



# **SPECIFICATION AND STANDARDS**

**FOR**

## **INTEGRITY TESTING OF WATER RETAINING STRUCTURES**

**IN**

# **BIOGAS INSTALLATIONS, IRELAND**

Prepared for Nephin Renewable Gas

Document reference 240719-1

Revision 1

| Issue | Date                       | Revision     | Author      |
|-------|----------------------------|--------------|-------------|
| 0     | 30 <sup>th</sup> July 2024 | PRELIMINARY  | B Jenkinson |
| 1     | 31 <sup>st</sup> July 2024 | Client Issue | B Jenkinson |
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Document reference 240719-1  
Revision 1

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## **Contents**

- 1. Executive Summary**
- 2. Introduction**
- 3. Summary**
- 4. Accepted hydraulic test procedure**
- 5. Construction quality assurance (CQA)**
- 6. Concrete testing and inspection techniques**

## **APPENDICES**

### **Appendix 1**

**Applicable Standards and guidance**

Client Issue

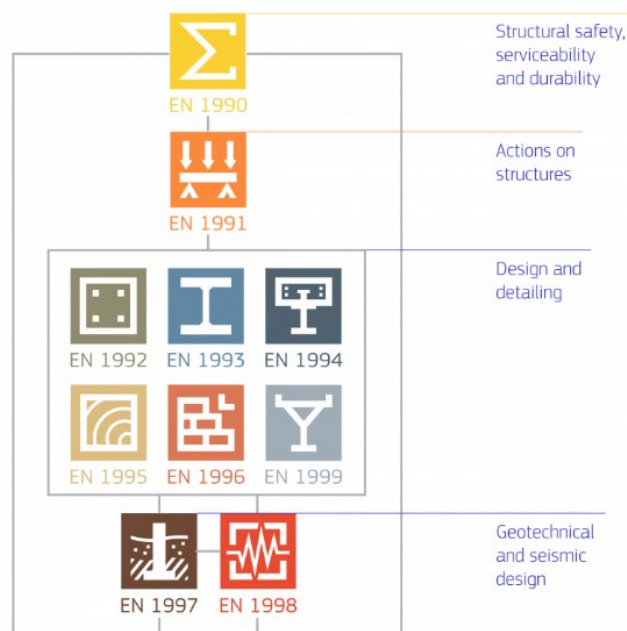
## 1. Executive Summary

Since the 2010 withdrawal of Design of concrete structures for retaining aqueous liquids (1987) and it being superseded by EN 1992-3:2006 Eurocode 2 – Design of concrete structures – Part 3: Liquid retaining and containment structures, there is no longer a specified requirement to undertake hydraulic testing of containment structures.

Instead the enhanced requirements of part 3 over those of parts 1 & 2 provide for the tolerances necessary in design and construction of a structure to achieve minimal cracking and watertightness. The process of autogenous healing of concrete is no longer referenced specifically but in designing to limit crack width this phenomenon is expedited in service.

When applied in conjunction with the other Eurocodes, as is the intention, a cohesive approach to all aspects of design is achieved. The need for insitu testing is dispensed with in favour of good engineering practice.

This is illustrated in the infographic below, reproduced from Eurocodes.



The use of large volumes of water for testing purposes is generally regarded as wasteful and therefore inappropriate and unnecessary, even by industries who historically undertook hydraulic testing as a matter of course. It has been mostly superseded by the implementation of quality assurance protocols to validate designs and monitor construction activities.

## 2. Introduction

Nephin Renewable Gas Ltd intends to develop a portfolio of anaerobic digestion plants for the production of biomethane to inject into the gas distribution network in Ireland. These plants shall be waste installations as defined by the Industrial Emissions Directive and therefore are required to meet the requirements of the BAT Conclusions for waste treatment under Directive 2010/75/EU of the European Parliament and of the Council, in order that they may be granted a license (permit) to operate under the provisions of the directive, the Environmental Protection Act 1992 (EPA Act) and the associated requirements of the regulator, the Environmental Protection Agency (EPA)

This document has been prepared to demonstrate how the performance and integrity of concrete water retaining structures, both primary (process tanks) and secondary (bunds) as defined in IS EN 1992-3:2006 Eurocode 2 – Design of concrete structures – Part 3: Liquid retaining and containment structures, may be demonstrated at commissioning and during the operating life of the plant.

As is outlined in Section 6.6.1 of IPC Guidance Note on Storage and Transfer of Materials for Scheduled Activities Environmental Protection Agency June 2004, it is anticipated that the EPA will condition the licence in relation to the testing of primary containment and engineered secondary containment structures (bunds) as follows:-

- *The integrity and water tightness of all tanks, bunding structures, containers and underground pipes and their resistance to penetration by water or other materials carried or stored therein shall be tested and demonstrated by the licensee within six months of the date of grant of this licence.*
- *In the case of new bunding structures, tanks, underground pipelines and containers installed on site, the testing for integrity and water tightness shall be undertaken in advance of utilisation;*
- *Testing shall be carried out by a suitably qualified and experienced person;*
- *Testing shall be carried out in accordance with any guidance published by the Agency;*
- *Testing shall be carried out at least once every three years thereafter and reported to the Agency on each occasion;*
- *Any repairs required to ensure the integrity and water tightness of tanks, bunding structures, containers and underground pipes shall be carried out as soon as practicable; and*
- *A written record of all integrity tests and any maintenance or remedial work arising from them shall be maintained by the licensee.*

The following report considers the technical and commercial implications of these anticipated inspection and testing requirements and provides narrative on a risk based approach to testing and inspection which considers all aspects of the design, construction and operation of the vessels.

### 3. Summary

Nephin Renewable Gas have determined that insitu cast concrete tanks and containment bund shall be designed to meet the provisions of IS EN 1992-3:2006 Eurocode 2 – Design of concrete structures – Part 3: Liquid retaining and containment structures ('Eurocode 2'), since this provides the most robust means of primary and secondary containment for the anaerobic digestion process.

Tank structural design shall meet BS EN 1990, *Eurocode- Basis of structural design*, (Eurocode 0). In accordance with Table 2-1 Indicative design working lives, for design purposes the design life category for concrete structures including tanks and bunds shall be category 4 with a 50 year design life.

**Table 2.1 - Indicative design working life**

| Design working life category | Indicative design working life (years) | Examples  |
|------------------------------|--|---|
| 1                            | 10                                     | Temporary structures <sup>(1)</sup>   |
| 2                            | 10 to 25                               | Replaceable structural parts, e.g. gantry girders, bearings                     |
| 3                            | 15 to 30                               | Agricultural and similar structures   |
| 4                            | 50                                     | Building structures and other common structures                                 |
| 5                            | 100                                    | Monumental building structures, bridges, and other civil engineering structures |

(1) Structures or parts of structures that can be dismantled with a view to being re-used should not be considered as temporary.

By application of the provisions of the relevant Eurocodes, a structured approach to design verification, and a programme of construction quality assurance it is possible to demonstrate, without the need for hydraulic testing, that negligible risk in design and execution has been achieved.

Eurocode 2 does not require the post construction hydraulic test as was described in the now withdrawn<sup>1</sup> BS 8007 Design of concrete structures for retaining aqueous liquids, or as may be described elsewhere in industry specifications such as the Civil Engineering Specification for the Water Industry (CESWI) 8<sup>th</sup> edition.

Specifiers and clients generally acknowledge that the testing of large volume structures in this way is contrary to the efficient use of resources and that the proper application of the Eurocode and construction quality monitoring are sufficient to prove adequacy in design, and by extension fitness for purpose. Allowing for filling, saturation of the concrete, a period of autogenous healing and the 7-day test, the duration of a hydraulic test may be up to 28 days for each vessel, which for an installation of the scale planned could result in significant programme delays and resourcing issues.

CQA and application of good practice record keeping can be augmented by testing and sampling of materials during construction (slump testing, cube samples) and post completion (28 day compressive strength, permeability) to demonstrate adherence to the design specifications.

BS 8007 acknowledges the ability of concrete for autogenous healing, or the self healing of fine cracks. Both BS 8007 and Eurocode 2 provides enhanced requirements for limiting crack width through

<sup>1</sup> BS8007 and BS8110 were withdrawn in 2010 and superseded by Eurocodes

provision of appropriate reinforcement and an increased cement content in the specified concrete factors which are proven to influence the expediency of autogenous healing of concrete.

Autogenous healing is further accelerated by the presence of minerals and/or fines in the stored inventory which can both improve the hydration of unhydrated cement particles, increase the rate of calcium carbonate (calcite) deposition and plug cracks with fines.

Any surface cracks in cast in situ concrete water retaining structures arising as part of the normal curing process of concrete will seal by autogenous healing in the initial stages of commissioning and tank filling.

With few exceptions all post construction concrete testing methods are destructive, requiring samples to be removed from the structure for testing and analysis. In the case of structural elements concrete cores may be removed from areas of the member that will not effect its performance and that may be subjected to a satisfactory repair method using proprietary products. The removal of any material from a liquid retaining structure is likely to be detrimental to its performance and therefore should be avoided at all costs.

Internal protection systems such as Wiretarp which are cast into the concrete wall to prevent acid erosion in both the gas space and the liquid space will prevent visual inspection of the concrete substrate. Their removal would compromise their performance. The external face of the tank is clad first with an insulating membrane with cast-in fixings then with trapezoidal steel sheeting as a weathering layer. Areas around pipe penetrations will be cut back and treated with an appropriate flashing to facilitate regular inspection of cast-in puddle pipes and/or mechanical sealing devices. (Linkseal/Ringseal)

The task of undertaking the internal inspection of a digestion vessel cannot be understated, notwithstanding the time necessary to ramp down and recommission each tank. The process of simply draining, cleaning down and making safe the vessel requires considerable resource. A typical digester will be between 5000m<sup>3</sup> and 6500m<sup>3</sup> in volume, to empty will require there either to be sufficient redundancy on the plant to displace that volume to or it will require approximately 230 road tankers to remove from the site, since there is currently no possibility for this to be spread to land it would have to be removed for treatment. The time to drain the digester would be governed by the rate at which a treatment plant could receive the substrate, the costs of sending all substrate for treatment would likely be financially punitive and therefore unviable.

Typically a digester will have 6m-8m wall height and therefore be 28-32m in diameter. The internal wall area will be approximately around 600m<sup>2</sup>, the majority of which will require specialist access provision to facilitate a visual inspection. In the case of a concrete lidded tank or a flexible gas retaining structure there will be no natural light inside the structure, unless in the case of the latter it can be removed, so in order to undertake a visual inspection extensive internal temporary lighting will be required. It must be noted that the unnecessary removal and reinstatement of the flexible gas dome is to be avoided due to the risk of damage.

It is impractical to undertake an inspection on each tank on a three year cycle simultaneously as that would effectively require the plant to be decommissioned and recommissioned in its entirety. A process which takes between six and nine months from initial seeding to achieving full design output. This would be commercially unviable. If inspections are undertaken on a rotation, this would effectively commence at commissioning and would require two process tanks to be out of commission every year, this too would result in a significantly depressed processing volume and therefore gas production. This would be commercially unviable.

During the normal operation of the plant it is generally necessary to undertake planned preventative maintenance on the tanks for the purposes of sediment removal which requires partial decommissioning of the plant. The frequency of these works is dictated by the feedstock ration and the operating viscosity of the substrate. Higher dry matter or greater viscosity substrates are capable of holding more inerts in suspension, such as those which may be associated with farmyard manure or chicken litter (layers) which results in a much lower rate of sedimentation and by extension a reduced requirement for intervention. The planned feed ration is likely to warrant periodic inspection of the tanks for assessment and removal of sediment accumulations at  $\geq 5$  year intervals. However, unless there is an appreciable drop in process efficacy, unnecessary interruptions to the process will be avoided. Wherever possible such intervention will be timed to coincide with other major planned preventative maintenance events such as critical equipment overhauls.

Regular, routine inspections of pipe penetrations to all tanks will be undertaken and recorded as evidence of their continued proper performance. These inspections and those associated with gas holding and conveyance will be included in the programme of leakage detection and repair (LDaR) in accordance with BAT 51 of Emissions from Storage and BAT 14 of Waste Treatment which shall be included in the Environmental Management System (EMS) for the installation.

By virtue of the vessels in question being employed in the retention of liquids their continued satisfactory performance negates any requirement for inspection and testing beyond that which may be undertaken without avoidable interruption to the process.

The regular inspection of containment bunds may be undertaken at any time since access is unimpeded and the structure is not employed for the routine operation of the facility. Hydraulic testing is impractical due to the volume of testing water required and the associated issues of procurement and disposal as well as risk to safety of personnel and damage to equipment.

## 4. Accepted Hydraulic Test Procedure

Paragraph 6.6.2 of IPC Guidance Note on Storage and Transfer of Materials for Scheduled Activities Environmental Protection Agency June 2004 states that

*All newly constructed bunds must be tested in accordance with the testing requirements specified in the codes and standards to which the bund has been designed. The required testing procedure should be carried out prior to any equipment, as well as the primary storage vessel(s), being installed within the bund.*

The following test specified in paragraph 6.6.3.1 of the IPC guidance note is reproduced from Section 9 of the now withdrawn BS 8007:1987 and describes the procedure for undertaking testing and inspection of structures for retaining aqueous liquids.

It must be noted that whilst Guidance Note on Storage and Transfer of Materials for Scheduled Activities references this standard it is now withdrawn and superseded by IS EN 1992-3:2006 Eurocode 2 – Design of concrete structures – Part 3: Liquid retaining and containment structures in which no such testing requirement is made. The use of hydraulic testing may therefore be regarded as outdated and redundant.

### **9.1 General**

*Inspection and testing of structures should be carried out in accordance with 2.8. Testing for liquid tightness should be in accordance with 9.2 and 9.3.*

### **9.2 Testing of structures**

*For a test of liquid retention, the structure should be cleaned and initially filled to the normal maximum level with the specified liquid (usually water) at a uniform rate of not greater than 2 m in 24 h.*

*When first filled, the liquid level should be maintained by the addition of further liquid for a stabilizing period while absorption and autogenous healing take place. The stabilizing period may be 7 days for a maximum design crack width of 0.1 mm or 21 days for 0.2 mm or greater.*

*After the stabilizing period the level of the liquid surface should be recorded at 24 h intervals for a test period of 7 days. During this 7-day test period the total permissible drop in level, after allowing for evaporation and rainfall, should not exceed 1/500<sup>th</sup> of the average water depth of the full tank, 10 mm or another specified amount.*

*Notwithstanding the satisfactory completion of the test, any evidence of seepage of the liquid to the outside faces of the liquid-retaining walls should be assessed against the requirements of the specification. Any necessary remedial treatment of the concrete, cracks, or joints should, where practicable, be carried out from the liquid face.*

*When a remedial lining is applied to inhibit leakage at a crack it should have adequate flexibility and have no reaction with the stored liquid.*

*Should the structure not satisfy the 7-day test, then after the completion of the remedial work it should be refilled and if necessary left for a further stabilizing period; a further test of 7 days' duration should then be undertaken in accordance with this clause.*

### **9.3 Testing of roofs**

*The roofs of liquid-retaining structures should be watertight and should, where practicable, be tested on completion by flooding the roof with water to a minimum depth of 25 mm for 24 h or longer if so specified. Where it is impracticable, because of roof falls or otherwise, to contain a 25 mm depth of water, the roof should have water applied by a continuous hose or sprinkler system to provide a sheet flow of water over the entire area of the roof for not less than 6 h. In either case the roof should be considered satisfactory if no leaks or damp patches show on the soffit. Should the structure not satisfy either of these tests, then after the completion of the remedial work it should be retested in accordance with this clause. The roof insulation and covering should be completed as soon as possible after satisfactory testing.*

Hydraulic testing as described above may be a practical means of demonstrating the integrity of small volume bunds such as those for fuel or chemical storage. Where the volumes of water necessary to complete the test may be readily sourced from town supplies, with the consent of the supplier or from a ground or surface water abstraction, subject to the necessary consents being obtained.

Obtaining the volumes of water required to undertake this test on a biogas plant of the scale proposed is impractical, costly and contrary to all environmental mandates to utilise resources responsibly.

**European Union (Water Policy) (Abstractions Registration) Regulations 2018 (S.I. No. 261 of 2018).**

Requires that abstraction of  $>25\text{m}^3/\text{day}$  requires registration and approval with the Agency. Clearly to provide the necessary  $\approx 6000\text{m}^3$  of test water for the typical digester at a rate to meet the fill rate described in the test procedure requires  $2000\text{m}^3/\text{day}$  or a flow rate of approximately 23 litres per second.

To meet this flow rate from a ground or surface water source is implausible as it is from a mains supply; a flow rate of around 8.0 litres per second is generally acceptable as the maximum discharge rate from a fire hydrant in case of emergency. This would be required uninterrupted for ten days to fulfil the test volume, assuming that consent for an uninterrupted, metered supply on an 80mm diameter standpipe were available. This is unlikely due to the potential for water quality issues arising on the network as a consequence of such increased flow and the use of potable water for testing purposes being regarded as unacceptable.

It is further worthy of note that upon completion of all hydraulic testing the water used would need to be removed from the plant. Controlled release to a suitable watercourse may not be possible and therefore it may be determined that test water is removed by road to a treatment facility, giving rise to a significant number of road tanker movements.

## 5. Construction Quality Assurance

Construction Quality Assurance (CQA) is a process that, when applied to the deployment of licensed plant and installation can evidence that that design decisions associated with the structures are validated as evidence of compliance with standards, followed by site supervision and recording augmented with a programme of insitu sampling and testing and laboratory testing of materials. Since each CQA plan will need to be tailored to the installation in consideration the following outlines the principles of CQA.

These principles are not dissimilar to those of Reliability Differentiation described in Annex B of EN1990:2002 (as Amended) Eurocode – Basis of Structural Design. In the case of the CQA validation is sought in respect of environmental consequence and reliability alone, although the structural performance of certain elements of the infrastructure will apply. The application of design and execution supervision will similarly apply only to environmental matters and the goal of BAT compliance.

CQA is essential in providing evidence to the licencing authority of compliance in design and execution, should there be any incidents resulting in pursuit of enforcement action on their part its absence can be used as evidence of guilt on the part of the license holder, in such circumstances the ability to prove infrastructure has been designed and executed to recognised standards

Compliance begins with the recognition of and adherence to the relevant provisions of appropriate standards for design i.e. Eurocode 2 and guidance notes such as IPC Guidance Note on Storage and Transfer of Materials for Scheduled Activities.

The selection of suitable development sites where the environmental risk profile for that site has been quantified using the 'source-pathway-receptor' model. Thereafter the appropriate emission control measures can be incorporated into the design. Baseline investigations such as intrusive geotechnical survey and testing, background noise survey, odour survey etc. inform the specifications and design methodology, in turn the design methodology informs the schedules and the construction methodology and ultimately the pricing documentation. The CQA process begins with the recording of the key design decisions relating to the selection of appropriate specifications and standards to the infrastructure and equipment, materials and methodologies appropriate to the duty that are deemed to be necessary to achieve BAT compliance.

Completed design work where BAT, such as containment structures, applies should be reviewed by an independent specialist who will provide feedback on the suitability of the design and design decisions to achieve BAT, thereafter once construction work begins on site monitoring, recording and checking should be augmented by periodic inspections by the same independent specialist.

Collection and collation of evidence during the construction can be completed by the appointed contractors or by a Resident Engineer or Clerk of Works appointed by the Client. Their role shall be to co-ordinate on site testing and inspection, check that materials and equipment delivered to the project meet with the specification and to keep records of the same. Extensive photographic evidence of construction stages shall also form a key part of the process.

In the case of primary containment structures such as the in situ cast process tanks the CQA process would follow the selection of that mode of containment as being appropriate for the material to be stored having assessed the properties of the substrate and demonstrated a negligible risk to the environment. That risk being further mitigated by the application of the recognised standard of Eurocode 2. The design produced in accordance with that code can be checked and validated by an

independent checker to validate the design and detailing. Once mobilised to site the design assumptions and execution of the work can be checked and validated as it proceeds.

This validation would consist of a number of regular inspections of the work in progress to include, but not necessarily be limited to the following:-

- Reinforcing steel supplied is in accordance with the design specifications and is fixed with appropriate laps and cover. Including, where applicable, anti-crack bars to cast in openings.
- Any water bars, crack inducers or similar are installed to the design and in accordance with the manufacturer's written instructions.
- Any cast-in pipes and/or fittings are properly supported and fixed in the correct location and in accordance with the manufacturer's written instructions.
- Formwork is installed to maintain cover to all reinforcement and is true to plumb, level and line.
- Concrete delivered is in accordance with the design specifications – mixture, slump etc. and is placed in a timely manner and well compacted. Complete pouring records.
- Sufficient samples of supplied concrete are taken and prepared for off site testing – cube tests etc.
- Formwork is struck after agreed curing time and is properly prepared for the next pour(s)
- Visual inspection of cast concrete after striking of formwork to ensure correct compaction. Appropriate remedial works are implemented to address any areas of poor compaction.
- Subsequent pours are undertaken within specified timescales to ensure that bonds are achieved and that joint faces are properly prepared.
- Cover meter survey of completed work is undertaken to validate minimum cover to reinforcement in accordance with the design
- Weather conditions during pour and curing period are maintained and that appropriate controls are implemented to ensure consistent curing, such as the application of curing membranes.
- Laboratory test results are collated and recorded against appropriate structures.

## 6. Concrete Testing & Inspection techniques

The following describes a range of concrete testing and inspection methods that may be used post construction and considers their suitability for use on water retaining structures. The majority of these testing techniques provide the tester with information relating to the structural performance of the concrete and reinforcement in service.

Descriptions are reproduced in whole, or in part from the Concrete Society and are freely accessible.

### 1. Half cell potential

*Corrosion of reinforcing steel is an electro-chemical process and the behaviour of the steel can be characterised by measuring its half-cell potential. The greater the potential the higher the risk that corrosion is taking place. An electrode forms one half of the cell and the reinforcing steel in the concrete the other. The preferred reference electrode for site use is silver/silver chloride in potassium chloride solution although the copper/copper sulphate electrode is still widely used.*

*The survey procedure is firstly to locate the steel and determine the bar spacing using a cover meter. The cover concrete is removed locally over a suitable bar and an electrical connection made to the steel. It is necessary to check that the steel is electrically continuous by measuring the resistance between two widely separated points. The reinforcing bar is connected to the half-cell via a digital voltmeter, see diagram. Readings of half-cell potential are taken over a regular grid of points (say ½ m apart) to give a potential map of the area.*

*Contour lines may be plotted between points of equal potential to indicate those areas that have the greatest risk of corrosion. Locally exposing and inspecting the reinforcement in areas where both high and low risks of corrosion are indicated can be used to approximately calibrate the potential readings for the structure with respect to its present corrosion and the need for further investigation or repair.*

**This technique may be considered after the structure has been in service for a number of years to establish whether there is any corrosion of reinforcing steel underway. It is intrusive and therefore should be limited external faces of the retaining structure and careful consideration needs to be given to the repair methodology. A 10 year frequency or greater may be considered.**

### 2. Ultrasonic pulse velocity

*Measurement of ultrasonic pulse velocity (UPV) is a means of assessing variations in the apparent strength of concrete. UPV equipment is also used for detecting the presence of voids, honeycombing or other discontinuities. The velocity of a pulse of ultrasonic energy in concrete is influenced by the elastic stiffness and mechanical strength of the concrete.*

*The equipment consists of two transducers, usually in the form of metal cylindrical heads, one of which is used to transmit an ultrasonic pulse and the other is a receiver. They are brought into contact with the concrete surface ('coupled') using a gel or grease. They are connected by cable to a control box which contains a pulse generator, timing circuit and digital display. The digital display indicates the time for the ultrasonic pulse to travel between the transmitting and receiving transducers. As in the case of the rebound hammer, it is possible to develop an empirical relationship between pulse velocity and strength but this relationship is influenced by type of cement, type and size of aggregate, presence of reinforcement, moisture condition, compaction and age of concrete.*

**This is a non intrusive technique that requires access to both faces of the structure simultaneously, it may provide valuable insight where poor compaction is suspected. It will be limited to those applications where no applied surface treatments have been employed.**

### **3. Near surface strength tests**

*There are various near-to-surface test methods which can be used to assess strength. Pull-out, pull-off, break-off and penetration resistance tests are described in BS 1881: Part 207.*

*The most common form of pull-out test is the internal fracture test which was developed by BRE. In this test a wedge anchor is pulled from a pre-drilled hole. Similarly, the Capo (Cut and Pull Out) test uses an expanding insert in an under-reamed hole. The LOK test relies on inserts cast into the concrete surface. A method for determining the pull-out force is given in BS EN 12504-3, Testing concrete in structures - Determination of pull-out force.*

*Pull-off tests measure the force required to pull a metal block (dolly) from the concrete surface to which it has been attached using a high strength adhesive. The break-off test measures the transverse force required to break off a core drilled 70 mm into the concrete surface. Finally, the penetration resistance test (Windsor probe) is based on measuring how far a hardened pointed metal rod penetrates into a concrete surface when fired into it by a driver unit similar to a gun.*

*For each of the above tests, there is no unique relationship between the measured parameter and strength. Information suggesting any such relationship that might be provided with the equipment should be treated with caution as its use could lead to errors in assessment of compressive strength.*

**Of limited value and therefore deemed inappropriate**

### **4. Rebound hammer**

*The rebound (Schmidt) hammer is one of the oldest and best known methods of comparing the concrete in various parts of a structure and indirectly assessing concrete strength. It is actually a measure of surface hardness. The rebound hammer should be considered as a means of determining variations of strength within a structure rather than an accurate means of assessing strength. The surface under test should be clean and smooth. Dirt or other loose material on the surface can be removed using a grinding stone prior to the test. Rough surfaces cannot be tested as they do not give reliable results.*

*If it is to be used as a means of assessing strength the correlation between rebound hammer reading and strength needs to be determined for the actual concrete under investigation. A procedure for doing this is given in BS EN 12504-2. The values obtained by using the hammer may be influenced by the particular operator, so care must be taken when considering results from different operators*

**Of limited value and therefore deemed inappropriate**

### **Cover to reinforcement**

*In nearly all instances, cracks develop at the surface of concrete and are restrained by the tensile reinforcement. If a good bond exists between the concrete and the steel, the width of the crack at the steel will be very small. The cracks therefore tend to be wedge-shaped: the further the surface is from the steel, the wider the crack will be at the surface.*

*It follows that if surface crack widths are to be controlled effectively, the reinforcement should be close to the surface of the concrete. The provision of adequate cover for durability by protecting the*

reinforcement from corrosion, and to provide fire resistance, should always take precedence over aesthetic considerations.

The designer has a significant role in determining whether or not the design minimum cover is achieved in practice. A realistic cover tolerance ( $\Delta c$ ) must be added to the minimum design cover to give a practical nominal cover.  $\Delta c$  values of at least 10mm are required to ensure the minimum cover can be achieved. Research and experience has shown that  $\Delta c$  values of less than 10mm in in-situ construction will lead to a high risk of actual covers being less than the minimum cover, even with high standards of workmanship. Low nominal covers will increase the risk of plastic settlement cracking.

**A cover meter survey of the structure can be undertaken as part of CQA process, it is non intrusive and does not present any risk to the integrity of the structure.**

#### **5. Crack width measurement**

The widths of cracks on the surface of concrete can be measured using a simple comparator consisting of a plastic strip with fixed width lines. Alternatively a hand-held microscope with a suitable scale can be used.

It may be necessary to assess if a crack is still moving, for example to determine whether it is due to temperature changes or to early thermal contraction. This may be done by using simple 'tell-tales' bonded across cracks, which will show if further movement takes place. If a more precise measure of the movement is required a Demec gauge, or similar may be used to measure the relative movement of studs bonded on the concrete's surface at a set distance apart across the crack

**This technique as described is suited to the monitoring of structural members exhibiting signs of tension cracking where the member is permanently exposed and can be subjected to continuous monitoring. It has some value as part of the CQA process in assessing the presence of surface cracks associated with curing that will repair through autogenous healing.**

## **APPENDICES**

### **1 Applicable Standards & Guidance**

IPC Guidance Note on Storage and Transfer of Materials for Scheduled Activities Environmental Protection Agency June 2004

IS EN 1992 -3:2006 Eurocode 2 – Design of concrete structures – Part 3: Liquid retaining and containment structures

Civil Engineering Specification for the Water Industry 8<sup>th</sup> Edition WRc Ltd April 2023 ISBN 978-1-898920-76-2

Concrete Advice No. 9 Autogenous Healing: the self healing of fine cracks. Concrete Society October 2016 (revision)

Client Issue