	
	Density and Moisture of materials	Moisture content of soil or concrete	X	X	
		Moisture content units	X	X	
		Wet density	X	X	
		Moisture-Density relationship	X	X	
		Target values for the gauge	X	X	
42.4 Equipment	Gamma source	Density measurement	X	X	
	Neutron back scattering gauge	Moisture measurement	X	X	
		Electronics control	X	X	
		Data acquisition system	X	X	
		Accuracy of measurement	X	X	
42.5 Information prior to testing	Information about the test object	Written instruction		X	
		Identification or designation material	X	X	
		Type of concrete or asphalt structures	X	X	
		Extent of test coverage		X	X
	Test condition and application of standards	Accessibility		X	X
		Requirements of test personnel		X	X
		Acceptance criteria		X	X
		Planning of measurement		X	X
	Technique and sequence of performing test	Surface condition	X	X	
		Equipment to be used		X	X
		Test setup		X	X
		Requirement for recording	X	X	X
	Instructions	Preparation of written procedures			X
		Preparation of written instructions		X	
		Performing inspection in accordance with written instruction	X	X	

TABLE 42. NUCLEONIC GAUGING — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
		Presentations of the procedures, codes and standards		X	X
42.6 Testing	Test site preparation	Site location Soils / ground surface preparation, by using the scraper plate. Placement of drill rod removal device	X	X	X
	Data acquisition	Nucleonic gauging equipment set-up	X	X	X
		Sampling frequency and settings in data acquisition system	X	X	X
		Accomplishing a measurement	X	X	X
		Data verification and validation	X	X	X
42.7 Evaluation and reporting	Report writing	Compliance with examination standard		X	X
		Recording of installation procedure		X	X
		Recording and saving of measurement data in digital format	X	X	X
		Presenting the measurements	X	X	X
		Conformed to test quality		X	X
		Achieved test class		X	X
	Interpretation	Interpretation of results		X	X
		Statistical treatment of results		X	X
42.8 Assessment	Conformity assessment of test reports	Assessing the reliability of the measurement records		X	X
42.9 Quality aspects	Reliability of measurements	Inadequate choice of instrument		X	X
		Equipment lack of calibration or malfunction		X	X
	Factors influencing the test	Concrete or asphalt surface condition	X	X	X
		Effect of temperature in measurements	X	X	X
	Faults possibility	Disconnection of gauges from concrete surface and connecting wires	X	X	X

TABLE 42. NUCLEONIC GAUGING — LEVELS 1, 2 AND 3

Content			**Level 1**	**Level 2**	**Level 3**
		Improper sampling frequency	X	X	X
	Personnel qualification	EN ISO 9712		X	X
		Other relevant NDT qualification and certification systems		X	X
42.10 developments	N/A				

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LIST OF ABBREVIATIONS

AT	Acoustic emission testing
CNR	Contrast to noise ratio
CR	Computed radiography
CT	Computed tomography
DDA	Digital detector array
FMC	Full matrix capture
FOV	Field of view
GPR	Ground penetrating radar
ISO	International Organization for Standardization
LDA	Linear detector array
LT	Leak testing
LUT	Look up table
MDD	Minimum detectable dimension
NBS	Neutron back scatter
NDT	Non-Destructive Testing
NDT-CE	Non-Destructive Testing for Civil Engineering
PAUT	Phased array ultrasonic testing
PDT	Partial destructive test
PEC	Pulsed eddy current
PIT	Pile integrity testing
RT	Radiographic testing
RT–D	Radiographic testing–digital
SNR	Signal to noise ratio
SNR_N	Normalized SNR
SOP	Standard operating procedure
SR_b	Basic spatial resolution

ST	Strain gauge testing
TFM	Total focusing method
TT	Thermographic testing
UT	Ultrasonic testing
VT	Visual testing

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