

TRAINING COURSE SERIES

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 VIENNA, 2024

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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.

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| REFI | ERENCE | ES | 99 |
| BIBI | LIOGRA | РНҮ | |
| LIST | OF ABI | BREVIATIONS | |
| CON | TRIBUT | CORS TO DRAFTING AND REVIEW | |

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.

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

TABLE 1. GENERAL CONTENT FOR GENERAL KNOWLEDGE ON CONCRETE

| TABLE 2. | GENERAL | KNOWLED | GE ON CON | NCRETE — I | LEVELS 1 | , 2 AND 3 |
|----------|---------|---------|-----------|------------|----------|-----------|
|----------|---------|---------|-----------|------------|----------|-----------|

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

| Content | | | Level 1 | Level 2 | Level 3 |
|----------------------------|--|--|---------|---------|---------|
| | | Steel properties and strength | X | X | Х |
| | | Fibre reinforcements | | X | X |
| | Main constructions | Types of construction | X | X | X |
| | Main elements | Typical functioning | X | X | X |
| | of constructions | Forms | | X | Х |
| | structural | Role of reinforcement | | Х | X |
| | behaviour | Changes of behaviour | | Х | Х |
| 2.2 Structural concepts | Construction methods | Types of methods | X | X | X |
| of concrete | 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 | Geometrical sizes and | Loads and project loads | | X | X |
| of concrete | tolerances | 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 | | Х | Х |

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

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.

| | Content | Level 1 | Level 2 | Level 3 |
|------|---|-------------|-------------|-------------|
| | | (% of total | (% of total | (% of total |
| | | duration) | duration) | duration) |
| 3.1 | Introduction to rebound hammer | 9 | 3 | 3 |
| 3.2 | Physical principles of the method and | 6 | 6 | 6 |
| | associated knowledge | | | |
| 3.3 | Product knowledge and capabilities of the | 3 | 3 | 3 |
| | method and its derived techniques | | | |
| 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 3. GENERAL CONTENT FOR REBOUND HAMMER

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

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

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

| Content | | | Level 1 | Level 2 | Level 3 |
|------------------------|-------------------|------------------------------------|---------|---------|---------|
| | | equipment according to instruction | | | |
| 4.7 Evaluation and | Reporting | Data quality assessment | X | | |
| reporting | | Record on worksheet | Х | | |
| | | Practical writing of a | Х | | |
| | | test report | | | |
| | Evaluation | Practical interpretation | | Х | X |
| | | of a test report | | | |
| | | Correlation of the test | | Х | X |
| | | results with concrete | | | |
| | | strength | | | |
| | | General survey and | | Х | Х |
| | | evaluation of the test | | | |
| | | and data quality | | | |
| 4.8 | Conformity | Accuracy of | | X | Х |
| Assessment | assessment of | measurement | | | |
| | test report | Assessing the | | X | X |
| | | reliability of the | | | |
| | | records | | 37 | |
| | | Assessment according | | X | X |
| | | to the technical | | | |
| 4.0 | Description | Specification | | | V |
| 4.9 Oveliter encode | Documents | National and | | | Λ |
| Quality aspects | | International standards | | | v |
| | | rocedures | | | Λ |
| | Procedures and | Concept | | x | X |
| | its contents | Application | | X | X |
| | | Development/ creation | | X | X |
| | | Essential components | | X | X |
| | | of procedures | | | |
| | | System verification | | X | X |
| | | Data quality | | X | X |
| | | Coverage of inspection | | X | X |
| | | area | | | |
| | Personnel | ISO 9712 | | X | X |
| | qualification | Other NDT | | Х | X |
| | | qualification and | | | |
| | | certification systems | | | |
| | Factors | Quality and cleaning | X | | |
| | affecting results | of the surface | | | |
| | | Characteristics of the | X | X | X |
| | | concrete | | | |
| | | Thickness of concrete | X | | |
| | | section related with | | | |
| | | impact energy | | | |
| | | Presence or low cover | | X | |
| | | of rebars | | | |
| | | Carbonation | | X | |
| | | Age of concrete | 1 | | 1 |

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

| | 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 5. GENERAL CONTENT FOR PENETRATION RESISTANCE TEST

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

| Content | | | Level 1 | Level 2 | Level 3 |
|---------------------|----------------|-------------------------|---------|---------|---------|
| 6.1 | History | Concrete strength | X | | |
| Introduction to | | (standard cube or | | | |
| penetration | | cylinder and core | | | |
| resistance test | | specimens) | N | | |
| | | On site samples | X | | |
| | D OIDT | (coring) | 37 | | |
| | Purpose of NDT | Application of NDT | X | | |
| | | The importance of | X | | |
| | | NDT | | | |
| | | NDT personnel | X | | |
| | | Tasks of the inspection | Х | | |
| | | personnel | | | |
| | Purpose of | Definition | X | | |
| | testing | Applicability and | Х | | |
| | | limitations | | | |
| | Relevant | Standards and | X | Х | X |
| | standards | regulations | | | |
| 6.2 | Basic physical | Penetration resistance | X | | |
| Physical principles | principles | test | | | |
| of the method and | | Test objective | X | | |
| associated | Advanced | Limitations of the | Х | Х | X |
| knowledge | physical | method | | | |
| | principles | Correlation between | | Х | X |
| | | testing and other | | | |
| | | characteristics of the | | | |
| | | element | | | |
| | | Influence of concrete | | Х | X |
| | | age | | | |
| | | Influence of | | Х | X |
| | | carbonation of | | | |
| | | concrete surface | | | |

| Content | | | Level 1 | Level 2 | Level 3 |
|----------------------|-------------------|-------------------------|-------------|------------|---------|
| 6.3 | Related | Strength of concrete | X | X | X |
| Product knowledge | capability of the | related to penetration | | | |
| and capabilities of | method and | of the probe | | | |
| the method and its | derived | Variability of the | | X | X |
| derived techniques | techniques | strength within a | | | |
| | | structure | | | |
| 6.4 | Description of | Description of the | X | X | |
| Equipment | basis equipment | resistance penetration | | | |
| | | test system | | | |
| | | Driver unit | X | | |
| | | Powder charge: energy | X | | |
| | | released | | | |
| | | Probes or pins | X | | |
| | | Positioning device | X | | |
| | | Measuring apparatus | X | | |
| 6.5 | Operating | Analyse the internal | X | | |
| Information prior to | principles | procedures / | | | |
| testing | | Manufacturer's | | | |
| | | instructions to use the | | | |
| | | device | | | |
| | | Test location | X | X | X |
| | | Representability of the | | X | X |
| | | test | | | |
| | | Number of | | X | X |
| | | measurements of | | | |
| | | testing | | N/ | V |
| | | Evaluation the level of | | X | X |
| | | damages produced by | | | |
| | D (| the test | v | V | V |
| 0.0 Testing | Preparation | Selection of powder | X | X | X |
| Testing | | and actuated device | | | |
| | | applicable to the type | | | |
| | | Initial varification | v | | |
| | | Solotion of test | Λ V | v | |
| | | Selection of test | Λ | Λ | |
| | | Dranaration of the grad | v | | |
| | Execution | Operating according to | | v | |
| | Execution | instruction | Λ | Λ | |
| | Reading the | Faulting and repetition | X | x | |
| | results | of test in cases where | | 1 | |
| | results | exposed length of steel | | | |
| | | probe/ pin are invalids | | | |
| | | Correlation between | | X | x |
| | | exposed probe length | | | |
| | | and concrete strength | | | |
| | Factors | Proper choice of the | | x | x |
| | influencing the | operative area in | | 2 1 | |
| | results | compliance with the | | | |
| | | structural requirements | | | |
| | 1 | | 1 | 1 | 1 |

 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 | | X | X |
| | Verification / calibration | Specifications according to every equipment | X | | |
| | | Periodic verification / calibration of equipment | | Х | X |
| | Operating procedure | Standard operating procedure (SOP) | X | Х | X |
| | Advanced practice | Dismantling and maintenance of equipment according to instruction | | X | X |
| 6.7 Evaluation and | Reporting | Data quality assessment | X | | |
| reporting | | Record on worksheet | X | | |
| 1 0 | | Practical writing of a test report | X | | |
| | Evaluation | Practical interpretation of a test report | X | Х | X |
| | | Correlation of the test results with concrete strength | | X | Х |
| | | General survey and evaluation of the test and data quality | | X | X |
| 6.8 Assessment | Conformity assessment of | Accuracy of measurement | | X | X |
| | test report | Assessing the reliability of the measurement records | | X | X |
| | | Assessment according to the technical specification | | Х | X |
| 6.9 Quality aspects | Documents | National and international standards | | Х | X |
| | | Issue of testing procedures | | X | X |
| | Procedures and | Concept | | X | X |
| | its contents | 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 | Other NDT | | X | Х |
| | qualification | qualification and | | | |
| | | certification systems | | | |
| | Other aspects | Supplementary | | | X |
| | | inspections | | | |
| | | Further quality | | | X |
| | | assurance measures | | | |
| | Factors | Quality and cleaning | X | | |
| | affecting results | of the surface | | | |
| | | Characteristics of the | X | X | X |
| | | concrete | | | |
| | | Thickness of concrete | X | | |
| | | section related with | | | |
| | | impact energy | | | |
| | | Presence or low cover | | X | |
| | | of rebars | | | |
| | | Carbonation | | Х | |
| | | Age of concrete | | Х | |
| | | Mis-calibration of | X | | |
| | | device | | | |
| | | Hits on rebars, coarse | X | | |
| | | aggregate or holes | | | |
| | | Misalignment of | X | | |
| | | driven steel probes | | | |
| | | Superficial humidity | | X | |
| | | Concrete sample not | | X | |
| | | fixed | | | |
| | Supplementary | Other NDTs | | X | X |
| | investigations | | | | |
| 6.10 | Advancement | Automated recording | | | Х |
| Developments | | of results | | | |
| | | Combined method | | | Х |
| | | (sonic vs penetration) | | | |

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

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.

| | Content | Level 1 | Level 2 | Level 3 |
|------|---|-------------|-------------|-------------|
| | | (% of total | (% of total | (% of total |
| | | duration) | duration) | duration) |
| 7.1 | Introduction to pull out test | 10 | 8 | 3 |
| 7.2 | Physical principles of the method and | 10 | 6 | 6 |
| | associated knowledge | | | |
| 7.3 | Product knowledge and capabilities of the | 5 | 3 | 3 |
| | method and its derived techniques | | | |
| 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 7. GENERAL CONTENT FOR PULL OUT TEST

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

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

| Content | | | Level 1 | Level 2 | Level 3 |
|------------------------------|-------------------|--------------------------|-------------|---------|----------|
| associated | Advanced | Correlation between | | X | Х |
| knowledge | physical | testing and other | | | |
| | principles | characteristics of the | | | |
| | | element | | | |
| | | Influence of concrete | | X | X |
| | | age | | | |
| | | Influence of | | X | X |
| | | carbonation of | | | |
| 0.2 | D 1 4 1 | concrete surface | V | V | v |
| 8.3 Droduct knowledge | Related | Strength of concrete | A | A | Λ |
| and conchilities of | capability of the | related to penetration | | | |
| the method and its | derived | Veriability of the | | v | v |
| derived techniques | techniques | strength within a | | Λ | Λ |
| derived teeninques | teeninques | structure | | | |
| 8 4 | Description of | Description of the | v | | |
| 5. 4 Fauinment | basic equipment | loading test system | Λ | | |
| Equipment | | Pressure gauge | X | | |
| | | Different types of | X | | |
| | | hydraulic and | | | |
| | | commercially | | | |
| | | available pull out | | | |
| | | tester | | | |
| | | Reaction frame | X | | |
| | | Embeds/inserts/ Dollv/ | X | | |
| | | fixtures for attachment | | | |
| | | to test specimen | | | |
| 8.5 | Operating | Analyze the internal | X | | |
| Information prior to | principles | procedures / | | | |
| testing | | Manufacturer's | | | |
| | | instructions to use the | | | |
| | | device | | | |
| | | Test location | X | X | X |
| | | Representability of the | | X | X |
| | | test | | | |
| | | Number of | | X | X |
| | | measurements of | | | |
| | | testing | | | |
| | | Evaluation the level of | | X | X |
| | | damages produced by | | | |
| | | the test | | | |
| 8.6 | Preparation | Selection of suitable | X | | X |
| Testing | | range of load capacity | | | |
| | | of the equipment | | | |
| | | according to the type | | | |
| | | instruction | | | |
| | | Instruction | v | | |
| | | Selection of test | Λ V | v | + |
| | | location | | | |
| | | Preparation of the area | v | | <u> </u> |
| | 1 | i reparation or the alea | Λ | 1 | 1 |

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

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

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

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

| Content | | | Level 1 | Level 2 | Level 3 |
|----------------------|-------------------|---|---------|---------|---------|
| | | Issue of testing procedures | | X | Х |
| | Procedures and | Concept | | X | X |
| | its contents | Application | | X | X |
| | | Development / | | X | Х |
| | | Essential components | | X | X |
| | | System verification | | X | X |
| | | Data quality | | X | X |
| | | Coverage of inspection | | X | X |
| | Personnel | ISO 9712 | | x | x |
| | qualification | Other NDT qualification and certification systems | | X | X |
| | Other aspects | Supplementary inspections | | | Х |
| | | Further quality assurance measures | | | Х |
| | Factors | Ouality of the surface | X | | |
| | affecting results | 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°) | Х | | |
| | | Concrete sample not rigid | X | | |
| 8.10 Developments | Advancement | Automated recording of results | | | Х |
| | | 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.

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.

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.

| | Content | Level 1 | Level 2 | Level 3 |
|------|---|-------------|-------------|-------------|
| | | (% of total | (% of total | (% of total |
| | | duration) | duration) | 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 9. GENERAL CONTENT FOR FLAT JACK TEST

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

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

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

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

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

| Content | | | Level 1 | Level 2 | Level 3 |
|------------------------|-------------------------|--|---------|---------|---------|
| | Advanced operating | General principle of single and parallel flat | | X | X |
| 10.6 Testing | Preparation | Dimension of flat jack | X | X | X |
| resting | | Initial verification | x | | |
| | | Selection of test | X | X | |
| | | location and position | 1 | Λ | |
| | | Preparation of the area | X | | |
| | Execution | Operation of single and parallel flat jack | X | | |
| | Reading the results | Faulting and repetition | X | X | |
| | | Correlation between test results and masonry stresses and / or strength | | X | X |
| | Factors influencing the | Influence of texture of masonry | | X | X |
| | results | 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 | Specifications | Х | | |
| | calibration | 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 | Х |
| 10.7 Evaluation and | Reporting | Data quality assessment | X | | |
| reporting | | 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 | | X | X |
| | | strength | | | |
| | | General survey and evaluation of the test and data quality | | X | X |
| 10.8 Assessment | Conformity assessment of | Accuracy of measurement | | X | X |
| | test report | Assessing the reliability of the measurement records | | Х | Х |
| | | Assessment according to the technical specification | | X | X |
| 10.9 Quality aspects | Documents | National and international standards | | Х | Х |
| | | Issue of testing procedures | | Х | Х |
| | Procedures and | Concept | | X | X |
| | its contents | Application | | X | X |
| | | Development / creation | | Х | X |
| | | Essential components of procedures | | Х | Х |
| | | System verification | | X | Х |
| | | Data quality | | X | Х |
| | | Coverage of inspection area | | X | X |
| | Personnel | ISO 9712 | | Х | Х |
| | qualification | Other NDT qualification and certification systems | | Х | 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.

| | Content | Level 1 | Level 2 | Level 3 |
|-------|--|-------------|-------------|-------------|
| | | (% of total | (% of total | (% of total |
| | | duration) | duration) | duration) |
| 11.1 | Introduction to carbonation and chloride tests | 15 | 10 | 3 |
| 11.2 | Physical principles of the method and | 6 | 6 | 3 |
| | associated knowledge | | | |
| 11.3 | Product knowledge and capabilities of the | 3 | 3 | 0 |
| | method and its derived techniques | | | |
| 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 11. GENERAL CONTENT FOR CARBONATION AND CHLORIDE TESTS

| TABLE 12. | CARBONATION | AND CHLORIDE | TESTS - LEV | ELS 1. 2 AND 3 |
|-----------|-------------|--------------|-------------|-----------------|
| | CIMBOLUTION | | ILDID LL | LLO I, LIII D J |

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

| Content | | | Level 1 | Level 2 | Level 3 |
|----------------------|-----------------------|--------------------------|---------|---------|---------|
| | | The importance of NDT | Х | | |
| | | NDT personnel | Х | | |
| | | Tasks of the inspection | Х | | |
| | | personnel | | | |
| | Purpose of | Definition | Х | | |
| | testing | Applicability and | Х | | |
| | | limitations | | | |
| | Relevant | Standards and | Х | X | X |
| | standards | regulations | | | |
| 12.2 | Basic physical | Determination of | Х | X | |
| Physical principles | principles | carbonation depth by | | | |
| of the method and | | using phenolphthalein | | | |
| associated | | method | | | |
| knowledge | | Determination of | Х | X | |
| 8 | | chloride content. | | | |
| | | chloride chemical test | | | |
| | | kit (non-standard) | | | |
| | Advanced | Limitations of the | X | X | X |
| | physical | method | | | |
| | principles | Propose alternative | | X | X |
| | principies | test methods | | | |
| 12.3 | Related | Depth of penetration | X | X | |
| Product knowledge | capability of the | of carbonation | | | |
| and capabilities of | method and derived | Overall chloride | X | X | |
| the method and its | | contents | | | |
| derived techniques | techniques | Depth of chloride | X | X | |
| 1 | 1 | penetration in | | | |
| | | aggressive | | | |
| | | environmental | | | |
| 12.4 | Description of | Description of the | X | X | |
| Equipment | basic equipment | testing equipment | | | |
| -1-1-1 | | Device for concrete | X | X | |
| | | core drilling or to take | | | |
| | | concrete dust | | | |
| | | Specified chemicals | X | X | |
| | | for field test | | | |
| | | determination | | | |
| | Description of | Any necessary | | X | X |
| | advanced | additional equipment / | | | |
| | equipment | Chemicals as per | | | |
| | | specified standards | | | |
| 12.5 | Operating | Analyse the internal | Х | | |
| Information prior to | principles | procedures / | | | |
| testing | | Manufacturer's | | | |
| c | | instructions to use the | | | |
| | | device | | | |
| | | Test location | Х | X | X |
| | | Representability of the | | X | X |
| | | test | | | |

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

| Content | | | Level 1 | Level 2 | Level 3 |
|-----------------|------------------|------------------------------|---------|---------|---------|
| | | Number of | | X | X |
| | | testing | | | |
| | | Evaluation the level of | | X | X |
| | | damages produced by the test | | | |
| 12.6 | Preparation | Selection of test | x | x | |
| Testing | Treputation | location | 21 | | |
| - | | Preparation of the area | Х | | |
| | Execution | According to | X | X | |
| | | instruction | | | |
| | Reading the | Faulting and repetition | X | X | |
| | results | of test in cases where | | | |
| | | the results of test are | | | |
| | | invalids | | | |
| | | For chloride content | X | X | X |
| | | test | | | |
| | | For carbonation test | Х | Х | X |
| | Factors | Proper choice of the | | X | X |
| | influencing the | operative area | | | |
| | results | Analysis of factors | | X | X |
| | | that influence the | | | |
| | | selection of test | | | |
| | | locations | | | |
| | Verification and | Periodic verification of | | Х | X |
| | calibration | chemicals and kits | | | |
| | Operating | Standard operating | Х | Х | Х |
| | procedure | procedure (SOP) | | | |
| | Advanced | Make determinations | | Х | Х |
| | practice | at different depths | | | |
| 12.7 | Reporting | Data quality | X | | |
| Evaluation and | | assessment | | | |
| reporting | | Record on worksheet | Х | | |
| | | Practical writing of a | X | | |
| | | test report | | | |
| | Evaluating a | Practical interpretation | Х | Х | X |
| | report | of a test report | | | |
| | | General survey and | | Х | Х |
| | | evaluation of the test | | | |
| | | and data quality | | | |
| 12.8 | Assessment of | Accuracy of | | Х | Х |
| Assessment | the results | measurement | | | |
| | | Assessing the | | Х | X |
| | | reliability of the | | | |
| | | measurement records | | | |
| | | Assessment according | | Х | X |
| | | to the technical | | | |
| | | specification | | | |
| 12.9 | Documents | National and | | Х | Х |
| Quality aspects | | international standards | | | |

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

| Content | | | Level 1 | Level 2 | Level 3 |
|-----------------------|--|---------------------------------------|---------|---------|---------|
| | | Issue of testing procedures | | X | Х |
| | Procedures and | Application | | Х | Х |
| | its contents | Development | | Х | Х |
| | | Essential components | | Х | Х |
| | | System verification | | Х | Х |
| | | Data quality | | Х | Х |
| | Personnel | ISO 9712 | | Х | Х |
| | qualification | Other NDT qualification and | | 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 |

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

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.

| | 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 13. GENERAL CONTENT FOR VISUAL TESTING

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

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

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

TABLE 14. VISUAL TESTING — LEVELS 1, 2 AND 3
| Content | | | Level 1 | Level 2 | Level 3 |
|-------------------------|-------------------|--------------------------|---------|---------|----------|
| | | Periodic verification / | | X | X |
| | | calibration of | | | |
| | | equipment | | | |
| | Operating | Standard operating | X | X | X |
| | procedure | procedure (SOP) | | | |
| | Advanced | Dismantling and | | X | X |
| | practice | maintenance of | | | |
| | | equipment according | | | |
| 147 | | to procedure | V | | |
| 14./ Esselvetion and | Reporting | Data quality | X | | |
| Evaluation and | | assessment | v | | |
| reporting | | Record on Worksheet | | | |
| | | Practical writing of a | Λ | | |
| | Evolucting o | Dractical interpretation | v | v | v |
| | Evaluating a | of a test report | Λ | Λ | |
| | report | General survey and | | v | v |
| | | evaluation of the test | | Λ | |
| | | and data quality | | | |
| 14.8 | Conformity | Accuracy of | | X | X |
| Assessment | assessment of | measurement | | | 24 |
| | test report | Assessing the | | X | X |
| | | reliability of the | | | |
| | | measurement records | | | |
| | | Assessment according | | X | X |
| | | to the technical | | | |
| | | specification | | | |
| 14.9 | Documents | National and | | X | Х |
| Quality aspects | | international standards | | | |
| | | Issue of testing | | X | X |
| | | procedures | | | |
| | Procedures and | Concept | | X | X |
| | its contents | Application | | X | X |
| | | Development | | X | X |
| | | Essential components | | X | X |
| | | System verification | | Х | X |
| | | Data quality | | Х | X |
| | Personnel | ISO 9712 | | Х | X |
| | qualification | Other NDT | | X | X |
| | | qualification and | | | |
| | | certification systems | | | |
| | Other aspects | Supplementary | | | X |
| | | inspections | | | |
| | | Further quality | | | X |
| | | assurance measures | | | <u> </u> |
| | Factors | Lack of detailed | X | X | |
| | attecting results | instructions | | | <u> </u> |
| | | Inadequate | X | X | |
| | | illumination | | 1 | |

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 | Х | Х | |
| | | Subjective causes: error of identification, visual fatigue, faulting records | Х | X | |
| | | Unsafe or inadequate environment conditions | X | X | |
| | | Lack of accessing media for reach the inspection site | Х | X | |
| 14.10 | Advancement | Automatized methods | | | Х |
| Developments | | Artificial intelligence | | | Х |

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

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 loadbearing 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.

| | Content | Level 1 | Level 2 | Level 3 |
|------|---|-----------------------|-----------------------|-----------------------|
| | | (% of total duration) | (% of total duration) | (% 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 | Level 2 | Level 3 |
|-------|---|-------------|-------------|-------------|
| | | (% of total | (% of total | (% of total |
| | | duration) | duration) | duration) |
| 15.2 | Physical principles of the method and | 13 | 13 | 3 |
| | associated knowledge | | | |
| 15.3 | Product knowledge and capabilities of the | 3 | 3 | 3 |
| | method and its derived techniques | | | |
| 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 15. GENERAL CONTENT FOR STRAIN GAUGE TESTING

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

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

| Content | | | Level 1 | Level 2 | Level 3 |
|--|---|---|---------|---------|---------|
| | | Stress-strain relation in general (Hooke's Law) | Х | X | |
| | | Stress-strain relation of steel and concrete | Х | X | |
| | Advanced physical principles | Limitations of the method | Х | Х | 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 | Х | Х | |
| 16.4 | Description of | Gauges | Х | X | |
| Equipment | basic equipment | Transducers | Х | 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 | Х | X | X |
| 16.5 Information prior to testing | Operating principles | Analyse the internal procedures / Manufacturer's instructions to use the device | Х | | |
| | | Test location | Х | X | Х |
| | | Representability of the test | | X | X |
| | | Number of measurements of testing | | Х | 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 | Х | Х | Х |
| | | Initial verification | X | | |
| | | Selection of test location | Х | X | |
| | | Preparation of the area | X | | |
| | Execution | How to operate with the instrument | Х | | |
| | Reading the results | Faulting and repetition of test in cases where | Х | X | |

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

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

| Content | | | Level 1 | Level 2 | Level 3 |
|--------------------|-----------------|--------------------------|---------|---------|---------|
| | | the results of test are | | | |
| | | Invalids | | 37 | |
| | | test results and | | X | X |
| | | concrete stress | | | |
| | Factors | Proper choice of the | | x | x |
| | influencing the | operative area in | | Λ | |
| | results | compliance with the | | | |
| | | structural requirements | | | |
| | | Analysis of factors | | X | X |
| | | that influence the | | | |
| | | selection of test | | | |
| | | locations | | | |
| | Verification/ | Specifications | Х | | |
| | calibration | according to every | | | |
| | | equipment | | | |
| | | Periodic verification / | | X | X |
| | | calibration of | | | |
| | Operating | Standard operating | V | V | v |
| | procedure | procedure (SOP) | X | X | X |
| | Advanced | Maintenance of | | v | v |
| | practice | equipment procedure | | Λ | Λ |
| 16.7 | Reporting | Data quality | x | | |
| Evaluation and | | assessment | 1 | | |
| reporting | | Record on worksheet | X | | |
| | | Practical writing of a | x | | |
| | | test report | | | |
| | Evaluating a | Practical interpretation | Х | Х | X |
| | report | of a test report | | | |
| | | Correlation of the test | | Х | X |
| | | results | | | |
| | | General survey and | | X | X |
| | | evaluation of the test | | | |
| 16.9 | Conformity | | | 37 | 37 |
| 10.0 Assessment | assessment of | measurement | | X | Х |
| | test reports | Assessing the | | v | v |
| | | reliability of the | | Λ | |
| | | measurement records | | | |
| | | Assessment according | | X | X |
| | | to the technical | | | |
| | | specification | | | |
| 16.9 | Documents | National and | | X | X |
| Quality aspects | | international standards | | | |
| | | Issue of testing | | X | X |
| | | procedures | | | |
| | Procedures and | Concept | | Х | X |
| | its contents | Application | | X | X |
| | | Development/ creation | | X | X |

| Content | | | Level 1 | Level 2 | Level 3 |
|-----------------------|------------------------------|---|---------|---------|---------|
| | | Essential components of procedures | | X | Х |
| | | System verification | | X | X |
| | | Data quality | | X | X |
| | | Coverage of inspection area | | X | X |
| | Personnel | ISO 9712 | | X | X |
| | qualification | 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 |
| Ĩ | | Measurement of multi- directional stresses | | | X |
| | | Combined methods | | | Х |

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

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.

| | Content | Level 1 | Level 2 | Level 3 |
|-------|---|-------------|-------------|-------------|
| | | (% of total | (% of total | (% of total |
| | | duration) | duration) | duration) |
| 17.1 | Introduction to leak testing (LT) | 9 | 3 | 3 |
| 17.2 | Physical principles of the method and | 13 | 13 | 0 |
| | associated knowledge | | | |
| 17.3 | Product knowledge and capabilities of the | 3 | 3 | 0 |
| | method and its derived techniques | | | |
| 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 17. GENERAL CONTENT FOR LEAK TESTING

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

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

| Content | | | Level 1 | Level 2 | Level 3 |
|--|---------------------------------------|---|---------|---------|---------|
| Physical principles | Advanced | Quantitative, semi- | | X | |
| of the method and | physical | quantitative and | | | |
| associated | principles | qualitative analysis | | | |
| knowledge | | Pressure measurement testing | X | X | |
| | | Vacuum box testing | Х | Х | |
| 18.3 | Related | Typology of structural | Х | Х | |
| Product knowledge and capabilities of | capability of the method and | elements affected by air penetration | | | |
| the method and its derived techniques | derived techniques | Properties of construction materials | X | X | |
| | 1 | Constructive joints | X | X | |
| 18 / | Description of | Hermetic surfaces | v | v | |
| Fauinment | basic equipment | Differential | | | |
| Equipment | | manometer | Λ | Λ | |
| | | Pressurising or | v | v | |
| | | ricssurising of | Λ | Λ | |
| | | Air flow meter | v | v | |
| | | All now meter | | | |
| | Lankaga | Smoke generator | Λ | | |
| | detection | Infrared comero | | | |
| | techniques | Initiated camera | | Λ | |
| 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 | | X | X |
| | | Number of measurements | | X | X |
| 18.6 Testing | Preparation | Selection of testing | X | X | X |
| resting | | Operation and installation of blow door | X | X | |
| | | Test location | X | X | |
| | | Preparation of the area | X | | 1 |
| | | Initial verification | X | | |
| | Execution | Testing | X | | |
| | | implementation | | | |
| | Reading the results | Faulting and repetition of test | X | X | |
| | | Visual testing | | 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

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

| Content | | | Level 1 | Level 2 | Level 3 |
|------------------------|----------------|--------------------------|---------|---------|---------|
| | | Environmental | Х | Х | |
| | | conditions | | | |
| | | Difficulty of implant | Х | Х | |
| | | the testing system | | | |
| | | Incompatibility | X | Х | |
| | Verification / | Specifications | X | | X |
| | calibration | Periodic verification / | | X | X |
| | | calibration of | | | |
| | | equipment | | | |
| | Operating | Standard operating | v | X | x |
| | procedure | procedure (SOP) | 11 | 1 | |
| | Advanced | Dismontling and | | v | v |
| | Auvaliceu | Disinanting and | | Λ | |
| | practice | maintenance of | | | |
| 10.7 | Denerting | Data guality | v | | |
| 18./ Evolution and | Reporting | Data quality | Λ | | |
| Evaluation and | | assessment | V | | |
| reporting | | Record on worksheet | X | | |
| | | Practical writing of a | X | | |
| | | test report | | | |
| | Evaluating a | Practical interpretation | Х | X | X |
| | report | General survey and | | X | X |
| | | evaluation | | | |
| 18.8 | Conformity | Accuracy of | | Х | Х |
| Assessment | assessment of | measurement | | | |
| | test report | Reliability of the | | X | X |
| | | measurement records | | | |
| | | Assessment according | | X | X |
| | | to the technical | | | |
| | | specification | | | |
| 18.9 | Documents | National and | | Х | Х |
| Ouality aspects | | international standards | | | |
| | | Issue of testing | | Х | X |
| | | procedures | | | |
| | Procedures and | Concept | | X | X |
| | its contents | Application | | X | X |
| | | Development / | | X | X |
| | | creation | | | |
| | | Essential components | | X | x |
| | · | System verification | | X | X |
| | | Dete quality | | | |
| | | Data quality | | | |
| | | Coverage of inspection | | Λ | Λ |
| | D | | | V | V |
| | Personnel | 180 9/12 | | X | X |
| | qualification | Other NDI | | X | |
| | | qualification and | | | |
| | | certification systems | | | |
| | Faults | Weather | X | X | |
| | possibility | considerations: | | | |
| | | Difficulty in placing | X | X | |
| | | the equipment | | | |
| | | Electrical plant | X | X | |

| Content | | | Level 1 | Level 2 | Level 3 |
|-----------------------|------------------------------|--|---------|---------|---------|
| | | Air conditioning systems | X | Х | |
| | 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 | | | Х |

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

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.

| | 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 | 10 | 5 | 5 |
| | associated knowledge | | | |

TABLE 19. GENERAL CONTENT FOR GROUND PENETRATING RADAR

| | Content | Level 1 (% of total | Level 2 (% of total | Level 3 (% of total |
|-------|---|------------------------|------------------------|------------------------|
| | | duration) | duration) | duration) |
| 19.3 | Product knowledge and capabilities of the | 10 | 5 | 0 |
| | method and its derived techniques | | | |
| 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 19. GENERAL CONTENT FOR GROUND PENETRATING RADAR

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

| Content | | | Level 1 | Level 2 | Level 3 |
|---------------------|-----------------|-----------------------------------|---------|---------|---------|
| 20.1 | History | Development of GPR | Х | | |
| Introduction to | Introduction | Purpose of NDT | Х | | |
| ground penetrating | | NDT application | Х | | |
| radar (GPR) | | The importance of NDT | X | | |
| | | NDT personnel | Х | | |
| | | Tasks of the inspection personnel | Х | | |
| | Purpose of | Definition | Х | | |
| | testing | Applicability and limitations | Х | | |
| | Relevant | Standards and | Х | | |
| | standards | regulations | | | |
| 20.2 | Theory and | Impulses | Х | X | |
| Physical principles | properties of | Electromagnetic | Х | X | |
| of the method and | electromagnetic | waves | | | |
| associated | waves | Propagation | Х | X | X |
| knowledge | | Wave types | Х | X | |
| | | Electromagnetic | Х | | |
| | | generation | | | |
| | | Frequency | Х | X | |
| | | Wave speed | Х | | |
| | | Wavelength | Х | Х | |
| | | Wave types | Х | | |
| | | Electromagnetic | X | | |
| | | radiation | | 37 | 37 |
| | Antennas | Resolution | X | X | X |
| | | Bandwidth | X | X | |
| | | Transmitter/ Receiver | X | X | ** |
| | | Polarization | X | X | X |
| | Basic GPR | Transit time | X | X | |
| | principle | Reflection coefficient | X | X | X |
| | | Signal representation | X | | X |
| | | Reflection | X | X | |
| | | Attenuation | X | Х | |

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

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

| Content | | | Level 1 | Level 2 | Level 3 |
|----------------|------------------|-------------------------|--------------|---------|---------|
| | | Presentation of the | | | Х |
| | | procedures, codes, and | | | |
| | | standards | | | |
| 20.6 | Measuring grid | Space distance | Х | Х | |
| Testing | | Line distance | Х | Х | |
| | | Polarization | Х | X | |
| | | Time-controlled | Х | Х | |
| | | Way-controlled | Х | Х | |
| | Filters | High pass | Х | Х | |
| | | Low pass | Х | Х | |
| | | Band-pass | Х | Х | |
| | | Background removal | Х | Х | |
| | | Averaging | Х | Х | |
| | Gain and | Device change | X | Х | |
| | adjustment | Depth scaling | X | Х | |
| | | Zero point | X | Х | |
| | | Calibration checks | X | X | |
| | | Reference checks in | X | X | |
| | | and out | | | |
| | | Maximum penetration | X | X | |
| | | depth | | | |
| | | Signal-to-noise-ratio | X | X | |
| | | Coverage of the | X | X | |
| | | inspection area | | | |
| | Examples for | Inspection tasks | X | X | X |
| | data acquisition | Laboratory examples | X | X | X |
| | autu uoquisition | On-site measurements | X | X | X |
| | | Alternative methods | 21 | X | X |
| 20.7 | Prenaration | Data quality | X | X | X |
| Evaluation and | rieparation | assessment | 21 | | 21 |
| renorting | | Flimination of | | x | x |
| reporting | | systematic errors | | | |
| | | Filtering | | X | X |
| | | Calibration in terms of | | | X |
| | | a subsequent depth | | | |
| | | scaling | | | |
| | | Zero-point correction | | | X |
| | | Migration | | | X |
| | | Hilbert transform | | | X |
| | Evaluation | Signal analysis for | | X | X |
| | E valaation | detection | | | |
| | | Indication | | X | X |
| | | interpretation | | 21 | 21 |
| | | Display of results (A- | X | X | |
| | | Scan B-Scan C-Scan) | | | |
| | | Marking of component | X | X | |
| | | / structure | 11 | | |
| | Examples for | Inspection tasks | X | X | X |
| | data evaluation | Laboratory examples | X | X | X |
| | | On-site evaluations | X | X | X |
| | | | 1 <u>*</u> * | | |

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

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

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

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.

| | 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 21. GENERAL CONTENT FOR THERMOGRAPHIC TESTING

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

| Content | | | Level 1 | Level 2 | Level 3 |
|----------------------------|--------------------|--|---------|---------|---------|
| associated | | Heat conductivity and | | | |
| knowledge | | head capacity | | | |
| C C | | 1 st and 2 nd law of | Х | X | |
| | | thermodynamics | | | |
| | | Stages of matter | X | X | |
| | | Temperature scales | X | | |
| | | Fundamentals of Heat | X | X | |
| | | Conduction | | | |
| | | Fundamentals of Heat | X | X | |
| | | Convection | | | |
| | | Fundamentals of | X | X | |
| | | thermal radiation | | | |
| | | Thermal properties of | X | | |
| | | materials | | | |
| | | Steady and transitional | X | X | |
| | | regime | | | |
| | | Thermal diffusivity | | X | |
| | Infrared theory | Flectromagnetic | X | | |
| | initiated theory | spectrum | | | |
| | | Fmissivity | X | | |
| | | Black body/grey body | X | | |
| | | Dependency of | X X | | |
| | | emission coefficient | Λ | | |
| | | from view angle | | | |
| | | Non grey bodies | v | | |
| | | Kirchhoff's law | X V | | |
| | | Atmospheric window | | | |
| | | Atmospheric window | Λ | v | v |
| | Tommonotumo | Absolption Macgurgement of | v | | |
| | Temperature | measurement of | Λ | Λ | Λ |
| | measurement | bodies | | | |
| 22.2 | Dringinlag of | Dodles Dodles | v | v | |
| 22.3 Draduat Irrawiadaa | the arms a smarthy | Passive technique | Λ | | |
| and appahilition of | unermography | Active techniques | | | |
| the method and its | | | | Λ | |
| derived techniques | | and temperature | | | |
| derived techniques | | Change (day/night) | v | v | |
| | | Qualitative | A | A | |
| | | | | V | |
| | | Quantitative | | A | |
| | Turne esting | | v | v | v |
| | Inspection | 1 emperature | A | A | A |
| | conditions | difference | V | V | V |
| | | l'emperature change in | X | X | X |
| | | time | V | V | V |
| | | Exposure to sun | X | X | X |
| | | radiations | 37 | 17 | |
| | | Distance | | | |
| | | Wind speed | X | X | X |
| | | Pressure difference | | X | X |
| | | Humidity | X | X | X |
| | | Adhesion defects | X | X | X |

| Content | | | Level 1 | Level 2 | Level 3 |
|---|--|---|---------|---------|---------|
| | Types of defects | Discontinuities | Х | X | Х |
| | that can be | Dis-bonding | Х | X | Х |
| | found | Cracks | Х | X | X |
| | | Construction and cold joints | X | X | X |
| | | Infiltration | Х | 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 | | Х | X |
| | Condition | Thermometers | X | | |
| | monitoring tools | Hygrometers | X | | |
| | | Differential | X | | |
| | | monometers | | | |
| | | Laser rulers | X | | |
| | Accessories | Filters | | X | X |
| | | Optical lenses | | X | X |
| | | Blower | | X | X |
| | Heat input | Types of heating | X | X | X |
| | devices (active thermography) | Criteria for the selection of the heat input device | | X | X |
| | | Safety | Х | Х | Х |
| 22.5 Information prior to testing | Information about the object to be inspected | General knowledge | Х | X | |
| C | Test conditions | Measurement planning | | X | Х |
| | and application | Accessibility | | X | X |
| | of standards | Surface preparation | Х | X | Х |
| | | Special test conditions | | X | Х |
| | | Relevant standards | | Х | Х |
| | | Preparation of written instructions | | X | X |
| | Guidelines | Measurement | X | | |
| 22.6 | Test conditions | Focus adjustment | X | | |
| Testing | Infrared instrument operations | Correction of atmospheric absorption and reflected radiation | | X | |
| | | Setting up emissivity | | X | X |

| Content | | | Level 1 | Level 2 | Level 3 |
|-----------------|---------------|------------------------|---------|---------|---------|
| | | Spatial resolution | | X | Х |
| | | assessment | | | |
| | | Distance | X | X | |
| | | Humidity | Х | X | |
| | | Measurement of the | | X | X |
| | | angle of incidence | | | |
| | | Temperature scale | Х | X | |
| | | range | | | |
| | | Setting the frame rate | X | X | |
| | | (sample rate) | | | |
| | | Data logging | X | | |
| | | Performing the | Х | X | |
| | | inspection in | | | |
| | | accordance with the | | | |
| | | written instructions | | | |
| | Execution | Color palettes | X | | |
| 22.7 | Image | Use of isotherms | | X | Х |
| Evaluation and | processing | Use of graphical tools | X | X | X |
| reporting | | for temperature | | | |
| | | measurement | | | |
| | | Operations on images | X | X | X |
| | | Visualization of the | | X | X |
| | | temperature trend over | | | |
| | | time | | | |
| | | Trend processing | | X | X |
| | | Temperature / time | | | |
| | | Relevant information | X | X | |
| | | about the test | | | |
| | Reporting | Interpretation and | | X | X |
| | | evaluation of results | | | |
| | | Acceptance and | | X | X |
| | | rejection criteria | | | |
| 22.8 | Conformity | Accuracy of | | X | Х |
| Assessment | assessment of | measurement | | | |
| | test report | Assessing the | | X | X |
| | | reliability of the | | | |
| | | measurement records | | | |
| | | Assessment according | | X | X |
| | | to the technical | | | |
| | | specification | | | |
| 22.9 | Personnel | ISO 9712 Certification | X | X | X |
| Quality aspects | qualification | Other NDT | | X | X |
| | | qualifications and | | | |
| | | certification schemes | | | |
| | Documentation | Controlling the | | X | X |
| | | application of written | | | |
| | | instructions | | | |
| | | Measurement | | | |
| | | reliability | | 37 | |
| | | Document traceability | | X | X |

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

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

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.

| | 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 23. GENERAL CONTENT FOR MAGNETIC DETECTION

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

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

| Content | | | Level 1 | Level 2 | Level 3 |
|----------------------|------------------|--|---------|-------------|---------|
| | Electromagnetism | Correlation between | X | X | Х |
| | | electric and magnetic | | | |
| | | fields | | | |
| | | Current induced by a | X | X | X |
| | | magnetic field | | | |
| | | Transformers. Primary | Х | X | X |
| | | and secondary circuits | | | |
| | | and currents | | | |
| | | Lenz's law | | X | X |
| 24.3 | Cover of | Necessity of covering | Х | Х | |
| Product knowledge | reinforcement | Minimum usual | X | X | |
| and capabilities of | | coverings accord | | | |
| the method and its | | relevant standards | | | |
| derived techniques | | Anchor of | | X | X |
| | | reinforcements in | | | |
| | | concrete | | | |
| | | Durability aspects of | | X | X |
| | | covers | | | |
| | | Increasing of | | X | X |
| | | minimum covers | | | |
| | | Covers of strands and | | X | X |
| | | tendons | | | |
| | Types of | Longitudinal and | X | X | |
| | reinforcement | transversal | | | |
| | | Welded and fabric | X | X | |
| | | panels | | | |
| | | Prestressing strands | X | X | X |
| | | and tendons | | | |
| | | Rebar bundles | | X | X |
| | | Tendon ducts in | | X | X |
| | | prestressed structures | | | |
| | | Steel fibres reinforced | | X | X |
| | - | structures | | | |
| 24.4 | Instruments | Use of magnetic field | X | X | |
| Equipment | | Eddy current devices | X | X | |
| | | Reluctance (Magnetic | X | X | |
| | | induction) devices | 37 | 37 | |
| | | Accessories | X | X | |
| | | Influence of electric | | X | X |
| | | conductor materials | | V | V |
| | | Accuracy of | | X | X |
| | | measurement | | V | V |
| - 24.5 | T.C. | Limitation of detection | 37 | X | X |
| 24.5 | Information | Available documents | X | X | |
| information prior to | about testing | Instruction and | X | X | |
| testing | 1 1 2 4 | | | | |
| | object | templates | | 37 | 17 |
| | object | Writing instructions | | X | X |
| | | Writing instructions and templates | | X | X |
| | Test condition | Writing instructions and templates Planning of manufactor | | X X X | X X |

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

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

| Content | | | Level 1 | Level 2 | Level 3 |
|----------------|-------------------|-------------------------|---------|---------|---------|
| | Example of on- | Typical walls, | Х | Х | |
| | site application | columns, slabs and | | | |
| | | beams reinforcement | | | |
| | | arrangement, both in | | | |
| | | concrete and masonry | | | |
| | | structures | | | |
| 24.6 | Previous test | Surface preparation | Х | | |
| Testing | preparations | and cleaning | | | |
| - | | Repetitive test | | X | X |
| | Procedure | Practice with probes of | | X | X |
| | including | adequate rebar | | | |
| | calibration | diameter for cover | | | |
| | | determination, or | | | |
| | | special geometry if | | | |
| | | necessary | | | |
| | | Rebar location, | | Х | Х |
| | | including field marks | | | |
| | | Concrete cover | | X | X |
| | | measurement | | | |
| | | Rebar size estimation | | X | X |
| | | Influence of other re- | | X | X |
| | | bars and reinforcement | | | |
| | | meshes | | | |
| | | Embedded | | X | X |
| | | ferromagnetic objects | | | |
| | | investigation and its | | | |
| | | influence on | | | |
| | | measurement | | | |
| | | Minimum detectable | | X | X |
| | | spacing of rebar | | | |
| 24.7 | Report writing | Recording of the test | X | X | |
| Evaluation and | incepoirt writing | Recording and saving | X | X | |
| reporting | | of measurement data | | | |
| reporting | | Marking of component | x | x | |
| | | | 11 | 1 | |
| | | Compile all results and | | V | V |
| | | readings | | 1 | 1 |
| | Interpretation | Analysis of records of | | x | X |
| | Interpretation | the test and reporting | | Λ | Λ |
| | | Interpretation of | | v | v |
| | | results | | Λ | |
| | Evaluation | Concrete cover | | X | X |
| | Lvaluation | conformity and | | Λ | Λ |
| | | number and | | | |
| | | arrangement of rebars | | | |
| | | as required by design | | | |
| | | Diameter estimation | | v | v |
| | Factors | Concrete surface | | | |
| | influencing the | condition | | | |
| | test | How longitudinal and | | v | v |
| | 1051 | tronsversel rehers | | | |
| | 1 | uansveisai ieuais | 1 | 1 | 1 |

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

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

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.

| | Content | Level 1 | Level 2 | Level 3 |
|-------|---|-------------|-------------|-------------|
| | | (% of total | (% of total | (% of total |
| | | duration) | duration) | duration) |
| 25.1 | Introduction to potential mapping | 4 | 4 | 2 |
| 25.2 | Physical principles of the method and | 18 | 16 | 2 |
| | associated knowledge | | | |
| 25.3 | Product knowledge and capabilities of the | 16 | 12 | 12 |
| | method and its derived techniques | | | |
| 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 25. GENERAL CONTENT FOR POTENTIAL MAPPING

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

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

| Physical principles of the method and associated knowledge Electric potential and galvanic currents X Image: constraint of the second galvanic currents Corrosion principles Corrosion of Electric potential and galvanic currents X Image: constraint of the second galvanic currents X Image: constraint of the second galvanic currents 26.3 Corrosion of principles Corrosion of the method and is steel in concrete Corrosion of steel in concrete Steel manufacturing Steel manufacturing X X 26.3 Corrosion of the method and its derived techniques Corrosion of steel in concrete Steel manufacturing X X 26.4 Fortoction against steel X X X X Equipment Instruments High impedance X X X 41df cell types X X X X X 26.5 Information about testing Information ad application of standards Available documents X X 26.6 Test condition of standards Instruments Surface preparation measurement X X 26.6 Proper consection of standards Sur | Content | | | Level 1 | Level 2 | Level 3 |
|---|----------------------|-------------------|--------------------------|---------|---------|---------|
| of the method and associated knowledge issociated issociated knowledge issociated issociated knowledge issociated issociated knowledge issociated issociated issociated issociated knowledge issociated issociated issociated knowledge issociated iss | Physical principles | | Electrical potential of | X | | |
| associated knowledge Electric potential and galvanic currents X Image: constraint of the second seco | of the method and | | elements | | | |
| knowledge galvanic currents | associated | | Electric potential and | X | | |
| Electrolytic cell X X Electric potential X X Corrosion principles Definition of corrosion X Image: Corrosion 26.3 Corrosion of Product knowledge and capabilities of the method and its derived techniques Corrosion of steel in concrete Iron in nature X X 26.4 Corrosion of the method and its derived techniques Corrosion of the method and its derived techniques Iron in nature X X 26.4 Carbonation process X X X 26.4 Instruments High impedance X X 26.4 Instruments High impedance X X Equipment Information about testing N X X 26.5 Information and application of standards X X X 26.5 Information and application of standards X X X Proper connection of testing Information and application of standards X X X Proveous work Surface preparation contex toplitive clamp. X X | knowledge | | galvanic currents | | | |
| Image: constraint of the second sec | | | Electrolytic cell | X | X | |
| Corrosion principlesDefinition of corrosion Electric potential and galvanic currentsXImage: Corrosion polarization26.3 Product knowledge and capabilities of the method and its derived techniquesCorrosion of steel in concreteIron in nature Steel manufacturing AXX26.4 Carbonation processXXXXCarbonation processXXXXEquipmentHigh impedanceXImpedanceXImpedanceSpecific devicesXImpedanceXImpedanceXImpedance26.5Informationabout testingImpedanceXImpedanceXImpedance26.5Information about testingInformation and ad applicationXXXImpedance26.6Test condition and applicationProper connection of testingXXXX26.6Previous work <t< td=""><td></td><td></td><td>Electric potential</td><td>X</td><td>X</td><td></td></t<> | | | Electric potential | X | X | |
| principlesElectric potential and galvanic currentsX26.3Corrosion of steel in concreteIron in natureXXPolarizationXXXand capabilities of the method and its derived techniquesForection against steelXXXCarbonation processXXXXCarbonation processXXXXCarbonation processXXXXChoride concentrationXXXXTutti diagramXXXXTutti diagramXXXXFquipmentInstrumentsHigh impedanceXXXBeific devicesXXXXProper connection of cables and clampsXXXThermometerXXXXProper connection of and applicationXXXProper connection of and applicationXXXPlaning of cables and clampsXXXPlaning of conact cost to connect positiveXXX26.6 TestingPrevious workSurface preparation connect positiveXXPlaning of contact solutionXXXRebar location with other NDT techniquesXXXProcedureInitial calibration of contact solutionXXXProcedureInitial calibration of contact solutionXX <td></td> <td>Corrosion</td> <td>Definition of corrosion</td> <td>Х</td> <td></td> <td></td> | | Corrosion | Definition of corrosion | Х | | |
| 26.3 Product knowledge and capabilities of the method and its derived techniquesCorrosion of steel in concreteIron in nature Steel manufacturingXXSteel manufacturing corrosionXXXXProtection against steel corrosionXXXXCarbonation process Tutti diagramXXXX26.4 EquipmentInstrumentsHigh impedance voltmeterXXX26.4 EquipmentInstrumentsHigh impedance voltmeterXXX26.5 Information prior to testingInformation about testing elementXXX26.5 Information prior to testingInformation ad application of standardsXXX26.6 TestingProvious workSurface preparation measurementXXX26.6 TestingPrevious workSurface preparation capital sciencesXXX26.6 TestingPrevious workSurface preparation connect positive clamp.XXX26.6 TestingPrevious workSurface preparation RXXXPlanning of measurementXXXX26.6 TestingPrevious workSurface preparation RXXX26.6 TestingPrevious workSurface preparation RXXX26.6 TestingPrevious workSurface preparation RXXX26.6 Testing </td <td></td> <td>principles</td> <td>Electric potential and</td> <td>Х</td> <td></td> <td></td> | | principles | Electric potential and | Х | | |
| 26.3 Product knowledge and capabilities of the method and its derived techniquesCorrosion of steel in concreteIron in natureXXSteel manufacturingXXXProtection against steelXXXCarbonation processXXXCaloride concentrationXXXChoride concentrationXXXChoride concentrationXXXTutti diagramXXXTutti diagramXXXFquipmentInstrumentsHigh inpedance voltmeterXXSpecific devicesXXXHalf cellXXXCables, clampsXXXProper connection of cables and clampsXXXInformation adout testing elementInformationsXXTest condition of standardsPlaning of measurementXX26.6 TestingPrevious workSurface preparation Rebar access to connect positive clamp.XXProcedure clamp.Planing of measurementXXRebar location with other NDT techniquesXXXProcedure clamp.Preparation of relamplatesXXProcedure clamp.Preparation of relamplatesXXProcedure clamp.Preparation of relamplatesXXProcedure clamp.Preparation of relamplatesXX </td <td></td> <td></td> <td>galvanic currents</td> <td></td> <td></td> <td></td> | | | galvanic currents | | | |
| 26.3 Product knowledge and capabilities of the method and its derived techniques Corrosion of steel in concrete Iron in nature X X 26.4 Equipment Earbonation process X X X 26.4 Equipment Instruments High impedance voltmeter X X X 26.4 Equipment Instruments High impedance voltmeter X X X 26.4 Equipment Instruments High impedance voltmeter X X X 26.5 Information about testing element Information ad application of standards X X X 26.5 Information and application of standards Information ad application of standards X X X 26.6 Test condition element Surface preparation of standards X X X 26.6 Test condition of standards Surface preparation of standards X X X 26.6 Previous work Surface preparation of standards X X X 26.6 Previous work Surface preparation of standards X X X 26.6 Previous work Surface preparation | | | Polarization | | X | |
| Product knowledge and capabilities of the method and its derived techniquessteel in concrete in concreteSteel manufacturing Protection against steel Carbonation processXXRelation derived techniquesXXXXACarbonation processXXXCarbonation processXXXXCarbonation processXXXXCarbonation processXXXXCarbonation processXXXXCarbonation processXXXXZ6.4InstrumentsHigh impedance voltmeterXXXEquipmentSpecific devicesXSpecific devicesXSpecific devicesXGables, clampsXInformation prior to testingabout testing elementTest condition and application of standardsSurface preparationXXXProvious workSurface preparation contact solutionRebar access to connect positive clampControl of electric continuity of rebarsProcedureInitial calibration of contact solutionXXX-ProcedureInitial calibration of contact solution <t< td=""><td>26.3</td><td>Corrosion of</td><td>Iron in nature</td><td>X</td><td>X</td><td></td></t<> | 26.3 | Corrosion of | Iron in nature | X | X | |
| and capabilities of the method and its derived techniquesProtection against steel corrosionXXXInstrumentsCarbonation processXXXChoride concentrationXXXLocalized corrosionXXXTutti diagramXXXEquipmentInstrumentsHigh impedanceXXVoltmeterSpecific devicesXHalf cell typesXWet spongeXCables, clampsXCables, and clampsXInformation about testing elementAvailable documentsXXTest condition and application of standardsNPrevious workSurface preparation contact solution atter NDT techniquesXXRebar access to connect positive clamp.XXXProcedureInitial calibration of reparing an electrical contact solutionXXRebar location with other NDT techniquesXXXProcedureInitial calibration of contact solutionXXXNote the NDT techniquesNNNNNote the NDT techniquesNNNNNote the NDT techniquesNNNNNote the NDT techniquesNNNNNote the NDT techniquesNNNN< | Product knowledge | steel in concrete | Steel manufacturing | X | X | |
| the method and its derived techniques $\left \begin{array}{c c c c c c } \mbox{carbon structure} & \begin{tabular}{ c c c } \mbox{correstion} & X & X & X & X & X & X & X & X & X & $ | and capabilities of | | Protection against steel | Х | X | X |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $ | the method and its | | corrosion | | | |
| 26.4 EquipmentInstrumentsChloride concentrationXXX14lf cell typesXXX26.4 EquipmentInstrumentsHigh impedance voltmeterXX26.4 EquipmentInstrumentsHigh impedance voltmeterXX26.4 EquipmentInstrumentsHigh impedance voltmeterXX26.5 Information prior to testingInformation about testing elementA-26.5 Information adout testing elementInformation about testing elementAvailable documents voltmeterX-26.6 TestingPrevious workSurface preparation Rebar access to connection with other NDT techniquesXXX26.6 TestingPrevious workSurface preparation reparation and of standardsX26.6 TestingPrevious workSurface preparation reparation and other NDT techniquesXXX26.6 TestingPrevious workSurface preparation reparation and electric connect positive clamp.XXX26.6 TestingPrevious workSurface preparation reparation an electrical contact solutionXXX26.7 TestingPrevious workSurface preparation reparation an electrical contact solutionXXX26.6 Tother NDT techniquesNXNN26.7 TestingPrevious workSurface preparation reparation an electrical contact solution | derived techniques | | Carbonation process | X | X | X |
| $ \begin{array}{ c c c c c c c c c c c c c c c c c c c$ | | | Chloride concentration | Х | X | X |
| $ \begin{array}{ c c c c c c c c c c c c c c c c c c c$ | | | Localized corrosion | | X | X |
| $ \begin{array}{ c c c c c c } \hline Half cell types & X & X & X \\ \hline Half cell types & X & X & X \\ \hline Half cell types & X & X & X \\ \hline Hulf impedance & X & & & \\ \hline Specific devices & X & & & \\ \hline Half cell & & \\ \hline Half cell & & \\ \hline Half cel$ | | | Tutti diagram | | X | X |
| 26.4 Instruments High impedance X Impedance X Equipment Instruments High impedance X Impedance X Specific devices X Impedance X Impedance Specific devices X Impedance Impedance Impedance Cables, clamps X Impedance Impedance Impedance Proper connection of cables, clamps X Impedance Impedance Information prior to testing Information about testing Available documents X X Instruction and application Instruction and X X X Test condition and application of standards Planning of X X Rebar access to connect positive X Impedance Cottrol of electric X X Rebar location with other NDT techniques Impedance Proparting an electrical contact solution </td <td></td> <td></td> <td>Half cell types</td> <td>X</td> <td>X</td> <td>X</td> | | | Half cell types | X | X | X |
| EquipmentNotimitedVoltmeterNotimitedEquipmentSpecific devicesXImage: Specific devicesImage: Specific devicesImage: Specific devicesSpecific devicesXImage: Specific devicesXImage: Specific devicesImage: Specific devicesSpecific devicesXImage: Specific devicesXImage: Specific devicesImage: Specific devicesVoltmeterXImage: Specific devicesXImage: Specific devicesImage: Specific devicesCables, clampsXImage: Specific devicesXImage: Specific devicesImage: Specific devicesCables, clampsImage: Specific devicesXImage: Specific devicesImage: Specific devicesImage: Specific deviceCables, clampImage: Specific deviceImage: Specific devicesXImage: Specific deviceImage: Specific deviceCables, clampImage: Specific deviceImage: Specific deviceImage: Specific deviceImage: Specific deviceImage: Specific deviceCables, clampImage: Specific deviceImage: Specific deviceImage: Specific deviceImage: Specific deviceImage: Specific device26.6Previous workSurface prepar | 26.4 | Instruments | High impedance | X | | |
| Specific devicesXHalf cellXHalf cellXWet spongeXCables, clampsXProper connection of cables and clampsThermometerXAccessoriesX26.5Information about testing elementAvailable documentsXInformation about testing elementInstructionsXXTest condition and application of standardsPlanning of measurementXX26.6Previous workSurface preparation connect positive clamp.XXRebar access to continuity of rebarsXProcedureInitial calibration of to the the time for the time f | Equipment | | voltmeter | | | |
| Pail cellXHalf cellXWet spongeXCables, clampsXCables, clampsXProper connection of cables and clampsXThermometerXAccessoriesXAccessoriesXInformation prior to testingInformation about testing elementTest condition and application of standardsPrevious work26.6 TestingPrevious workSurface preparation connect positive clamp.26.6 TestingPrevious workSurface preparation connect positive clamp.26.7 TestingPrevious workSurface preparation control of electric control of electric control of electric control of electric control of electric control of electric contact solutionXProcedureInitial calibration of to the the clampX | 1 1 | | Specific devices | X | | |
| Wet spongeXCables, clampsXCables, clampsXProper connection of cables and clampsXThermometerXAccessoriesX26.5Information about testing elementAvailable documents Instruction and templatesX26.6Test condition and application of standardsProper previous workX26.6Previous workSurface preparation connect positive clamp.XX26.6Previous workSurface preparation connect positive clamp.XX26.6Prevent positive clamp.XXX26.6Previous workSurface | | | Half cell | X | | |
| InterpolationInterpolationCables, clampsXCables, clampsXProper connection of cables and clampsThermometerXAccessoriesX26.5Information about testing elementInformation prior to testingInformation about testing elementTest condition and application of standardsAvailable documents Writing instructions26.6Previous workSurface preparation connect positive clamp.XZ6.6Previous workSurface preparation connect positive clamp.Control of electric continuity of rebarsXProcedureInitial calibration of Preparing an electrical contact solutionProcedureInitial calibration of KProcedureInitial calibration of K | | | Wet sponge | X | | |
| 26.5Information about testing elementAvailable documents Writing instructionsXImage: construction (cables and clamps)26.5Information about testing elementAvailable documents Writing instructionsXX26.5Information about testing elementAvailable documents Instruction and templatesXX7Test condition of standardsPlanning of measurementXXX26.6Previous workSurface preparation connect positive clamp.XXX26.6Previous workSurface preparation (connect positive)XXX26.6Previous workSurface preparation (connect positive)XXX26.7Preparing an electrical (contact solution)XXX26.8Preparing an electrical (contact sol | | | Cables clamps | X | | |
| 26.5 Information prior to testingInformation about testing elementA cables and clampsN26.5 Information prior to testingInformation about testing elementAvailable documents Mriting instructionsXXMitting templatesMriting instructionsXXTest condition of standardsPlanning of measurementXX26.6 TestingPrevious workSurface preparation connect positive clamp.XX26.6 TestingPrevious workSurface preparation connect positive clamp.XX26.6 TestingPreparing an electrical contact solutionXX26.6 TestingPreparing an electrical contact solutionXX27.0 TestingPreparing an electrical contact solut | | | Proper connection of | X | | |
| 26.5Information about testing elementAccessories AccessoriesXImage: constraint of the testing26.5Information about testing elementAvailable documents Writing instructionsXXInformation prior to testingabout testing elementWriting instructionsXXTest condition and application of standardsPlanning of measurementXXX26.6Previous workSurface preparation connect positive clamp.XXX26.6Previous workSurface preparation connect positive clamp.XXX26.6Previous workSurface preparation connect positive clamp.XXX26.6Previous workSurface preparation connect positive clamp.XXXPreparing an electrical control of electric contact solutionXXXProcedureInitial calibration of to the time with writeXX | | | cables and clamps | | | |
| 26.5Information about testing elementAccessories AccessoriesX26.5Information about testing elementAvailable documents Writing instructionsXXWriting instructionsXXXTest condition and application of standardsPlanning of measurementXX26.6Previous workSurface preparation connect positive clamp.XXRebar access to connect positive clamp.XXRebar location with other NDT techniquesXXPreparing an electrical contact solutionXXProcedureInitial calibration of the with with withX | | | Thermometer | x | | |
| 26.5 Information about testing element Available documents X X Writing instructions X X X Test condition and application of standards Test condition and application of standards Planning of measurement X X 26.6 Previous work Surface preparation connect positive clamp. X X Rebar location with other NDT techniques X X X Procedure Initial calibration of standards X X | | | Accessories | X | | |
| 20.5InformationArtificative declarentsAAInformation prior to testingabout testing elementWriting instructionsXXInstruction and templatesXXXTest condition of standardsPlanning of measurementXX26.6 TestingPrevious workSurface preparation connect positive clamp.XXRebar access to connect positive clamp.XXXRebar location with other NDT techniquesXXXProcedure to to to the positionInitial calibration of to the positionXXProcedureInitial calibration of to the positionXX | 26.5 | Information | Available documents | X | X | |
| Information prior to testing about testing writing instructions X X X testing element Instruction and templates X X X X Test condition and application of standards Planning of measurement X X X X 26.6 Previous work Surface preparation X X X Rebar access to clamp. X X X X Rebar location with other NDT techniques X X X Control of electric continuity of rebars X X X Procedure Initial calibration of X X X | Information prior to | about testing | Writing instructions | Λ | X | x |
| cosingconnectinstruction and templatesXXXTest condition and application of standardsPlanning of measurementXXX26.6Previous workSurface preparation connect positive clamp.XRebar access to connect positive clamp.XRebar location with other NDT techniquesXPreparing an electrical contact solutionXXXXProcedureInitial calibration of xXXX | testing | element | Instruction and | x | X | X |
| Test condition and application of standardsPlanning of measurementXX26.6 TestingPrevious workSurface preparationX26.6 TestingPrevious workSurface preparationXRebar access to connect positive clamp.XRebar location with other NDT techniquesXControl of electric contact solutionXXXPreparing an electrical contact solutionXXXProcedureInitial calibration of Low bitXX | testing | | templates | | Λ | Λ |
| Test condition and application of standardsTraining of measurementXX26.6 TestingPrevious workSurface preparation Rebar access to connect positive clamp.X | | Test condition | Planning of | | v | x |
| 26.6 Previous work Surface preparation X Testing Previous work Surface preparation X Rebar access to X Connect positive Connect positive Clamp. Rebar location with X Control of electric Control of electric X Control of electric X Preparing an electrical X X X Procedure Initial calibration of X X | | and application | measurement | | Λ | |
| 26.6 Previous work Surface preparation X Testing Previous work Surface preparation X Rebar access to connect positive clamp. X Image: Connect positive clamp. Rebar location with other NDT techniques X Image: Control of electric X Control of electric X Image: Control of electric X Image: Control of electric X Preparing an electrical contact solution X X X Procedure Initial calibration of X X X | | of standards | measurement | | | |
| Testing Revisus work Surface preparation R Rebar access to clamp. X X Rebar location with other NDT techniques X Control of electric continuity of rebars X Preparing an electrical contact solution X Procedure Initial calibration of Location with other NDT | 26.6 | Previous work | Surface preparation | X | | |
| Procedure Intervention access to the transmission of the tra | Testing | | Rebar access to | X | | |
| Procedure Initial calibration of X X Procedure Initial calibration of X X | resting | | connect positive | | | |
| Procedure Initial calibration of X Procedure Initial calibration of X | | | clamp | | | |
| Interview Interview Interview other NDT techniques Interview Control of electric X continuity of rebars Interview Preparing an electrical X X Procedure Initial calibration of X | | | Rebar location with | | X | |
| Other Procedure Other Procedure Procedure Initial calibration of | | | other NDT techniques | | | |
| Control of clother A continuity of rebars | | | Control of electric | x | | |
| Preparing an electrical X X Procedure Initial calibration of X X | | | continuity of rebars | | | |
| Procedure Initial calibration of X X Violation Violation X X | | | Prenaring an electrical | X | x | x |
| Procedure Initial calibration of X X | | | contact solution | | | |
| | | Procedure | Initial calibration of | v | v | |
| including half cell with | | including | half cell with | | | |
| calibration hydrogen electrode | | calibration | hydrogen electrode | | | |

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

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

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

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

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

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.

| | 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 27. GENERAL CONTENT FOR RESISTIVITY MEASUREMENT

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

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

| Content | | | Level 1 | Level 2 | Level 3 |
|------------------------------|----------------------------|---|---------|---------|---------|
| | | Four-point technique | Х | Х | Х |
| | Code and standards | Applicable codes | | X | X |
| | Test conditions | Moisture | X | X | X |
| | and application | Salts content | | X | X |
| | of standard | Steel fiber | X | X | X |
| | | reinforcement | | | |
| | | Temperature | Х | Х | X |
| | | Water / cement ratio | | Х | X |
| | | Mix proportions | | Х | Х |
| | | Application standard | | Х | Х |
| | | Requirement of test personnel | | X | X |
| | | Acceptance criteria | | Х | X |
| 28.4 Equipment | Resistivity measurement | Instrument (resistivity meters) | X | X | Х |
| 1 1 | system | Electrodes | Х | Х | Х |
| | Output | Measured resistivity | Х | X | X |
| 28.5 | Information | Written instruction | Х | | |
| Information prior to testing | about the test object | Identification or designation material: | X | X | X |
| C | | — Type of concrete structures: | X | X | X |
| | | — Process of manufacture: | X | X | X |
| | | - Catalogue of defects: | | X | X |
| | | - Extent of test | | X | X |
| | Technique and | Surface condition | v | v | v |
| | sequence of | Surface preparation | | | |
| | nerforming test | Post test | Λ | | |
| | performing test | documentation | | Λ | Λ |
| | | Equipment to be used | | X | x |
| | | Requirement for | x | X | X |
| | | recording | | 21 | 21 |
| | Instructions | Preparation of written | | X | X |
| | | Preparation of written | | X | |
| | | Instructions | V | | |
| | | Performing inspection | Λ | v | v |
| | | Documentation | | X V | Λ V |
| | | standards | | A | Λ |
| 28.6 | Probe selection | Product | | X | X |
| Testing | | Grade | | X | X |
| | | Metallurgical condition | | X | X |
| | | Shape | | Х | Х |

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

| Content | | | Level 1 | Level 2 | Level 3 |
|-------------------------|-----------------|-------------------------|---------|---------|---------|
| | | Type of discontinuity | | X | Х |
| | | sought | | | |
| | | Location | | Х | X |
| | | Extent of examination | | Х | X |
| | Operating | Moisture | | Х | X |
| | conditions | Salt content | | Х | Х |
| | | Temperature | | Х | Х |
| | | Water/cement ratio | | Х | Х |
| | | Mix proportions | | Х | Х |
| | Parameters | Spacing | Х | Х | Х |
| | setting | Surface coupling | Х | Х | Х |
| | | Frequency | Х | Х | Х |
| | | Data acquisition | Х | Х | Х |
| | | Written procedure | | Х | Х |
| | | Written instruction | Х | Х | |
| 28.7 | Reporting | Reporting level | | Х | Х |
| Evaluation and | | Examination report | Х | Х | X |
| reporting | Evaluation | Characterization of the | | Х | X |
| | | indications | | | |
| | | Two-point technique | | X | X |
| | | analysis | | | |
| | | Four-point technique | | X | X |
| | | analysis | | | |
| | | Data analysis | | X | X |
| 28.8 | Evaluation and | Acceptance criteria | | X | X |
| Assessment | confirmation of | Training of Level 1 | | | X |
| | test reports | and Level 2 of the | | | |
| 20.0 | | acceptance criteria | V | V | V |
| 28.9 Oveliter encode | Factors | Personnel qualification | X | X | X |
| Quality aspects | affecting the | 1SO 9/12 | X | X | X |
| | quality of | Other NDI | | | X |
| | testing | qualification and | | | |
| | | Format and soona of | | | v |
| | | working procedures | | | |
| | | Qualification of NDT | | | x |
| | | procedures | | | Λ |
| | | Authorization | | | X |
| | | Developing written | | x | |
| | | instruction | | 1 | |
| | | Working correctly to | X | | |
| | | written instruction | 21 | | |
| | | Traceability of | | X | X |
| | | documents | | 21 | |
| | | Reliability of | | X | X |
| | | measurements | | | |
| | Knowledge of | Correct technique | 1 | X | |
| | applicable NDT | selection | | | |
| | application and | Use of correct test | | Х | |
| | ** | parameters | | | |
| | | | • | | • |

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

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

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

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.

| | 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 | Level 2 | Level 3 | |
|-------|--------------------------|-------------|-------------|-------------|--|
| | | (% of total | (% of total | (% of total | |
| | | duration) | duration) | 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 29. GENERAL CONTENT FOR ULTRASONIC AND SONIC TESTING

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

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

| Content | | | Level 1 | Level 2 | Level 3 |
|---------------------|------------------|--------------------------|---------|---------|---------|
| | Propagation of | Near fields (Fresnel | Х | X | |
| | waves in elastic | zone) | | | |
| | bodies | Far fields (Fraunhofer | Х | X | |
| | | zone) | | | |
| | | Beam divergence | Х | X | |
| | | Influence of transducer | Х | X | X |
| | | frequency and | | | |
| | | diameter to signal | | | |
| | | Relation between | | | X |
| | | velocity and elastic | | | |
| | Deflection / | properties | v | v | v |
| | Reflection / | Effects at interfaces at | Λ | Λ | Λ |
| | transmission of | normal incidence | | | |
| | bodies | | | | |
| 30.3 | General defects | Honeycombing | v | v | |
| Product knowledge | in concrete | Debonding | X | | |
| and canabilities of | materials | Shaft (nile) defects | X | | |
| the method and its | | Air voids | X | | |
| derived techniques | | Cracks | X | | |
| aerri ea teeninques | | Deviations from the | X | | x |
| | | specification of | Λ | Λ | |
| | | physic-mechanical | | | |
| | | characteristics | | | |
| | Implementation | According to product | X | X | |
| | of the | According to expected | X | X | |
| | techniques | discontinuities | | | |
| | | Codes, standards, and | | X | X |
| | | specifications | | | |
| | Influence of | Surface roughness | Х | X | |
| | surface and | Dimension of contact | Х | X | |
| | geometry on | surface (curvature/ | | | |
| | acoustics signal | irregular shape) | | | |
| | | Part geometry | Х | X | |
| | Influence of | Sound attenuation | Х | X | |
| | material | Acoustic noise | Х | X | |
| | properties | Signal to noise ratio | Х | X | |
| | | (SNR) | | | |
| | | Simulation of beam | | | X |
| | | propagation | | | |
| 30.4 | Ultrasonic | Types | X | X | |
| Equipment | instruments | Difference between | | | X |
| | (design and | digital and analog | | | |
| | function) | Impact echo and Pile | X | X | |
| | | integrity testing (PIT) | | | |
| | | equipment | 37 | 37 | |
| | | Ultrasonic pulse | | | |
| | | velocity system | 37 | 37 | |
| | | Pulse-echo equipment | X | X | v |
| | | Automated and semi- | | X | X |
| | | automated systems | 1 | 1 | 1 |

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

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

| Content | | | Level 1 | Level 2 | Level 3 |
|----------------------|------------------|-------------------------|---------|---------|---------|
| | Probes (design | Probe types | Х | Х | |
| | and application) | Probe characteristics | | | |
| | | Frequency bandwidth | | | Х |
| | | Measurement of pulse | | | Х |
| | | length | | | |
| | | Measurement of beam | | | X |
| | | direction | | | |
| | | Dynamic range | | | X |
| | Impactor | Impactor types | X | Х | |
| | (design and | Impactor | X | Х | |
| | application | characteristics | | | |
| | Couplant (as | Types of couplant | X | Х | |
| | applicable) | Contact techniques | Х | Х | |
| | Cables and | Type of cables and | X | Х | |
| | connectors | connectors | | | |
| | | Length of cables and | | Х | X |
| | | impedance | | | |
| | Calibration / | Zero-point setting | X | Х | Х |
| | Reference | Velocity in the field | X | Х | Х |
| | blocks | Equipment functional | X | Х | X |
| | | check | | | |
| | | Artificial reflector in | X | Х | X |
| | | reference block | | | |
| 30.5 | Object to be | Geometry | X | X | X |
| Information prior to | tested | Surface | X | X | X |
| testing | | Rebar location | X | X | X |
| | | Structure | X | X | X |
| | Kind of | Composition | X | X | X |
| | manufacture | Properties of concrete | X | X | X |
| | Extend of test | Void | X | X | |
| | coverage | Crack | X | Х | |
| | | Debonding | X | X | |
| | | Honeycombing | X | X | |
| | | Heat damaged | X | X | |
| | Test conditions | Accessibility | | X | X |
| | and application | Applicable standards | | | X |
| | of standards | Technical | | | X |
| | | specifications | | | |
| | | Testing stage | | | X |
| | | Requirements of test | | X | X |
| | | personnel | | | |
| | | Acceptance criteria | | X | X |
| | Written | Preparation of written | | X | |
| | instructions and | instruction | | | *7 |
| | procedures | Preparation of written | | | X |
| | | procedure | 37 | | |
| | | Performing inspection | X | | |
| | | in accordance to | | | |
| | | written instruction | | | |

| Content | | | Level 1 | Level 2 | Level 3 |
|----------------|----------------|-------------------------|---------|---------|---------|
| 30.6 | Preparation | Variation of artificial | X | X | Х |
| Testing | | reflectors | | | |
| | | Range setting | Х | Х | |
| | | Sensitivity setting | Х | Х | |
| | | Functional tests | Х | Х | Х |
| | | Verify the settings | Х | Х | Х |
| | Techniques | Pulse – echo | Х | Х | |
| | | Through transmission | Х | Х | |
| | | Ultrasonic thickness | Х | Х | |
| | | measurement | | | |
| | | Ultrasonic pulsed | Х | Х | |
| | | velocity measurement | | | |
| | | Impact echo | Х | Х | |
| | | Pile integrity testing | | Х | |
| | | (PIT) | | | |
| | | Impulse response | | Х | |
| | | Multiple probe arrays | | Х | X |
| | | Other techniques | X | Х | X |
| | | Verification of | | | X |
| | | procedures and | | | |
| | | instructions | | | |
| 30.7 | Interpretation | Referencing standards, | | Х | Х |
| Evaluation and | | specifications, and | | | |
| reporting | | manuals | | | |
| | | Conventional or | Х | Х | X |
| | | computer aided | | | |
| | | methods | | | |
| | | Impact echo, pile | X | Х | X |
| | | integrity testing (PIT) | | | |
| | | and impulse response | | | |
| | | results | | | |
| | | Displays (images) | Х | Х | X |
| | | Acceptance criteria: | | Х | X |
| | | Standards, | | | |
| | | specification, and | | | |
| | | other documents | ** | | |
| | Detecting, | Testing reporting | X | X | X |
| | locating, and | Storage of data-file | X | X | X |
| | sizing | and generated report | | | |
| | techniques | Detecting true/false | X | Х | X |
| | | display indication | ** | | |
| | | Sizing techniques | X | X | |
| | | Position and depth of | X | X | |
| 20.0 | | defects | | 37 | 37 |
| 30.8 | Application of | Type of defect | | X | X |
| Assessment | the acceptance | Size of detect | | X | X |
| | criteria | Localization | | X | X |
| | according to | Regularity | | X | X |
| | standards, | Influence of material | | X | X |
| | procedures | origin | | | |

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

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

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

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.
| | Content | Level 1 (% of total duration) | Level 2 (% of total duration) | Level 3 (% of total duration) |
|-------|---|-------------------------------------|-------------------------------------|-------------------------------------|
| 31.1 | Introduction to ultrasonic and sonic array | 4 | 7 | 5 |
| 31.2 | testing Physical principles of the method and | 14 | 12 | 7 |
| 51.2 | associated knowledge | 17 | 12 | , |
| 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 31. GENERAL CONTENT FOR ULTRASONIC AND SONIC ARRAY TESTING

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

| Content | | | Level 1 | Level 2 | Level 3 |
|--------------------------------------|------------------------|-------------------------------------|---------|---------|---------|
| 32.1 | Ultrasonic and | Basic knowledge | Х | X | |
| Introduction to ultrasonic and sonic | sonic array testing | Applicability and limitation | X | X | |
| array testing | | 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 | ISO standards | | X | X |
| | standards and | EN standards | | X | X |
| | specifications | ASTM standards | | X | X |
| | | ASME standards | | X | X |
| | | Others | | X | Х |
| 32.2 | Mathematical | Basic of sound beam | X | X | |
| Physical principles | and physical | Waves | X | X | |
| of the method and associated | basics | Influence of sound bandwidth | X | X | |
| knowledge | | Terms relating to sound | X | X | |
| | | Terms relating to arrays | X | X | |
| | | Influence of band width | X | X | |
| | Generation of | Basics of transducers | Х | X | |
| | signal | Sound beam characteristics | X | X | |
| | | Impulse characteristics | X | X | |
| | | Near fields (Fresnel | Х | Х | 1 |
| | | zone) | | | |

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

| TABLE 32. ULTRASONIC AND SONIC ARRAY TESTING - LEY | VELS 1, 2 AND 3 |
|--|-----------------|
|--|-----------------|

| Content | | | Level 1 | Level 2 | Level 3 |
|---|--|--|---------|---------|---------|
| | Calibration / Reference blocks | Artificial reflector in reference block | Х | Х | Х |
| 32.5 Information prior to testing | Applied codes, standards, and specifications | Related codes, standards and specifications | Х | Х | Х |
| 8 | | Requirements for procedure | | X | X |
| | | Developing written procedure | | | Х |
| 32.6 | Techniques for | Linear scanning | Х | Х | |
| Testing | testing | Multi group scanning | Х | Х | |
| C | Test setting | Sensitivity setting | Х | Х | |
| | | Range setting | | Х | |
| | | Typical application of array techniques | X | X | Х |
| | | Typical application of FMC/TFM techniques | X | X | X |
| 32.7 Evaluation and | Interpretation | Distinction between defect and geometry | Х | X | Х |
| reporting | | Type of defect | Х | X | |
| | | Location and sizing of defect | X | X | |
| | | Interpretation and evaluation of indication | | X | X |
| | | Sizing of defect | Х | X | |
| | | A-, B-, and C- scan interpretation | X | X | Х |
| | Generation of | Recording | Х | Х | |
| | test report | Classification of results according to the written procedure | | Х | Х |
| | | Location and sizing of defect | Х | Х | |
| | | Storage of data | X | X | |
| 32.8 | Application the | Type of defect | | X | X |
| Assessment | acceptance | Size of defect | | Х | Х |
| | criteria to | Localization | | Х | Х |
| | standards, code, | Regularity | | Х | Х |
| | procedure, or specification | Influence of material origin | | X | X |
| 32.9 Quality aspects | Reliability of measurements | Limits of the techniques | | X | Х |
| · - * | | Detectable flaw size | | X | X |
| | | Factors influencing the test | | X | X |
| | | Quality of evaluated images | | X | X |
| | Documents | National and international standards | | X | Х |

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

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

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

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 realtime 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.

| | Content | Level 1 (% of total | Level 2 (% of total | Level 3 (% of total |
|-------|---|------------------------|------------------------|------------------------|
| | | duration) | duration) | 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 33. GENERAL CONTENT FOR ACOUSTIC EMISSION TESTING

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

 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 | | X | Х |
| | | velocity | | | |
| | | Mode conversion | X | X | Х |
| | | Reflection and | X | X | |
| | | refraction | | | |
| | | Wave attenuation | X | X | X |
| | | Wave dispersion | | X | X |
| | | Geometric effects | | X | |
| | | Shadowing effects | | X | |
| | Source location | One sensor location | X | | |
| | | Linear location with | X | | |
| | | delta – t | | | |
| | | Planar location with | X | | |
| | | delta – t | | | |
| | | Continuous emission | | X | |
| | | Zone location | | X | X |
| | | Thin-walled and thick- | | X | |
| | | walled structure | | | |
| | | Location uncertainty | | X | |
| | | Guard sensor | X | X | |
| 34.3 | General defects | Defects in cement | X | X | |
| Product knowledge | in composite | matrix composite | | | |
| and capabilities of | materials | Initial imperfections | X | X | |
| the method and its | | Degradation due to | X | X | |
| derived techniques | | aging | | | |
| | Implementation | According to product | | X | X |
| | of the AT | According to expected | X | X | X |
| | techniques | discontinuities | | | |
| | | Standards, | | X | X |
| | | specifications and | | | |
| | I CI C | codes | 37 | | |
| | Influence of | influence of surface | X | X | |
| | testing parts | and geometry | V | V | |
| | | Influence of material | X | X | |
| 24.4 | Sangang | Piezoalastriaity | v | | |
| 54.4 Equinment | Sensors | Construction | | | |
| Equipment | | Construction | | | |
| | | Wide hand and | | | |
| | | wide – band and | Λ | | |
| | | Coupling and | v | | |
| | | coupling and | Λ | | |
| | | Integral electronics / | v | | |
| | | differential | | | |
| | | Connectors | x | | |
| | | Cables | | | |
| | | A diustment methods | Δ | v | |
| | 1 | Aujusiment methous | 1 | Λ | 1 |

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

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

| | | Level 1 | Level 2 | Level 3 |
|-----------------|-------------------------|---------|---------|---------|
| | Sensor selection | | Х | |
| | Ground – loop | | Х | |
| | Temperature effect | | Х | |
| | Acoustic impedance | Х | Х | |
| | Wave guide | | Х | |
| Preamplifiers | Single ended / | X | | |
| • | differential | | | |
| | Unit of gain (dB scale) | Х | | |
| | Electronic noise | Х | | |
| | Filters | Х | | |
| | Frequency filter | | X | |
| | selection | | | |
| | Cable length effect | | X | |
| | Common mode | | X | |
| | rejection | | | |
| | Signal saturation | | X | |
| Signal | Acoustic emission | | X | |
| processing | testing parameters | | | |
| 18 | (ISO 12716) | | | |
| | Energy (true, MARSE, | | X | |
| | alternative) | | | |
| | Continuous signal | X | | |
| | Transient signal | X | | |
| | Background noise | X | | |
| | ALS | X | | |
| | RMS | X | | |
| | Amplitude | X | | |
| | Threshold | X | | |
| | Single vs multichannel | X | | |
| | system | | | |
| | Acquisition rate | | X | |
| | Waveform digitization | | X | |
| | Waveform recording | | X | |
| Source location | Algorithm | x | X | |
| processing | Overview | X | | |
| processing | Knowledge | | X | |
| | Selection | | X | |
| | Linear location | x | | |
| | Zone location | X | | |
| | Hit sequence | X V | | |
| | location | | | |
| | Planar location | x | | |
| | Three – dimension | Λ | v | |
| | location | | | |
| | Location uncertainty | | X | |
| | Guard channel | | X | |
| Advanced signal | External parameters | v | | |
| nrocessing | Distribution plate | | | |
| processing | Correlation plots | | | |
| | FFT | Λ | v | |
| | ГГІ | | Λ | |

| Content | | | Level 1 | Level 2 | Level 3 |
|----------------------|--------------------------------|--------------------------|---------|---------|---------|
| | | Waveform future | | X | |
| | | extraction | | | |
| | | Timing consideration | | X | |
| | Equipment | Sensor verification in | Х | | |
| | adjustments | lab | | | |
| | | Sensor adjustment in lab | | X | |
| | | Acoustic Emission | Х | | |
| | | testing verification | | | |
| | | Acoustic Emission | | X | |
| | | testing adjustment | | | |
| | | Applicable standards | | X | |
| | Fundamentals of | Knowledge and use of | Х | X | |
| | informatics | computers | | | |
| | | Knowledge of | | X | X |
| | | software | | | |
| 34.5 | Information | Object to be tested | Х | X | |
| Information prior to | about testing | Kind of manufacture | Х | X | |
| testing | object | Catalogue of defects | | X | X |
| - | | Extent of test coverage | Х | X | |
| | Test condition | Accessibility | | X | |
| | and application | Particular test | | X | |
| | of standards | condition | | | |
| | | Application standard | | X | |
| | | Standards assigned to | | X | X |
| | | the test object | | | |
| | | Requirements of test | | X | X |
| | | personnel | | | |
| | | Acceptance criteria | | X | X |
| | Technique and | Surface condition | | X | |
| | sequence of performing test | Surface preparation | | X | |
| | | Post – test | | X | X |
| | | documentation | | | |
| | Instructions | Preparation of written | | X | X |
| | | instruction | | | |
| | | Performing inspection | X | | |
| | | in accordance to | | | |
| | | written instruction | | | |
| 34.6 | Equipment set- | Sensor placement | Х | | |
| Testing | up | Equipment verification | Х | | |
| C | | Noise identification | Х | | |
| | | and elimination | | | |
| | | Velocity and | Х | | |
| | | attenuation | | | |
| | | measurement | | | |
| | | Location and | X | | |
| | | simulated source | | | |
| | | Factors affecting the | | X | X |
| | | selection of the test | | | |
| | | equipment | | | |
| | | 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 | Data acquisition | X | | |
| | and data display | Significance of the plots for the data | X | | |
| | during the test | display (time-based | | | |
| | | load-based location | | | |
| | | correlation) | | | |
| | | Comparison with the | x | | |
| | | verification | | | |
| | | Comparison with | X | | |
| | | location of simulated | | | |
| | | source | | | |
| | | Establishing of | | X | X |
| | | accepting criteria | | | |
| | | Selection of plots. | | X | |
| | | correlation and | | | |
| | | distribution | | | |
| | Necessary | Stop criteria | X | | |
| | action during the | Verification of on-line | | X | X |
| | test | detected Acoustic | | | |
| | | emission testing | | | |
| | | sources by other NDT | | | |
| | | method | | | |
| 34.7 | Data display | Time display | X | | |
| Evaluation and | | Load-based plots | X | | |
| reporting | | Parameter-based plots | X | | |
| | | Location plots | X | | |
| | | Distribution plots | X | | |
| | | Correlation plots | X | | |
| | | Acoustic testing | | Х | |
| | | source correlation | | | |
| | Data | Noise and other non- | X | | |
| | interpretation | relevant identification | | | |
| | | Acoustic Emission | X | | |
| | | testing source | | | |
| | | correlation | | | |
| | | Post processing noise | | X | |
| | | identification and | | | |
| | | filtering | | | |
| | | Source activity | | Х | |
| | Data evaluation | Source severity | | X | X |
| | | Source criticality | | X | X |
| | | Advanced evaluation | | X | X |
| | | process | | | |
| | 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 | Evaluation and | Application of the | | X | Х |
| Assessment | confirmation of | acceptance criteria to | | | |
| | test reports | standards, code, | | | |
| | | procedure or | | | |
| | | specification (quality | | | |
| | | of concrete) | | | |
| 34.9 | Construction | Safe Life | X | X | |
| Quality aspects | concept | Damage tolerance | X | X | Х |
| | Reliability of | Limits of AT | | X | X |
| | measurements | Detectable flaw size | | X | X |
| | | Factors influencing the | | X | X |
| | | test | | | |
| | Documents | National and | | X | X |
| | | international standards | | | |
| | | Issue of testing | | X | X |
| | | procedures | | | |
| | Personnel | ISO 9712 | Х | X | X |
| | qualification | Other NDT | | X | X |
| | | qualification and | | | |
| | | certification systems | | | |
| 34.10 | Advanced | TR method | | | Х |
| Developments | imaging | | | | |
| | Combination | Use of data from other | | | X |
| | with other | methods, e. g. | | | |
| | monitoring | changing wave | | | |
| | methods, e. g. | velocities | | | |
| | ultrasonic | | | | |
| | Simulation of | Simulation of wave | | | X |
| | Acoustic | propagation in | | | |
| | Emission | concrete | | | |
| | Testing | | | | |
| | Integration into | Thresholds, alarm | | | Х |
| | decision making | systems | | | |

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

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.

| | Content | Level 1 | Level 2 | Level 3 |
|-------|---|-------------|-------------|-------------|
| | | (% of total | (% of total | (% of total |
| | | duration) | duration) | duration) |
| 35.1 | Introduction to radiographic testing | 6 | 5 | 3 |
| 35.2 | Physical principles of the method and | 15 | 15 | 5 |
| | associated knowledge | | | |
| 35.3 | Product knowledge and capabilities of the | 18 | 10 | 10 |
| | method and its derived techniques | | | |
| 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 35. GENERAL CONTENT FOR RADIOGRAPHIC TESTING

| Content | | | Level 1 | Level 2 | Level 3 |
|----------------------|-----------------|-----------------------|---------|---------|---------|
| 36.1 | Non-destructive | Basic knowledge to | X | Х | |
| Introduction to | testing (NDT) | NDT | | | |
| radiographic testing | | Main NDT methods | Х | Х | |
| (RT) | Radiographic | Basic knowledge to | X | Х | |
| | testing (RT) | RT | | | |
| | | Applicability and | X | Х | |
| | | limitations | | | |
| | Terminology | Ionizing radiation | X | Х | |
| | | Energy | Х | Х | |
| | | Dose and dose rate | Х | Х | |
| | | Dose rate constant | Х | Х | |
| | | Activity | Х | Х | |
| | | Intensity | X | Х | |
| | | Ionization | X | Х | |
| | | Radiographic | X | X | |
| | | sensitivity | | | |
| | | Radiographic contrast | X | Х | |
| | Relevant | ISO Standards | | Х | Х |
| | standards | European standards | | Х | Х |

| Content | | | Level 1 | Level 2 | Level 3 |
|---------------------|-----------------|-------------------------|---------|---------|---------|
| | | ASTM standards | | X | Х |
| | | ASME standards | | X | X |
| | | Other applicable | | X | X |
| | | standards | | | |
| 36.2 | General | Structure of atom | Х | X | |
| Physical principles | | Electromagnetic | Х | X | |
| of the method and | | spectrum | | | |
| associated | | Sources of radiation in | Х | X | |
| knowledge | | RT applications | | | |
| | | Essential radiographic | Х | X | |
| | | parameters (kV, mA, | | | |
| | | activity) | | | |
| | | Radiation filters | | Х | |
| | | Focal spot | Х | Х | |
| | Attenuation of | General mechanism of | | | |
| | radiation | interaction: | | | |
| | | — Photoelectric | X | X | |
| | | effect; | | | |
| | | — Compton effect; | Х | Х | |
| | | — Pair production; | Х | Х | |
| | | - HVL, TVL and | Х | Х | |
| | | attenuation law; | | | |
| | | — Hardening of | Х | X | |
| | | radiation; | | | |
| | | — Scattered radiation | X | X | |
| | | and build up | | | |
| | | factor; | | | |
| | | — Filtering and | X | X | |
| | | collimation; | | | |
| | | — X-ray | X | X | |
| | | fluorescence; | | | |
| | | — Attenuation of | | | X |
| | | neutrons and | | | |
| | | electrons. | 37 | 37 | |
| | Radiographic | Radiographic contrast | Х | X | |
| | sensitivity | Specific contrast | | Х | |
| | | Scatter radiation | Х | Х | |
| | | Un-sharpness | Х | Х | |
| | Optimization of | Radiation scattering | Х | Х | X |
| | image | Source energy | | Х | X |
| | quality | Physical arrangement | | Х | X |
| | Geometrical | Geometrical | Х | X | X |
| | projection | Un-sharpness | | | |
| | conditions | Image magnification | | Х | X |
| | | Inverse Square Law | Х | X | X |
| | Image quality | Wire type | Х | X | X |
| | indicators | Step hole type | Х | X | X |
| | | Plate hole type | Х | X | X |
| | | Duplex wire type | Х | X | X |
| 36.3 | | Initial defect | Х | Х | X |

| Content | | | Level 1 | Level 2 | Level 3 |
|---------------------|-----------------|-------------------------|---------|-----------|---------|
| Product knowledge | General defects | Degradation due to | Х | X | Х |
| and capabilities of | in concrete | aging | | | |
| the method and its | materials | | | | |
| derived techniques | Application of | Pre-service | Х | X | X |
| | radiographic | In-service | Х | X | X |
| | testing | Post disaster/ incident | Х | X | X |
| | Influence of | Type of defect | Х | X | X |
| | detectability | Size of defect | Х | X | X |
| | | Orientation | Х | Х | X |
| | | Number of exposures | | X | X |
| | | Beam direction | Х | Х | X |
| | | Increase in wall | | X | X |
| | | thickness | | | |
| | | Thickness ranges for | | X | X |
| | | X-ray and | | | |
| | | gamma ray | | | |
| | Influence of | Types of concrete | | | |
| | testing part | basic structures: | | | |
| | | — Slab; | X | X | X |
| | | — Column; | X | X | X |
| | | — Beam; | X | X | X |
| | | — Wall; | Х | X | X |
| | | — Thickness and | | X | X |
| | | geometry; | | | |
| | | — Concrete | | X | X |
| | | properties. | | | |
| 36.4 | X-ray | Construction and | X | X | |
| Equipment | | function of X-ray | | | |
| | | tubes | 37 | NZ NZ | |
| | | X-ray generation | X | X | |
| | | X-Ray beam | X | X | |
| | | Parameters | X | X | |
| | Gamma | Gamma Container: | 37 | 37 | |
| | | — Shielding; | X | X | |
| | | — Iransportation; | X | X | |
| | | — Source assembly; | 37 | X | |
| | | — Handling and | X | X | |
| | | projection; | | v | |
| | | — Special design; | V | | |
| | | — Collimation; | Λ | | v |
| | | — Classes of | | A | A |
| | | Containers. | | | |
| | | Parameters: | v | v | |
| | | — Source type; | | | |
| | | — Spectrum; | | | |
| | | <u> </u> | | | |
| | | - Activity; | | | |
| | | — Source Size; | | | |
| | 1 | — пан ше. | Λ | Λ | |

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

| Content | | | Level 1 | Level 2 | Level 3 |
|----------------------|-----------------|-------------------------|---------|---------|---------|
| | Film | Radiographic image | Х | Х | |
| | | development | | | |
| | | Film characteristics: | | | |
| | | — Film properties: | X | X | |
| | | — Characteristic | X | X | |
| | | curve: | | 21 | |
| | | — Development time: | x | X | |
| | | — Film granularity: | X | X | |
| | | — Film classification: | X | X | |
| | | — Film quality | | X | |
| | | assurance | | 1 | |
| | | Film screens | X | x | |
| | Darkroom | Darkroom design | X V | X V | V |
| | facilities and | Film chemicals | X V | X V | Λ |
| | practice | Film development | | | |
| | practice | process | Λ | Λ | |
| | | process | | | |
| | Accessories | Work setup: | 37 | 37 | |
| | | — Lead letters and | X | X | |
| | | tape; | | | |
| | | — Holding magnets; | X | X | |
| | | — Rubber bands. | X | X | |
| | | Safety: | | | |
| | | — Lead shielding; | Х | Х | X |
| | | — Collimator; | Х | Х | X |
| | | — Radiation | Х | Х | X |
| | | protection | | | |
| | | equipment; | | | |
| | | — Emergency | Х | Х | X |
| | | equipment. | | | |
| 36.5 | Information | Technical documents | Х | Х | Х |
| Information prior to | about the test | Identification or | Х | Х | X |
| testing | object | designation of material | | | |
| | | Type of concrete | Х | Х | X |
| | | structures | | | |
| | | Catalogue of defects | | Х | Х |
| | | Extent of test coverage | | Х | Х |
| | Test conditions | Accessibility | | Х | Х |
| | and application | Related standards | | Х | Х |
| | of standard | Requirements of test | | Х | X |
| | | personnel | | | |
| | | Acceptance criteria | | Х | Х |
| | Technique and | Surface condition | | Х | Х |
| | sequence of | Equipment to be used | | Х | Х |
| | performing test | Test setup | | Х | Х |
| | | Requirement for | | Х | Х |
| | | recording | | | |
| | | Post-test | | Х | Х |
| | | documentation | | | |
| | | Preparation of written | | Х | |
| | | instructions | | | |

| Content | | | Level 1 | Level 2 | Level 3 |
|----------------|-----------------------------|--|---------|---------|---------|
| | Written instructions and | Preparation of written procedures. | | | X |
| | procedures | Testing preparation in accordance with | Х | X | |
| | | written instruction | | | 17 |
| | | Presentation of the | | | X |
| | | standards | | | |
| 36.6 | Standard | Performing inspection | Х | Х | |
| Testing | practice and | in accordance with | | | |
| - | evaluation | written instruction / | | | |
| | standards | procedure | | | |
| | | Selection of technique | | Х | Х |
| | | Different exposure | | X | Х |
| | | settings | | | |
| | | Interpretation of | | X | Х |
| | | images | | | |
| | | Evaluation of flaws | | X | Х |
| 36.7 | Basic of | Viewing conditions: | | | |
| Evaluation and | evaluation | — Room condition; | Х | Х | Х |
| reporting | | — Viewing time; | Х | Х | |
| | | — Lapsed time after | Х | X | |
| | | dazzling; | | | |
| | | — Luminance; | | Х | |
| | | — Density | Х | Х | |
| | | measurement; | | | |
| | | — Mach effect. | | Х | |
| | | Film viewer: | | | |
| | | — Introduction; | Х | Х | |
| | | — Minimum | | Х | |
| | | luminance; | | | |
| | | — Homogeneity | | Х | |
| | | factor. | | | |
| | Physical factors | Eyesight | | Х | |
| | | Adaption prior | | Х | |
| | | viewing | | | |
| | Evaluation of | Verification of the | Х | Х | Х |
| | radiographs | image quality | | | |
| | | Report of | | Х | Х |
| | | imperfections | | | |
| | Test report | Complies with | | Х | Х |
| | | examination | | | |
| | | standard | | | |
| | | Conformed to test quality | | X | X |
| 36.8 | Evaluation of | Type of defect | | X | Х |
| Assessment | defect | Size of defect | | Х | Х |
| | | Localization | | X | X |
| | | Regularity | | X | Х |
| | | Influence of material | | Х | Х |
| | | origin | | | |

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

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.

| | 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 37. GENERAL CONTENT FOR RADIOGRAPHIC TESTING-DIGITAL

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

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

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 | Geometrical | | X | X |
| | projection | Un-sharpness | | | |
| | conditions | Image magnification | X | X | X |
| | | Inverse Square Law | X | X | X |
| | Image quality | Wire type | Х | X | X |
| | indicators | Step hole type | Х | Х | X |
| | | Plate hole type | Х | Х | X |
| | | Duplex wire type | Х | X | X |
| | | Measurement of SRb | | X | X |
| | | Converging line pairs | | X | X |
| 38.3 | | Line pair gauges (MTF) | | | X |
| | General defects | Initial defect | X | X | Х |
| Product knowledge and capabilities of | in concrete materials: | Degradation due to aging | X | X | X |
| the method and its | Application of | Pre-service | x | x | X |
| derived techniques | radiographic testing-digital Influence of detectability | In-service | X | X | X |
| | | Post disaster/incident | X | X | X |
| | | 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 | | X | X |
| | | thickness | | | |
| | | Thickness ranges for | | X | X |
| | | X-ray and gamma ray | | | |
| | Influence of testing part | Types of concrete | | | |
| | | basic structures: | | | |
| | | — Slab; | Х | X | X |
| | | — Column; | Х | X | X |
| | | — Beam; | Х | X | X |
| | | — Wall; | Х | Х | X |
| | | — Thickness and | | X | X |
| | | geometry; | | | |
| | | — Concrete | | X | X |
| | | properties. | | | |
| 38.4 | X-ray | Construction and | X | X | |
| Equipment | | function of X-ray | | | |
| | | tubes | 37 | NZ NZ | |
| | | A-ray generation | X | X | |
| | | X-Ray beam | X | | |
| | | Parameters | X | X | |
| | Gamma | Gamma container: | | | |
| | | — Shielding; | X | X | |
| | | — Transportation; | X | X | |

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

| Content | | | Level 1 | Level 2 | Level 3 |
|---|-----------------------------|-----------------------------------|---------|---------|---------|
| | | — Handling, | | | Х |
| Content 38.5 Information prior to | | archiving; | | | |
| | | — Classification. | | X | X |
| | Accessories | Work setup: | | | |
| | | — Lead letters and | X | X | |
| | | tape; | | | |
| | | — Holding magnets; | X | X | |
| | | — Rubber bands. | Х | X | |
| | | Safety: | | | |
| | | — Lead shielding; | X | X | X |
| | | — Collimator; | Х | X | X |
| | | - Radiation | X | X | X |
| | | protection | | | |
| | | equipment; | | | |
| | | — Emergency | Х | X | X |
| | | equipment. | | | |
| | Data | A/D interface | X | X | X |
| | acquisition, | Computer structure | | X | X |
| | detector | Image integration | | X | X |
| | adjustment | | | | |
| 38.5 | Information | Written instruction | X | x | |
| Information prior to | about the test | Identification or | X | X | X |
| testing | object | designation of material | Λ | Λ | |
| testing | | Type of concrete | v | v | v |
| | | structures | Λ | Λ | |
| | | Catalogue of defects | | v | v |
| | Test conditions | Accessibility | | X | X |
| | and application | Related standards | | | |
| | of standard | Related standards | | | |
| | of standard | nerconnel | | Λ | |
| | | Accentance criteria | | v | v |
| | Technique and | Surface condition | | | |
| | rechnique and | Equipment to be used | | | |
| | nerforming test | Test setur | | | |
| | performing test | Dequinement for | | | |
| | | requirement for | | Λ | |
| | | Dest test | | v | v |
| | | Post-test documentation | | Λ | |
| | Written | Descention of written | | v | |
| | written instructions and | instructions | | Λ | |
| | instructions and | Dran anation of sumittan | | | v |
| | procedure | Preparation of written | | | |
| | | procedure Descentations of the | | | V |
| | | Presentations of the | | | A |
| | | procedures, codes, and | | | |
| 20 (| Ctau day 1 | Standards | v | v | v |
| JO.D | Standard | reriorming test | Λ | A | А |
| resung | practice and | inspection in | | | |
| | evaluation | accordance with | | | |
| | standards | written instruction / | | | |
| | | procedure | 1 | | 1 |

| Content | | | Level 1 | Level 2 | Level 3 |
|----------------|-----------------------------|--|---------|---------|---------|
| | | Selection of technique | | Х | Х |
| | | Different exposure settings | | X | X |
| | | Interpretation of images | | X | X |
| | | Evaluation of flaws | | X | X |
| 38.7 | Basic of | Viewing conditions: | | | |
| Evaluation and | evaluation | — Room condition; | X | X | |
| reporting | | — Viewing time; | X | X | |
| | | — Luminance; | | X | |
| | Physical factors | Eyesight | | X | |
| | Evaluation of | Verification of the | | X | X |
| | radiographs | image quality | | | |
| | | 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) | | Х | X |
| | | Basic operation | | X | X |
| | | Point operations | | X | X |
| | | Matrix operation, filters | | X | X |
| | | Measurement tools: | | | |
| | | — Adjustment; | | X | X |
| | | — Line profile; | | X | Х |
| | | — Measurement of flaw length; | | X | X |
| | | — Measurement of areas: | | X | Х |
| | | — Measurement of depth. | | X | Х |
| | | Correction of raw | | | |
| | | — Introduction: | | X | X |
| | | — Linearization, | | | X |
| | | - Bad pixel | | | X |
| | Automated | Principles | | v | v |
| | image | Binarization | | | |
| | interpretation | Measurement of | | X | X |
| | morpretation | dimensions | | | |
| 38.8 | Evaluation of | Type of defect | | X | X |
| Assessment | defect | Size of defect | | X | X |
| | | Localization | | Х | Х |

| Content | | | Level 1 | Level 2 | Level 3 |
|-----------------------|-------------------------|---|---------|---------|---------|
| | | Regularity | | X | Х |
| | | Influence of material origin | | X | X |
| 38.9 | Personnel | ISO 9712 | | Х | Х |
| Quality aspects | qualification | Other NDT qualification and certification systems | | Х | 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 | Correct technique selection | | X | X |
| | NDT application and | Use of correct test parameters | | X | X |
| | product | NDT method selection | | X | X |
| | standards | Job specific training | | X | X |
| | | Equipment verification | | X | X |
| 38.10 Developments | Other techniques | Computed tomography (CT) | | X | X |
| _ | | Stereo radiography | | X | X |
| | | Laminography | | Х | Х |

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

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.

| | 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 |

| ΗY |
|----|
| |

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

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

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

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

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

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

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

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

| Content | | | Level 1 | Level 2 | Level 3 |
|----------------|------------------|-------------------------|---------|---------|---------|
| | | Presentations of the | | | Х |
| | | procedures, codes, and | | | |
| | | standards | | | |
| 40.6 | Data acquisition | CT equipment set-up | Х | Х | Х |
| Testing | | Accomplishing a | Х | Х | X |
| | | measurement | | | |
| | | Optimum | Х | Х | X |
| | | magnification and | | | |
| | | unsharpness | | | |
| | | Noise and artefacts | Х | Х | X |
| | | Image reconstruction | | Х | X |
| | | algorithms and | | | |
| | | processing | | | |
| | | Contrast sensitivity | | Х | X |
| | | Image resolution | | Х | X |
| | | Errors in image | | Х | X |
| | | reconstruction | | | |
| | | CT image quality | | Х | X |
| | | CT simulator software | | X | X |
| 40.7 | Visualization | Viewing conditions: | | | |
| Evaluation and | and evaluation | — Room condition; | Х | Х | |
| reporting | | — Viewing time; | Х | Х | |
| | | — Lapsed time after | X | X | |
| | | dazzling; | | | |
| | | — Luminance; | | X | |
| | | — Density | X | X | |
| | | measurement; | | | |
| | | — Homogeneity | | X | |
| | D1 1.0 | factor. | | | |
| | Physical factors | Eyesight | | X | |
| | | Adaption prior | | Х | |
| | | Viewing | V | V | V |
| | Evaluation of | Verification of the | X | X | X |
| | tomographs | image quality | | | |
| | | parameters Demont of | | v | v |
| | | Report of | | A | A |
| | Test report | Complies with | | v | v |
| | restreport | examination standard | | Λ | |
| | | Conformed to test | | v | x |
| | | quality | | Λ | |
| | | A chieved test class | X | X | X |
| | | Achieved diagnostic | X | X | X |
| | | coverage of test object | 24 | 21 | |
| 40.8 | Evaluation of | Type | | X | X |
| Assessment | discontinuities | Size | | X | X |
| | | Localization | | X | X |
| | | Regularity | | X | X |
| | | Influence of | | X | X |
| | | manufacture and | | | |
| | | material | | | |

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

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

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.

| | Content | Level 1 | Level 2 | Level 3 |
|-------|---|-------------|-------------|-------------|
| | | (% of total | (% of total | (% of total |
| | | duration) | duration) | duration) |
| 41.1 | Introduction to nucleonic gauging | 4 | 3 | 5 |
| 41.2 | Physical principles of the method and | 6 | 9 | 5 |
| | associated knowledge | | | |
| 41.3 | Product knowledge and capabilities of the | 4 | 6 | 0 |
| | method and its derived techniques | | | |
| 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 41. GENERAL CONTENT FOR NUCLEONIC GAUGING

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

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

| Content | | | Level 1 | Level 2 | Level 3 |
|-----------|------------------|-------------------------|---------|---------|---------|
| | Bitumen | Introduction | Х | X | |
| | | Different types of | Х | Х | |
| | | bitumen | | | |
| | | Properties of bitumen | Х | X | |
| | | Grade of bitumen | Х | X | |
| | | (60/70) | | | |
| | Hydrogenous | Cement, gypsum, coal, | Х | X | |
| | materials | mica, lime etc. | | | |
| | Neutron | Boron, cadmium etc. | Х | X | |
| | absorbers | | | | |
| | materials | | | | |
| | Density and | Moisture content of | X | X | |
| | Moisture of | soil or concrete | | | |
| | materials | Moisture content units | X | X | |
| | | Wet density | X | X | |
| | | Moisture-Density | X | X | |
| | | relationship | | | |
| | | Target values for the | X | X | |
| | | gauge | 37 | 37 | |
| 42.4 | Gamma source | Density measurement | X | X | |
| Equipment | Neutron back | Moisture measurement | X | X | |
| | scattering gauge | Electronics control | X | X | |
| | | Data acquisition | X | X | |
| | | system | V | NZ. | |
| | | Accuracy of | Х | X | |
| 42.5 | T. f | measurement | | v | |
| 42.5 | Information | Written instruction | v | X | |
| tosting | about the test | Identification or | А | Λ | |
| testing | object | Turna of comparate or | v | v | |
| | | Type of concrete or | Λ | Λ | |
| | | Extent of test acverage | | v | V |
| | Test condition | A coassibility | | | |
| | and application | Paquirements of test | | | |
| | of standards | nersonnel | | Λ | Λ |
| | of standards | Acceptance criteria | | x | X |
| | | Planning of | | X | X |
| | | measurement | | 1 | |
| | Technique and | Surface condition | X | x | |
| | sequence of | Equipment to be used | | X | X |
| | performing test | Test setun | | X | X |
| | p man g man | Requirement for | X | X | X |
| | | recording | 21 | | |
| | Instructions | Preparation of written | | | X |
| | | procedures | | | |
| | | Preparation of written | | X | |
| | | instructions | | | |
| | | Performing inspection | Х | X | 1 |
| | | in accordance with | | | |
| | | written instruction | | | |

| Content | | | Level 1 | Level 2 | Level 3 |
|-----------------|------------------|--------------------------|---------|---------|---------|
| | | Presentations of the | | X | Х |
| | | procedures, codes and | | | |
| | | standards | | | |
| 42.6 | Test site | Site location | X | X | X |
| Testing | preparation | Soils / ground surface | | | |
| | | preparation, by using | | | |
| | | The scraper plate. | | | |
| | | Placement of drift rod | | | |
| | Data acquisition | Nucleonic gauging | v | v | v |
| | Data acquisition | Action of the set up | Λ | Λ | Λ |
| | | Sampling frequency | v | v | v |
| | | and settings in data | Λ | Λ | Λ |
| | | acquisition system | | | |
| | | Accomplishing a | X | X | X |
| | | measurement | | | |
| | | Data verification and | X | X | X |
| | | validation | | | |
| 42.7 | Report writing | Compliance with | | X | Х |
| Evaluation and | 1 0 | examination | | | |
| reporting | | standard | | | |
| | | Recording of | | Х | Х |
| | | installation procedure | | | |
| | | Recording and saving | X | X | X |
| | | of measurement data | | | |
| | | in digital format | | | |
| | | Presenting the | X | X | X |
| | | measurements | | | |
| | | Conformed to test | | X | X |
| | | quality | | | |
| | T | Achieved test class | | X | X |
| | Interpretation | Interpretation of | | X | X |
| | | results | | V | V |
| | | Statistical treatment of | | X | X |
| 42.0 | Conformity | results | | v | v |
| 42.0 | Conformity | Assessing the | | Λ | Λ |
| Assessment | test reports | measurement records | | | |
| 42.9 | Reliability of | Inadequate choice of | | x | x |
| Quality aspects | measurements | instrument | | 1 | 1 |
| Quality aspects | mousurements | Equipment lack of | | X | X |
| | | calibration or | | | |
| | | malfunction | | | |
| | Factors | Concrete or asphalt | X | X | X |
| | influencing the | surface condition | | | |
| | test | Effect of temperature | Х | Х | Х |
| | | in measurements | | | |
| | Faults | Disconnection of | Х | X | X |
| | possibility | gauges from concrete | | | |
| | | surface and connecting | | | |
| | | wires | | | |

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

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LIST OF ABBREVIATIONS

| AT | Acoustic emission testing |
|------------------|--|
| CNR | Contrast to noise ratio |
| CR | Computed radiography |
| СТ | 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 |

STStrain gauge testingTFMTotal focusing methodTTThermographic testingUTUltrasonic testingVTVisual testing

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