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कंक्रीट पर गैर विनाशक परीक्षणों की फील्ड प्रक्रिया

FIELD PROCEDURE OF NON DESTRUCTIVE TESTING ON CONCRETE

कैमटेक/2018/सी/एन.डी.टी./1.0
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अअमासंRDSO
रेल अग्रदूत Transforming Railways

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प्राक्कथन

गैर विनाशक परीक्षण (एनडीटी) सामान्य तौर से कंक्रीट संरचना पर प्रयोग किये जाते हैं। इन परीक्षणों के द्वारा, हम संरचना को विकृत तथा उनके गुणों में परिवर्तन किए बिना उनकी ताकत, एकरूपता, कठोरता, विकृतता आदि जैसे संरचनात्मक गुणों का विश्लेषण कर सकते हैं।

कंक्रीट संरचना के विभिन्न मानकों को मापने के लिए कई एनडीटी परीक्षण निर्धारित किये गये हैं। कैमटेक द्वारा तैयार की गई पुस्तिका में इन्ही विभिन्न प्रकार के एनडीटी परीक्षणों की फील्ड प्रक्रिया को शामिल किया गया है।

यह आशा की जाती है कि कैमटेक द्वारा तैयार पुस्तिका सिविल संरचनाओं के निर्माण एवं रखरखाव की गतिविधियों में लगे भारतीय रेलवे के इंजीनियरिंग कर्मियों के लिए काफी मददगार होगी।

केमटेक / ग्वालियर **अनिरुद्ध गौतम**

दिनाँक 26**,** अक्तूबर ***कार्यकारी निदेशक***

FOREWORD

Non Destructive Tests are often used on concrete structure. By these test, one can analyse the structural qualities like strength, homogeneity, hardness, deterioration etc. without deforming or disturbing nature of the structure.

Many NDT tests are available for measuring various parameters of concrete structure. This booklet prepared by CAMTECH incorporates field procedure of various NDT tests on concrete.

It is expected that the booklet will be quite helpful to the engineering personnel of Indian Railways engaged in construction and maintenance activities.

CAMTECH/Gwalior ***(Anirudh Gautam)***
October 26, 2018 ***Executive Director***

भूमिका

एनडीटी (गैर विनाशक परीक्षण) संरचना की वास्तविक स्थिति की जांच और मूल्यांकन के लिए प्रभावी ढंग से उपयोग किये जा सकते है। यह परीक्षण अपेक्षाकृत तेज़, उपयोग में आसान तथा सस्ते है, और कंक्रीट के आवश्यक गुणों की सामान्य जानकारी देते है।

"कंक्रीट पर गैर विनाशक परीक्षणों की फील्ड प्रक्रिया" पर यह पुस्तिका भारतीय रेलवे के इंजीनियरों को कंक्रीट के लिए विभिन्न विनाशकारी परीक्षणों के बारे में जानकारी प्रसारित करने के उद्देश्य से तैयार की गई है।

यह पुस्तिका संवैधानिक नहीं है तथा सामग्री केवल ज्ञान प्रसार के उद्देश्य के लिए है। किसी न किसी रूप में अधिकांश डेटा एवं जानकारी, उपलब्ध साहित्य तथा इंटरनेट खोज पर आधारित है। अधिक गहराई से जानकारी / ज्ञान के लिए, विषय पर उपलब्ध प्रासंगिक विस्तृत साहित्य, भारतीय मानक ब्यूरो संहिताओं, आदि को संदर्भ रूप में देखा जा सकता है।

इस पुस्तिका के और अधिक सुधार हेतु हम अपने पाठकों के सुझावों का स्वागत करते हैं।

केमटेक / ग्वालियर ***(डी. के. गुप्ता)***

दिनाँक 25**,** अक्तूबर ***संयुक्त निदेशक***

PREFACE

NDT (Non Destructive Tests) can be used effectively for investigating and evaluating the actual condition of structure. They are relatively quick, easy to use, cheap and gives general indication of the required properties of the concrete.

This handbook on "F**ield Procedure of Non Destructive Testing on Concrete"** is prepared with the objective to disseminate the knowledge to the engineers of Indian Railways about the various aspect of Non Destructive Tests for Concrete.

This handbook is not statutory and contents are only for the purpose of knowledge dissemination. Most of the data & information in some form or the other are based on literature available and internet search. For more in-depth information / knowledge, the relevant detailed literature, BIS Codes, etc. available on the subject may be referred to.

We welcome any suggestions from our readers for further improvement of this handbook.

CAMTECH/Gwalior ***(D.K. Gupta)***
25, October, 2018 ***Joint Director/Civil***

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संशोधन पर्चियों का प्रकाशन
ISSUE OF CORRECTION SLIPS

इस हस्तपुस्तिका के लिए भविष्य में प्रकाशित होने वाली संशोधन पर्चियों को निम्नानुसार संख्यांकित किया जाएगा :

The correction slips to be issued in future for this handbook will be numbered as follows:

कैमटेक/2018/सी/एन.डी.टी./1.0/सुधार पर्ची # XX दिनाँक----------

CAMTECH/2018/C/NDT/1.0/CS # XX date_____

जहाँ xx संबन्धित संशोधन पर्ची की क्रम संख्या है (01 से प्रारम्भ होकर आगे की ओर)

Where "XX" is the serial number of the concerned correction slip (starting from 01 onwards).

प्रकाशित संशोधन पर्चियाँ
CORRECTION SLIPS ISSUED

क्र.सं./ Sr. No.	**प्रकाशन दिनांक/ Date of issue**	**संशोधित पृष्ठ संख्या तथा मद संख्या/ Page no. and Item No. modified**	**टिप्पणी/ Remarks**

1.0 परिचय / INTRODUCTION

The quality of new concrete structure is dependent on many factors such as type of cement, type of aggregate, W/C ratio, environmental conditions etc. In structure under construction, the present system of checking of slump and testing of cubes is not sufficient to assess the strength of concrete as the actual strength of the structure depend on many other factors such as proper compaction, effective cover etc.

Present method of inspection of concrete structure is mostly visual and gives only subjective assessment of the conditions of the structure. Moreover, visual inspection, which is an essential precursor to any intended non-destructive test, is not capable to assess the hidden defects, if any.

To assess such defects in the structure, an experienced civil or structural engineer may be able to establish the possible cause(s) of damage to a concrete structure and hence identify the hidden defects which of the various NDT methods available could be most useful for any further investigation of the problem.

The NDT (Non Destructive testing) can be used effectively for investigation and evaluating the actual condition of structure. This is relatively quick, easy to use, cheap and gives a general indications of the required property of the concrete.

For the assessment of the actual condition of a concrete bridge, the detection of internal crack, void, lamination etc. is very much necessary. The NDT methods for testing surface hardness, strength and for checking the condition of reinforcement do not indicate the internal condition of concrete. Sometimes these internal cracks, voids etc. may lead to the corrosion of reinforcement, cracking of section which may ultimately result into reduced life of bridge.

2.0 गैर विनाशक परीक्षण का उद्देश्य/ PURPOSE OF NON DESTRUCTIVE TEST

The Non Destructive testing evaluation techniques are being increasingly adopted in concrete structures for the following purposes:-

i) To estimate the in-situ compressive strength.
ii) To estimate the uniformity and homogeneity.
iii) To estimate the quality in relation to standard requirement.
iv) To identify the area of lower integrity in comparison to other parts.
v) To detect cracks, voids, and other imperfection.
vi) To assess the change in structure of the concrete which may occur with time.
vii) To assess the identification of reinforcement provided & measurement of cover, bar dia. etc.
viii) To assess the conditions of pre-stressing/reinforcement steel with respect to corrosion.
ix) To measure chloride, sulphate, alkali contents or degree of carbonation.
x) To measure the elastic modulus.
xi) To assess the condition of grouting in pre-stressing cable ducts etc.

3.0 गैर विनाशक परीक्षण के प्रकार / TYPES OF NON DESTRUCTIVE TEST

There are so many types of NDT methods used for determination of above factors. In this book, some of them are covered with their procedure for the knowledge and guidance.

1. Rebound Hammer Method
2. Ultrasonic Pulse Velocity (UPV) Technique
3. Pull-Off Test
4. Pull Out Test
5. Penetration Resistance Test (Windsor Probe).
6. Core Drilling Method
7. Permeability Test
8. Bond Test
9. Maturity Method
10. Complete Structural Testing
11. Half-Cell Potential Measurement Method
12. Resistivity Test
13. Tests For Carbonation Of Concrete
14. Test For Chloride Content Of Concrete
15. Endoscopy Technique
16. Profometer
17. Micro Covermeter

The following methods are normally used for detection of cracks/voids/laminations etc. in concrete bridges:–

1. Infrared thermographic techniques
2. Acoustic Emission technique
3. Short pulse radar methods
4. Stress wave propagation methods
5. Crack Detection Microscope
6. Boroscope
7. Nuclear Method

Some of these methods are used extensively all over the world for condition assessment of various components of concrete bridges while some methods are still in the laboratory trial stage.

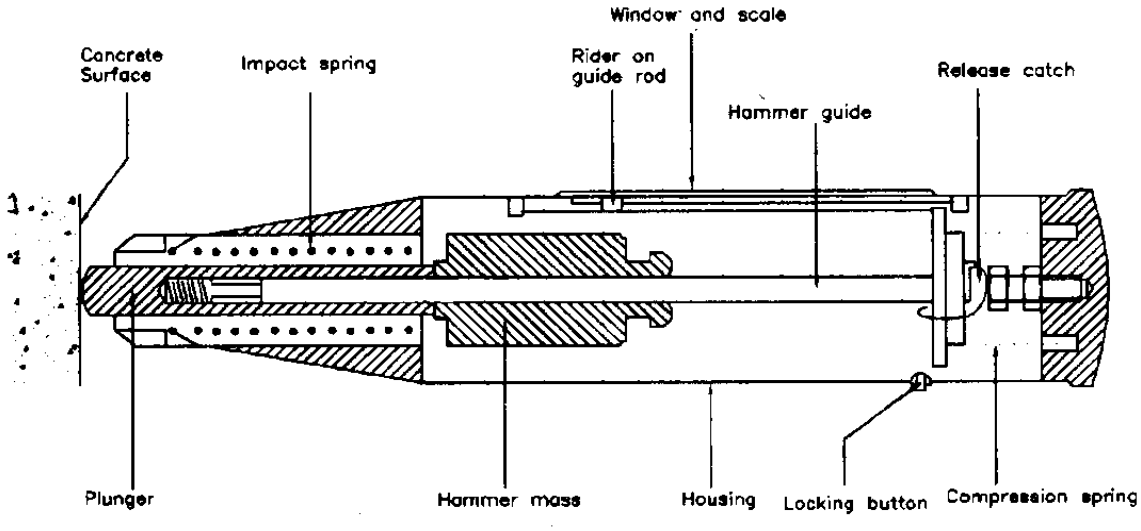
4.0 रेबौण्ड हैमर विधि / REBOUND HAMMER METHOD

In this method, a simple handy tool is used to provide a convenient and rapid indication of the compressive strength of concrete, to establish the uniformity of concrete and to assess the quality of one element of concrete in relation to another.



Principle: The tool consists of a spring controlled mass that slides on a plunger within a tubular housing. When the plunger is

pressed against the surface of the concrete, the spring controlled mass rebounds and the extents of such rebound depend upon the surface hardness of concrete. The surface hardness and therefore, the rebound is taken to be related to the compressive strength of the material. The rebound is read off along a graduated scale and is designated as the rebound number or rebound index.



Typical Rebound Hammer

Types of test hammer:

Type	Applications	Approximate Impact Energy Required for the rebound Hammers (N-M)
N	For testing normal grades of concrete in ordinary buildings and bridge constructions.	2.25
L	For light-weight concrete or small and impact sensitive parts of concrete or artificial stones	0.75
M	For testing mass concrete in roads, airfield pavements and hydraulic structures.	30.0
P	For testing cement mortars and plasters, concrete of low strength (5 to 25 N/mm^2)	0.90

Procedure: Before starting the test, it is necessary that the Rebound Hammer is checked against the testing anvil to ensure reliable results. Testing anvil should be of steel having Brienell hardness of about 5000 N/mm^2.

i) For testing, smooth, clean and dry surface is to be selected. If loosely adhering scale is present, this should be rubbed off with a grinding wheel or stone.
ii) Point of impact should be at least 20 mm away from any edge or shape disconitutity.
iii) For taking measurement, the rebound hammer should be held at right angle to the surface of the concrete member. If the situation demands, the rebound hammer can be held at intermediate angle also.
iv) Rebound hammer test is conducted around all the points of observation on all accessible faces of the structural element of concrete. Around each point of observation, six readings

of rebound indices are taken and average of these reading after deleting outliers as per IS 89000:1978 becomes the rebound index for the point of observation.

The test results are influenced by a number of factors like type of cement and aggregate, surface condition and moisture content, age of concrete and extent of carbonation. For example –

- Concrete made with high alumina cement can give strength 100 % higher than that with ordinary Portland cement.
- Concrete made with supersulphated cement can give 50% lower strength than that ordinary Portland cement.

For different types of aggregate gives different values. A wet surface will give rise to under estimation of the strength of concrete calibrated under dry conditions. In structural concrete, this can be about 20% lower than in an equivalent dry concrete. Carbonated concrete gives an over estimate of strength which in extreme case can be up to 50%.

Interpretation of result: The estimation of strength of concrete by rebound hammer method cannot be held to be very accurate and the probable accuracy of prediction of concrete strength is 25 %. It is also pointed out that rebound indices are indicative of compressive strength of concrete to a limited depth from the surface. If the concrete in a particular member has internal micro cracking, flaws or heterogeneity across the cross-section, rebound hammer indices will not indicate the same.

5.0 अल्ट्रासॉनिक पल्स वेलोसिटी (यूपीवी) तकनीक /ULTRASONIC PULSE VELOCITY (UPV) TECHNIQUE

A handy battery operated and portable instrument is used for assessing elastic properties of concrete quality. The apparatus for ultrasonic pulse velocity measurement consists of Electrical Pulse Generator, Transducer - one pair, Amplifier and Electronic Timing Device.



The Ultrasonic Pulse Velocity method can be used to establish:

- The homogeneity of the concrete
- The presence of cracks, voids and other imperfections.
- Changes in the structure of concrete, which may occur with time.
- The quality of the concrete in relation to standard requirements.
- The quality of one element of concrete in relation to another.
- The value of elastic modulus of the concrete.

Principle: An Electro-acoustic transducer generates the ultrasonic pulse. When the pulse is induced into the concrete from a transducer, it undergoes multiple reflections at the boundaries of the different material phases within the concrete. The longitudinal (compressional), shear (transverse) and surface (Raleigh) waves are developed and received by transducer. The transducer detects the one set of the longitudinal waves, which is the fastest.

The underlying principle of assessing the quality of concrete is that comparatively higher velocities are obtained when the quality of concrete in terms density, homogeneity and uniformity is good. In case of poorer quality, lower velocities are obtained. If there is a crack, void or flaw inside the concrete, which comes in the way of transmission of the pulses, the pulse strength is attenuated and it passes around the discontinuity, thereby, making the path length longer. Consequently, lower velocities are obtained. The actual pulse velocity obtained depends primarily upon the materials and mix proportions of concrete. Density and modulus of elasticity of aggregate also significantly affect the pulse velocity.

Procedure: After traversing a known path length (L) in the concrete, the pulse of vibrations is converted into an electrical signal by the second transducer held in contact with the other surface of the concrete member and an electronic timing circuit enables the transit time (T) of the pulse to be measured.

The pulse velocity (V) is given by V= L/T

The natural frequency of transducers should preferably be within the range of 20 to 150 kHz. Generally, high frequency transducers are preferably chosen for short path lengths and low frequency transducers for long path length. Transducers with a frequency of 50 to 60 kHz are useful for most all round applications.

Since the size of aggregate influences the pulse velocity measurement, it is recommended that the minimum path length should be 100 mm for concrete in which the nominal maximum size of aggregate is 20 mm or less and 150 mm for concrete in which the nominal size of aggregate is between 20 to 40 mm.

For good quality of concrete pulse velocity will be higher and for poor quality it will be less as given in table below.

SN.	Pulse velocity by Cross Probing (Km/Sec)	Grading of concrete quality
1	Above 4.5	Excellent
2	3.5 to 4.5	Good
3	3.0 to 3.5	Medium
4	Below 3.0	Doubtful

Influences: Following factors influence to the results:

a) Surface conditions and moisture content of concrete.
   - In general pulse velocity through concrete increases with increased moisture content of concrete. This influence is more for low strength concrete than high strength concrete. The pulse velocity of saturated concrete may be up to 02% higher than that of similar dry concrete.
   - Shape and size of concrete member and Path length
   - As concrete is inherently heterogeneous, it is essential that path lengths be sufficiently long so as to avoid any error introduced due to its heterogeneity. The shape and size of concrete member do not influence the pulse velocity unless the least lateral dimension is less than a certain minimum value.

Path length (mm)	Natural frequency of transducer (khz)	Minimum transverse Dimensions of member (mm)
Up to 500	150	25
500 to 700	More than 60	70
700 to 1500	More than 40	150
Above 1500	More than 20	300

b) Temperature of concrete
   - Variation of the concrete temperature between 5 to 30 degree do not significantly affect the pulse velocity measurement in concrete. At temperature between 30 to 60 degree can be reduction in pulse velocity up to 05 %. Below freezing temperature is an increase in pulse velocity up to 7.5 %.

c) Stress in concrete
   - When concrete is subjected to a stress which is abnormal high for the quality of concrete, the pulse velocity may be reduced due to development of micro cracks. This influence is likely to be greatest when the pulse path is normal to the predominant direction of the planes of such micro cracks. This occurs when the pulse path is perpendicular to the direction of a uniaxial compressive stress in a member.

d) Reinforcing bars
   - Pulse velocity measured in reinforced concrete in the vicinity of reinforcing bars is usually higher than in plain concrete of the same composition. The apparent increase in pulse velocity depends upon the proximity of the measurement to the reinforcing bars, the diameter and number of the bars and their orientation with respect to the path of propagation. This is because the pulse velocity in steel is 1.2 to 1.9 times of the velocity in plain concrete and, under certain conditions the first pulse to arrive at the receiving transducer travels partly in concrete and steel.

6.0 पुल ऑफ टेस्ट/ PULL OFF TEST



Pull off tester is a microprocessor based portable hand operated mechanical unit used for measuring the tensile strength of concrete of in-situ concrete. The apparatus for pull off test should consist of 50 mm dia steel disc with threaded rod screw and Pull off tester. Equipments are available from 5 kN to 100 kN tensile force capacities.

Pull off test can be used to establish the followings:

i) The compressive strength of concrete.
ii) Tensile strength of in-situ concrete.
iii) The adhesive strength of all kinds of applied coatings.
iv) The bond strength of repairs and renovation works on concrete surface.

Principle: The pull off test is based on the concept that the tensile force required to a pull a metal disc, together with a layer of concrete, from the surface to which it is attached, is related to compressive strength of concrete. There are two basic approaches that can be used. One is where the metal disc is glued directly to the concrete surface and the stressed volume of the concrete lies close to the face of the disc and the other is where surface carbonation or skin effect are present and these can be avoided by use of partial coring to an appropriate depth.

Procedure: The first step is to remove any laitance from the concrete surface to expose the top of the coarse aggregate particles. This is usually done using some sort of abrasion, using typically a wire brush.

The exposed concrete surface and metal disk are then degreased to ensure good bonding of the adhesive. The adhesive is generally a two part epoxy system. A thin layer of adhesive is spread over the disk area and the metal disk is pressed firmly onto the concrete surface. Excessive adhesive that is squeezed out during this process should be removed before it sets. The curing time needed for the adhesive depends upon the type of epoxy used and surrounding environmental condition, although in most of the situations a curing time of not more than 24 hours is required.

After the adhesive has cured sufficiently, the metal disk is “pulled” from the concrete surface. The apparatus used for applying and recording this tensile force is known as “Limpet” and this applies a tensile force through a threaded rod screwed into the metal disk.

Advantages and Limitations

- The main advantage of pull off test is that it is simple and quick to perform.
- The entire process of preparing the surface and bonding the steel disk normally doesn’t take more than 15 minutes.
- The damage caused to concrete surface after conducting the test is very minor and can be repaired easily.
- The main limitation of this method is, the curing time, required for the adhesive. In most situations, it is normal practice to apply the disk one day and complete the test next day.

- Another problem is the failure of adhesive. The adhesive may fail because of inferior quality of adhesive or improper surface preparation or unfavorable environmental conditions. If during testing, the adhesive fails, the test result becomes meaningless. To compensate for this type of problem, it is recommended that at least six disks be used to estimate the compressive strength and, if necessary, one of the individual test results can be eliminated if an adhesive failure has occurred.
- Another aspect of the pull off test is the correlation used to determine the compressive strength. The single factor that has the greatest effect on this relationship is the type of coarse aggregate used in the concrete, the greatest difference being between natural gravels and crushed rocks. Therefore, care should always be taken to ensure that the correlation being used is applicable in that situation.

7.0 पुल आउट टेस्ट / PULL OUT TEST

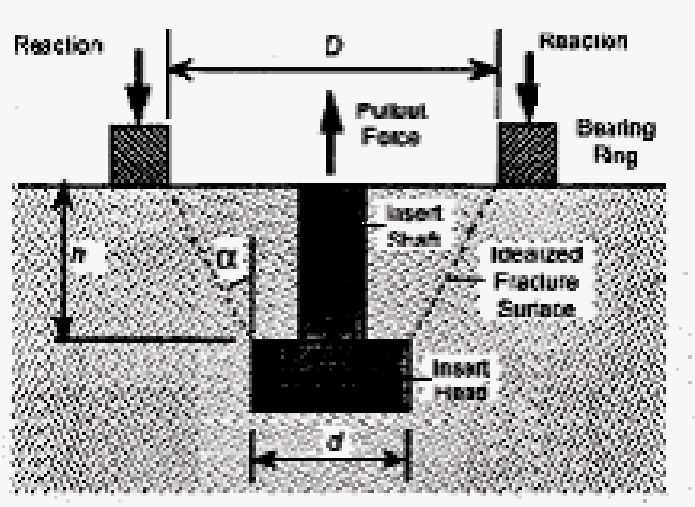
The pull out test can be used to determine the following properties:

(a) Compressive strength of concrete
(b) Normally planned for new structures to help decide, whether critical activities such as form removal, application of post tensioning etc. can be started.
(c) Can be used for existing structures and surveys of matured concrete.

The pull out test measures the force needed to extract an embedded insert from a concrete mass. By using a previously established relationship, the measured ultimate pullout load is used to estimate the in place compressive strength of the concrete. The equipments required for pull out test shall consist of the following:

(a) Specially shaped steel rod or discs
(b) Dynamometer to apply the force
(c) Loading ram seated on a bearing ring for applying pull out force

Principle: The pullout test measures the force required to pull an embedded metal insert with an enlarged head from a concrete specimen or a structure.



The test is considered superior to the rebound hammer and the penetration resistance test, because large volume and greater depth of concrete are involved in the test. The pull out strength is proportional to the compressive strength of concrete. The pull out strength is of the same order of magnitude as the direct shear strength of concrete, and is 10 to 30% of the compressive strength.

The pull out test subjects the concrete to slowly applied load and measures actual strength property of the concrete. The concrete is subjected, however, to a complex three dimensional

state of stress, and the pull out strength is not likely to be related simply to uniaxial strength properties. Nevertheless, by use of a previously established correlation, the pull out test can be used to make reliable estimates of in-situ strength.

Procedure: The pull out tests falls into two basic categories

(i) Cast-in-Method, in which an insert is cast along with concrete i.e. the test is preplanned for new structures
(ii) Drilled Hole Method, in which insert is fixed by under cutting and subsequent expanding procedure in the hardened concrete of existing structures.

This insert is pulled by a loading ram seated on a bearing ring that is concentric with the inner shaft. The bearing ring transmits the reaction force to the concrete. As the insert is pulled out, a conical-shaped fragment of concrete is extracted from the concrete mass. The ultimate pullout load measured during the in place test is converted to an equivalent compressive strength.

Advantages & Limitations

- The recommended practise is to develop the strength relationship for the particular concrete to be used in construction. A large number of correlation studies have reported that compressive strength is linear function of pull out strength.
- The locations and number of pullout tests in a given placement should be decided very carefully.
- The inserts should be located in the most critical portions of the structure and sufficient number of tests should be conducted to provide statistically significant results.
- The test is considered superior to the rebound hammer and the penetration resistance test, because large volume and greater depth of concrete are involved in the test.

8.0 पेनिट्रेसन प्रतिरोध परीक्षण (विंडसर प्रोब) / PENETRATION RESISTANCE TEST (Windsor Probe)



Penetration resistance methods are based on the determination of the depth of penetration of probes (steel rods or pins) into concrete. This provides a measure of the hardness or penetration resistance of the material that can be related to its strength. Amongst the penetration methods presently available, the most well known and widely used is Windsor Probe test.

The Windsor probe, like the rebound hammer, is a hardness tester, and the penetration of probe can be related to the compressive strength of concrete below the surface, using previously developed correlations between strength properties and penetration of the probe. The Windsor probe consists of powder – actuated gun or driver, hardened alloy steel probes, loaded cartridges, a depth gauge for measuring the penetration of probes and other related equipment.

The Windsor probe test is used to determine:-

(a) Compressive strength of in situ concrete.
(b) For ensuring quality control.
(c) For determining safe form removal time.
(d) The uniformity of concrete and to delineate zones of poor quality or deteriorated concrete in structures.

The probes have a tip dia of 6.3 mm, a length of 79.5mm, and a conical point. Probes of 7.9mm dia are also available for the testing of concrete made with light weight aggregates.

Principle: The underlying principal of this penetration resistance technique is that for standard test conditions, the penetration of probe in to the concrete is inversely proportional to the compressive strength of the concrete. In other words, larger the exposed length of the probe, greater the compressive strength of concrete.

Procedure: The method of testing is simple as per manual supplied by the manufacturer.

- The area to be tested must have a smooth surface. To test structure with coarser finish, the surface must be first ground smooth in the area of the test.
- The powder actuated driver is used to drive a probe into concrete. If flat surfaces are to be tested, a suitable locating template to provide 158 mm equilateral triangular pattern is used and three probes are driven into the concrete at each corner.
- The exposed length of individual probes is measured by a depth gauge.
- For testing structures with curved surfaces, three probes are driven individually using the single probe locating template.
- In either case, the measured average value of exposed probe length may then be used to estimate the compressive strength of concrete by means of appropriate correlation data.

The manufacturer of the Windsor probe test system supply tables relating exposed length of the probe with compressive strength of concrete. For each exposed length value, different values of compressive strength are given, depending upon the hardness of aggregate. However the manufacturer's table does not always give satisfactory results. Sometimes they considerably over estimate the actual strength and in some cases they underestimate the strength.

It is, therefore, imperative to correlate probe test result with the type of concrete being used. In addition to hardness of the coarse aggregate, the type and size of coarse aggregate also have a significant effect on probe penetration. The degree of carbonation and the age of concrete may also affect the probe penetration strength relationship.

Advantages & Limitations

- Windsor probe testing method is basically hardness method, and like other hardness methods, should not be expected to yield absolute values of strength of concrete in a structure. However, like surface hardness tests, penetration tests provide an excellent means of determining the relative strength of concrete in the same structure, or relative strength in different structures.
- One of the limitations of this test is minimum size requirements for the concrete member to be tested. The minimum distance from a test location to any edges of the concrete

member or between two given test locations is of the order of 150mm to 200 mm, while the minimum thickness of the member is about three times the expected depth of penetration.

- The test also causes some minor damage to the surface, which generally needs to be repaired.
- The main advantages of this test are the speed and simplicity and only one surface is required for testing.

9.0 कोर ड्रिलिंग विधि / CORE DRILLING METHOD

Core drilling method is the most direct way of measuring the actual strength of concrete in the structure. It mostly involves proper selection of location and number of samples to be obtained.

Core should be taken so as to avoid the reinforcement. If avoidance of secondary reinforcement or surface reinforcement is inescapable, strength of Core can be taken as 10% less than measured strength. Cylindrical specimen of 100 mm or 150 mm diameter are common; other sizes may also be permitted but the least lateral dimension should not be less than 3 times the maximum size of the aggregates used. The core specimen to be tested should preferably have height of specimen as twice the diameter. If there are difficulties of obtaining samples of such size, the length to diameter ratio is permitted to be lower, but in no case lower than 0.95.

The samples are to be stored in water for two days prior to testing and are to be tested in moist condition. The ends of specimens are trimmed and flatten and capped with molten sulphur or high alumina cement or some other permissible capping material to obtain a true flat surface. The specimen is then tested in compression.

Although drilling of cores and compressive strength test are quite simple (and are covered in IS:1199 and IS:516), but the procedures and influencing factors are to be carefully understood as they affect the measured value and therefore the assessment of the quality of in-place concrete.

The provision of IS 456: 2000 vide clause 17.4.3 in this regard is given below:

“Concrete in the member represented by a core test shall be considered acceptable if the average equivalent cube strength of the cores is equal to at least 85 percent of the cube strength of the grade of concrete specified for the corresponding age and no individual core has strength less than 75 percent.”

10.0 पारगम्यता परीक्षण / PERMEABILITY TEST



The permeability tester is a measuring instrument which is suitable for the determination of the air permeability of cover concrete by a non destructive method.

The fundamental significance of thin surface layer for the durability of concrete structures is that owing to the small distance between form work and reinforcement

and as a result of process such as segregation and bleeding, finishing and curing, the formulation of micro-cracks, etc., the composition and properties of the cover concrete may differ very considerably from those of the good quality of cover concrete. In addition, the concrete test specimens used for quality controls can never represent the quality and properties of the cover concrete since they are produced and stored in a completely different manner.

Principle: Significance of permeability in addition to compressive strength in assessing quality of concrete has become more important due to increasing instances of corrosion in reinforcement concrete. The rate at which the air from the concrete cover may extracted, is a measure of permeability of concrete. This method can be used to assess the resistance of concrete to carbonation, penetration of aggressive ions and quality of grout in post tension ducts.

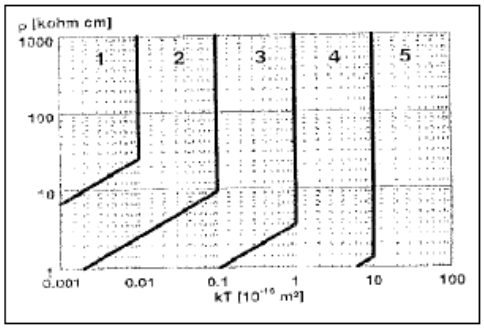
Procedure: It operates under vacuum and can be used at the site and also in the laboratory. The essential features of the method of measurement are a two chamber vacuum cell and a pressure regulator which ensures an air flow at right angles to the surface and into the inner chamber.

- Dry surface without cracks should be selected for test.
- It should be insured that inner chambers should not be located above the reinforcement bar.
- Pressure loss is calibrated from time to time and after a large change in temperature and pressure.
- 3 to 6 measurements of electrical resistance of the concrete and its mean value is taken for the measurement of coefficient of permeability. This permits the calculation of the permeability coefficient kT on the basis of theoretical model.

In case of dry concrete, the results are in good agreement with laboratory methods, such as oxygen permeability, capillary suction, chloride penetration and others. The quality class of the cover concrete is determined from kT using a table as shown below.

Quality of cover concrete	**index**	**kT (10^{-16} m^2)**
Very bad	5	More than 10
Bad	4	1.0 to 10
Normal	3	0.1 to 1.0
Good	2	0.01 to 0.1
Very good	1	Less than 0.01

The humidity, a main influence on the permeability, is compensated by additionally measuring the electrical resistance ρ of the concrete. With kT and ρ the quality class is obtained from a monogram shown in fig below.



Limitations:

- The determination of kT and ρ should not be carried out on wet surfaces (the moisture entering the unit could damage the membrane in the pressure regulator).
- The most accurate values are obtained for dry concrete (ρ measurement is superfluous).
- In order to obtain an exact idea of the quality of the cover concrete of a structure or of a finished component, several measurements must always be carried out.
- The quality classification of cover concrete from table and the monogram related to young concrete i.e. concrete age about 1-3 months. Some measurements on concrete a few years old have shown that the classification in Table and the monogram cannot be directly applied.
- The moisture content of the concrete has a major effect on the gas permeability. The correction of this effect by the measurement of the electrical resistance generally leads to satisfactory results in the case of young concrete. For old concrete, further investigations must be carried out.
- The investigations were performed using a vacuum pump with a suction capacity of 1.5 m3/h and a motor power of 0.13 kW, this pump makes it possible to achieve a vacuum of a few mbar. Pumps of lower power do not reach the same vacuum and it is therefore advisable to use only pumps of similar power.
- There may be three further reasons why the desired vacuum (10-50 mbar) is not reached.
  - The concrete cover is too permeable (normal function of the unit).
  - The concrete surface is too uneven: the rubber seals can compensate only a certain degree of unevenness (abnormal function).
  - The unit has a leak (abnormal function).

11.0 बॉन्ड टेस्ट / BOND TEST

The bond testing equipment measures in place bonding or direct tensile strength between two layers e.g. a repair overlay and the parent concrete material or adhesion of shotcrete and membrane.

Procedure: The test location is so selected with the help of a metal detector that reinforcement disturbance, if any, is controlled and minimized during cutting operation.

- The test consists of drilling a 100 mm nominal diameter core through the overlay into the parent concrete material.
- The drilled core is left without breaking.
- The top surface of the core is cleaned and dried and a cylindrical steel disc 85 mm in diameter is fastened to it with epoxy resin and adhesive.
- After hardening of the epoxy, the counter pressure ring with an inside diameter of 105 mm is placed concentric with the core on the overlay surface and connected to the pull bolts with countering plate and coupling.
- Load is applied by turning the instrument handle to a required pull force up to failure of the core in tension.
- The disadvantage is that a small damage to the concrete is required to be repaired.

12.0 परिपक्वता विधि / MATURITY METHOD

The maturity method is used for estimating later-age potential cylinder strength based on measured early-age strength (Concrete strength).

Compressive strength of well cured concrete increases with time, but this increase is dependent on the temperature of curing also. The combined influence of time and temperature is considered as the maturity. It is thus defined as the integral of time multiplied by temperature with a datum temperature of -10^0 C, since below this temperature cement in concrete ceases to hydrate.

The maturity of in-place can be monitored by thermocouples or by instruments called "Maturity Meters". The strength of in-place concrete is then estimated using the established correlation graph between maturity and compressive strength of concrete.

The advantage of maturity concept is that by prior placing of maturity meters in the formwork at the time of the construction, the strength of early age concrete can be monitored and accordingly formwork can be removed confidently.

13.0 पूर्ण संरचनात्मक परीक्षण / COMPLETE STRUCTURAL TESTING

This integrated technique provides an approach that can be used to detect damage, general evaluation and development of load ratings for all type of steel, concrete and timber structures.

The technique is based on the principle of "semi- static" live load test. In this technique up to 65 recessable strain transducers are indented to the structural members of the bridge and strains recorded vehicle with known weight crosses at crawling speed. High speed passes are also needed to conduct in order to determine actual impact.

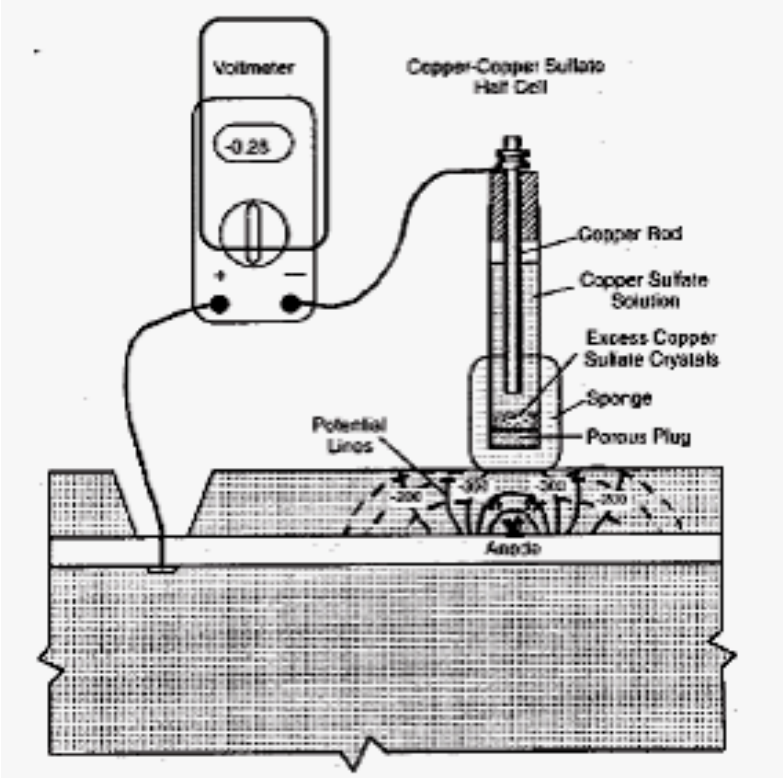
Advantage:

- In this technique no holes or welds are required.
- Each strain sensors needs very short period of time (about 5 minutes) to install.
- In need, only one lane to be closed at a time.

Indian Railways has planned to procure the complete structural testing equipment for performing live load tests on short to medium span Railway Bridge for static load, low speed, full sectional speed i.e. upto 200 kmph, braking and acceleration of trains so as to complete the full test for load rating of bridge.

14.0 अर्धसेल पोटैन्शयल मापन विधि / HALF-CELL POTENTIAL MEASUREMENT METHOD

This test is used to assess the corrosion conditions in a reinforced concrete structure. The method detects the likelihood of corrosion of steel but cannot indicate the rate of corrosion. By making measurements over the whole surface, a distinction can be made between corroded and non-corroded locations.



When there is active corrosion, current flow through the concrete between anodic and cathodic sites is accompanied by an electric potential field surrounding the corroding bar. The equipotential lines intersect the surface of the concrete and the potential at any point can be measured using the half potential method.

The apparatus includes copper - copper sulphate half-cell, connecting wires and a high impedance voltmeter. This half-cell is composed of a copper bar immersed in a saturated copper sulphate solution. It is one of the many half cells that can be used as a reference to measure the electrical potential of embedded bars. A high impedance voltmeter (normally greater than 10MW) is used so that there is very little current through the circuit. The copper sulphate half-cell makes electrical contact with the concrete by means of porous plug and a sponge that is moistened with a wetting solution (such as liquid detergent).

One of the instruments available in the market is CANIN corrosion analyzer, which is a computer based device for making half cell potential measurement. This particular instrument stores data acquired at different test points and display equipotential contours.

Principle: Corrosion analyzer is based on electro-chemical process to detect corrosion in the reinforcement bars of structure. It represents a galvanic element similar to a battery, producing an electrical current, measurable as an electric field on the surface of concrete. The potential field can be measured with an electrode known as half cell.

The electrical activity of the steel reinforcement and concrete leads them to be considered as one half of battery cell with the steel acting as one electrode and concrete as electrolyte. The name half cell surveying derives from the fact that the one half of the battery cell is considered to be the steel reinforcing bars and surrounding concrete. The electrical potential of a point on the surface of steel reinforcing bar can be measured comparing its potential that of copper – copper sulphate reference electrode/silver- silver nitrate reference electrode on the surface. The positive terminal of the voltmeter is attached to the reinforcement and the negative terminal is attached to the copper-copper sulphate half cell. If there is any corrosion in the bars, the excess electrons in the bar would tend to flow from the bar to the half cell. Because of the way the terminals of the voltmeter are connected in the electrical circuit, the voltmeter indicates a negative voltage. The measured half cell potential is the open circuit potential, because it is measured under the condition of no current in the measuring circuit. A more negative voltage reading at the surface is

to interpret to mean that the embedded bar has more excess electrons, and there is, therefore, a higher likelihood that the bar is corroding.

The half cell potential readings are indicative of the probability of corrosion activity of the reinforcing bars located beneath the copper-copper sulphate reference cell. However, this is true only if the reinforcing steel is electrically connected to the bar attached to the voltmeter.

Procedure: The corrosion analyzing instrument CANIN operates as digital voltmeter. Voltage of + 999 mV DC can be measured using this instrument. The potential in milivolts is measured with rod electrodes at different locations on the structure. The measured voltage depends upon the type of the half-cell, and conversion factors are available to convert readings obtained with other half cells to copper-sulphate half cell.

- Testing is usually performed at points arranged in a grid.
- The required spacing between test points depends on the particular structure.
- Excessive spacing can miss points of activity or provide insufficient data for proper evaluation, while closer spacing increase the cost of survey.
- If the difference in voltage between adjacent points exceeds 150 mV, a closer spacing is suggested.
- A key aspect of this test is to ensure that the concrete is sufficiently moist to complete the circuit necessary for a valid measurement.
- If the measured value of the half cell potential varies with time, pre wetting of the concrete is required. Although pre wetting is necessary, there should be no free surface water between test points at the time of potential measurement.
- The concrete is sufficiently moist if the measured potential at a test point does not change by more than + 20 mV within a 5 min. period.
- If stability cannot be achieved by pre-wetting, it may be because of stray electrical currents or excessive electrical resistance in the circuit.
- Testing should be performed between temperature range of 17 to 28^0C.

Interpretation of test results

The potential measured at the surface of concrete can be interpreted as per table given below:-

SN.	Phase of Corrosion Activity	Potential as measured by Copper Half Cell
1.	Initial Phase - corrosion activity not taking place	< - 200 mV
2.	Transient Phase – Corrosion activity uncertain	- 200 mV to - 350 mV
3.	Final phase – corrosion occurring positively	> - 350 mV

Source: Appendix of ASTM C 876

In the potential difference technique, the areas of active corrosion are identified on the basis of the potential gradients. In the equipotential contour plot, the closer spacing of the voltage contour indicates regions of high gradients. The higher gradient indicates higher risk of corrosion. The

potential difference technique is considered more reliable for identifying regions of active corrosion than is the use of numerical limits.

Limitations: For conducting this test access to the reinforcement is must. The method cannot be applied to epoxy coated reinforcement or concrete with coated surfaces. The concrete should be sufficiently moist for conducting this test. This test only indicates the likely hood of corrosion activity at the time of measurement. It does not furnish direct information on the rate of corrosion of the reinforcement.

15.0 प्रतिरोध परीक्षण / RESISTIVITY TEST

This test is used to assess the probability or likelihood of corrosion of the reinforcement bar. This test is used to measure the electrical resistance of the cover concrete. The resistivity increases as the capillary pore space in the paste is reduced, so high resistivity also indicates the good quality of concrete.

Once the reinforcement bar loses its passivity, the corrosion rate depends on the availability of oxygen for the cathodic reaction. It also depends on the concrete, which controls the ease with which ion migrates through the concrete between anodic and cathodic site. Electrical resistance, in turn, depends on the microstructure of the paste and the moisture content of the concrete.



The combination of resistance measurement by resistivity meter and potential measurement by corrosion analyzing instrument give very reliable information about the corrosion condition of the rebar.

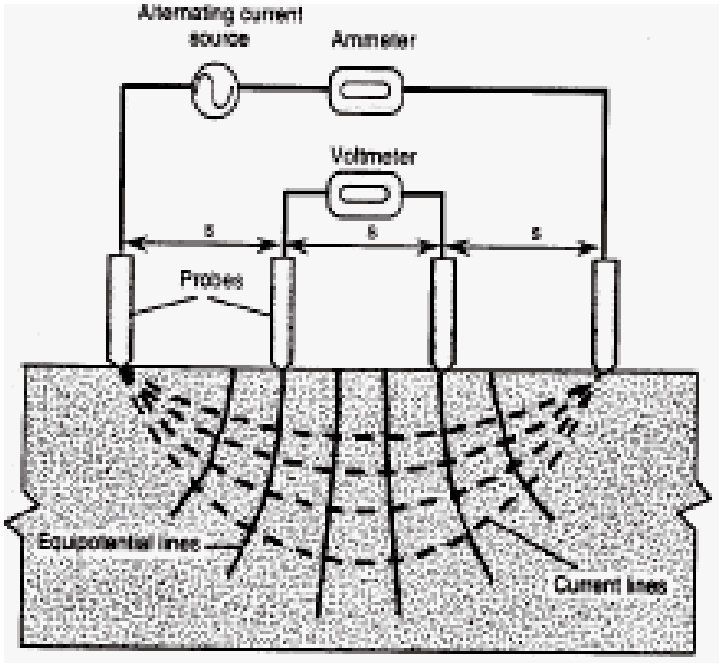
The equipment used for this test is a portable, battery operated, four probe device which measures concrete resistivity.

Principle: The corrosion of steel in concrete is an electrochemical process, which generates a flow of current and can dissolve metals. The lower the electrical resistance, the more readily the corrosion current flows through the concrete and greater is the probability of corrosion. The resistivity is numerically equal to the electrical resistance of a unit cube of a material and has units of resistance (in ohms) times length.

The resistance (R) of a conductor of area A and length L is related to the resistivity ρ as follows:

$$R = \rho L/A$$

This is based on the classical four electrode system in which four equally spaced electrodes are electrically connected to the concrete surface. The outer electrodes are connected to a source of alternating current, and the two inner electrodes are connected to voltmeter. The schematic diagram showing the set up for measurement of concrete resistivity is shown in Fig. below.



Procedure: One of commercial equipment available for measurement of resistivity is Resistivity Meter which is a four probe device used for measuring resistivity. The set of four probes are fitted with super conductive foam tips to ensure full contact on irregular surfaces. Once the probes are kept in contact with the concrete surface, the LCD display will indicate the resistivity directly on the screen. The limits of possible corrosion are related with resistivity as under:

1.	With ρ =12 K W cm	Corrosion is improbable
2.	With ρ = 8 to 12 K W cm	Corrosion is improbable
3.	With ρ = 8 K W cm	Corrosion is fairly certain
	Where, ρ (rho) is the resistivity	

Limitations: The method is slow because it covers small area at a time. The system should not be used in isolation because it gives better indication of corrosion in reinforced concrete if used in combination with half - cell potentiometer.

16.0 कंक्रीट के कार्बनेशन के लिए परीक्षण / TESTS FOR CARBONATION OF CONCRETE

Carbonation of concrete in cover results in loss of protection to the steel against corrosion. The depth of carbonation can be measured by spraying the freshly fractured concrete surface with a 0.2% solution of phenolphthalein in ethanol. Since phenolphthalein is a pH indicator, the magenta (pink colour) area presents uncarbonated concrete and the remaining (colourless) portion, the carbonated area. The change in colour occurs at around pH 10 of concrete.

The test must be applied only to freshly exposed surfaces, because reaction with atmospheric carbon dioxide starts immediately. Relating carbonation depth to concrete cover is one of the main indicators of corrosion.

17.0 कंक्रीट की क्लोराइड के लिए परीक्षण / TEST FOR CHLORIDE CONTENT OF CONCRETE

The presence of chloride in the concrete is the contributory factor towards corrosion of reinforcement.

Portable equipments are available in the market, which can be used for rapid on site measurement of chloride content of concrete. The chloride content of concrete can also be determined by chemical analysis of concrete in the laboratory.

A rotary percussion drill is used to collect a pulverized sample of concrete and a special acid extracts the chlorides. The amount of acid soluble chloride is determined directly by a chloride sensitive electrode connected to a electrometer. If different samples are obtained from different concrete depths, it can be established whether the chloride contamination was there in the original concrete or the same has come from the environment.

18.0 एंडोस्कोपी तकनीक / ENDOSCOPY TECHNIQUE

This is a most useful method for inspecting or detecting voids in the grout and corrosion in steel in the cable ducts. It is also useful for detail examination of other part of the bridge structure, which could not otherwise be assessed.

Endoscope consists of inserting a rigid or flexible viewing tube into holes drilled into concrete bridge components or cable ducts and views them with light provided by optical glass fibers from an external source.

Endoscopes are available as attachments for a camera or a TV monitor. It, however, needs an experienced engineer to make assessment of most likely locations of voids in the grout and probable points of entry of chlorides into the ducts.

19.0 प्रोफ़ोमीटर / PROFOMETER

This test is used to assess the location and diameter of reinforcement bars and concrete cover. This equipment can be used effectively for evaluation of new as well as old structures. The method can be used both for quality control as well as quality assurance.



One of the equipment which is commercially available in the market is quite handy and weighing less than two kgs. It works on normal batteries and thus does not require any electrical connection.

Principle: The instrument is based upon measurement of change of an electromagnetic field caused by steel embedded in the concrete.

Procedure: To ensure satisfactory working of profometer and to get accurate results, it should be calibrated before starting the operations and at the end of the test. For this purpose, test block provided with the instrument should be used.

- To check the calibration accuracy, the size and cover of the reinforcement of the test block is measured at different locations on test block and the recorded data should match with the standard values prescribed on the test block.
- Path measuring device and spot probes are together used for path measurements and scanning of rebars. These are connected with profometer with cables and are moved on the concrete surface for scanning the rebars and measuring the spacing.
- As soon as the bar is located, it is displayed on the screen. Once the bar is located, it is marked on the concrete surface. Diameter probe is used for measuring the dia of bars. It is also connected with profometer by one cable.
- After finding out the location of rebar, the dia probe is placed on the bar parallel to bar axis.
- Four readings are displayed and mean value of these readings is taken as diameter of bar.
- Depth probe of the profometer is used to measure the cover. It is also connected with profometer by cable and is placed exactly on the bar.
- As soon as, the depth probe is above a rebar or nearest to it, it gives an audio signal through a short beep and visual display. Simultaneously, the measured concrete cover is stored in memory.
- For carrying out this test, the proper assess is essential. For this purpose, proper staging, ladder or a suspended platform may be provided.
- Before actual scanning, marking is done with chalk on the concrete surface by dividing it into panels of equal areas.

Advantages and Limitations

This is a purely non-destructive test for evaluation of concrete structure particularly old structures. The method is very fast and gives quite accurate results if the reinforcement is not heavily congested. The equipment is very light and even one person can perform the test without any assistance.

The equipment is not being manufactured in India and needs to be imported. Some of the Indian Firms are marketing the instrument and this is costly equipment.

20.0 माइक्रो कवर मीटर / MICRO COVERMETER

The test is aimed mainly to detect the location and cover of reinforcement. The test may be used for analyzing the integrity of the structures as the cover thickness is an important aspect of construction. In the coastal areas, the test can be used for deciding the effectiveness of cover as well as rehabilitation measures required.

This is a portable and handy instrument weighing about 0.5 kg. This is normally provided with two types of search heads one for parallel bars having range approx. 360mm and other for mesh and close spaced bars having range of approx. 120 mm. It can function over the temperature range of 0°C to 45°C. The equipment is of 180mm x 100mm x 45mm size approximately. The equipment is available with volatile memory that helps in storing data while taking measurements.



Principle: The equipment consists of a highly permeable U-shape magnetic core on which two coils are mounted. When an alternating current is passed through one of these coils, the current induced in the other coil can be measured. The presence of steel affects the electromagnetic field. The induced current depends upon the mutual inductance of the coils and the nearness of the steel bars. A moving coil meter measures the current.

For measurement of the cover, the probe is placed directly over the concrete member and moved slowly until reading is obtained on the dial. The probe should be kept parallel to the length of rebar. Depending upon the diameter of the bar, the dial reading gives directly the cover to the reinforcement.

Procedure: The equipment should be calibrated before starting and at the end of the test to get accurate results. For this purpose, one spacer is provided with each equipment.

- For calibration, the cover should be measured at one location and then it is re-measured after placing the spacer between the concrete surface and probe.
- The difference between two readings should not vary more than +/- 5% of the thickness of the spacer.
- For locating the reinforcement bar, the search head should be placed on the surface of concrete in such a way so that the length of the search head should be parallel to the reinforcement provided in the structure.
- The location of the main reinforcement should be decided based upon the geometry of the structure.
- The search head should be moved from one end to other end in a direction perpendicular to the main reinforcement.
- The sound of the buzzer /beep will be strongest when the bar will come just above or below the probe.
- For measurement of cover, the search head is moved on the surface.
- While moving, the cover displayed on the screen reduces and sound of the buzzer/beep increases when probe comes near reinforcement bars.
- The minimum reading displayed will be the cover and the sound of the buzzer is strongest when the reinforcement bar is just below the search head.

Advantages and Limitations

The method is very fast and large area can be covered within short time. The instrument work on batteries and does not require any electric supply. Since the equipment is very small and portable, the test can be conducted by single person without any assistance.

21.0 अवरक्त थेर्मोग्राफीक तकनीक / INFRARED THERMOGRAPHIC TECHNIQUES

This technique can be used to detect concrete subsurface delamination on bridge decks. This can also detect the internal voids, cracks and honeycombing in concrete structures. This method gives the fairly accurate picture about the condition of concrete inside and can be effectively applied for larger surfaces.

Principle: Infrared thermographic investigation techniques are based on the principle that the materials with subsurface anomalies, such as voids caused by corrosion of reinforcing steel, or voids caused by poor compaction called honeycombing, in a material affect heat flow through that material. These changes in heat flow cause localized differences in surface temperatures. Thus, by measuring surface temperatures under conditions of heat flow into or out of the material, one can determine the presence and location of any subsurface anomalies.

An infrared thermographic scanning system measures surface temperature only, but the surface temperatures of a concrete mass depend on three factors.

(a) The subsurface configuration
(b) The surface conditions
(c) The environment

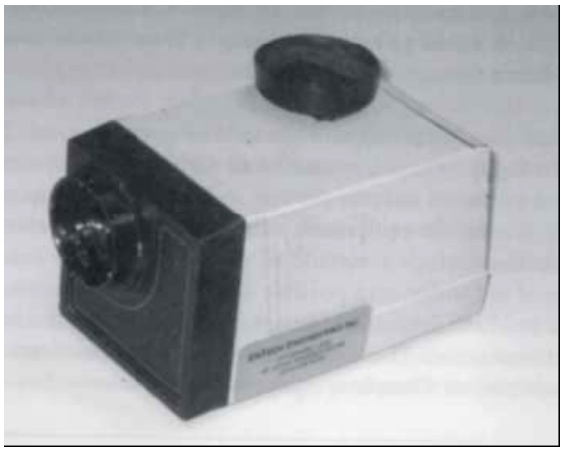
Normally the testing should be conducted during times of the day or night when the solar radiation or lack of solar radiation would produce the most rapid heating or cooling of the concrete surface. The test should not be conducted when sky is cloudy. The measurements should be taken when wind speed is lower than 25kmph. The test should not be conducted when the temperature is below 0°C. If the concrete surface is covered with standing water, the test should not be conducted.

Procedure: For performing this test efficiently, a movement of heat must be established in the structure. Normally the inspection should be conducted during the sunny day, i.e. the testing should be avoided during monsoon. The inspection may begin either 2 to 3 hours after sunrise or 2 to 3 hours after sunset, both are times of rapid heat transfer.

- The surface to be tested should be cleaned thoroughly.
- The next step is to locate a section of sound concrete.
- This work can be done by chain dragging (sounding), coring, or ground penetrating radar or by using some other suitable method.
- Image the reference area and set the equipment controls so that an adequate temperature image is viewed and recorded.
- The next step is to image the area, which is known to have defects i.e. voids/delamination/ cracks etc. and images of this defective area are viewed and recorded.

- Now the setting of the equipment should be done in such a way to allow viewing of both the sound and defective reference areas in the same image with the widest contrast possible.
- If a black and white monitor is used, better contrast images will normally be produced when the following convention is used, black is defective concrete and white is sound material.
- If a colour monitor or computer enhanced screen is used, three colours are normally used to designate definite sound areas, definite defective areas and indeterminate areas.
- When tests are performed during day light hours, the defective concrete areas will appear warmer, whereas during test performed after dark, defective areas will appear cooler.
- Once the control are set, the recording of images can be done and stored.

For conducting this test, high resolution infrared thermographic radiometers are used to inspect large areas of concrete efficiently and quickly. This type of equipment allows larger areas to be scanned, and the resulting data can be displayed as pictures with areas of differing temperatures designated by differing grey tones in black and white image or by various colours on a colour image.



A complete thermographic data collection and analysis system can be divided into four main subsystems.

1) The first is the infrared sensor head that normally can be used with interchangeable lenses. It is similar in appearance to a portable video camera.
2) The second major component of the infrared scanning system is a real-time microprocessor coupled to a black-and-white or colour display monitor. With this, component, cooler items being scanned are normally represented by darker grey ones, and warmer areas are represented by lighter gray tones. Now-a-days, colour monitors are also used, which displays the different temperature levels as contrasting colours and patterns, which are easier to decipher.
3) The third major component of the infrared scanning system is the data acquisition and analysis equipment. It is composed of an analog-to-digital converter for use with analog sensors, a computer with a high resolution colour monitor, and data storage and analysis software.
4) The fourth major component consists of various types of image recording and retrieving devices. These are used to record both visual and thermal images.

Advantages & Limitations

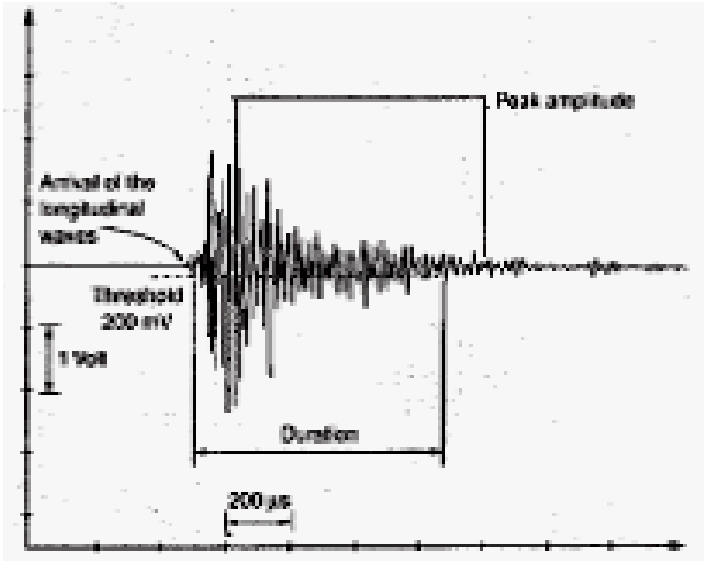
- The main advantage of this method is that it is an area testing technique, whereas other destructive and non-destructive methods are points testing or line testing methods. This method is completely non-destructive, repeatable, accurate, efficient and economical. The method can cover large areas within short time.

- One of the biggest advantages of this method is that this is absolutely safe and equipment does not emit any radiation.
- The main limitation is that the depth or thickness of a void cannot be determined using this method. It cannot be determined whether a subsurface void is near the surface or away from the surface.
- When used in combination with ground penetrating radar method this method gives useful information about the internal defects.

22.0 ध्वनिक उत्सर्जन तकनीक / ACOUSTIC EMISSION TECHNIQUE

This method is used mainly to detect the cracking in concrete, whether due to externally applied loads, drying shrinkage or thermal stresses. This method can be helpful in determining the internal structure of the material and to know the structural changes during the process of loading. The method can also be used to establish whether the material or the structure meet certain design or fabrication criteria.
In this case, the load is increased only to some predetermined level. The amount and nature of acoustic emissions may be used to establish the integrity of the specimen or structure and may also be used to predict the service life.

Principle: When an acoustic emission event occurs at a source with the material, due to inelastic deformation or cracking, the stress. Waves travel directly from the source to the receiver as body waves. Surface waves may then arise from mode conversion. When the stress waves arrive at the receiver, the transducer responds to the surface motion that occurs.



By using a number of transducers to monitor acoustic emission events, and determining the time differences between the detection of each event at different transducer positions, the location of acoustic emission event may be determined by using triangulation techniques.

Procedure: Acoustic emission test may be carried out in the laboratory or in the field. Basically one or more acoustic emission transducers are attached to the specimen. The specimen is then loaded slowly, and the resulting acoustic emissions are recorded. The test is generally conducted in two ways.

(a) When the specimens are loaded till failure (to know about internal structure/to study about structural changes during loading).
(b) When the specimens are loaded to some predetermined level (to ascertain whether the material or structure meet certain design or fabrication criteria).

Acoustic emission is the sound (both audible and sub-audible), that are generated when a material undergoes irreversible changes, such as those due to cracking. In general, acoustic emissions are defined as the class of phenomena whereby transient elastic waves are generated by the rapid release of energy from localized sources within a material. These waves propagate through the material, and their arrival at the surface can be detected by the piezoelectric transducers.

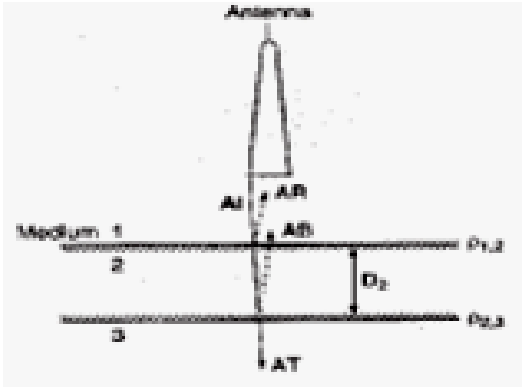
The main elements of a modern acoustic emission detection system are briefly described as follows:

a) Transducers – Piezoelectric transducers (generally made of lead zirconate titanate, PZT) are used to convert the surface displacements into electric signals. There are mainly two types of transducers – wide band transducers and narrow band transducers. The transducers must be properly coupled to the specimen, often using some form of silicon grease as the coupling medium.
(b) Preamplifier – Because of the low voltage output, the leads from the transducer to the preamplifier must be as short as possible. Sometimes the preamplifier is integrated within the transducer itself. This amplifies the output signals.
(c) Passband filters – These are used to suppress the acoustic emission signals that lie outside the frequency range of interest.
(d) Main amplifier - This further amplifies the signals, typically within a gain of 20 to 60 dB.
(e) The discriminator – It is used to set the threshold voltage above which signals are counted.

Limitations: The acoustic emission techniques may be very useful in the laboratory to supplement other measurement of concrete properties. However, their use in the field is still very limited. Another drawback is that acoustic emissions are only generated when the loads on a structure are increased and this creates considerable practical problems.

23.0 लघु पल्स रेडार विधि / SHORT PULSE RADAR METHOD

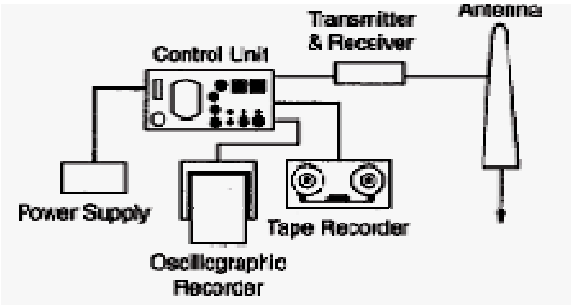
The method can be effectively used for detection of delamination in concrete. The method can also be used for determination of degree of hydration of concrete, water content in fresh concrete, and for measurement of concrete layer thickness etc. Method can also be used for locating the position of rebars.



Principle: When an electromagnetic wave (such as microwave) strikes an interface, or boundary between two materials of different dielectric constants, a portion of the energy is reflected and the remaining penetrates through the interface into the second material.

Short Pulse radar systems are used in applications related to inspection of concrete. This is the electromagnetic analog of sonic & ultrasonic pulse echo methods. In this method, the electro-magnetic waves propagate through materials of different dielectric constants.

A basic radar system consists of a control unit, a monostatic antenna (i.e. an antenna that is used for both transmitting & receiving), an oscillograph recorder, and a power convertor for DC operation.



For inspection of concrete structures, it is desirable to use a radar antenna with relatively high resolution or short pulse width.

Procedure: For inspection of concrete bridges, an antenna is placed with its transmitting face parallel to and at a distance from the surface of the concrete. However, if the concrete member is relatively thick and the expected deterioration is deep or if the antenna does not have sufficient power or penetration, the antenna may be placed directly over the concrete surface. With the adjustments in the control unit the radar signals are recorded with a properly calibrated oscillograph recorder. This is called the static mode of measurement, since the antenna is stationary with respect to the concrete being tested. If relatively large concrete area has to be inspected the antenna is mounted on the front or rear of an inspection vehicle.

The vehicle will make several passes over the area to be tested to cover the entire area. During each pass the antenna scans a different area. The stream of the radar signals are recorded continuously with an instrumentation tape recorder. With two antenna or multi antenna system, the requirement of number of passes will be less. These recordings are later on studied and interpreted for detection of defects.

Advantages and Limitations

This method is very much effective for inspection of deck slab of road bridges, provided with asphalt overlays. The disruption to road traffic is minimal while inspection is done. There are no restrictions, regarding the timing of inspection or the availability of certain ambient conditions during inspections and inspection can be done any time and in any type of ambient conditions. The major limitation is that the interpretation of signals received at radar is very cumbersome because of the presence of interfering signals.

24.0 तनाव लहर प्रसार विधि / STRESS WAVE PROPAGATION METHODS

There are several test methods, based on stress wave propagation, used for non-destructive testing of concrete. The echo methods (impact echo and pulse echo) are used for thickness measurements, flaw detection and integrity testing of piles.

The impulse response method is also used to test piles and slab like structures. The following stress wave propagation methods are generally used for testing of concrete.

(a) Pulse Echo method
(b) Impact Echo method
(c) Impulse response method

25.0 क्रैक डिटेक्शन माइक्रोस्कोप / CRACK DETECTION MICROSCOPE

It is a high quality product designed for measuring crack width, both in concrete and other materials. The high definition microscope is connected to an adjustable light source which provides a well- illuminated image under all working conditions. The image is focused by turning the knob at the side of the microscope and the eye-piece graticule can be rotated through 360^0 to align with the direction of the crack under examination. The 4 mm range of measurement has a lower scale divided into 0.2 mm divisions. These 0.2 mm divisions are sub-divided into 0.02 mm divisions. Current Codes of practice, state that calculated maximum crack widths should not exceed certain values: e.g.0.3 mm in BS 8110 : Part 2 for most types of environment. This value is 15 divisions on the graticule.



The Crack Detection microscope is very easy to use and comes with simple instructions in a wooden carrying box.

Specifications –

Magnification	= 40 times
Measuring Range	= 4 mm
Divisions	= 0.02 mm
Weight including battery and box	= 560 gr
Dimensions of box	= 150x100 50 mm deep

Procedure: Place the scale of Crack Detection Microscope on the crack. Read the number of divisions which falls on the crack. Multiply the number of division by L.C. of the microscope. This will give the width of the crack in mm. L.C. stands for least count and its value is 0.02 mm.

Advantages : It can measure the width of fine cracks. It can measure visible cracks only.

Disadvantages : It can not measure the depth of cracks.

26.0 बोरस्कोप / BOROSCOPE

This method can be used for concrete, steel and masonry structures. The method is most commonly used on concrete and masonry structures. A boroscope is used to look inside inaccessible or small voids.

The boroscope equipment includes a lighting source and a fibre optic cable to transfer the light to the boroscope. A system of lenses enables the boroscope to be used as a monocular. A camera or video camera can also be mounted on the boroscope for photo documentation. Generally speaking, the method is appropriate and may also be used for inspections of structural components such as expansion joints, honeycombs and cracks/slots.

For example, if cable ducts are not injected, it is possible to inspect the strands by means of an endoscope through a contact drilling (here a drilled hole from the surface to the cable duct).

For steel structures the method is usually used for investigation of closed profiles to gain information regarding the condition of the interior surfaces of the closed profiles.

For masonry structures the boroscope can be used to gain information of the depth of the outer layer of bricks or natural stones and it can provide information of the filling material in between the arches. It may also be used to examine the mortar between bricks or natural stone.

The many variations and features which can be obtained for boroscopes make them an almost universal tool for internal inspections. These include a wide range of lengths and diameters, solid tubular or flexible bodies, lenses for forward, sideways or retro viewing, still and video camera attachments, and mains or battery power supplies.

27.0 नाभिकीय विधि / NUCLEAR METHODS

Neutron Moisture Gauges are used to measure moisture content in concrete. They are based on the principle that hydrogen containing materials (water) act as excellent moderators for fast neutrons, i.e. such materials produce a rapid decrease in neutron energy, depending on amount of hydrogen.

Thus, counting of the slowed down neutrons gives a measure of the hydrogen content of the concrete. Isotopic neutron sources (such as radium with beryllium) are generally used in moisture gauges.

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संदर्भ / REFERANCE

1.	**IS : 13311-1992 (Part-I)**
2.	**IS : 13311-1992 (Part-II)**
3.	**IRICEN Publications**
4.	**IRWM and other literature of Railway**
5.	**Literature based on INTERNET Search**

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टिप्पणी / NOTES

गुणवत्ता नीति

रेलों में यात्री और माल यातायात की बढ़ती माँग को पूरा करने के लिए गुणवत्ता प्रबंध प्रणाली में अनुसंधान, डिज़ाइनों और मानकों में उत्कृष्टता तथा सतत सुधारों के माध्यम से सांविधिक और नियामक अपेक्षाओं को पूरा करते हुए सुरक्षित, आधुनिक और किफ़ायती रेल प्रौद्योगिकी का विकास करना।

QUALITY POLICY

To develop safe, modern and cost effective Railway technology complying with Statutory and Regulatory requirements, through excellence in Research, Designs & Standards and Continual improvements in Quality Management System to cater to growing demand of passenger and freight traffic on the Railways.

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हमारा उद्देश्य

अनुरक्षण प्रौद्योगिकी और कार्यप्रणाली को उन्नयन करना तथा उत्पादकता और रेल्वे की परिसंपत्ति एवं जनशक्ति के निष्पादन में सुधार करना जिससे अन्तर्विषयों में विश्वसनीयता, उपयोगिता और दक्षता प्राप्त की जा सके।

यदि आप इस संदर्भ में कोई विचार और सुझाव देना चाहते हों तो कृपया हमें इस पते पर लिखें।

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Our Objective

To upgrade Maintenance Technologies and Methodologies and achieve improvement in productivity and performance of all Railway assets and manpower which inter-alia would cover Reliability, Availability, and Utilisation.

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