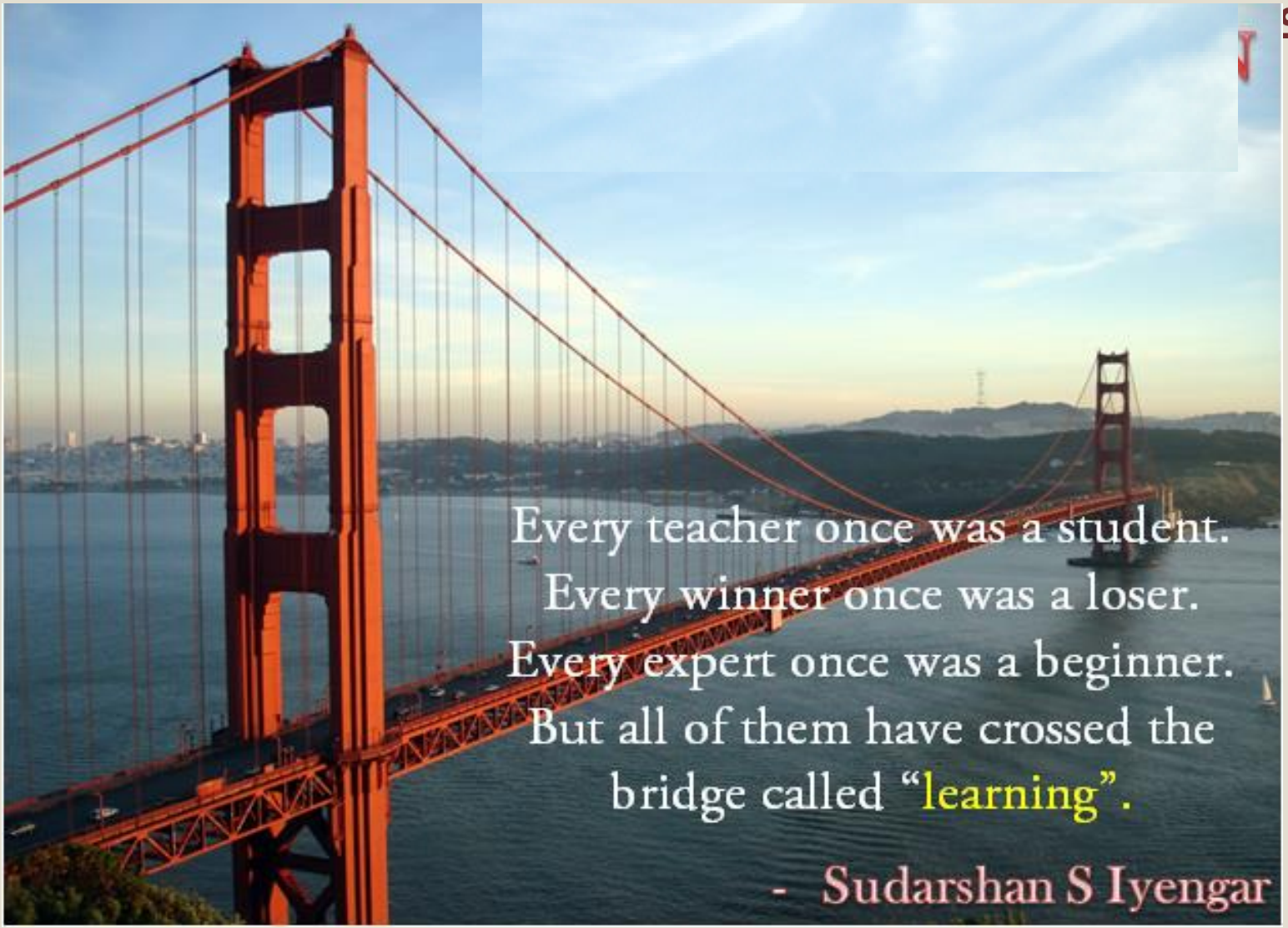

Every teacher once was a student.
Every winner once was a loser.
Every expert once was a beginner.
But all of them have crossed the
bridge called "learning".
- Sudarshan S Iyengar

DIAGNOSTIC DEVICES FOR FORENSIC INVESTIGATIONS

SUDARSHAN . S . IYENGAR

Senior Director

(NDT, Restoration & Rehabilitation)

***STEDRANT* TECHNOCLINIC PRIVATE LIMITED**

NABL ACCREDIDATED LABORATORY AS PER ISO/IEC 17025-2005

STPL

"For forensic studies a large number of Diagnostic devices are available to concrete engineers"

"The assessment through most of these devices are highly Reliable & Precise"

Sudarshan S. Iyengar

IN CONCRETE, THE IMPORTANT PROPERTIES TO BE EVALUATED ARE:

- QUALITY AND STRENGTH
- DURABILITY
- DETERIORATION
- STRUCTURAL CAPACITY

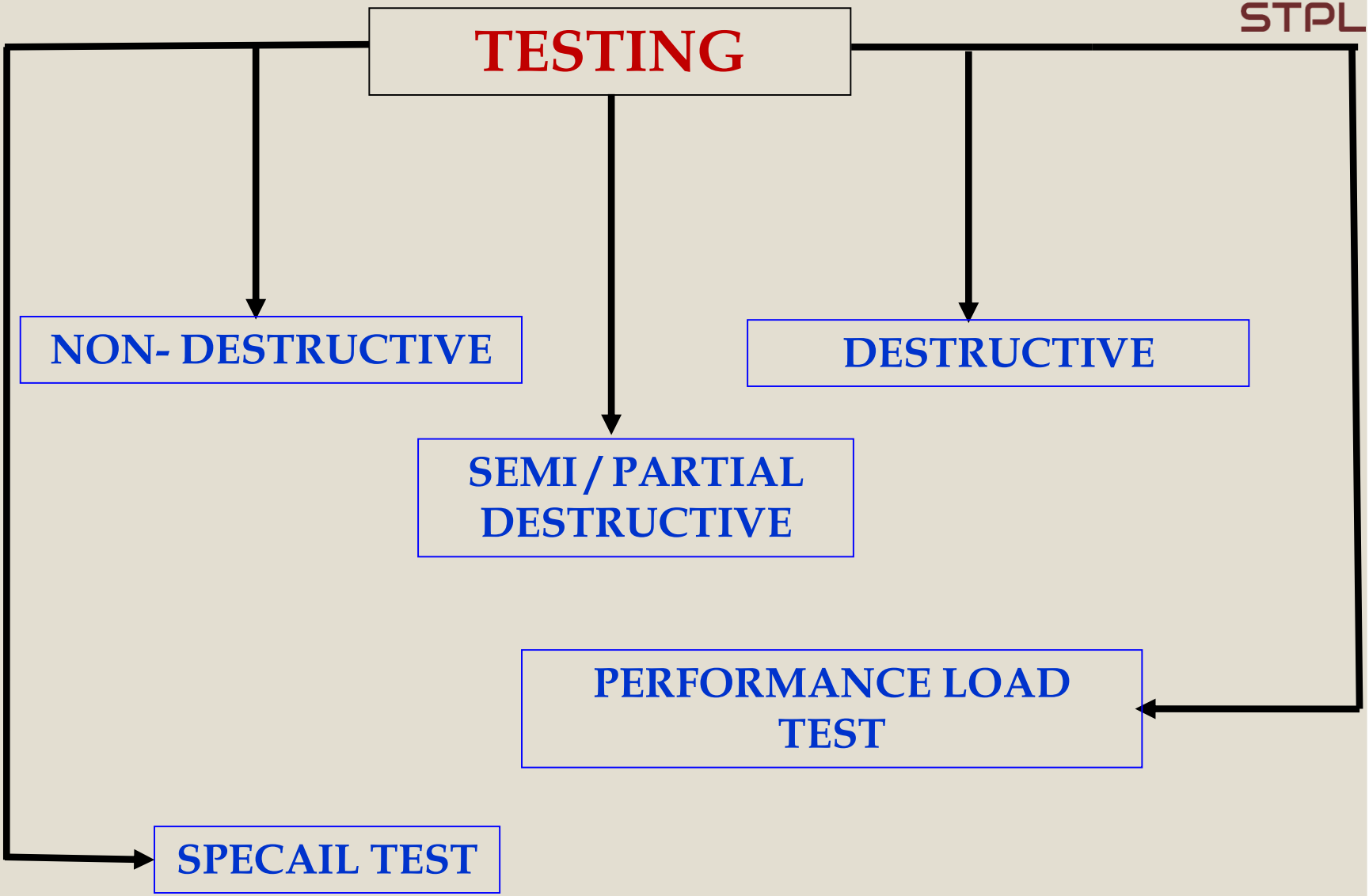
NEED FOR TESTING

STPL

TO ASCERTAIN THE QUALITY OF CONCRETE AND STRUCTURE AS A WHOLE

WHAT IT INDICATES ?

- THE MAGNITUDE OF DEFECTS
- EXTENT OF DISTRESS
- QUALITY OF CONCRETE
- WORKMANSHIP
- CONFORMITY TO STANDARDS
- CONFORMITY TO SPECIFICATIONS
- DETERIORATION
- DURABILITY



STPL

Sudarshan S. Iyengar

STPL

NON-DESTRUCTIVE TEST

TESTING OF STRUCTURAL MEMBERS WITHOUT

DESTRUCTION / DAMAGE

SEMI / PARTIAL DESTRUCTIVE TEST

TESTING OF STRUCTURAL MEMBERS WITHOUT

AFFECTING THE STRUCTURAL INTEGRITY

Sudarshan S. Iyengar

DESTRUCTIVE TEST

TESTING OF STRUCTURAL MEMBER UPTO ITS FAILURE LOAD. THE STRUCTURE MAY BE SUBJECTED TO DAMAGE / DISTRESS DURING THE TEST.

Sudarshan S. Iyengar

LIST OF FEW DEVICES / INSTRUMENTS FOR FORENSIC STUDIES ARE:

STPL

A. Non-Destructive Methods

- Schmidt Rebound Hammer
- Ultrasonic Pulse Velocity Device
- Impact Echo Tester
- Cover Meter
- X-ray / γ - ray Device
- Ground Penetrating Radar (GPR)
- Half-Cell Potentiometer

Contd/...

A. Non-Destructive methods (Contd/...)

- Field Permeability Apparatus
- Endoscope / Boroscope Device
- Crack measuring Device
- Infrared Thermography
- Cross Hole Sonic Logging Test
- Pile Integrity Test
- Pile Driving Analyzer

B. Semi-Destructive methods

- Windsor Probe Test
- Capo Test
- Lok Test / Pull-Off Test
- Core Test
- Bond or Adhesion Test
- Chemical Kit for Testing of Hardened Concrete
- Performance Load Test

NON-DESTRUCTIVE TESTS

Sudarshan S. Iyengar

Rebound Hammer Test

"SCHMIDT" Rebound Hammer – 'N' Type

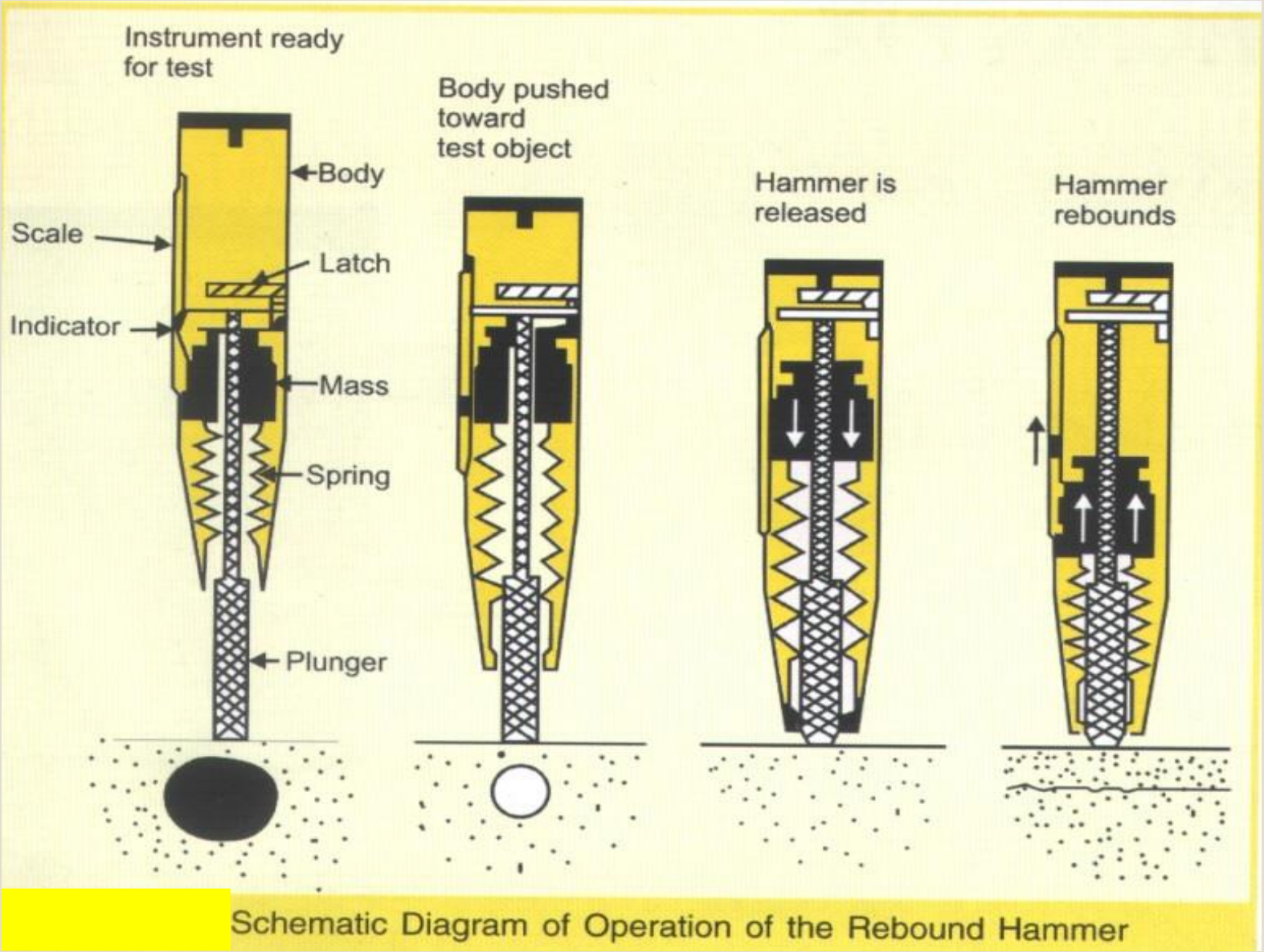
Proceq, Switzerland

Sudarshan S. Iyengar

Principle

Rebound Hammer is a device to measure the in-situ strength of concrete near to surface, hardness and penetration resistance.

The hammer measures the rebound of a spring loaded mass impacting against the surface of the member. The plunger of hammer will hit the concrete surface with a defined energy. Its rebound is dependent on the hardness of the concrete and is measured by the test equipment. By referring the reference chart the rebound value can be used to determine the compressive strength.



Schematic Diagram of Operation of the Rebound Hammer

STPL

Sudarshan S. Iyengar

STPL

Rebound Hammer – ‘N’ Type

Proceq, Switzerland

Sudarshan S. Iyengar

STPL

Sudarshan S. Iyengar

STPL

Rebound Hammers from different manufacturer's

Sudarshan S. Iyengar

STPL

Rebound Hammer - SILVER SCHMIDT

Proceq, Switzerland

Sudarshan S. Iyengar

Anvil and different types of Rebound Hammers for specific applications - ‘P’, ‘L’, ‘L9’ TYPES

Proceq, Switzerland

Sudarshan S. Iyengar

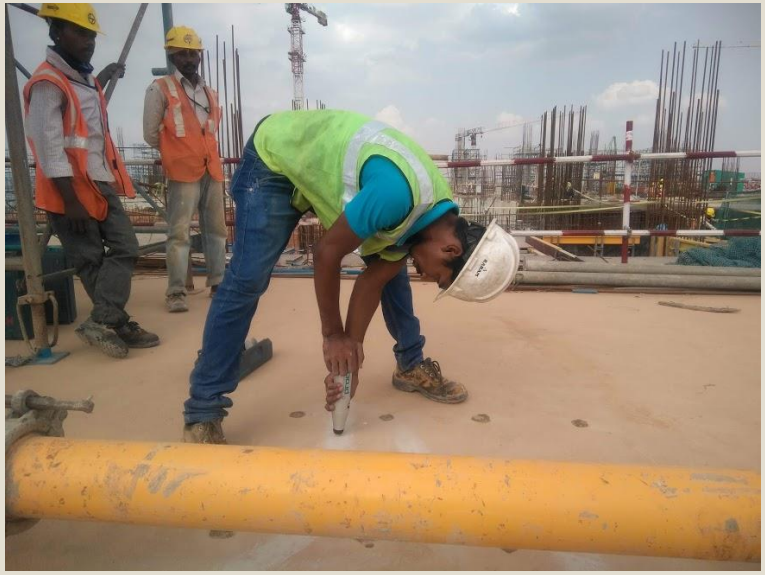
CORRECTION FACTOR FOR POSITION OF HAMMER

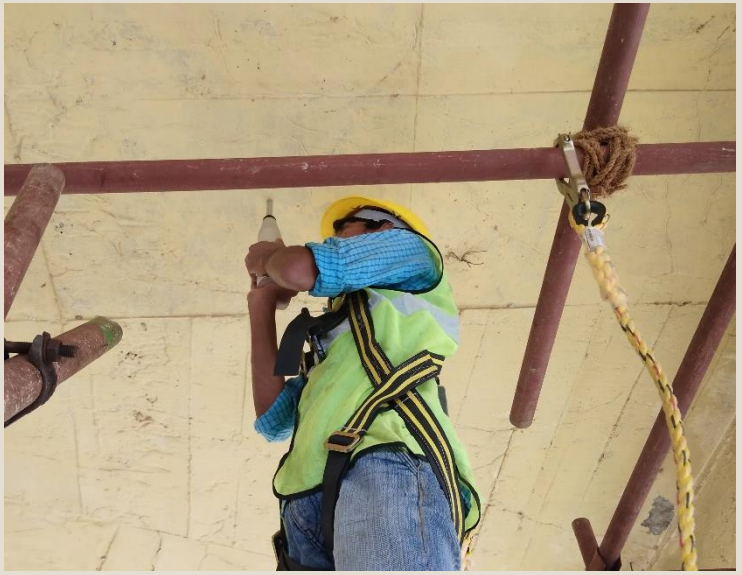
(AS PER INSTRUMENT MANUAL)

Rebound value Ra	Correction for position of Rebound Hammer			
	Upwards		Downwards	
	+ 90°	+ 45°	- 45°	- 90°
10	-	-	+ 2.4	+ 3.2
20	- 5.4	- 3.5	+ 2.5	+ 3.4
30	- 4.7	- 3.1	+ 2.3	+ 3.1
40	- 3.9	- 2.6	+ 2.0	+ 2.7
50	- 3.1	- 2.1	+ 1.6	+ 2.2
60	- 2.3	- 1.6	+ 1.3	+ 1.7

Sudarshan S. Iyengar

Methods of test





Sudarshan S. Iyengar

LIMITATIONS

STPL

IF ALL THE FACTORS ARE TAKEN INTO CONSIDERATION, THE STRENGTH OF CONCRETE CAN BE DETERMINED WITH AN ACCURACY OF 15%. WHEN LITTLE INFORMATION IS AVAILABLE ABOUT CONCRETE THEN THE POSSIBLE ERROR MAY BE UPTO 25%.

Ultrasonic Pulse Velocity Test

STPL

Sudarshan S. Iyengar

STPL

Principle

The measurement of Ultrasonic Pulse generated through the piezo electric crystal probes through the concrete which is indicated in timing device.

This test is generally used to check the compaction, uniformity of concrete, delamination, cracks, presence of honeycombs / voids etc.

Natural Frequency of Transducers for Different Path Length as specified by manufacturer

Path Length (mm)	Natural Frequency of Transducer (kH_z)	Minimum Transverse Dimensions of Members (mm)
Upto 500	150	25
500 – 700	> 60	70
700 – 1500	> 40	150
above 1500	> 20	300

METHOD OF TEST

FOR TEST PROCEDURE / METHOD, IS: 13311- (PART-1) 1992 SHALL BE FOLLOWED. THERE ARE THREE METHODS WHICH ARE GENERALLY ADOPTED AT SITE DEPENDING ON THE ACCESSIBILITY OF STRUCTURAL MEMBERS.

a. DIRECT TRANSMISSION

b. INDIRECT TRANSMISSION ; and

c. SEMI-DIRECT TRANSMISSION

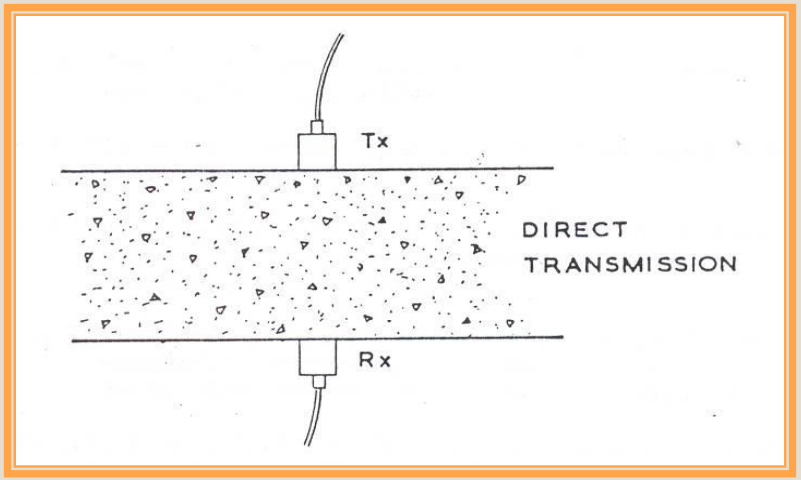
ULTRASONIC PULSE VELOCITY (UPV) TEST

STPL

ULTRASONIC METHODS

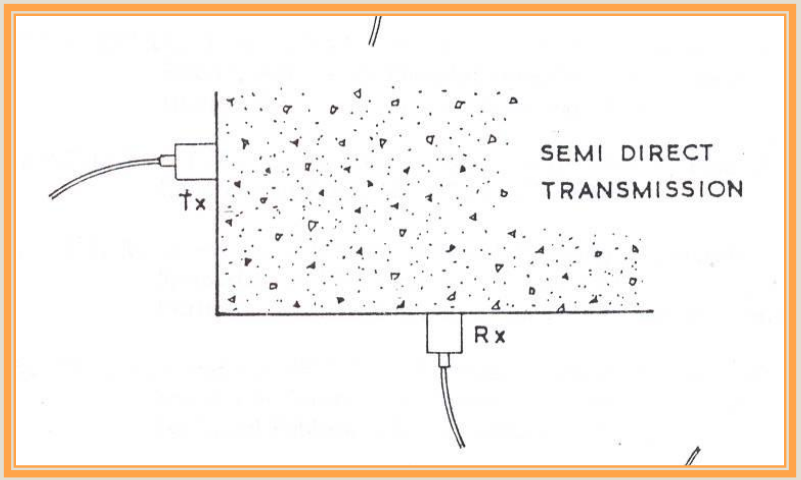
Direct method

a. On opposite faces



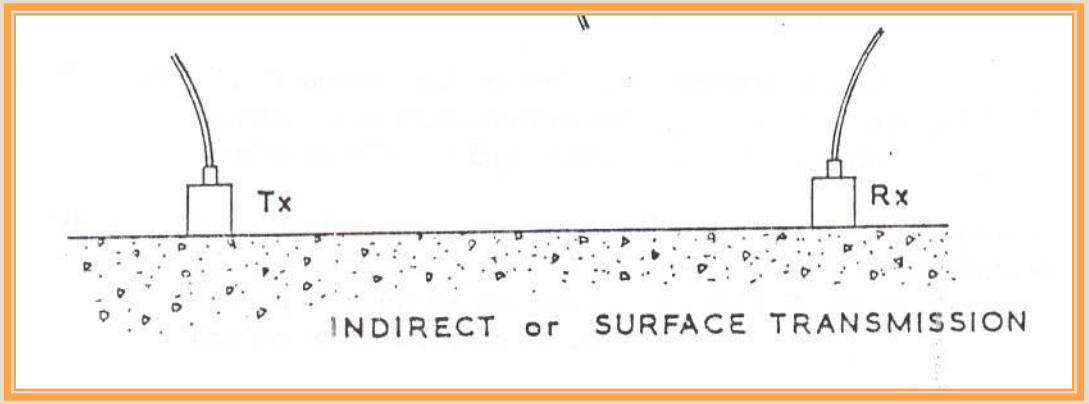
Semi-Direct method

b. On adjacent faces



In-direct method

c. On same face

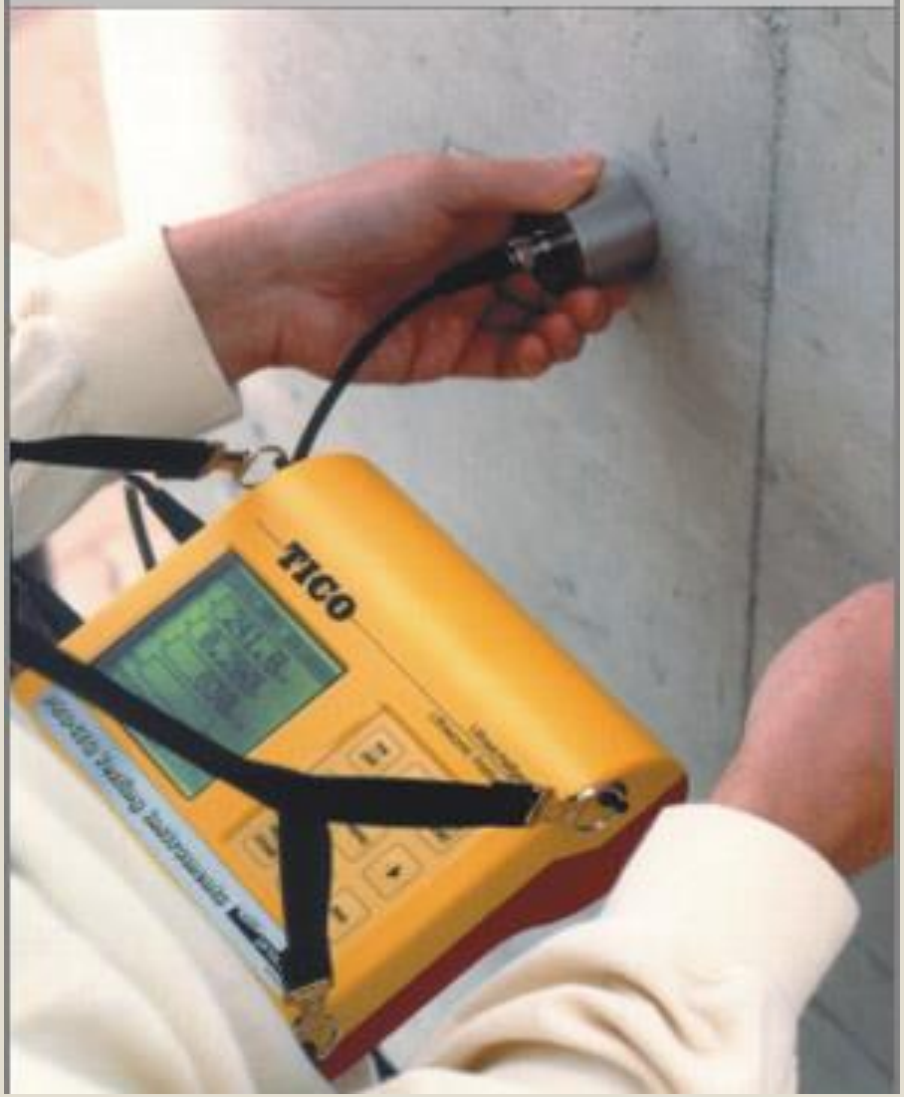


Sudarshan S. Iyengar

UST, U.K

Sudarshan S. Iyengar

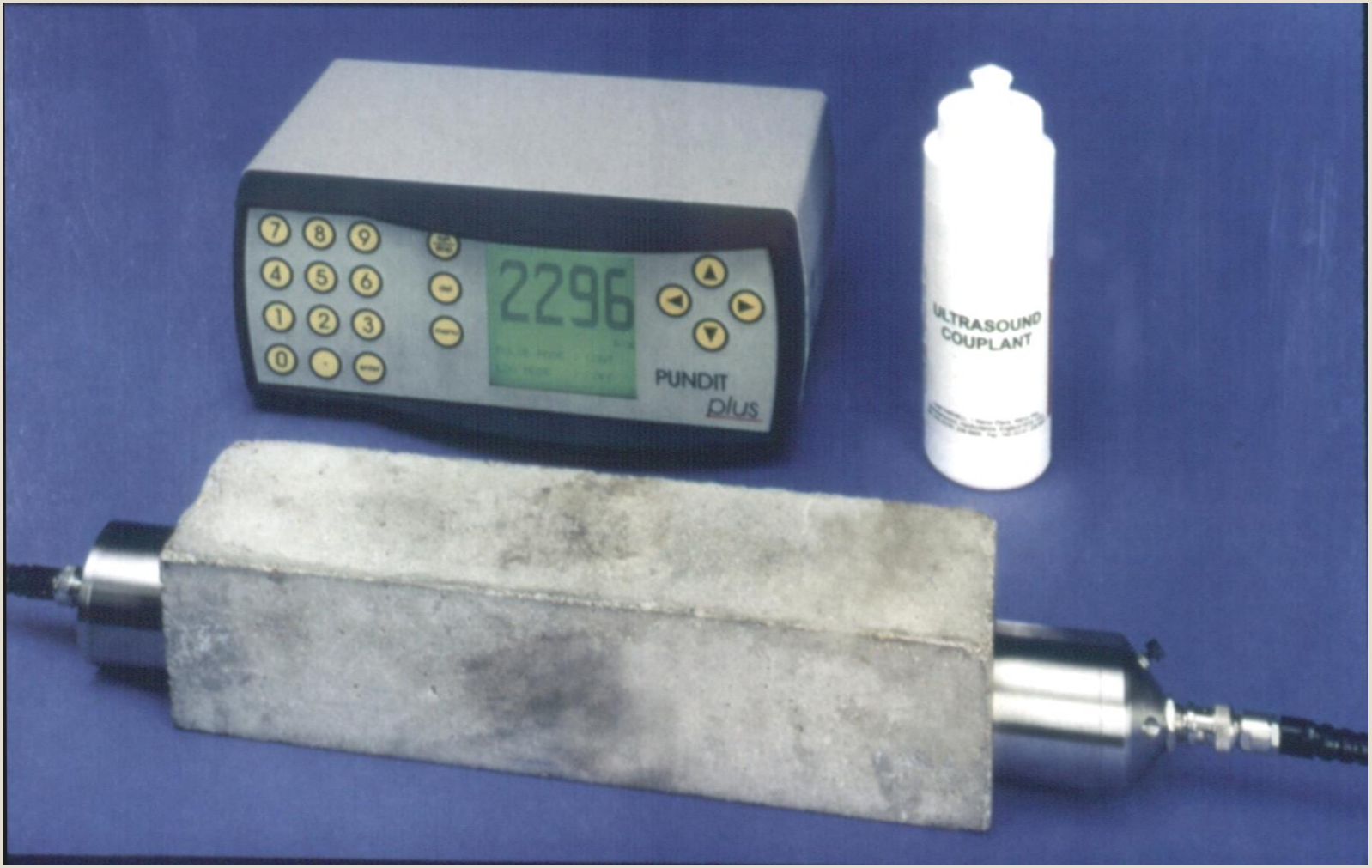
TICO METER



Proceq, Switzerland

Sudarshan S. Iyengar

STPL



PUNDIT Plus – CNS Farnell, U.K

Sudarshan S. Iyengar

STPL

Ultrasonic Concrete Testing equipment

Cosmos, India

Sudarshan S. Iyengar

STPL

PUNDIT 7, CNS Electronics UK *Sudarshan S. Iyengar*

STPL

Sudarshan S. Iyengar

Method of test

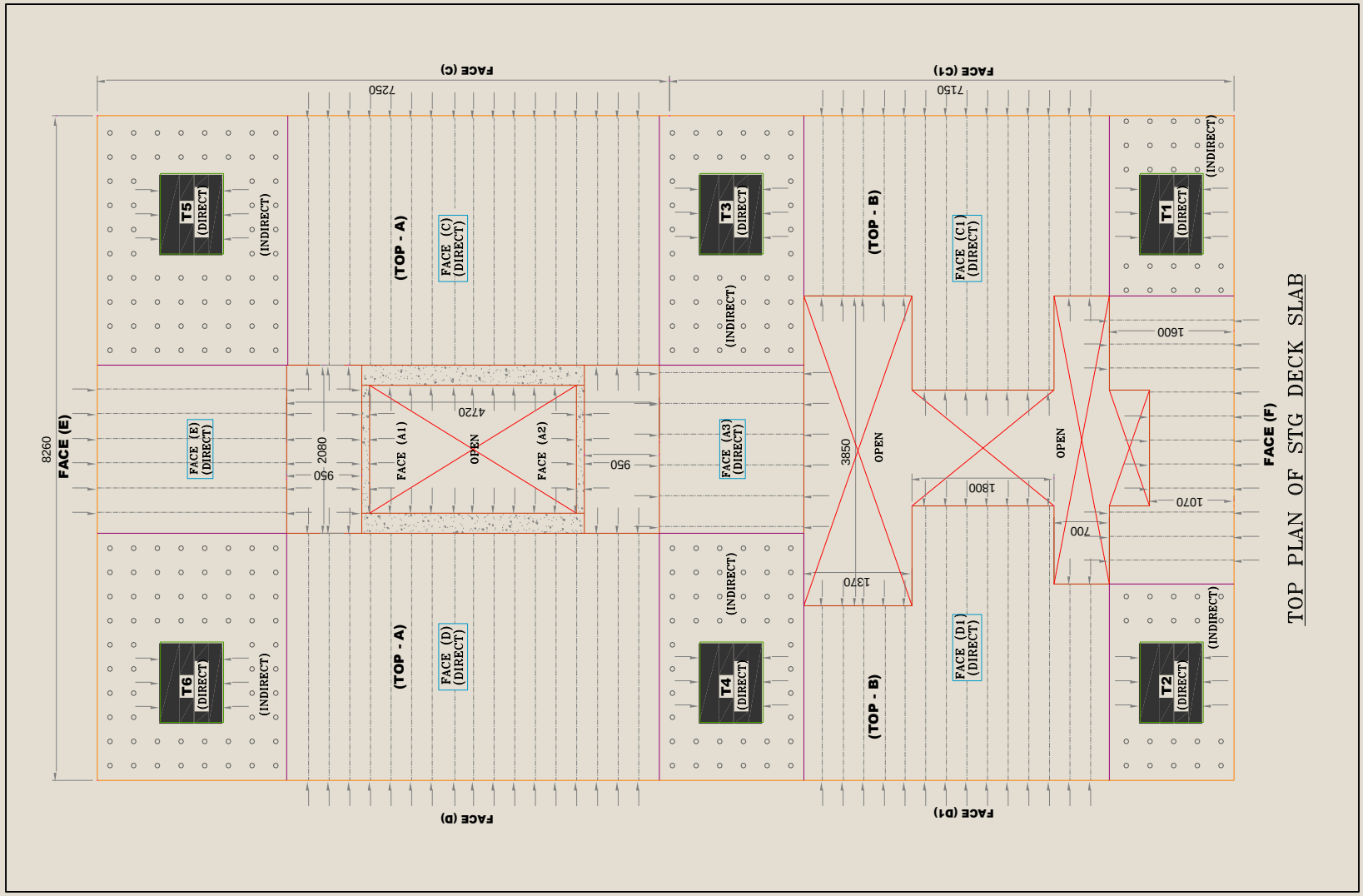
Sudarshan S. Iyengar

BHEL Thermal Power Project at Tuticorin, Tamilnadu

Sudarshan S. Iyengar

STPL

Sudarshan S. Iyengar



Direction of Pulse transmission in TG foundation

Sudarshan S. Iyengar

METHOD OF CALCULATION OF PULSE VELOCITY

$$\text{VELOCITY} = \frac{\text{PATH LENGTH}}{\text{TIME TAKEN}}$$

PULSE VELOCITY IN CONCRETE WILL BE REPRESENTED IN Km/sec

APPROPRIATE CORRECTION FACTORS HAVE TO BE APPLIED DEPENDING ON SITE CONDITION & FACTORS INFLUENCING VELOCITY OF PULSE.

Sudarshan S. Iyengar

QUALITY GRADING CHART

STPL

PULSE VELOCITY (Km/sec)	CONCRETE QUALITY GRADING (Table-1 of IS: 516- Part 5 / Sec 1: 2018)
Below 3.00	**Poor**
3.00 to 3.75	**Doubtful**
3.75 to 4.40	**Good**
Above 4.40	**Excellent**

TO EVALUATE ESTIMATED STRENGTH OF CONCRETE BASED ON THE PULSE VELOCITY AN APPROPRIATE CALIBRATION CHART HAS TO BE ESTABLISHED BASED ON THE LABORATORY TESTS.

Sudarshan S. Iyengar

STPL

LIMITATIONS

ULTRASONIC PULSE VELOCITY TEST METHOD IS THE MOST APPROPRIATE ONE TO ASSESS THE UNIFORMITY, INTEGRITY & QUALITY OF CONCRETE IN R.C. MEMBERS.

Impact Echo Tester

STPL

Sudarshan S. Iyengar

Principle

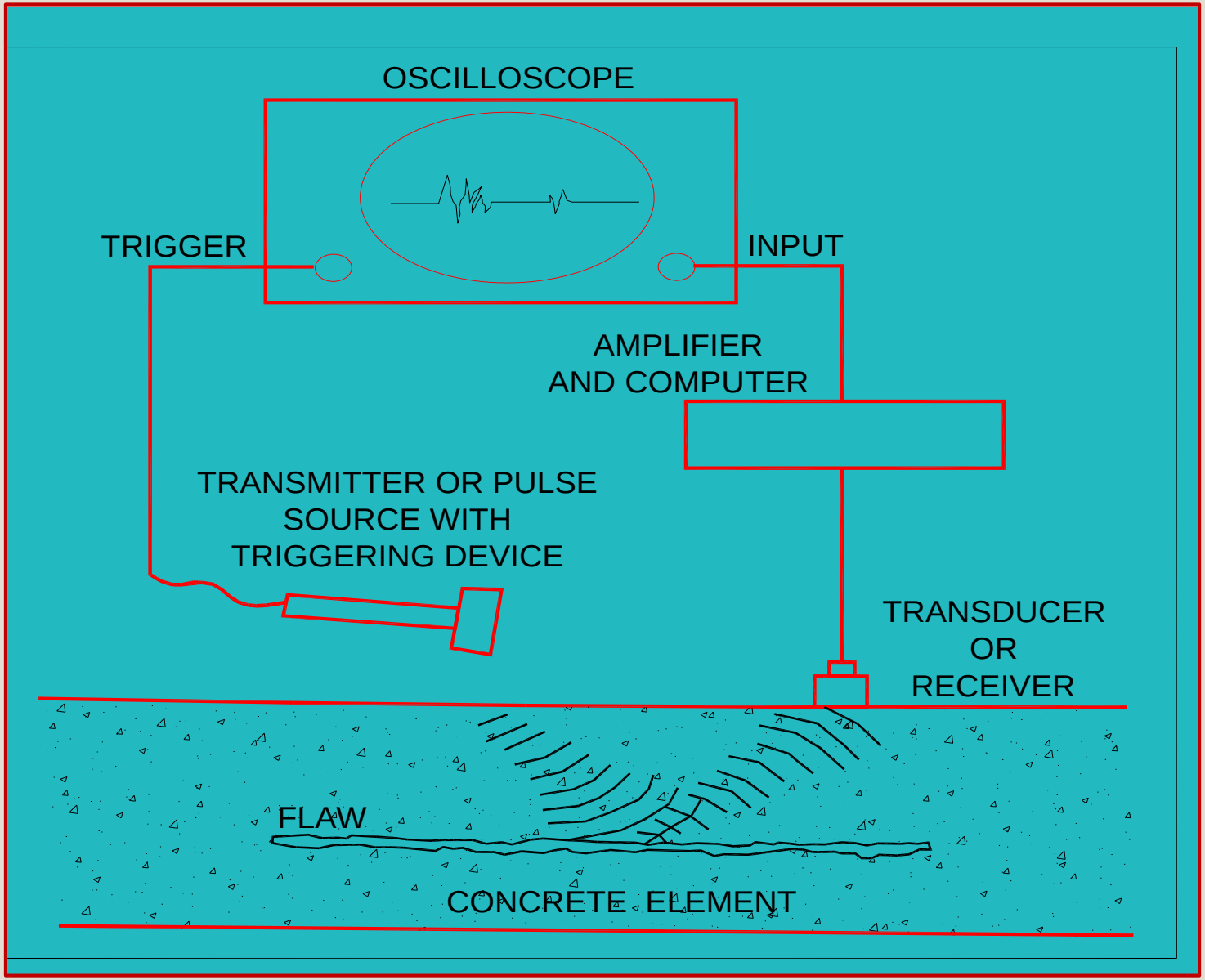
STPL

- The impact produces low frequency waves that propagate into concrete and are reflected by flaws or external surfaces.
- Surface displacement caused by reflection of waves are recorded by transducer, located adjacent to impact.
- The resulting displacement v/s time signals are transformed to frequency domain.

(Contd/...)

Principle (Contd/...)

- Plots of amplitude v/s frequency (spectra) are obtained.
- Multiple reflections give rise to transient resonances, which can be used to evaluate the integrity.
- In a solid structure distinctive wave forms and spectra is produced.
- If flaws are present, these patterns are disrupted and changed, to provide qualitative and quantitative information about flaws.
- This test is most useful when only one surface is accessible



STPL

Sudarshan S. Iyengar

STPL

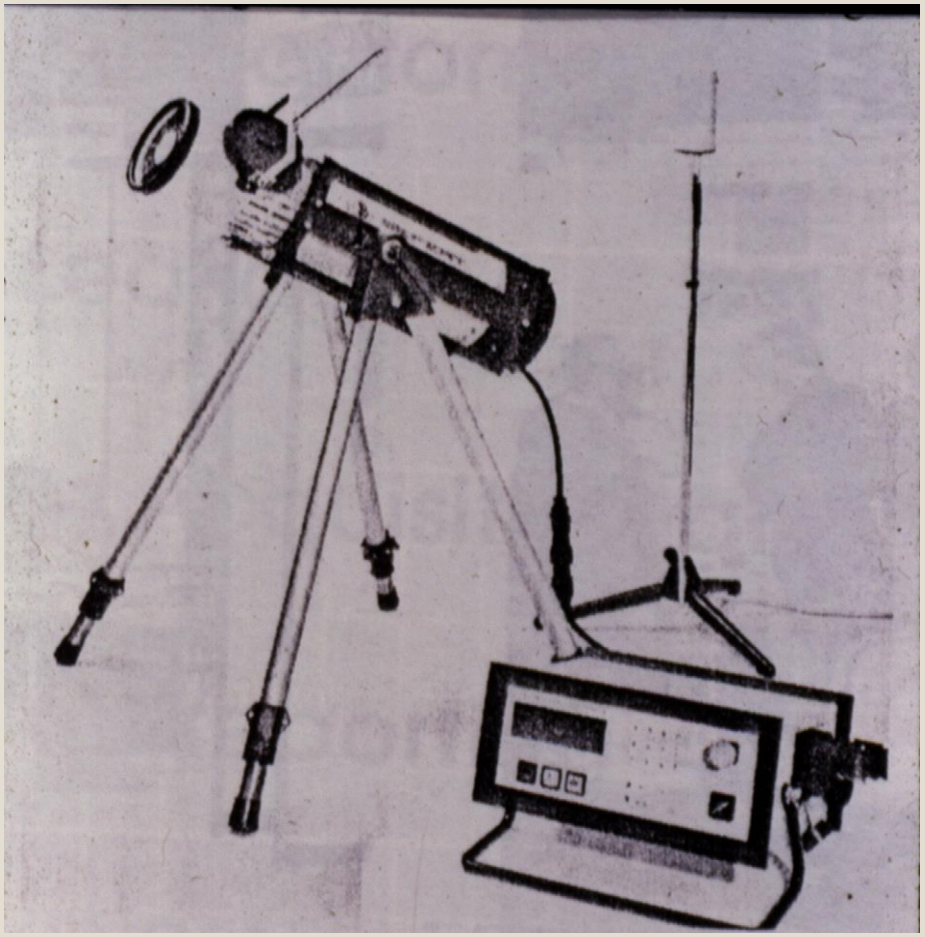
Sudarshan S. Iyengar

STPL

Sudarshan S. Iyengar

RADIOGRAPHIC TEST

STPL



Eresco 200 MF portable
X-ray equipment from Seifert X-Ray (UK)

Sudarshan S. Iyengar

Principle

X-rays and gamma rays both components of high energy region on the electromagnetic spectrum penetrate concrete but undergo attenuation in the process. The degree of attenuation depends on the kind of matter transversed, its thickness and wave length of the radiation. The intensity of incident of gamma rays and the emerging gamma rays after passing through members are measured. These two values are used for calculating the density of concrete. Gamma rays transmission method is used to measure thickness of concrete slabs of known density.

STPL

View of embedded rebars

Sudarshan S. Iyengar

Cover Meter test

STPL

Profometer 2, Proceq, Switzerland

Sudarshan S. Iyengar

Principle

STPL

Cover meters are electromagnetic devices consisting of a search head and a control box. The Covermeter test is used to assess the concrete cover and mapping of rebars. It can also be used for estimating the size / dia of rebars. The rebars which are close to surface can be detected. However, it may not detect second layer of rebars, if any. Further, if rebars are closely spaced / congested then the estimation of number of rebars may not be reliable.

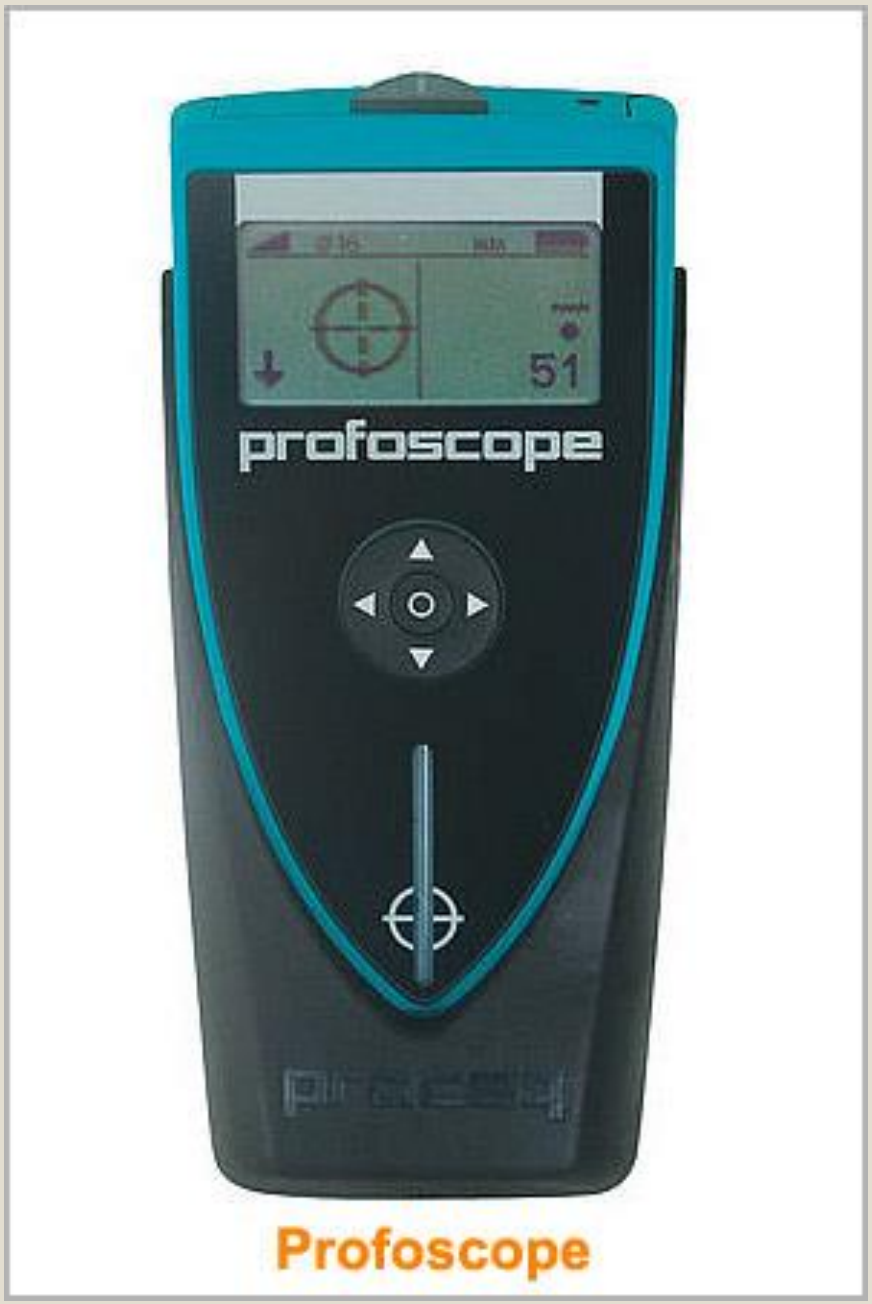
The accuracy of data on rebar diameter, generally vary in the range of 10% to 20%.

Protovale cover master

Sudarshan S. Iyengar

STPL

Sudarshan S. Iyengar



Proceq, Switzerland

Sudarshan S. Iyengar

Profometer-3 (Cover meter)

STPL

Proceq, Switzerland

Sudarshan S. Iyengar

Profometer-4 (Covermeter)

STPL

Proceq, Switzerland

Sudarshan S. Iyengar

Profometer-5

Proceq, Switzerland

Sudarshan S. Iyengar

Profometer-5+

Proceq, Switzerland

Sudarshan S. Iyengar

Profometer - 6

Sudarshan S. Iyengar

STPL

Rebar Scanning

Sudarshan S. Iyengar

STPL

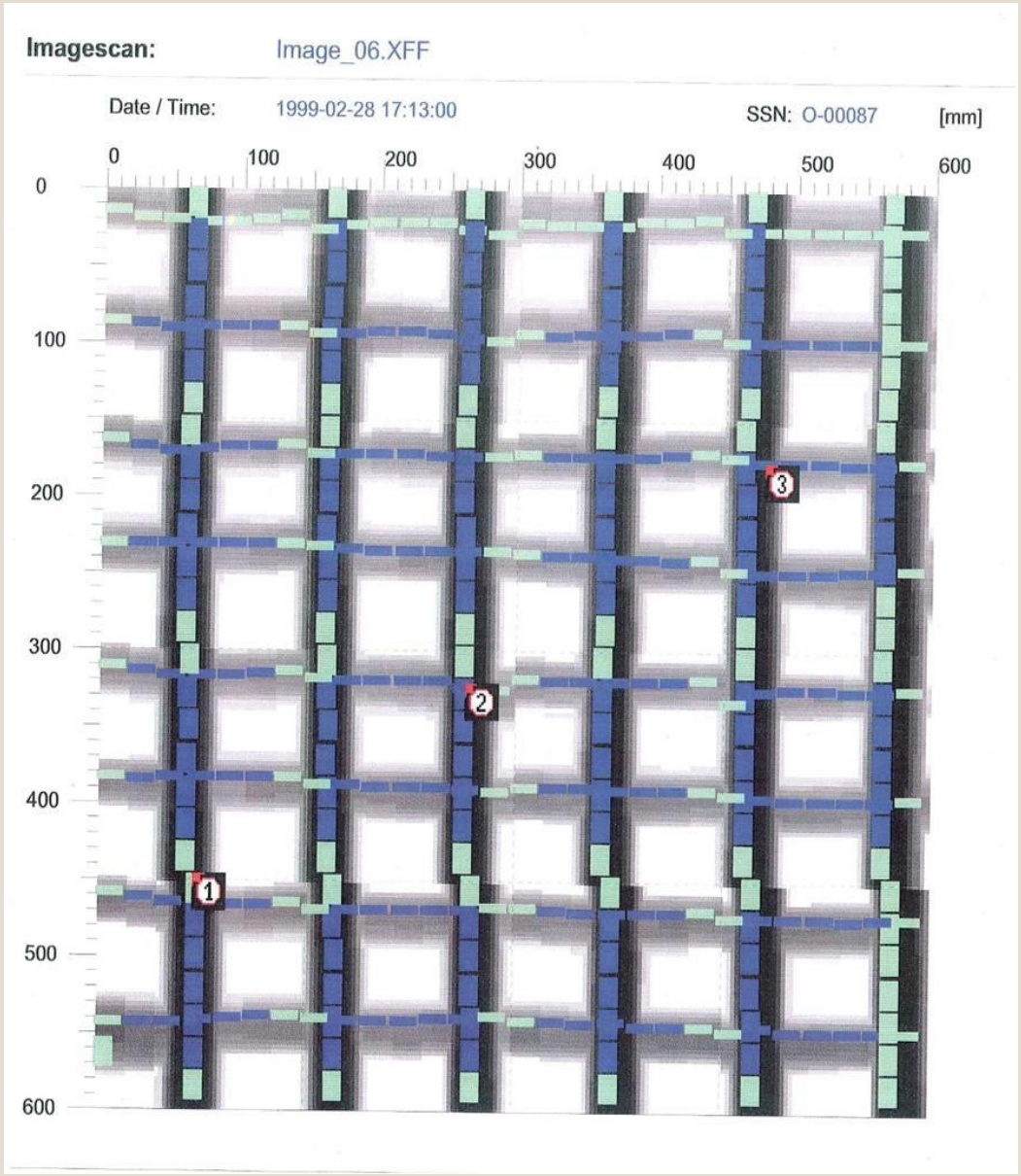
Sudarshan S. Iyengar

STPL

FERROSCAN

Hilti, Germany

Sudarshan S. Iyengar



Rebar images

Sudarshan S. Iyengar

Complete GPR Systems for Concrete Inspection and Analysis

1 All-in-One handheld GPR system

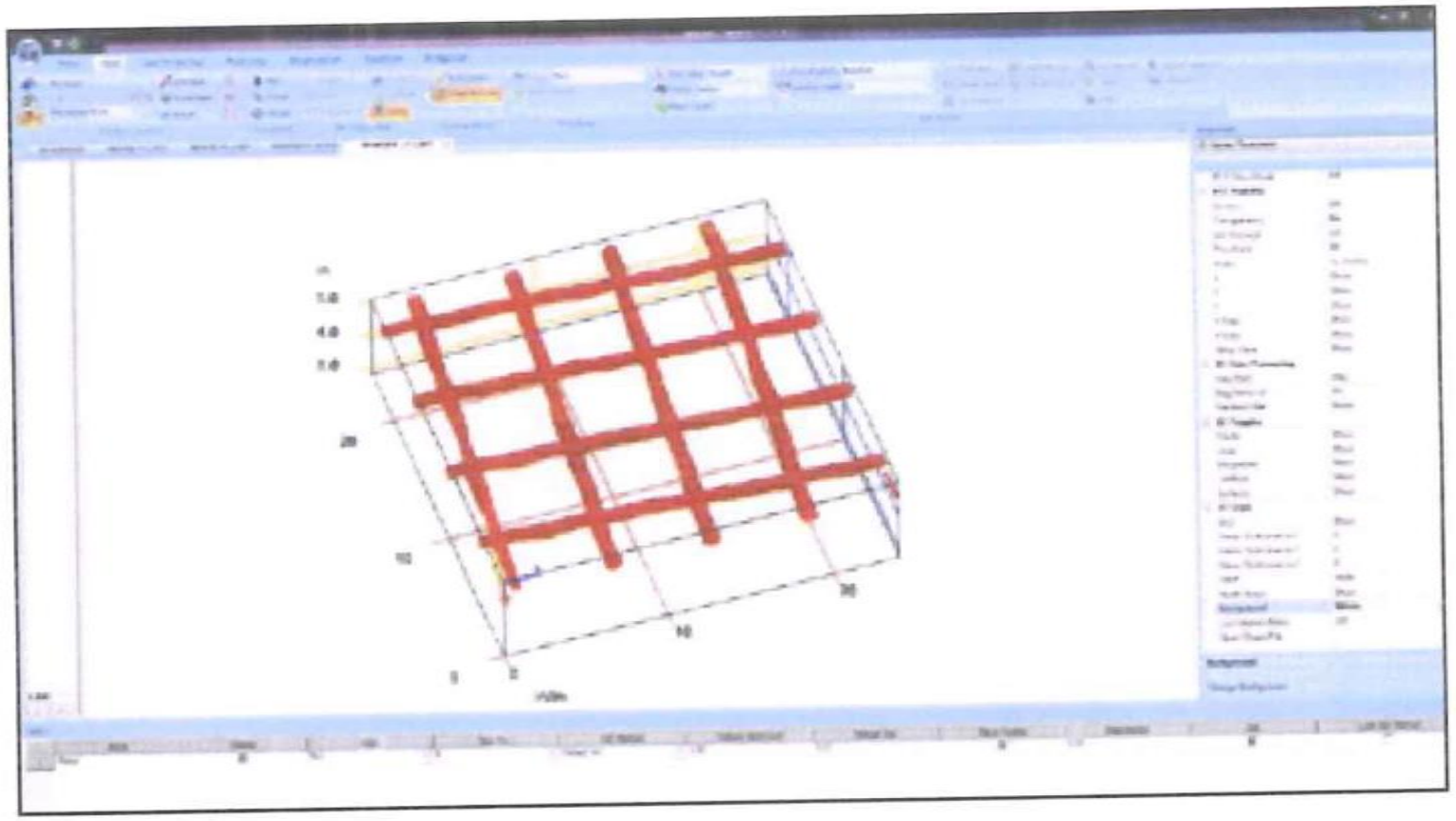
2 Ergonomic handle and controls

3 Easy to use operator interface with color display screen

4 Survey wheel encoder

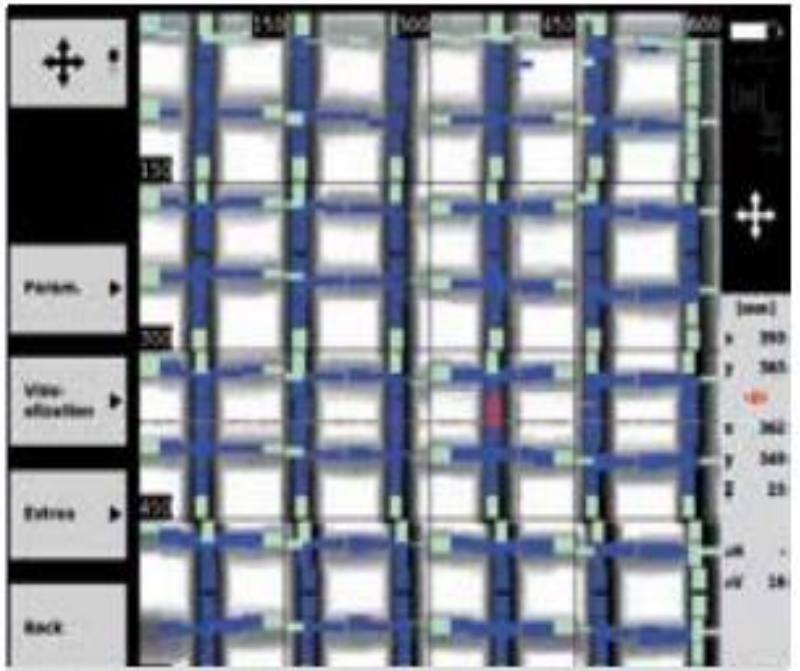
5 Guiding laser for locating

Sudarshan S. Iyengar



Screen shot of RADAN 7 3D Module; three-dimensional image of a rebar mat.

Method of test



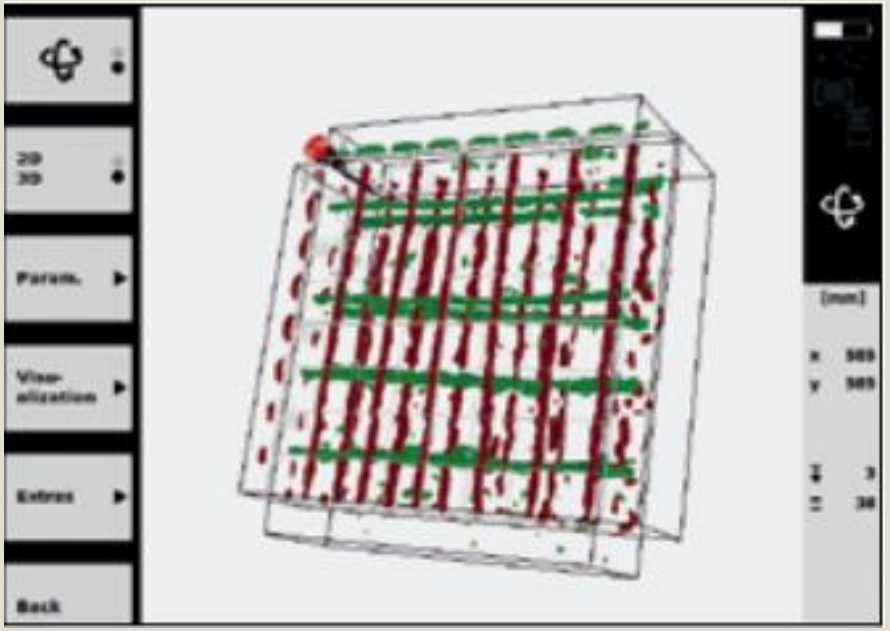
Imagescan displayed on the Monitor PSA 100 for on-the-spot analysis of re-inforcement (location, depth, diameter).

Rebar Scanner PSA 100 from Hilti

Sudarshan S. Iyengar

STPL

Rebar Scanner PSA 100 from Hilti



Sudarshan S. Iyengar

LIMITATIONS OF THE EQUIPMENT

STPL

1. The accuracy of data on the diameter of rebar will vary generally in the range of 10 to 20%
2. The actual numbers and position of rebars cannot be located if the rebars are closely spaced in one location.
3. If the depth of cover concrete is beyond 60 mm then the estimation of diameter of rebars will not be accurate.

GROUND PENETRATING RADAR

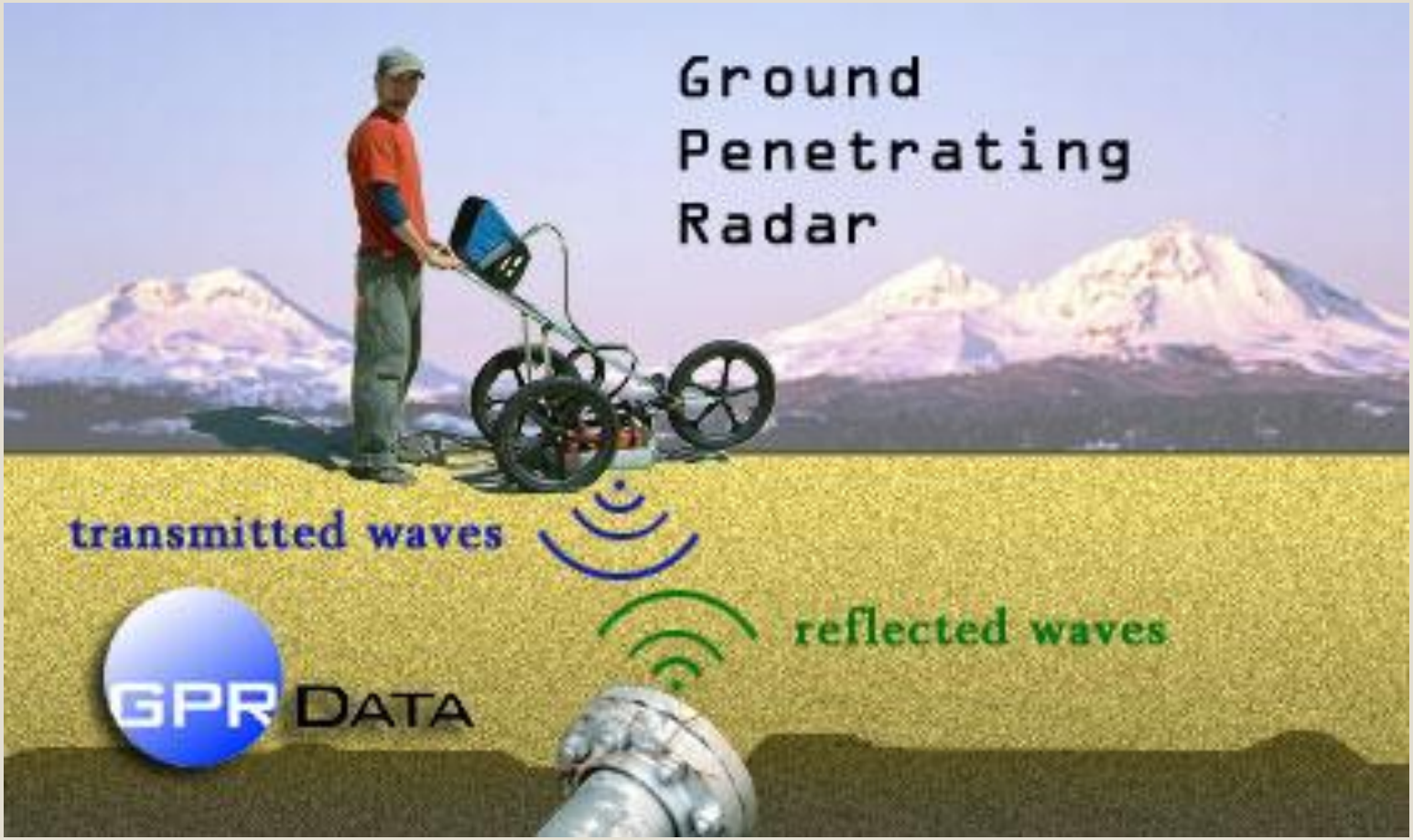
STPL

Sudarshan S. Iyengar

Principle

GPR is a geophysical method that uses radar pulse to image the subsurface. This uses high frequency radio waves and transmits into the ground. When the wave hits a bursted object or a boundary with different detective constraints, the receiving antenna records variations in the reflected return signal.

STPL



Sudarshan S. Iyengar

STPL

Underground investigation by GPR

Sudarshan S. Iyengar

Armoury house of Tippu Sultan at Srirangapatna

Sudarshan S. Iyengar

STPL

Sudarshan S. Iyengar

HALF-CELL POTENTIOMETER

STPL

Sudarshan S. Iyengar

Principle

STPL

The Half-cell Potential measurement test essentially consists of measurement of absolute potential at the concrete surface with a reference electrode. The measured absolute potential considered to be the best criterion for assessing the corrosion status of the embedded rebars.

The measured values are correlated with standard values for determination of corrosion in rebars for RC members.

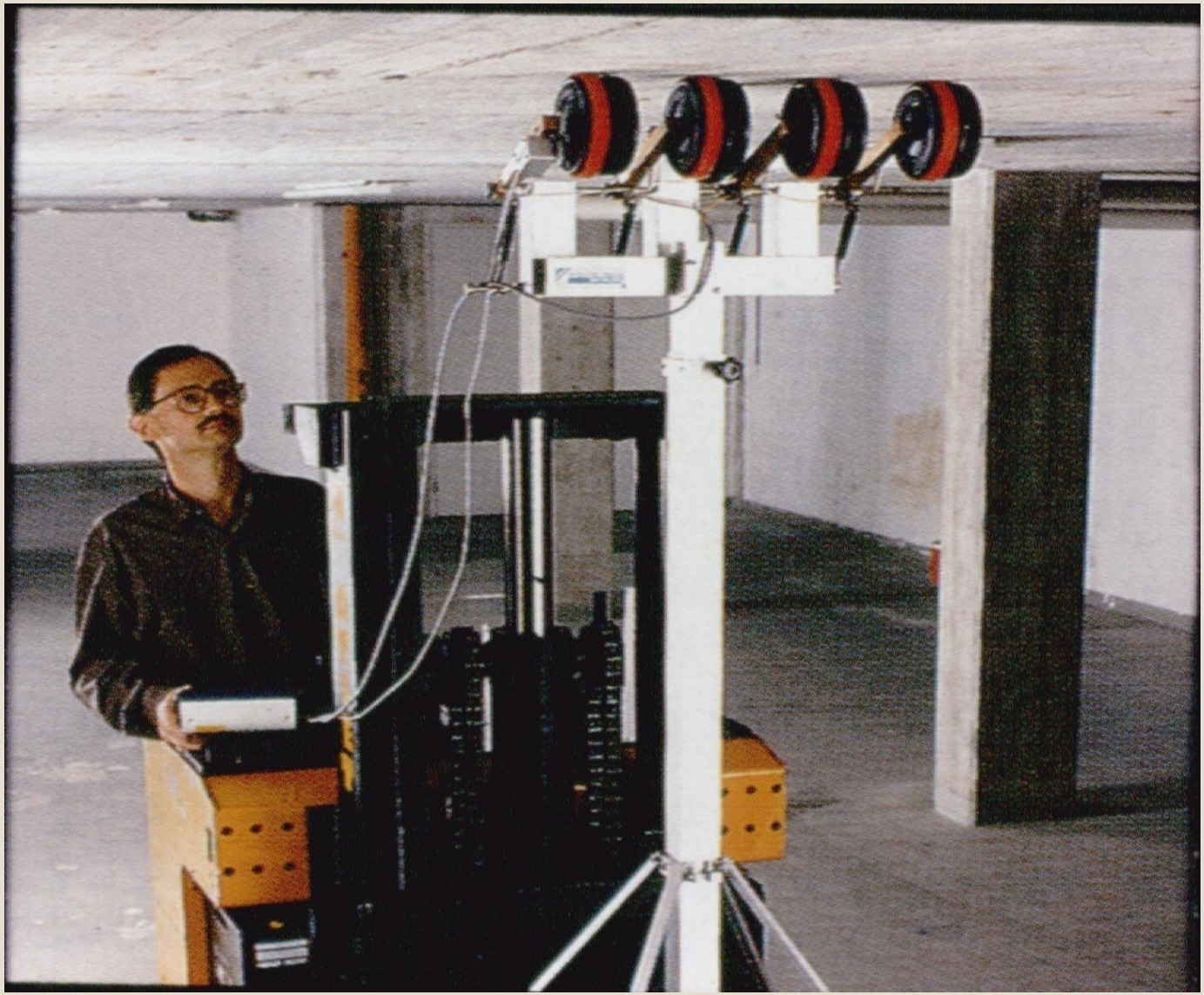
Series of Half-Cells

Sudarshan S. Iyengar

STPL

Sudarshan S. Iyengar

Continuous scanning



Sudarshan S. Iyengar

REFERENCE CHART FOR HALF CELL POTENTIAL

STPL

SL. No.	Measured Potential Difference	Probability of Corrosion
1	More negative than (-) 350 mv	High probability of corrosion (i.e advanced stage)
2	Between (-) 200 mv to (-) 350 mv	Uncertainty of corrosion (i.e moderate stage)
3	More positive than (-) 200 mv	High probability of No corrosion (i.e Initial stage)

Sudarshan S. Iyengar

Field Permeability Apparatus

STPL

Sudarshan S. Iyengar

Principle

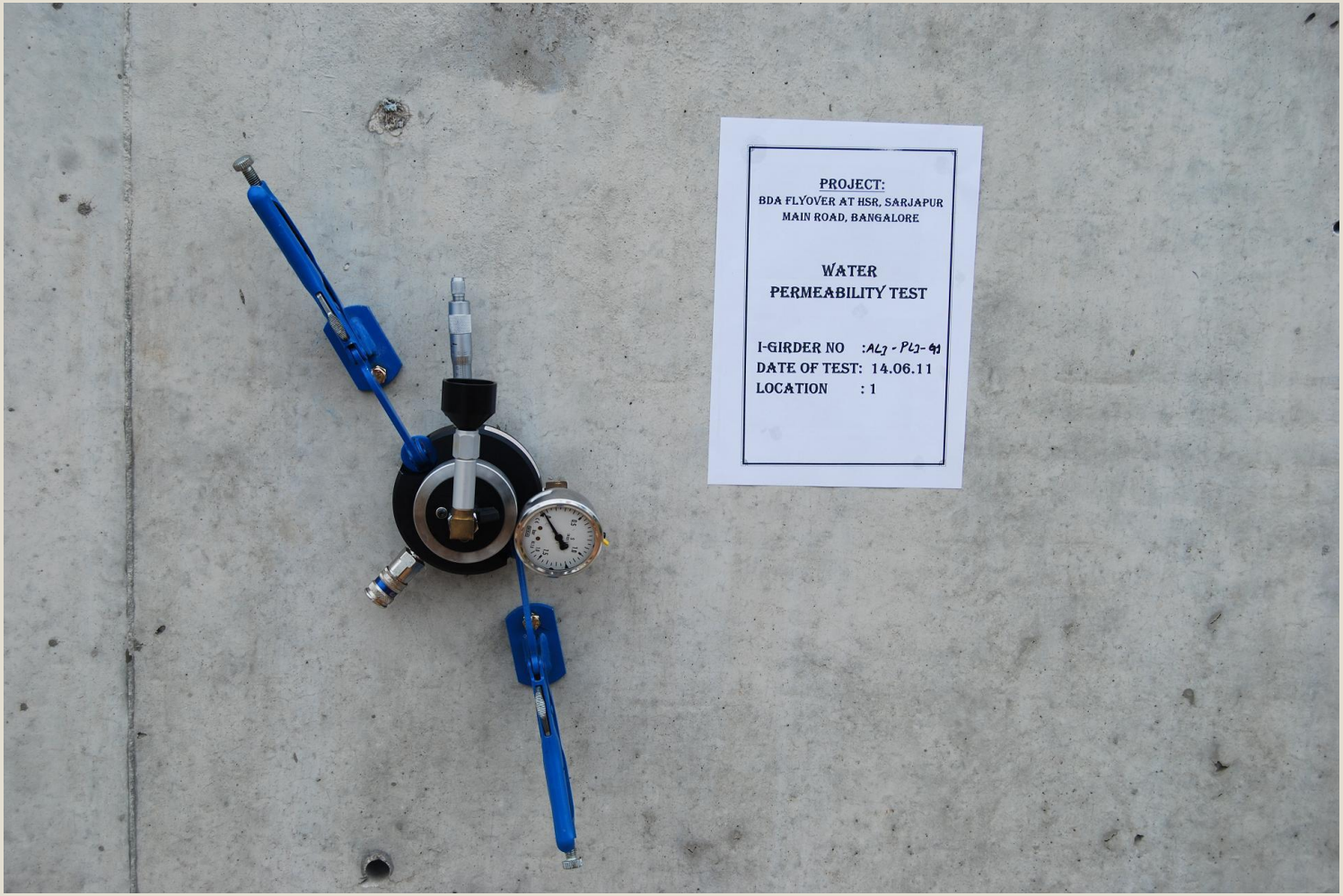
STPL

In-situ permeability test is conducted on the concrete surface.

Gas / water under pressure is allowed to diffuse into the concrete media. The reduction in pressure with time is an indication of porosity in concrete.

Based on the rate of reduction in pressure permeability can be calculated. This serves as a measure to evaluate concrete quality.

STPL



Sudarshan S. Iyengar

STPL

TORRENT : Permeability Tester

Sudarshan S. Iyengar

Endoscope / Boro scope Device

STPL

Sudarshan S. Iyengar

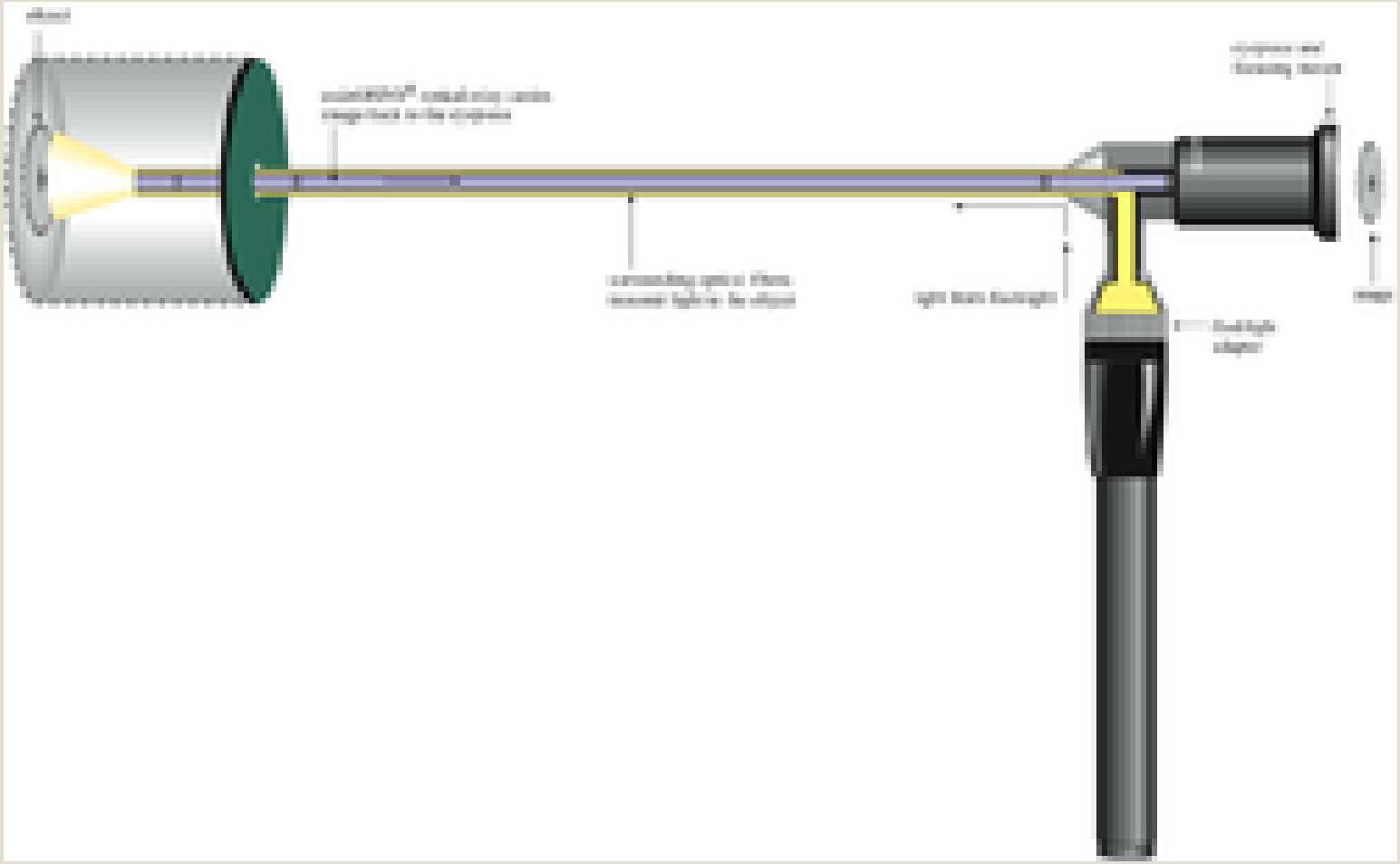
Principle

STPL

Boro scope is an optical device consisting of a rigid or flexible tube with an eyepiece on one end, an objective lens on the other linked together by a relay optical system in between. The optical system is usually surrounded by optical fibers used for illumination of the remote object. An internal image of the illuminated object is formed by the objective lens and magnified by the eyepiece which presents it to the viewer's eye.

The same equipment has also been used in Civil Engineering for inspection & health monitoring of embedded PSC cables in the bridge girders and other concrete members.

Sudarshan S. Iyengar

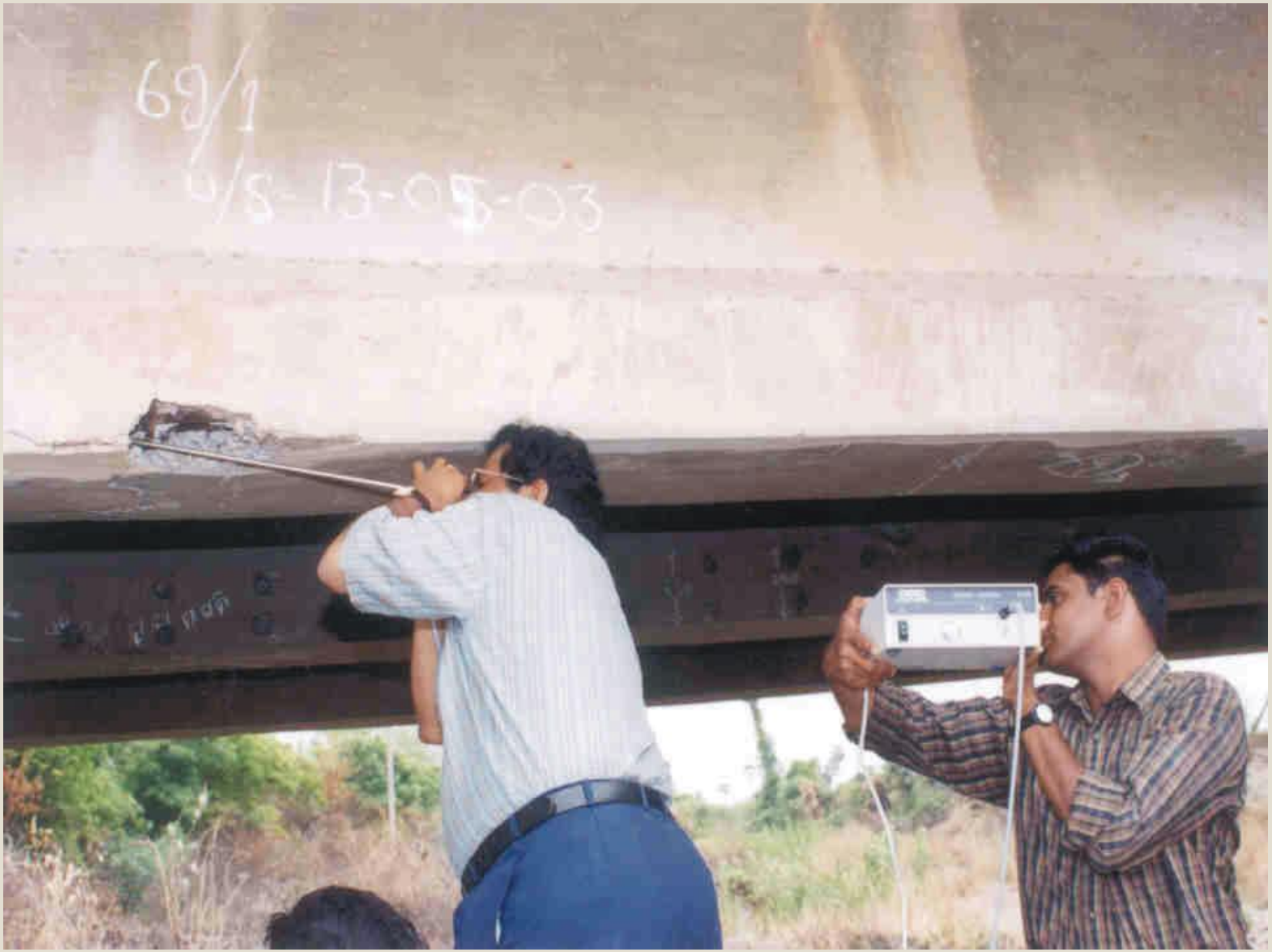


RIGID BORO SCOPE WITH ACCESSORIES

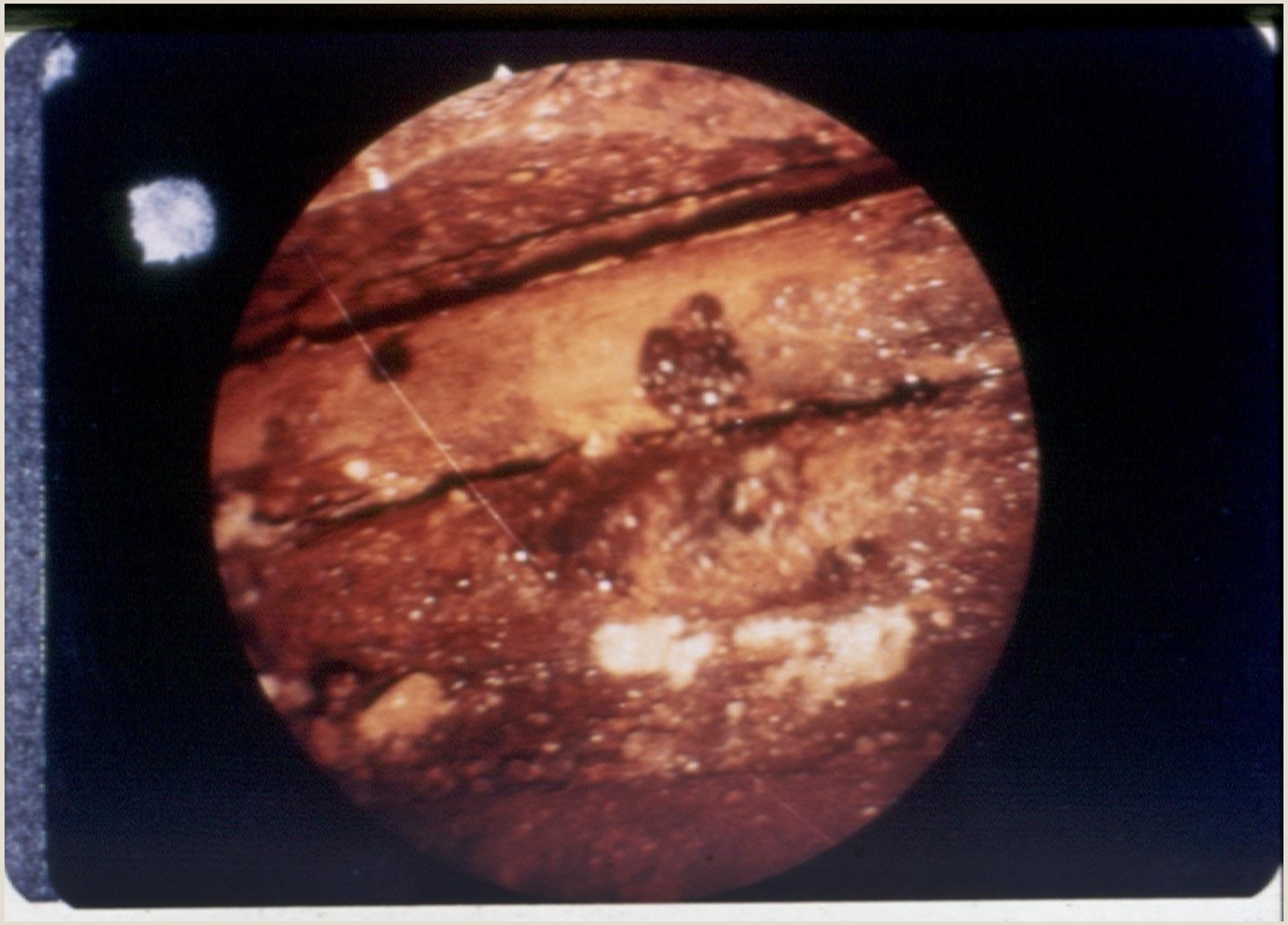
STPL

Sudarshan S. Iyengar

STPL



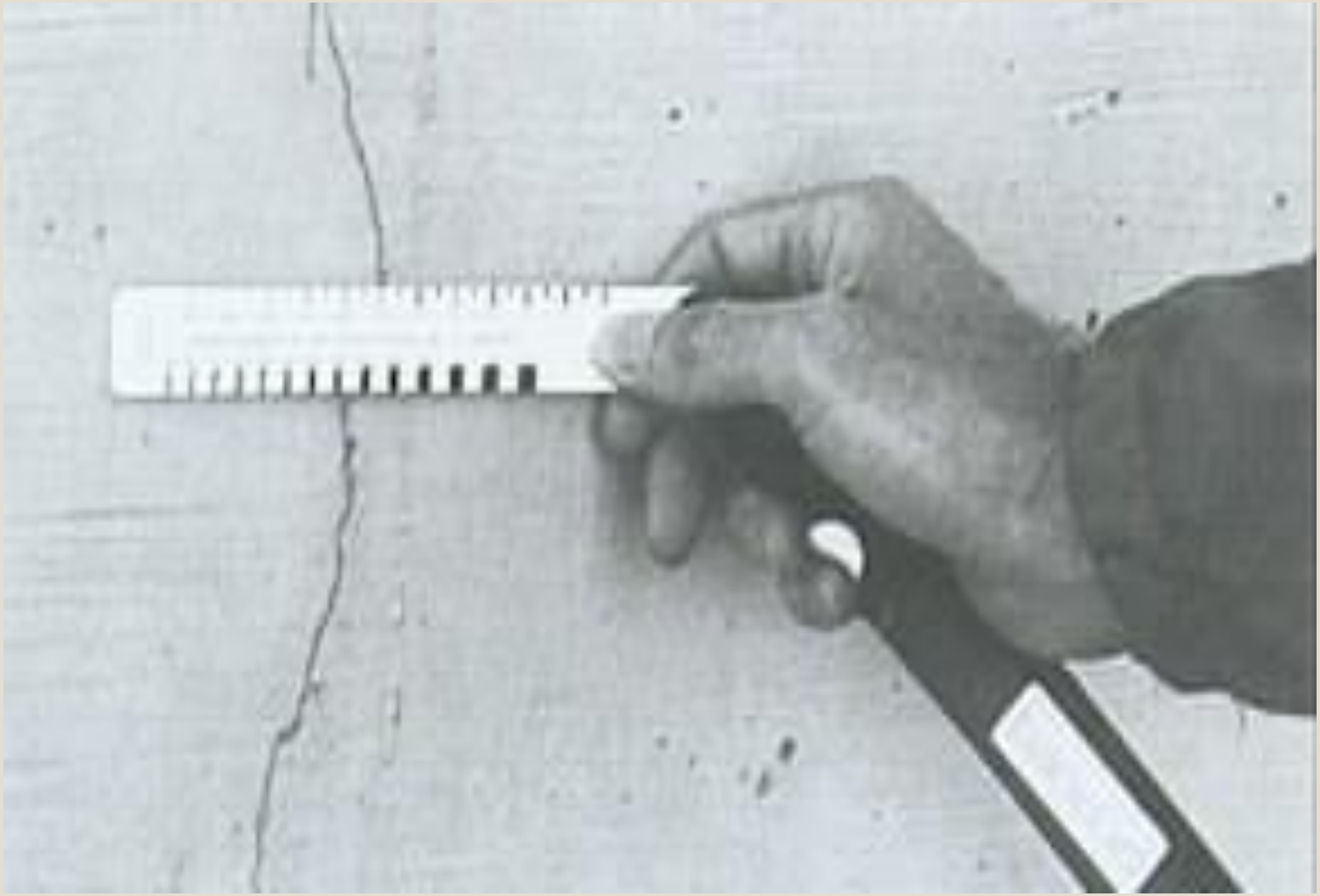
Sudarshan S. Iyengar



View showing heavy corrosion and surface scaling of wires. Also part of grout is seen

Sudarshan S. Iyengar

Crack Measuring Devices



Graduated crack measuring scale

Sudarshan S. Iyengar

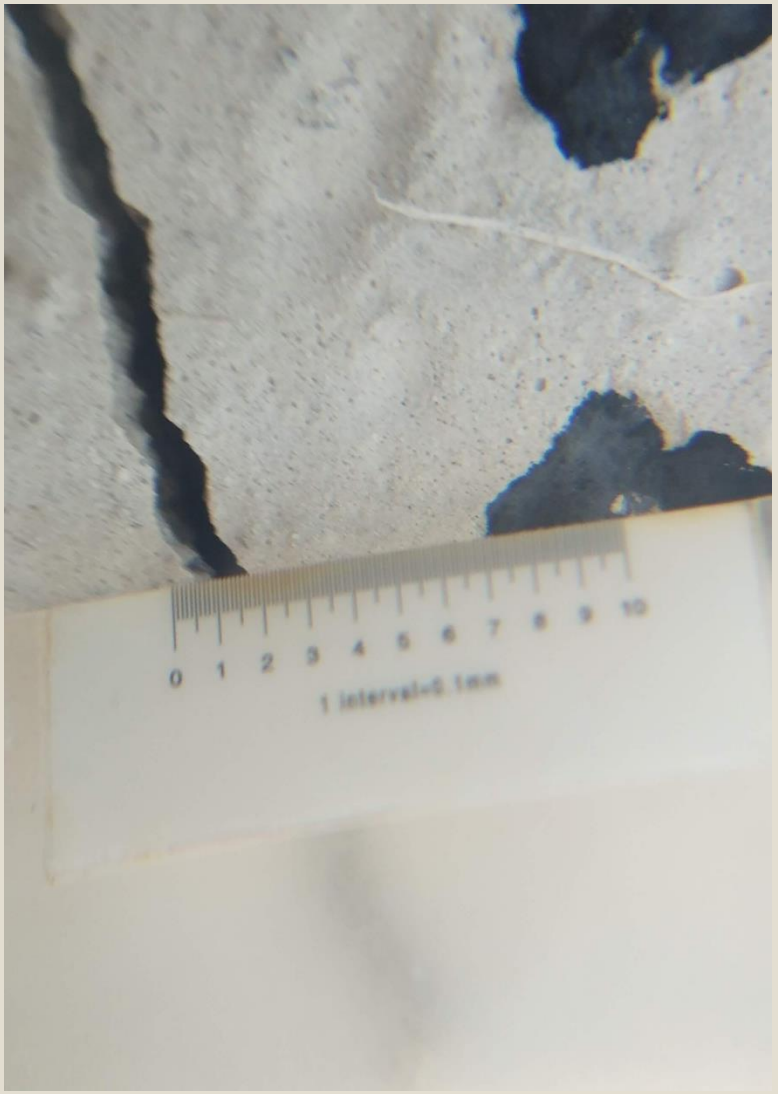
Principle

STPL

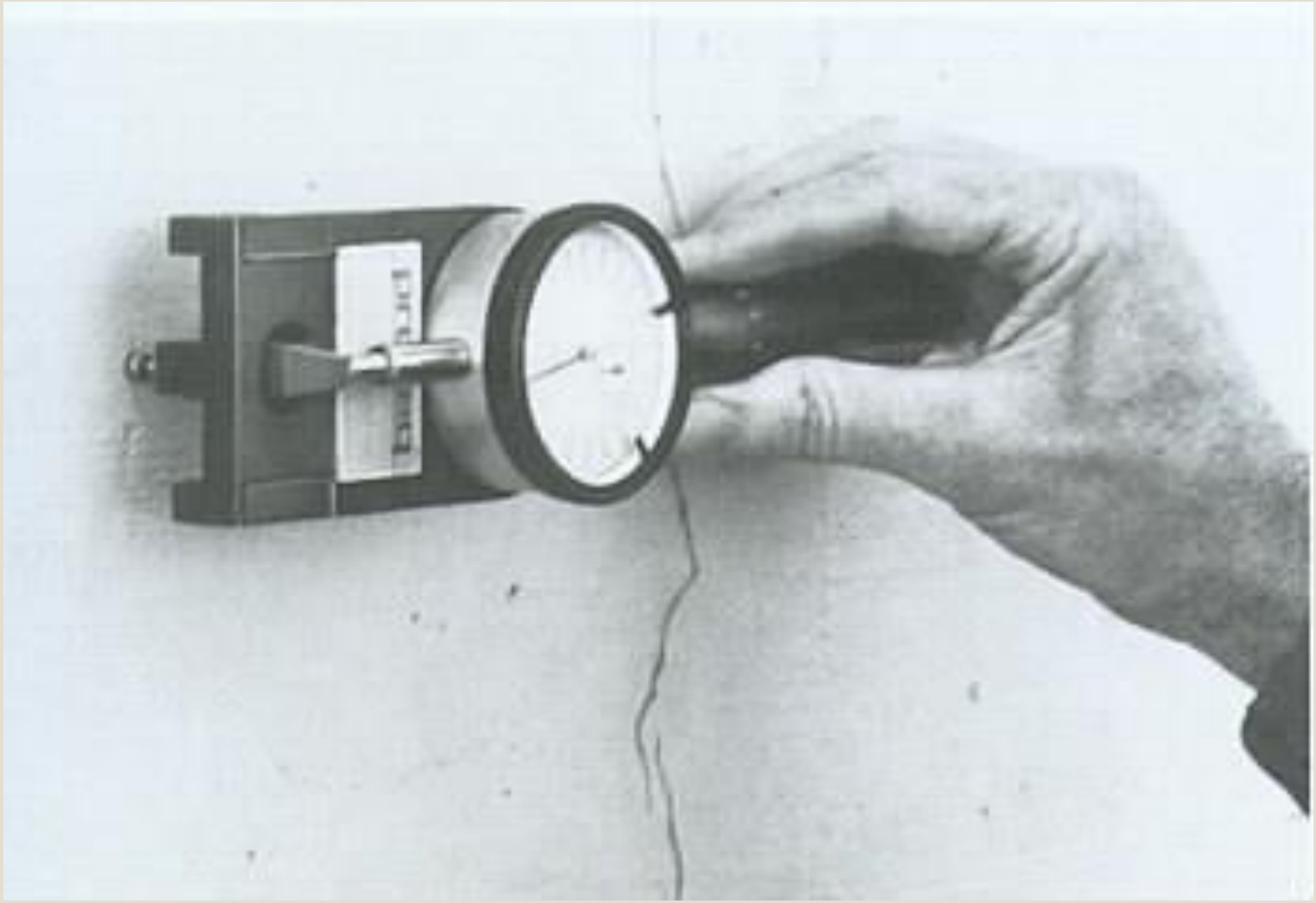
The cracks being measured most precisely using appropriate measuring devices viz., graduated scale, Demac gauge, graduated built in scale with magnifying lens with light source etc.

The accuracy of such instrument is in order of ± 0.0025 mm with a least division of 0.05 mm and magnification not less than 25 times. The width of the crack is one of the criteria for accepting or otherwise of the structural members for the service intended.

STPL

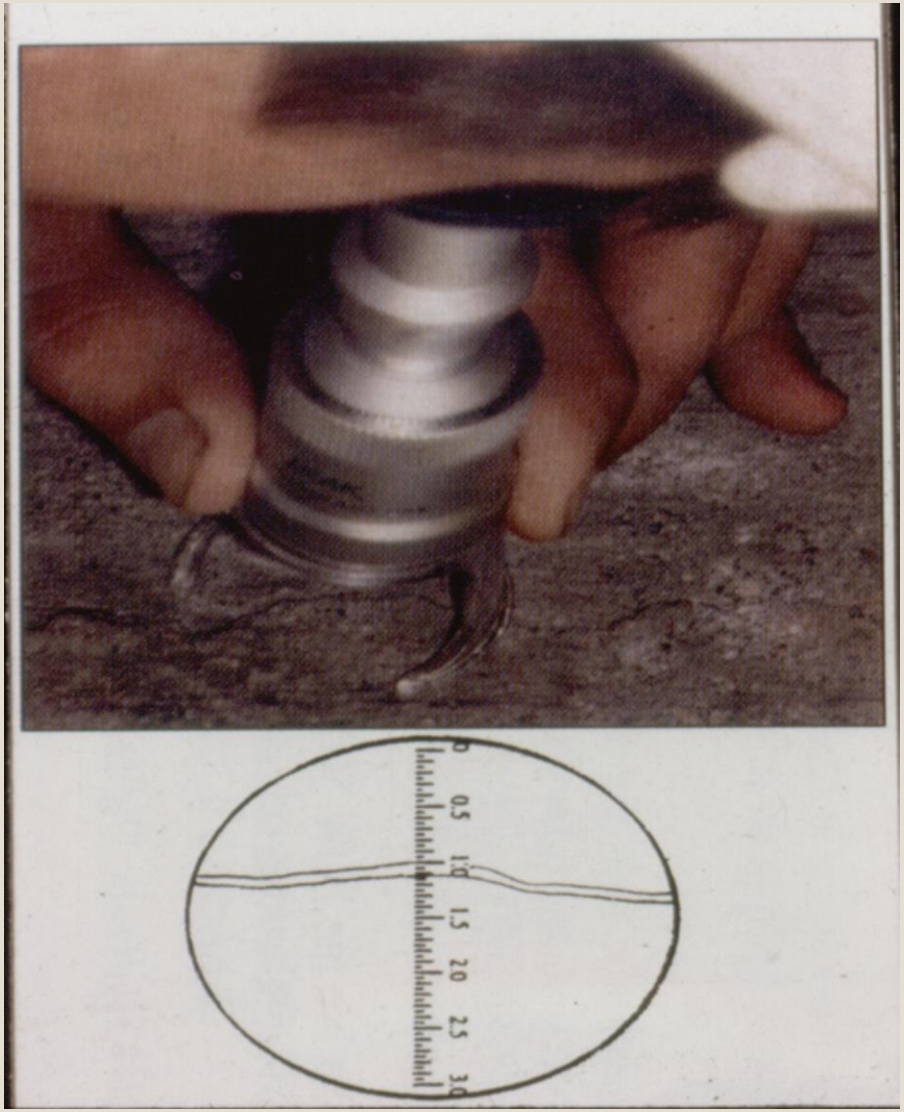


Sudarshan S. Iyengar



Demec Gauge

Sudarshan S. Iyengar



View of measured crack width

Sudarshan S. Iyengar

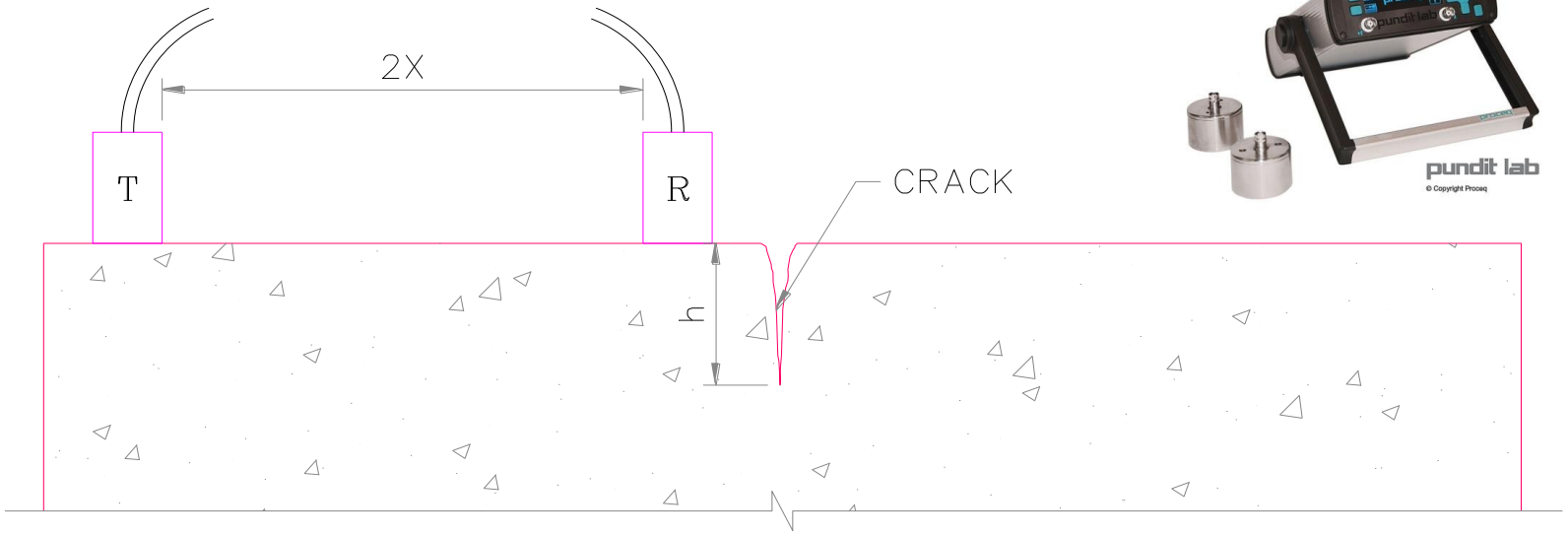
STPL

Sudarshan S. Iyengar

ESTIMATION OF CRACK DEPTH

STPL

Method of calculation



h = depth of crack

STEP – 1

T – TRANSDUCER
R – RECEIVER

Example:

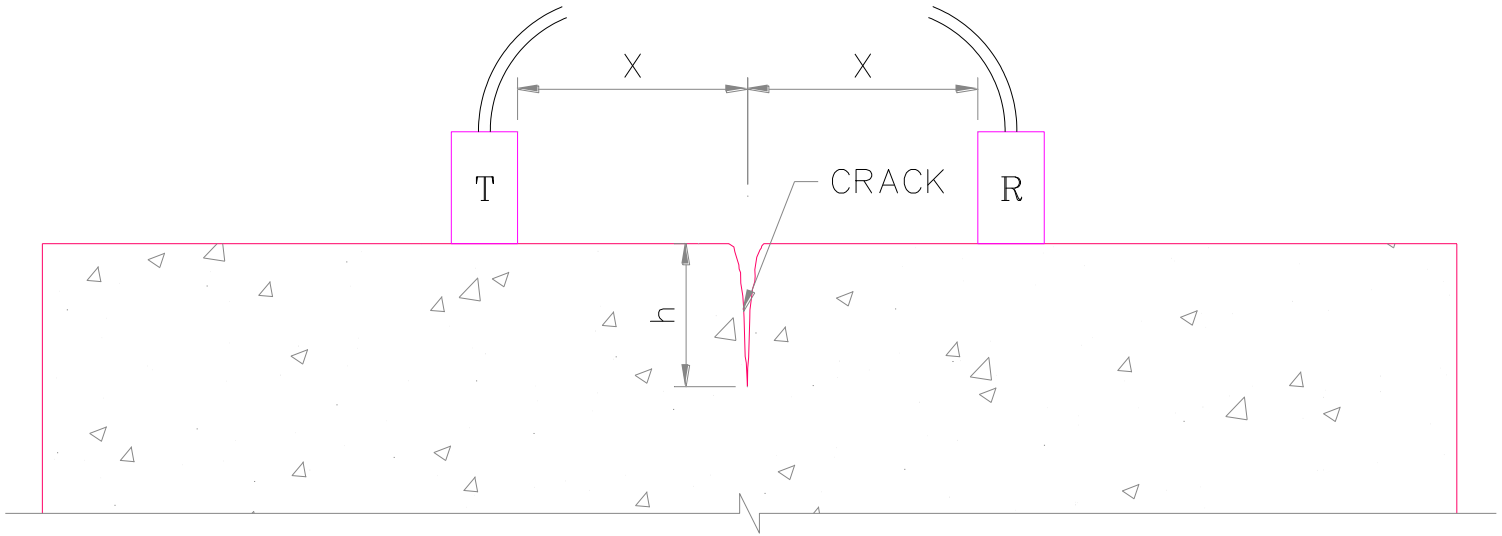
Path length (2x) = 200 mm (away from the crack)

Pulse velocity (Ts) = 45 micro sec.

Sudarshan S. Iyengar

ESTIMATION OF CRACK DEPTH (Contd/...)

Method of calculation



h = depth of crack

Example (Contd/…)

Path length (2x) **= 200 mm (across the crack)**

Pulse velocity (Tc) **= 60 micro sec.**

ESTIMATION OF CRACK DEPTH (Contd/...)

STPL

Method of calculation:

Formula

$$h = x \sqrt{(Tc^2 / Ts^2 - 1)}$$

h = crack depth

x = path length upto crack (i.e., 2x / 2)

Tc^2 = Velocity of pulse around the crack

Ts^2 = Velocity of pulse away from the crack

ESTIMATION OF CRACK DEPTH (Contd/...)

$$h = 100 \sqrt{(60^2 / 45^2 - 1)}$$

$$h = 100 \sqrt{(3600 / 2025 - 1)}$$

$$h = 100 \sqrt{(1.77 - 1)}$$

$$h = 100 \sqrt{0.778}$$

$$h = 100 \times 0.88$$

$$h = 88$$

Estimated depth of crack = 88 mm

Sudarshan S. Iyengar

Infrared Thermography

STPL

Flir Infrared Camera

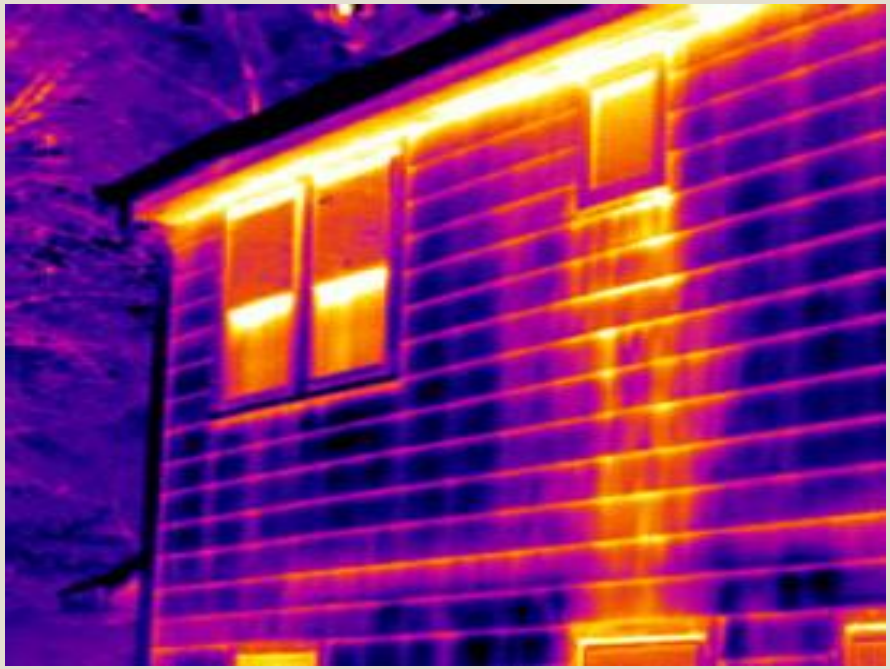
Sudarshan S. Iyengar

Principle

STPL

Thermography uses temperature sensors to detect temperature difference on the surface of concrete, which may be due to defects such as voids, areas of de-lamination or poor compaction. In thermographic surveys the sun is often used as the heat source. Thermography employs scanner similar to still or video cameras but which respond to infra red rather than visible radiation. Output can be to a T V monitor with different colours assigned to temperature ranges or data can be captured on computer.

STPL



Sudarshan S. Iyengar

Cross Hole Sonic Logging Test

STPL

Sudarshan S. Iyengar

Principle

The CSL method is considered to be more accurate for the determination of structural soundness of concrete within the drilled shaft inside of the rebar cage.

Also known as Cross hole Acoustical Testing, CSL normally requires steel (preferred) or HDPE access tubes installed in the drilled shaft and tied to the rebar cage. Before the rebar cage is placed in the hole, the CSL access tubes are attached to the interior of the rebar cage.

Contd/...

Principle (Contd/...)

STPL

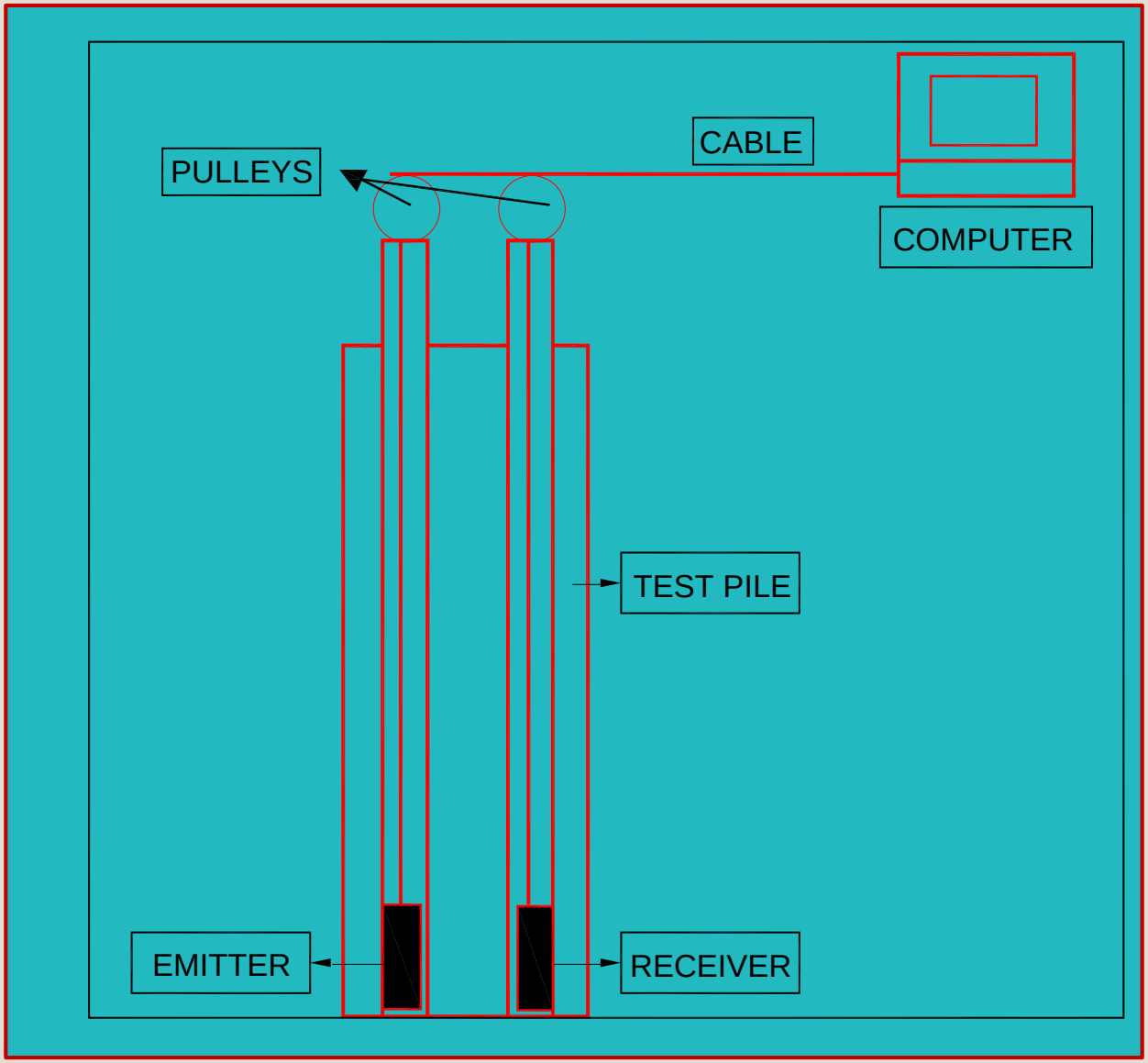
After concreting and curing period is over, the tubes are filled with water as an intermediate medium. Sound source and receiver sensor are lowered into the tube, maintaining a consistent elevation between source and sensor.

A signal generator generates a sonic pulse from the emitter which is recorded by the sensor. Relative energy, waveform and differential time are recorded, and logged.

Contd/...

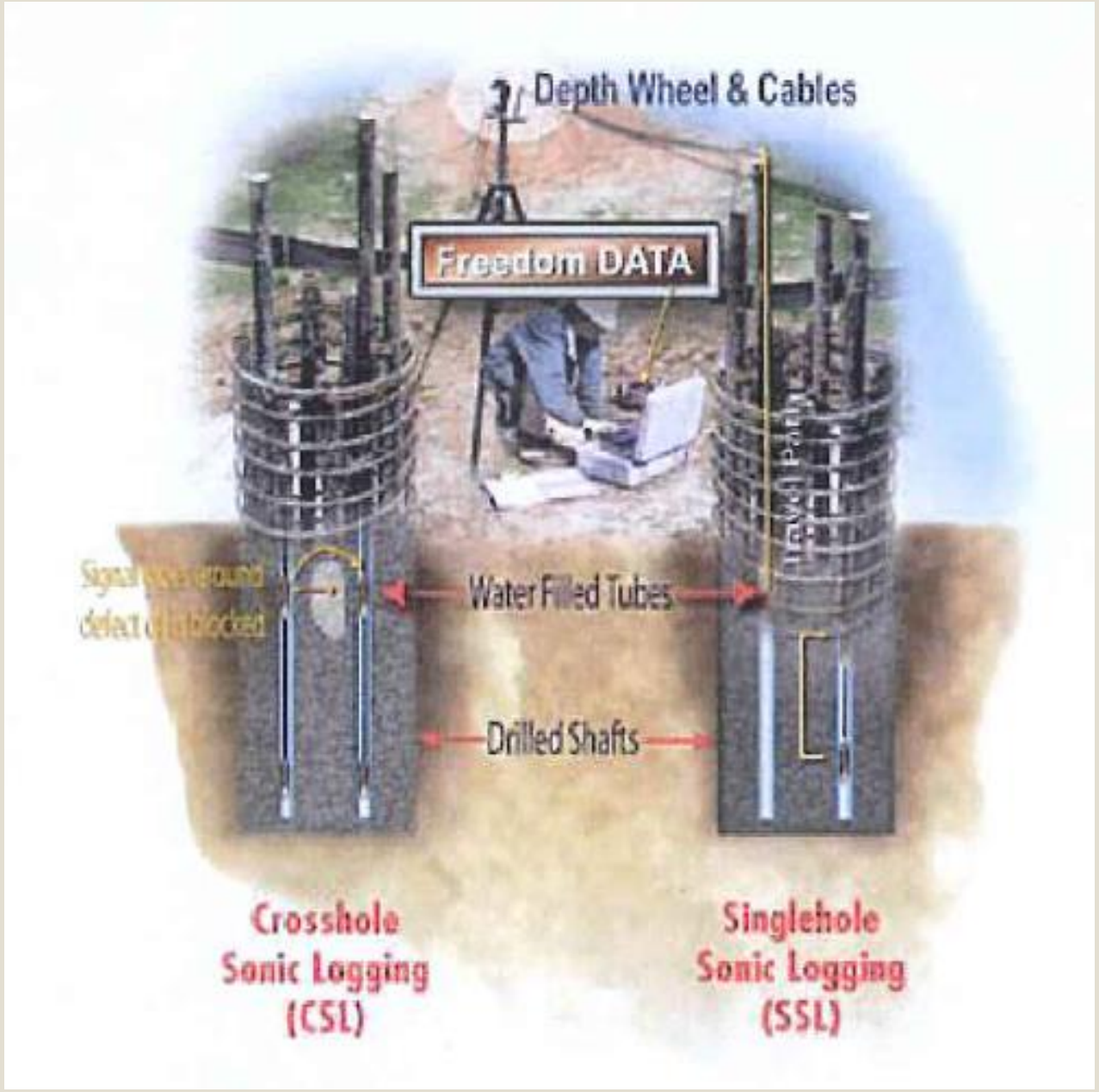
Principle (Contd/...)

This procedure is repeated at regular intervals throughout the pile and then mapped. By comparing the graphs from the various combinations of access tubes, a qualitative idea of the structural soundness of the concrete throughout the pile can be obtained.



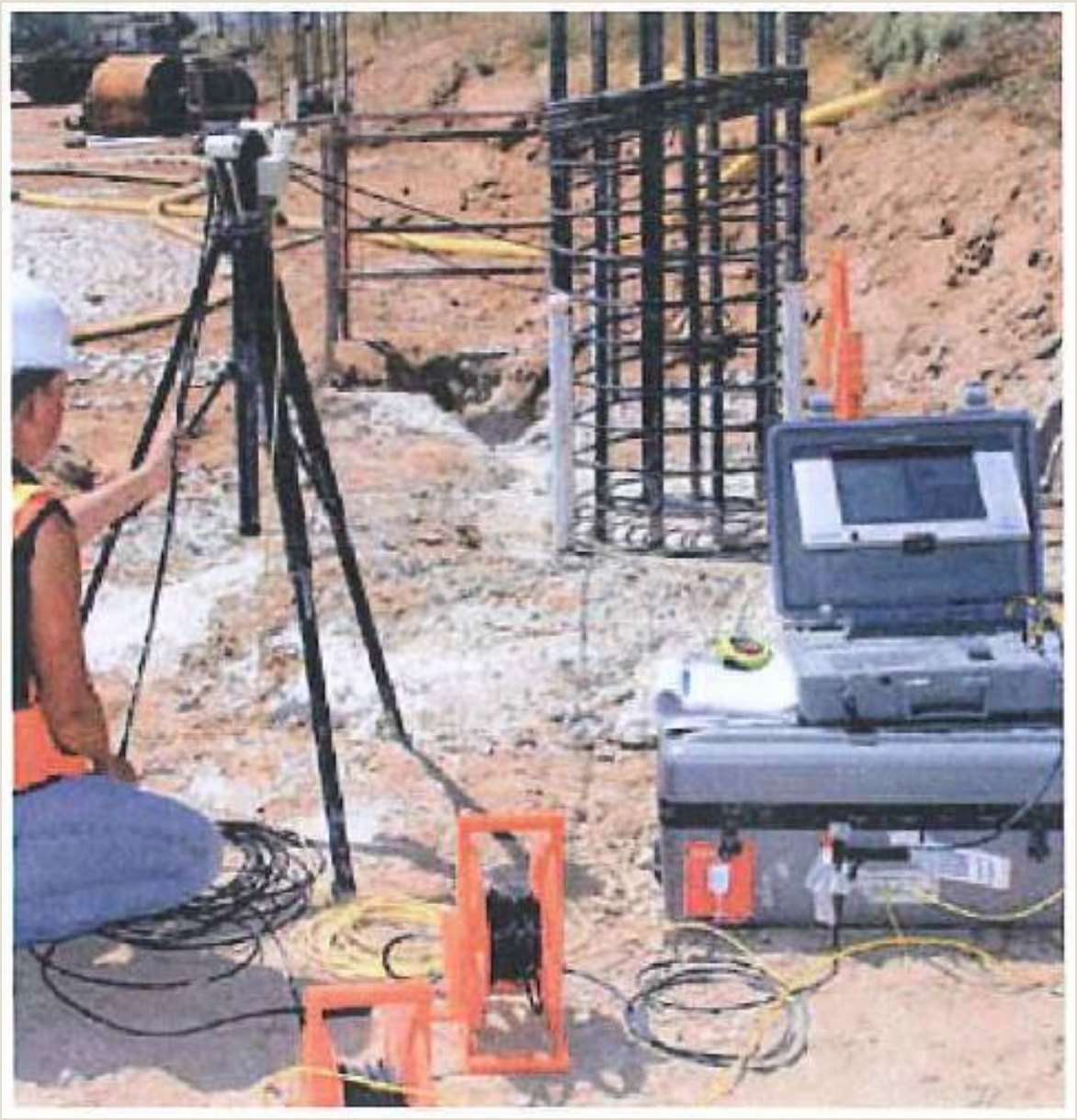
Schematic diagram of Cross Hole Sonic logging test

Sudarshan S. Iyengar



STPL

Sudarshan S. Iyengar



Sudarshan S. Iyengar

Pile Integrity Test

STPL

Sudarshan S. Iyengar

Principle

The Pile Integrity Test is meant for testing pile to determine the discontinuities in pile shaft if any, defects in the pile shaft such as major cracks, change in cross sectional area such as necking and bulging of pile shaft and soundness of pile concrete.

Also, from a given wave speed of concrete the length of the pile can be estimated.

The test provides no information regarding the load carrying capacity of pile.

Pile Integrity test

Sudarshan S. Iyengar

Pile Driving Analyzer

STPL

Pile Driving Analyser

Sudarshan S. Iyengar

Principle

The basic purpose of high strain dynamic pile testing is to evaluate safe pile load and its structural integrity using measurement of both force and velocity.

Strain induced under the impact of a heavy falling hammer from a pre-determined height are measured with the help of strain transducers attached to the pile, whereas accelerometers record the accelerations generated in the pile.

Contd/...

Principle (Contd/...)

When a hammer or drop weight strikes the top of a foundation, a compressive stress wave travels down its shaft at a speed, which is a function of the elastic modulus and mass density.

Contd/...

Principle (Contd/...)

STPL

The impact induces a force and a particle velocity at the top of the foundation. The force is computed by multiplying the measured signals from a pair of strain transducers attached near the top of the pile by the pile area and modulus. The velocity measurement is obtained by integrating signals from a pair of accelerometers also attached near the top of the pile.

Principle (Contd/...)

Strain transducers and accelerometers transmit data to a high strain dynamic testing system such as the Pile Driving Analyzer (PDA) for signal processing and results.

Set up for Pile Dynamic Analyzer

Sudarshan S. Iyengar

STPL

Pile Dynamic Test in progress

Sudarshan S. Iyengar

STPL

SEMI-DESTRUCTIVE TESTS

Sudarshan S. Iyengar

Windsor Probe Test

Windsor probe

Sudarshan S. Iyengar

STPL

Steel pins with gun

Sudarshan S. Iyengar

STPL

Principle

In this type of Semi-Destructive test, a standard steel pin is driven into the surface of concrete with a special tool (gun) operated by spring charge. The depth of penetration is measured.

Since the depth of penetration is inversely proportional to compressive strength, the device provides a fast and safe way of determining the strength of concrete.

The device can also be used for testing of mortar in masonry joints.

CAPO TEST

PULL MACHINE

TEST kit

Consists of:

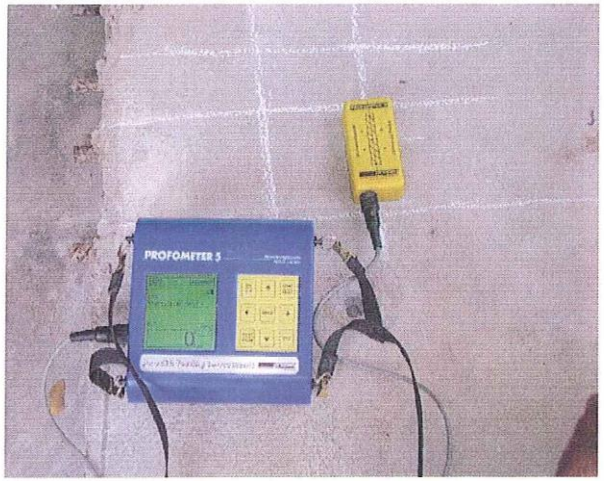
- **Standard Pull machine, Bourdon Gauge, 0-60 kN, 0.6% accuracy**
- **Calibration table in MPa or PSI**
- **Accessories and tools**
- **Carrying case**

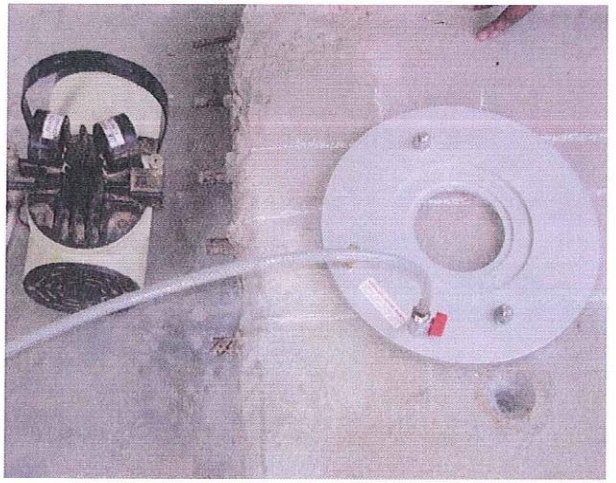
Sudarshan S. Iyengar

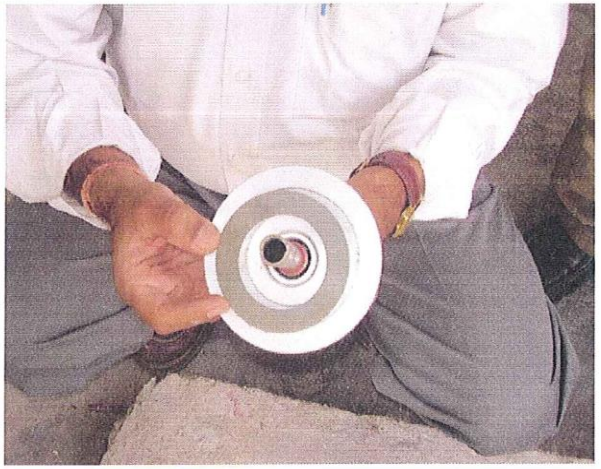
Principle

In this type of Semi-Destructive test, appropriate dia and depth of hole are made using a special tool. The specially designed tool with enlarged mouth will be driven into the hole and thoroughly fastened. Then the insert will be pulled off with hydraulic system. The required force to pull the inserts along with concrete is measured and correlated with calibration chart furnished by the manufacturer for the test equipment for assessment of strength of concrete.

STAGES OF CAPO TEST

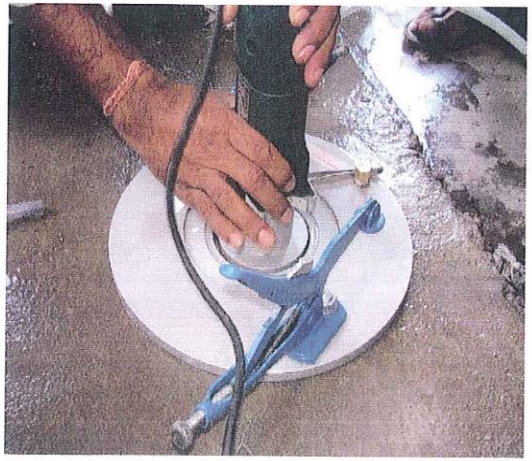


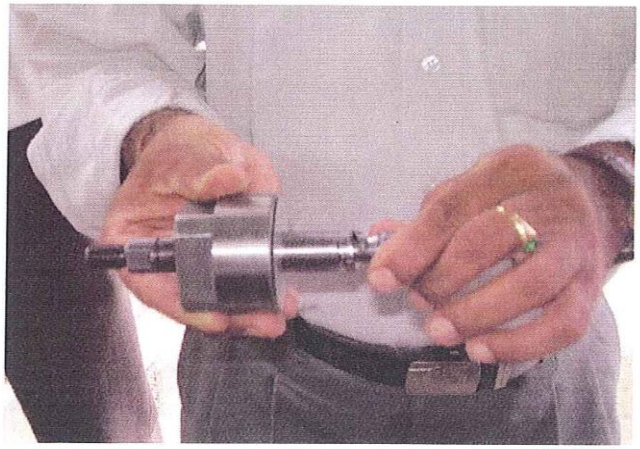


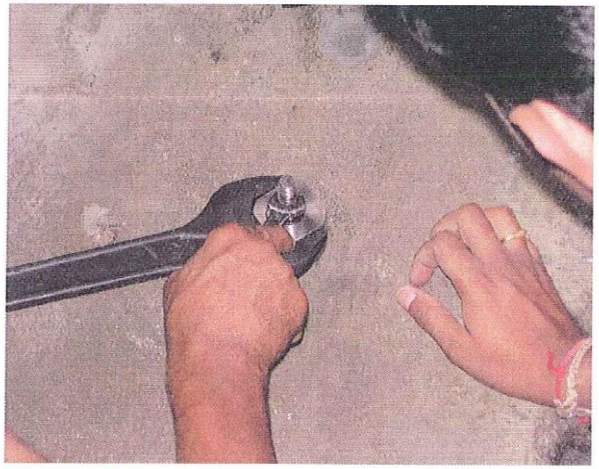


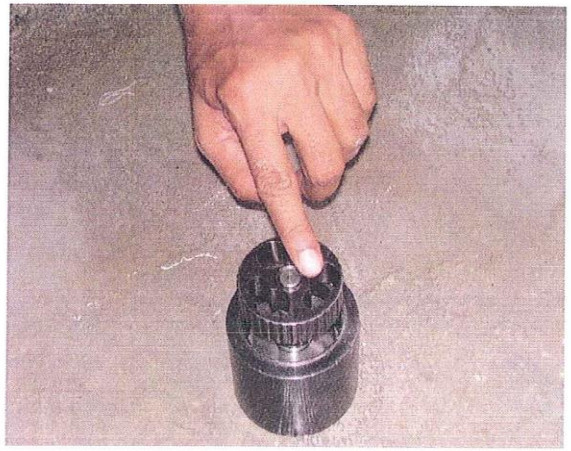
Sudarshan S. Iyengar

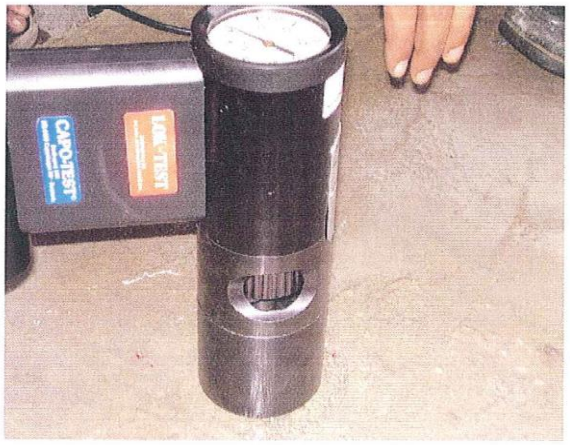
STAGES OF CAPO TEST (Contd/…)



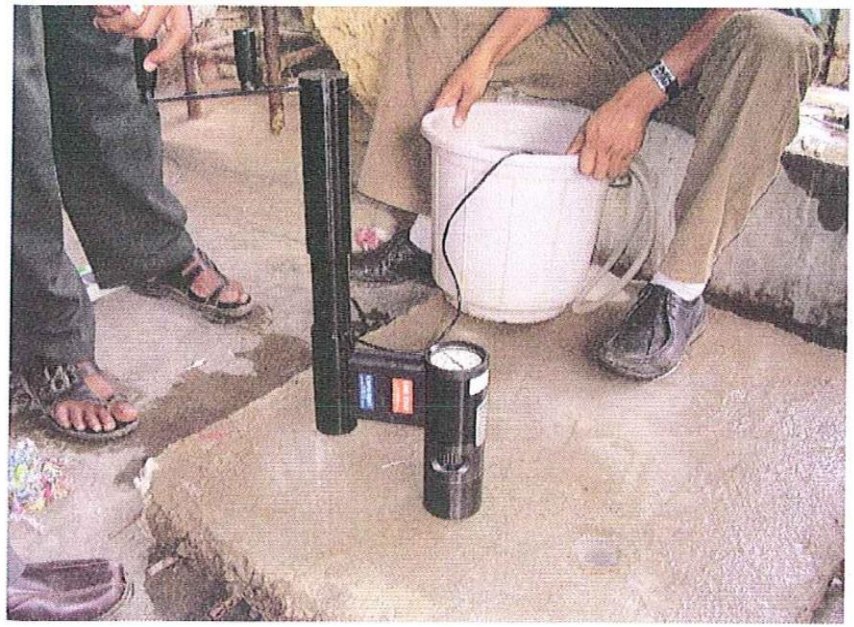






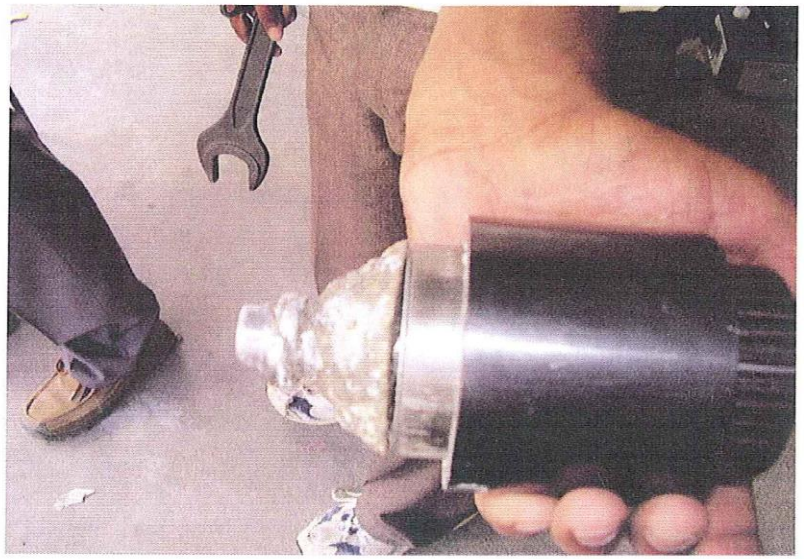


Sudarshan S. Iyengar



PULLING OF INSERTS THROUGH HYDRAULIC SYSTEM

CONE FAILURE OF CONCRETE

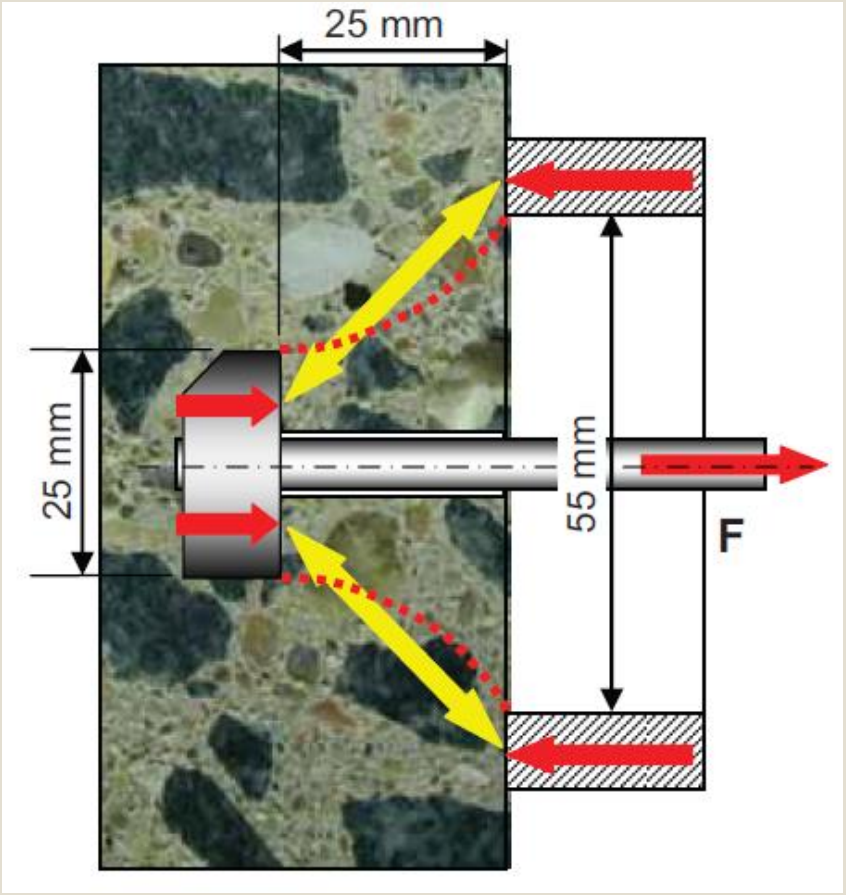


LOK TEST EQUIPMENT

STPL

Lok Test / Pull-off Test

Sudarshan S. Iyengar



STPL

Inserts

Sudarshan S. Iyengar

STPL

Principle

Pull out test is also known as lok test. A specially shaped steel insert with enlarged end will be cast while concreting at the proposed test location.

The extended end of the steel insert above concrete is pulled through a pulling device and insert is pulled out with a cone of concrete.

The force required to pull the insert is measured.

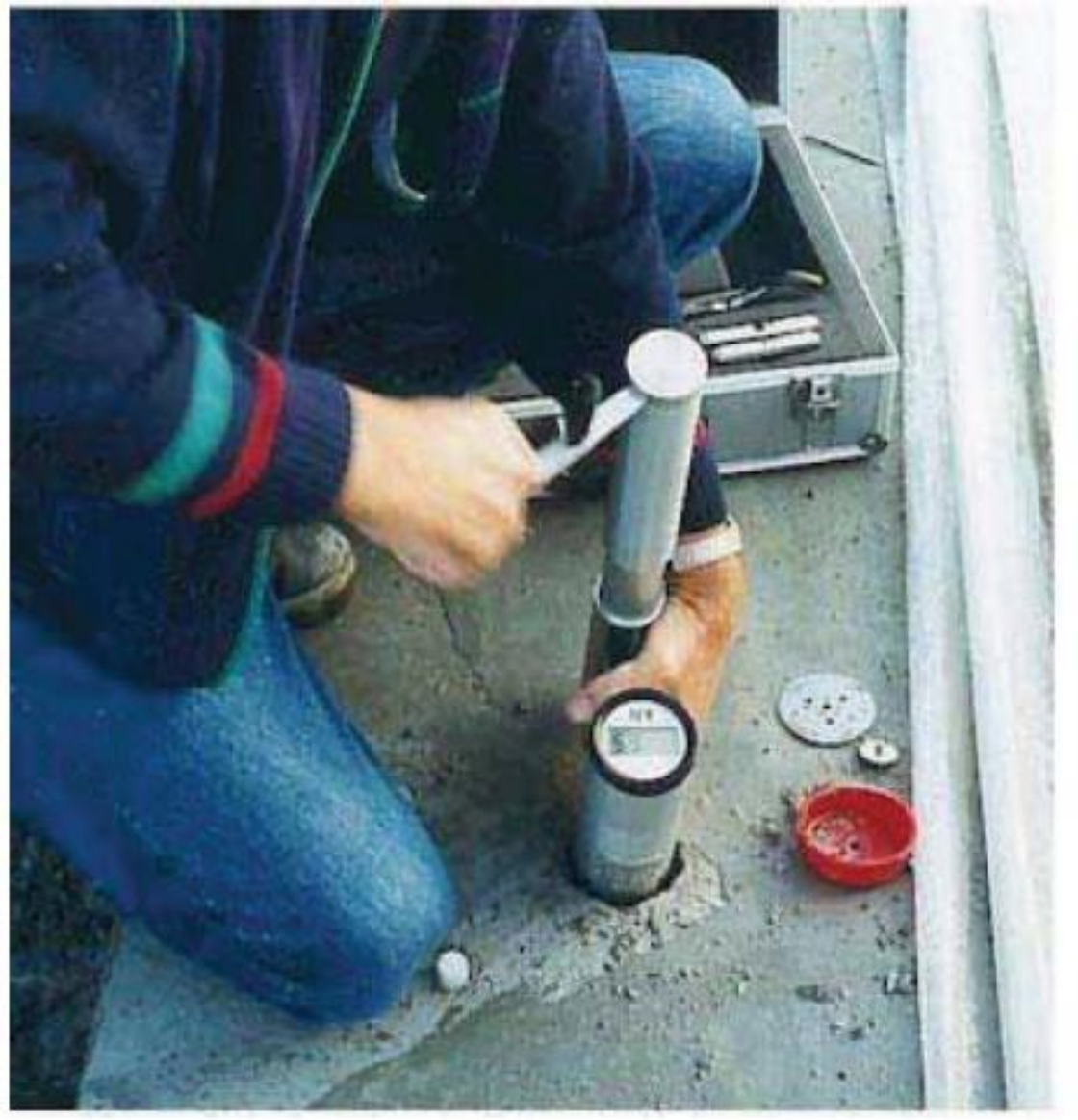
(Contd/...)

Principle (Contd/...)

An appropriate calibration chart shall be established in the laboratory to correlate the pull out force with estimated compressive strength of concrete.

Most popular equipment used for the above test is pull out tester from German equipments.

The equipment consists of specially designed inserts, pulling device with a load indicator.



Pulling device

Sudarshan S. Iyengar

CORE TEST

CORE DRILLING EQUIPMENT'S

STPL

Sudarshan S. Iyengar

Principle

Cores test is one of the most appropriate method to assess the strength, homogeneity and quality of interior concrete.

Electrically driven motor provided with diamond / TC segment core bit are generally used for extraction of cores.

The maximum size of coarse aggregate used in concrete decides the criteria for selecting the dia of core to be extracted. Core will be extracted after scanning the concrete surface for avoiding existing rebars interference during core extraction.

Contd/...

Principle (Contd/...)

STPL

The both ends of the extracted cores will be trimmed and capped with sulpher / high strength free flow grout or epoxy to ensure the ends are even and horizontal.

After ensuring the strength of capped material, the core shall be subjected to compressive strength test in a testing machine.

Core test is the most acceptable method especially when there is dispute regarding strength of concrete. Core test results are also used for calibrating other NDT equipments.

STPL

Extraction of core sample from RC Column

Sudarshan S. Iyengar


Concerete Core Extraction

Capping of core specimen by high strength grout

STPL

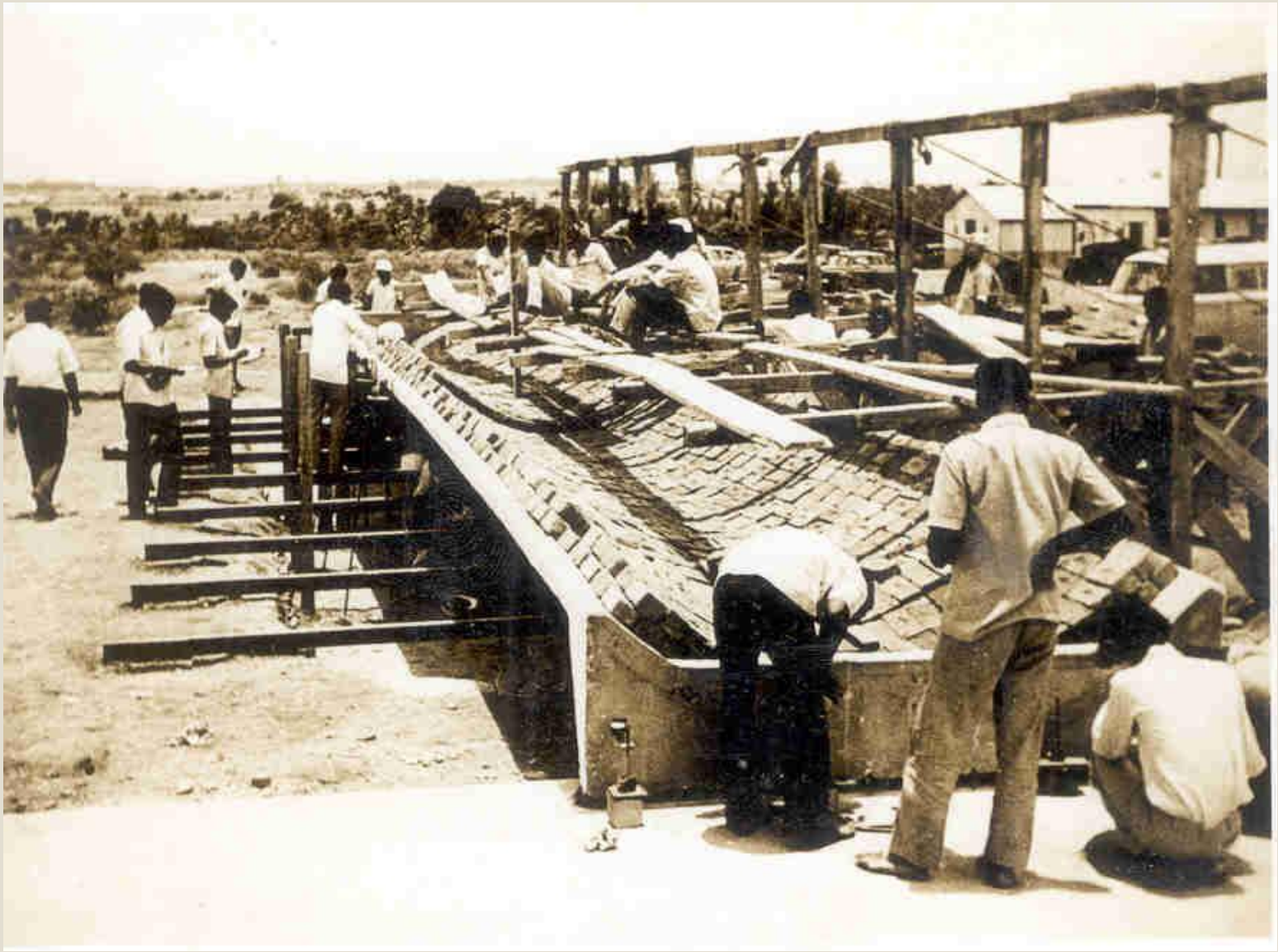
Close-up view of core specimen under test

Sudarshan S. Iyengar

STPL

DESTRUCTIVE TESTING

Sudarshan S. Iyengar



Full scale load test on parabolic shell roof element

Sudarshan S. Iyengar

View of failure of parabolic shell roof element during load test

STPL

Sudarshan S. Iyengar

STPL

PERFORMANCE

LOAD TEST

Sudarshan S. Iyengar

Principle

STPL

If the NDT and SDT results fail to give satisfactory information regarding the strength and quality, then load test will be conducted and it is most acceptable method of test for flexural members only.

The structure is subjected to load equal to full dead load of structure plus 1.25 times the imposed load for a period of 24 hours and imposed load shall be removed. The deflection due to imposed loading shall be recorded and recovery of deflection is calculated.

(Contd/...)

Principle (Contd/...)

Recovery of deflection is a measure of the acceptability of the structure as per approved standards.

Deflectometer and LVDT

Sudarshan S. Iyengar

Test load on steel stair case

Sudarshan S. Iyengar

STPL

Deflection indicating device

Sudarshan S. Iyengar

Load test on PSC box girder

STPL

Sudarshan S. Iyengar

STPL

View of flyover

Sudarshan S. Iyengar

VIEW of tyre print marking on carriage way for carrying out load test

Sudarshan S. Iyengar

STPL

Position of axle for application of test load

Sudarshan S. Iyengar

STPL

Total test load on deck

Sudarshan S. Iyengar

Load test on Slab – Water loading

STPL

Sudarshan S. Iyengar

STPL

Load test on drive way

Sudarshan S. Iyengar

STPL

Load test on Drive way (In elevation)

Sudarshan S. Iyengar

STPL

Arrangements for measurement of deflection of girders

Sudarshan S. Iyengar

Loading in progress

Sudarshan S. Iyengar

View of after completion of test load

STPL

Sudarshan S. Iyengar

STPL

Load test on temporary staging provided for Maha Mastakabhisheka

Sudarshan S. Iyengar

Load test on sitting platform for the designed load

Sudarshan S. Iyengar

Hydraulic jacks were fitted to the MS stools

Sudarshan S. Iyengar

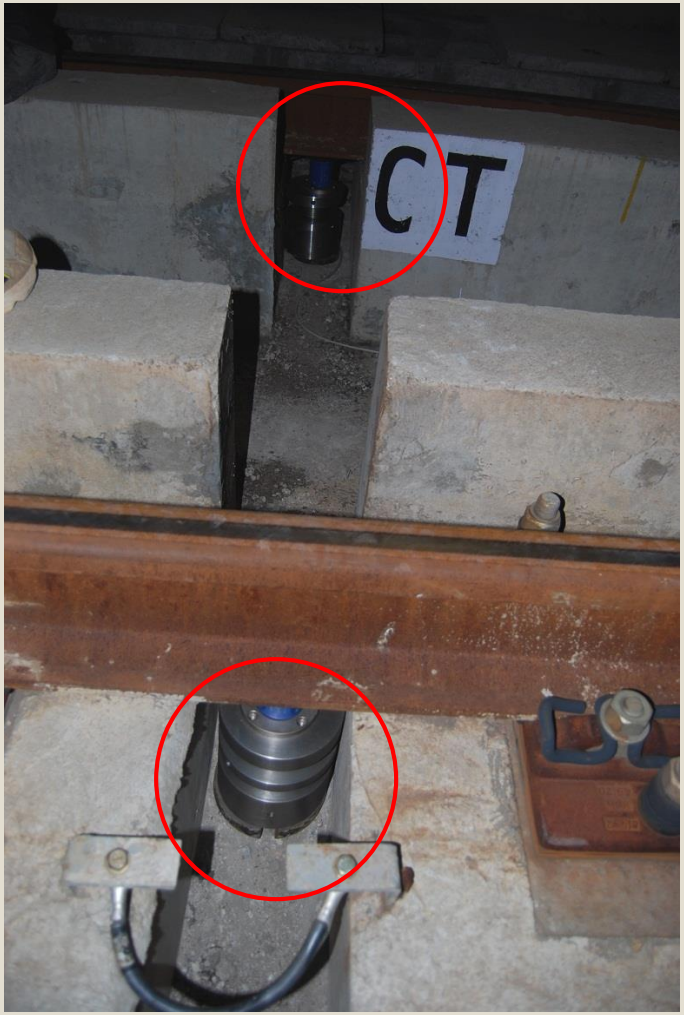
View of set up prior to commencement of load test

Sudarshan S. Iyengar

STPL

Load test on Viaduct of BMRCL

Sudarshan S. Iyengar



Placement of load cell below rails to measure the Axle load while moving of train (Single Track)

Sudarshan S. Iyengar

Placement of load cell below rails to measure the Axle load while moving of train (both the Track)

Sudarshan S. Iyengar

STPL

Load measuring device

Sudarshan S. Iyengar

STPL

Arrangements of plate load test on grade slab

Sudarshan S. Iyengar

STPL

SPECIAL TEST

Sudarshan S. Iyengar

STPL

Bond or Adhesion Test

Sudarshan S. Iyengar

STPL

Principle

To assess the bond /adhesion strength of Mortar on concrete surface / Tiles on mortar /various protective coating on concrete/mortar surface will be assessed by conducting bonding /adhesion test using Dyna Pull-Off tester from M/s. Proceq, Switzerland.

Methodology

STPL

The identified region of mortar /tiles /coating shall be separated from the surrounding area using 50 mm dia core cutting equipment, to achieve defined circular surface. The test dolly of pull machine (dyna pull off) shall be fixed / glued to the test surface using quick setting adhesive. After ensuring effective bond with the surface, the dolly/test disc shall be pulled off. The failure load shall be recorded for interpretation of results. To arrive proper conclusion a Minimum of 3 tests shall be carried out.

STPL

50 mm Dia core hole to separating out the surrounding area

Sudarshan S. Iyengar

View of separated surrounding area

STPL

Dyna pull-out test in progress

Sudarshan S. Iyengar

Transverse strength test on PSC pole

Sudarshan S. Iyengar

STPL

Sudarshan S. Iyengar

Pull-out Test on Anchor bolts/ Rebar Anchors embedded in concrete

Sudarshan S. Iyengar

Principle

To check /ensure the behaviour of anchor bolts/ rebar anchors embedded in concrete or in any other media, Pull-out test will be conducted at site

Since, there is no specific instruments for conducting pull-out test was not available, hence, a suitable instrument to design will be used for this purpose. To measure the pull-out force, calibrated load cells of specific capacity will be coupled with the instrument and load will be applied through hydraulic jack.

STPL

Load will be applied till the :

a. desired test load is achieved or pull out of anchor bolt /rebar anchor from the anchoring media.

b. Crushing /cracking of concrete or embedded media in case of anchor bolts

c. failure of bond between rebar anchor and anchoring material.

d. failure of bond between concrete surface and anchoring material

e. failure of rebar anchor or anchor bolts, whichever is occur first.

STPL

Pull-out test on Rebar Anchor

Pull-out test on Anchor bolt

Sudarshan S. Iyengar

STPL

Pull-out test on Anchor system

Sudarshan S. Iyengar

STPL

Pull-out test on Nylon plug and anchor system

Sudarshan S. Iyengar

STPL

Pull-out test on Anchor bolt

Sudarshan S. Iyengar

CHEMICAL KIT FOR TESTING OF WATER AND AGGREGATES

Chemical kit for field test on concrete

Sudarshan S. Iyengar

Failure Analysis of RC Aqueduct by using Non Destructive and Semi Destructive Tests

Sudarshan S. Iyengar

View of trough with r.c stiffeners

STPL

Sudarshan S. Iyengar

Aqueduct in elevation

View of Collapsed Structure

Sudarshan S. Iyengar

STPL

Sudarshan S. Iyengar

STPL

Sudarshan S. Iyengar

- **Inadequate anchoring bars at the interface of pier head with r.c. trough (collapsed region)**

- Absence of dowels at pier head & trough interface

Sudarshan S. Iyengar

- Over lapping of main reinforcement at same region in piers (collapsed region)

- **Insufficient clearance between outer & inner layer of rebars**

Sudarshan S. Iyengar

- **Smooth concrete surface at pier head lift interface**

Sudarshan S. Iyengar

To assess the cause of the failure of Aqueduct, following investigative studies were carried out:

- Soil investigation
- Dimensional verification
- Non-Destructive & Semi-Destructive tests
- Tests on reinforcing steel
- Theoretical verification of original analysis and design

NON-DESTRUCTIVE & SEMI-DESTRUCTIVE TESTS ON R.C.MEMBERS

STPL

To assess the quality and in-situ strength of concrete in r.c. members, following tests were carried out:

1. Rebound Hammer Test
2. Ultrasonic Pulse Velocity Test
3. Cover-meter Test
4. Tests on concrete cores
5. Half-cell Potential Measurement Test

Rebound Hammer Test on partially collapsed pier above ground level

STPL

Sudarshan S. Iyengar

Rebound Hammer Test on partially collapsed pier below ground level

STPL

Sudarshan S. Iyengar

Ultrasonic Pulse Velocity Test on collapsed pier

STPL

Sudarshan S. Iyengar

Ultrasonic Pulse Velocity Test on partially collapsed pier

STPL

Sudarshan S. Iyengar

Ultrasonic Pulse Velocity Test on un-collapsed pier

STPL

Sudarshan S. Iyengar

Ultrasonic Pulse Velocity Test on collapsed pier cap

STPL

Sudarshan S. Iyengar

Mapping of existing rebars in undisturbed pier

Sudarshan S. Iyengar

Mapping of existing rebars in collapsed pier

STPL

Sudarshan S. Iyengar

Half-cell Potential Measurement Test on pier cap

STPL

Sudarshan S. Iyengar

Half-cell Potential Measurement Test on pier collapsed pier

STPL

Sudarshan S. Iyengar

Extraction of core from partially collapsed pier

STPL

Sudarshan S. Iyengar

Extraction of core from trough side wall

Sudarshan S. Iyengar

A perfect tool (UPV) to assess the quality of interior concrete of bridge girders in distress for working out restoration measures

Sudarshan S. Iyengar

View of piers and deck

Sudarshan S. Iyengar

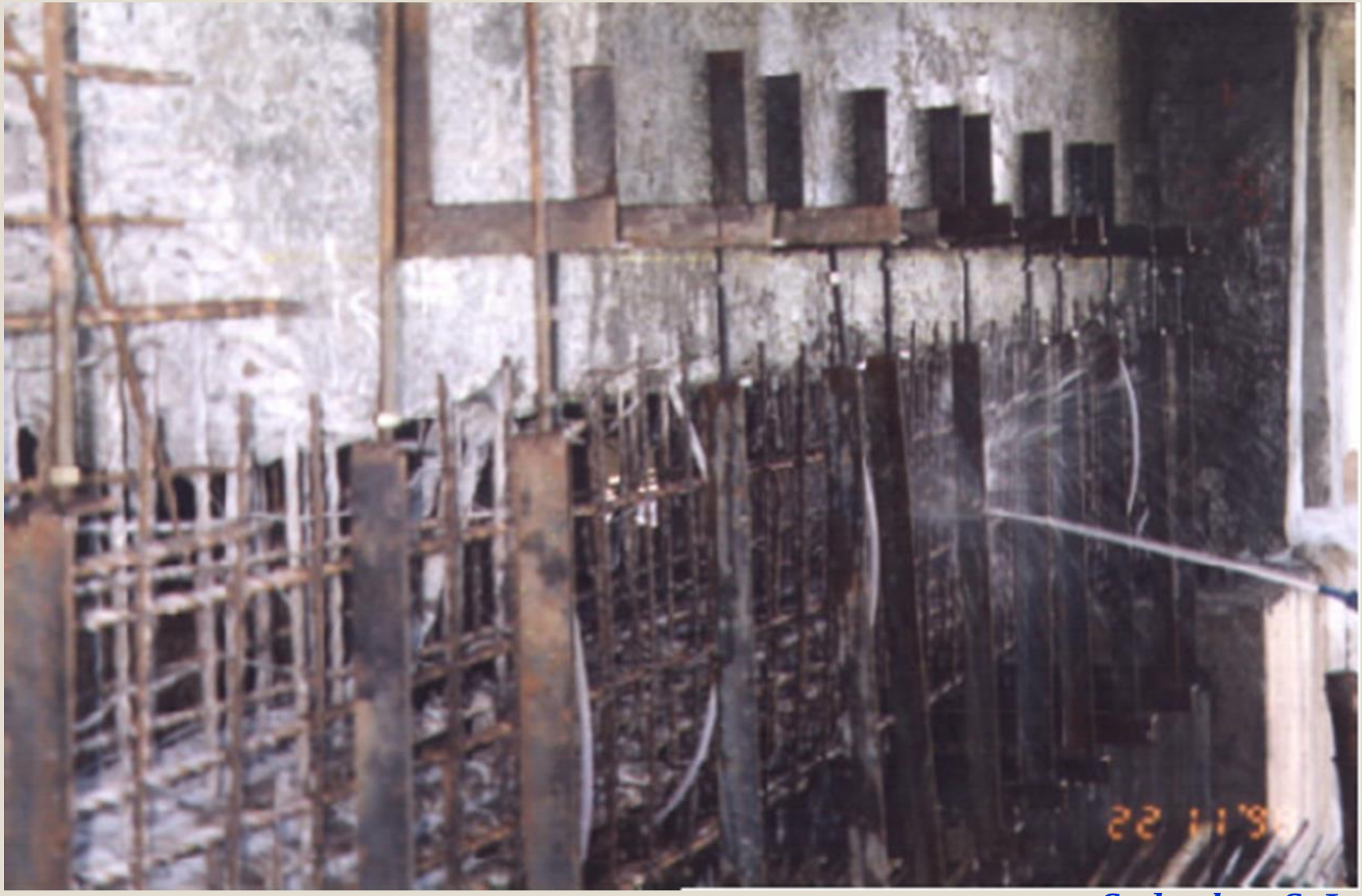
Sudarshan S. Iyengar

Sudarshan S. Iyengar

STPL

Sudarshan S. Iyengar

Sudarshan S. Iyengar



Sudarshan S. Iyengar

STPL

Sudarshan S. Iyengar

STPL

Sudarshan S. Iyengar

Conclusions

All these test results will give very good information about the condition of the structural members. However, the interpretation of the results rests with the experts.

It is very important that, the person who conducts the test should be technically sound and have experience to achieve accurate and reliable results.

ACKNOWLEDGEMENT

- **Torsteel Research Foundation In India (TRFI)**
- **Civil Aid Technoclinic Pvt Ltd (CTPL)**
- **Bureau Veritas India Ltd (BVQ & I)**
- **Stedrant Technoclinic Pvt Ltd (STPL)**
- **Govt, Public and Private sectors.**

THANK YOU

Sudarshan S. Iyengar
Senior Director
Mobile: 9880926063
Email - s.sudarshan@stedrant.com