GUIDEBOOK FOR TESTING OF FRESH AND HARDENED CONCRETE

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1.0 INTRODUCTION

The main purpose of this compilation is to provide a simple and easy-to-understand reference for various fresh and hardened concrete tests commonly used in the construction and in reinforced concrete structural appraisal. The following are thirteen (13) types of test for fresh and hardened concrete.

For each type of test, a brief description is given that covers, the purpose of the test, the equipment required, a step-by-step test procedure, the compliance and a list of references at the end of the description.

(1) Slump Test
(2) Compressive Strength Tests (cubes)
(3) Covermeter Measurement
(4) Compressive Strength Tests (cores)
(5) Rebound Hammer
(6) Ultrasonic Pulse Velocity Test (UPV)
(7) Penetration Resistance Test (Windsor Probe)
(8) Carbonation Test
(9) Half-cell Potential Measurement
(10) Initial Surface Absorption Test (ISAT)
(11) Rapid Chloride Penetrability Test
(12) Water Absorption Test
(13) Sorption Test

2.0 SLUMP TEST

2.1 INTRODUCTION

Concrete slump test (or simply the slump test) is an in-situ test or a laboratory test used to determine and measure workability a given sample of fresh concrete. Slump is a relative measurement in concrete consistency.

2.2 EQUIPMENT

Testing for Slump Test involves a few apparatus as described below and illustrated in **Figure 2.1**:

1) Mixing pan (500mm x 500mm)
2) Slump cone (100mm x 200mm x 300mm)
3) Steel tamping rod (600mm x 16mm)
4) Measuring tape
5) Plasterer"s steel float

Figure 2.1: Slump test apparatus

2.3 PROCEDURE

a) Place the mixing pan on the floor and moisten it with some water. Make sure it is damp but no free water is left and put the slump cone standing on it as shown in **Figure 2.2.**

Figure 2.2: Slump cone and mixing pan

b) Firmly hold the slump cone in place using 2 foot hold as shown in **Figure 2.3**.

Figure 2.3: Hold the slump cone using 2 foot

c) Fill one-third of the cone with the concrete mixture. Then tamp the layer 25 times using the steel rod in a circular motion, making sure not to stir.

d) Add more concrete mixture to the two-third mark. Repeat tamping for 25 times again. Tamp just barely into the previous layer.

e) Fill up the whole cone up to the top with some excess concrete coming out of top, and then repeat tamping 25 times. If there is not enough concrete from tamping compression, stop tamping, add more, the continue tamping at previous number.

f) Remove excess concrete from the opening of the slump cone by using tamping rod in a rolling motion until flat.

g) Slowly and carefully remove the cone by lifting it vertically (5 seconds +/- 2 seconds), making sure that the concrete sample does not move as shown in **Figure 2.4.**

Figure 2.4: Slump cone slowly be removed

h) Wait for the concrete mixture as it slowly slumps.

i) After the concrete stabilizes, measure the slump-height by turning the slump cone upside down next to the sample, placing the tamping rod on

the slump cone and measuring the distance from the rod to the original displaced center as shown in **Figure 2.5**.

Figure 2.5 : Measured to determine slumps

2.4 COMPLIANCE

For slump measurement made in concrete taken from the same sample, the repeatability is 15mm at 95% probability level, which for normal concrete having a measured slump within the range of 50mm to 75mm.

REFERENCES

1) British Standard, BS 1881: Part 102 "*Method for Determination of Slump*". British Standard Institute, 1983.

2) ASTM C 143 or AASHTO T 119 "*Standard Test Method for Slump of Hydraulic-Cement Concrete*".

3.0 COMPRESSIVE STRENGTH TEST (CUBES)

3.1 INTRODUCTION

Compressive cube strength test involves testing of cube specimens prepared according to test standard. The cube is compressed in a compression machine to obtain the compressive strength of the cube, expressed in Newton per millimeter square (N/mm^2). Practically the test is carried out:

- as a means of quality control; and
- to asses concrete strength or grade.

Concrete with Grade 30/20 means the characteristic 28-days cube strength of the concrete is 30 N/mm^2, with 5 percent failure, and the maximum nominal aggregate size is 20mm.

To prepare the cubes, concrete mixture is placed in steel or cast-iron moulds, generally 150 mm cubes. Before the placing of concrete mixture, one coat of release agent (grease) is applied to the inner surface of mould to prevent bonding between concrete and steel mould. Concrete is to fill the mould in three layers, with each layer compacted by a vibrating hammer, or using a vibrating table, or by not less than 35 strokes of a steel punner. After 24 hours in a vibration-free place, the cube is removed and cured under water to the required period until compression test is to be carried out. The cube is subjected to a constant rate of stress increase until failure. The maximum load the cube can sustain is recorded and divided by cross section area of cube to obtain cube compressive strength in Newton per millimeter square (N/mm^2).

3.2 EQUIPMENT

The equipment used for the preparation of cube samples of the fresh concrete are described below, and illustrated in **Figures 3.1** and **3.2**:

1. 150mm (L) x150mm (W) x150mm (H) steel mould
2. Scoop
3. Grease
4. Compacting bar
5. Plasterer‟s steel float
6. Brush – for applying grease to mould
7. Spanner – for tightening cube mould
8. Compression machine

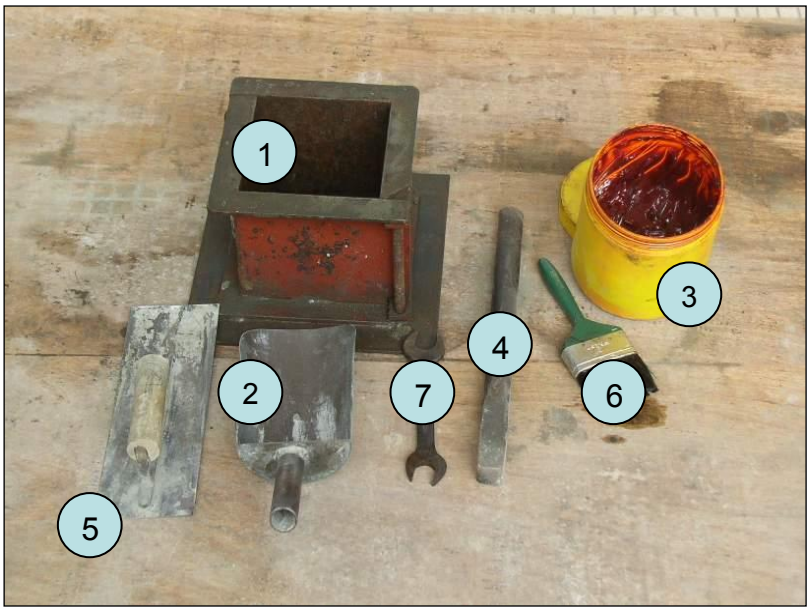

Figure 3.1: Cube compression test apparatus

Figure 3.2: Cube compression test machine

3.3 PROCEDURE

The procedure for preparing cube samples and laboratory testing of the cubes are described in the following sub-sections. The procedures described below assume that the all safety procedures are strictly adhered to.

a) Prepare the sample of fresh concrete in according to MS 26: Part 1: 1991. Cube can be mix manually or with the use of concrete mixer as shown in **Figure 3.3**. Cube should be made as soon as possible after sampling.

Figure 3.3: Preparing fresh concrete mixture

b) After assembling and tightening the mould, apply a thin coat of oil or grease or other release agent to prevent adhesion of the concrete as shown in **Figure 3.4**.

Figure 3.4: Applying grease to internal surfaces of mould

c) By using the scoop, place the concrete in the mould in three (3) layers of approximately 50mm deep each.

d) Using a compacting bar, compact each layer of concrete filled in the mould not less than 35 strokes per layer of concrete, as illustrated in **Figure 3.5**. Compaction should be done in a uniform manner over the cross section of the mould.

Figure 3.5: Compaction of concrete with a compacting bar.

e) After the top layer has been compacted, smooth the top of the mould level with a plasterer‟s float, as shown in **Figure 3.6**.

Figure 3.6: Levelling of mould surface with a plasterer's float

f) De-mould the specimen after storing it in a vibration free place and in condition that prevent loss of moisture for 24 hours. Immediately

submerge the specimen in water at 27±2ºC. **Figure 3.7** illustrates cubes being stored in a water tank.

Figure 3.7: Store the specimen in water

g) Remove the cube from the curing tank and test while it is still wet.

h) Wipe the bearing surfaces of the testing machine and of any auxiliary platens clean and remove any water, loose sand or other material from the ends of the core. Centre the cube carefully on the lower platen of the machine. Wherever possible use a jig to align the specimen. Do not use any packing other than auxiliary steel platens between the ends of the core and the platens of the testing machine.

i) Without shock apply and increase the load continuously at a constant rate within the range of 0.22 N/mm^2.s to 0.4 N/mm^2.s until no greater load can be sustained. **Figure 3.8** illustrates a compression on cube is in progress.

Figure 3.8: Testing for cube compressive strength

j) Record the maximum load.

k) Calculate the compressive strength of cube to the nearest 0.5 N/mm^2, by dividing the maximum load by the cross-sectional area, measured from the cube nominal dimension.

REFERENCES

1) Malaysia Standard, MS 26: Part 2 "*Method for Determination of Compressive Strength of Concrete Cubes"*. Malaysia Standard Institute, 1991.

2) British Standard, BS 1881: Part 108 "*Method for Making Test Cubes From Fresh Concrete"*. British Standards Institute, London, 1983.

3) British Standard, BS 1881: Part 116 "*Method for Determination of Compressive Strength of Concrete Cubes"*. British Standards Institute, London, 1983.

4.0 COVERMETER MEASUREMENT

4.1 INTRODUCTION

A cover meter is an instrument to locate rebar and measure the exact concrete cover. Rebar detectors are less sophisticated devices that can only locate metallic objects below the surface. Due to the cost-effective design, the pulse-induction method is one of the most commonly used solutions and illustrated in **Figure 4.1**. Electromagnetic covermeter can be used for:

a) Quality control, to ensure correct location and cover to reinforcing bars after concrete placement.
b) Investigation of concrete members for which records are not available or need to be checked.
c) Location of reinforcement as a preliminary to some other form of testing in which reinforcement should avoid or its nature to taken account.
d) Location of buried ferromagnetic objects other than reinforcement such as water pipe, steel joist, etc.

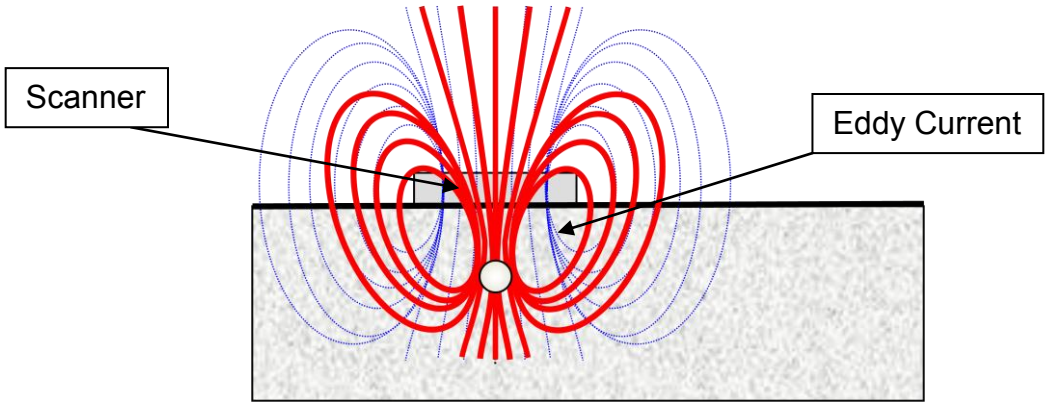

Figure 4.1 : The pulse induction method

The pulse-induction method is based on electromagnetic pulse induction technology to detect rebar. Coils in the probe are periodically charged by current pulses and thus generate a magnetic field. On the surface of any electrically conductive material which is in the magnetic field Eddy current are produced. They induce a magnetic

field in opposite directions. The resulting change in voltage can be utilized for the measurement. Rebars that are closer to the probe or of larger size produce a stronger magnetic field. Modern rebar detectors use different coil arrangement to generate several magnetic fields. Advanced signal processing supports not only the localization of rebars but also the determination of the cover and the estimation of the bar diameter. This method is unaffected by all non conductive materials such as concrete, wood, plastics, bricks etc.

4.2 EQUIPMENT

Apparatus and materials used for electromagnetic covermeter in accordance to BS 1881: Part 204; are described below and shown in **Figure 4.2:**

1) Search head/scanner - to scanned concrete surface
2) Meter - to indicates by analogue or digital means the reinforcement proximity.
3) Interconnecting cable

Figure 4.2: Covermeter probe

4.3 PROCEDURE

a) Calibrated of the covermeter should be carried out to establish the accuracy of the instrument. A basic calibration method is given in BS4408: Part 1 involving a cube of concrete of given proportions with reinforcing bars at specified distances from surface.

b) If different search heads are to be used with the same meter, calibration checks should be carried out for each head.

c) The covermeter is switched on and the meter adjusted so that the needle on the indicator dial corresponds to the appropriate calibration mark as indicated by the manufacturer.

d) The search head is then scanned over the surface of the concrete to be examined for the presence of reinforcement. If reinforcement exists below the surface and within the working range of the covermeter, this will be indicated by the meter and illustrated in **Figure 4.3**.

Figure 4.3: Scanned over the concrete surface

4.4 COMPLIANCE

For electromagnetic covermeter, there are limitations for using this method such as:

a) It is very slow and labour intensive.

b) The results are affected by the presence of more than one reinforcing bar in the test area, by laps, by second layers, by metal tie wires and by bar supports.

c) For maximum accuracy it has to be calibrated for concrete used in the structure to eliminate the influence of iron content of the aggregate and cement used.

d) The method is unsuitable in the case of closely packed bar assemblies.

e) The accuracy is reduced if rough or undulating surfaces are present, e.g. exposed aggregate finishes. The effect on the indicated cover will be similar in magnitude to the surface irregularities within the area of the search head.

f) Calibrated meter scales are generally valid for a particular grade of reinforcing steel. The effect of different types of steel on the readings obtained is generally small but, in special cases, such as high tensile prestressing bars, it may include errors as high as ±5% or more. Where such materials are present, the covermeter should be calibrated for the reinforcing steel used by constructing a calibration curve.

g) For accurate measurement of cover and size, the bar has to be both straight and parallel to the concrete surface.

h) Where significant corrosion to reinforcement has occurred, in particular, scaling and migration of corrosion products, misleading indicated cover readings are likely to be obtained.

i) Interference effects will occur in the neighbourhood of metallic structures of significant size, such as window fixings, scaffolding and steel pipes, especially when are they are immediately behind the search head. The degree of influence will depend on the particular covermeter used but all are affected by either stray magnetic fields or electric fields or both. In such cases reliable use of the instrument may be severely restricted.

REFERENCES

1) British Standard, BS 1881: Part 204 "*Recommendations on the Use of Electromagnetic Covermeters*". British Standard Institute, 1988.

5.0 COMPRESSIVE STRENGTH TEST (CORES)

5.1 INTRODUCTION

Compression test of concrete cores extracted from existing structures is the most reliable method of assessing in-situ compressive strength of concrete. Under this method, a cylindrical core is cut from the hardened concrete by diamond-tipped drill and later tested by crushing with the compression machine in the laboratory. The maximum load that the core sample can sustain is recorded and divided by the sample‟s cross-section area to obtain compressive strength of the sample, expressed in Newton per millimeter square (N/mm^2).

The preferred core diameter is 100 or 150 mm. Ratio of diameter to the maximum aggregate size should not be less than 3. The usable length of core should be such that length/diameter ratio for strength testing should be between 1 and 2.

5.2 EQUIPMENT

The components of coring equipment used for the extraction of core samples of the hardened concrete are described below, and illustrated in **Figures 5.1** and **5.2:**

1. Coring machine
2. Core bit
3. Coring machine stand
4. Drill equipment
5. Anchor Bolt – to anchor and hold the coring equipment when coring
6. Water pump – to supply water during coring
7. Screw driver, chisel, and hammer – to extract core after coring
8. Safety socket
9. Compression test machine

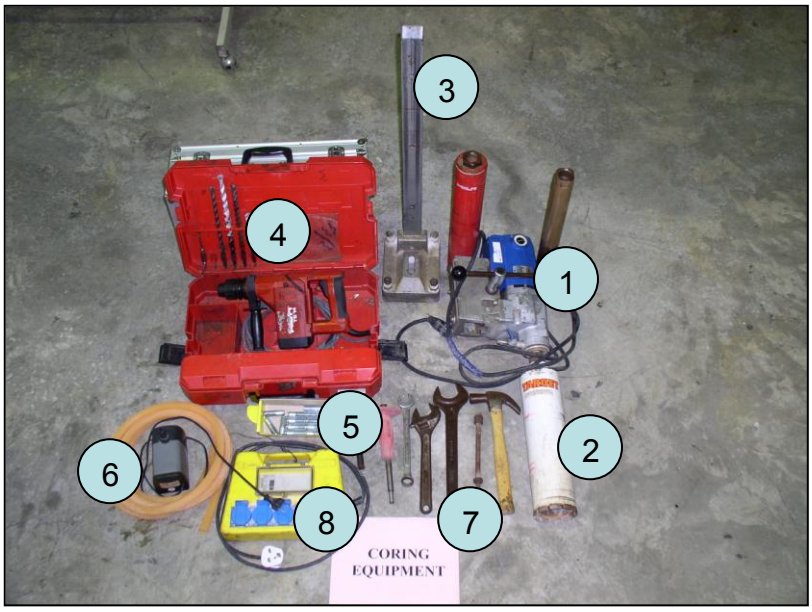

Figure 5.1: Coring equipment and apparatus

Figure 5.2: Compression Test Machine

5.3 PROCEDURE

The procedure for extracting of samples and laboratory testing of the cores are described in the following sub-sections. The procedures described below assume that the setting out of location for coring is finalized and that all safety procedures are strictly adhered to:

a) After determining the reinforcement location, core the selected structure member perpendicularly using 150 mm diameter diamond core bit, as shown in **Figure 5.3**.

Figure 5.3: Coring process

b) After the coring process reaches a depth of between 150 mm and 300 mm, extract out the core manually using chisel and hammer, as shown in **Figure 5.4**.

Figure 5.4: Extracting core from the structure

c) Samples are then brought back to laboratory for compression test. Prepare the sample by grinding both ends of the specimen as shown in **Figure 5.5.** Grinding is the preferred end preparation; however, if grinding is impractical, cap both ends of the core specimen as shown in **Figure 5.6** by using either:

i) Mortar that consist of high alumina cement and fine sand (3:1); or

ii) Mixture of sulphur and fine siliceous sand (1:1) together with a small proportion of carbon black (1%-2%) or polysulphide rubber (2%-4%).

Figure 5.5: Grinding of specimen with grinding machine

Figure 5.6: Capping the ends of specimen

d) After grinding or capping, immerse the specimen in water at 27±2ºC as shown in **Figure 5.7** until it is in saturated condition for testing.

Figure 5.7: Store the specimen in water

e) Test the core in compression not less than 2 days after end preparation and immersing in water. Test the core immediately on removal from the water and whilst it is still wet.

f) Wipe the bearing surfaces of the testing machine and of any auxiliary platens clean and remove any water, loose sand or other material from the ends of the core. Centre the core carefully on the lower platen of the machine. Wherever possible use a jig to align the specimen. Do not use any packing other than auxiliary steel platens between the ends of the core and the platens of the testing machine.

g) Without shock, apply and increase the load continuously at a constant rate within the range of 0.22 N/mm^2.s to 0.4 N/mm^2.s until no greater load can be sustained. **Figure 5.8** illustrates a compression test is in progress.

Figure 5.8: Testing for core compressive strength

h) Record the maximum load.

i) Calculate the compressive strength to the nearest 0.5 N/mm^2, by dividing the maximum load by the cross-sectional area, calculated from the average diameter.

REFERENCES

1. Malaysia Standard, MS 26: Part 2 "*Method for Determination of the Compressive Strength of Concrete Cores"*. Malaysia Standard Institute, 1991.

2. British Standard, BS 1881: Part 120 "*Method for Determination of the Compressive Strength of Concrete Cores"*. British Standard Institute, London, 1983.

6.0 REBOUND HAMMER

6.1 INTRODUCTION

Rebound hammer, also known as Schmidt Hammer or Impact Hammer, is the most popular test device to study the surface hardness of concrete, which measures the hardness of the concrete surface. The test is based on the principle that the extent of rebound of an elastic mass depends on the hardness of the surface against which the mass strikes, expressed as a „Rebound Number".

In any case, the rebound hammer test measures the properties of only the surface zone of concrete, which is 30 mm according to BS 1881: Part 202: 1986. Some of the usages of the surface hardness method include:

- Checking the uniformity of concrete;
- Comparing a given concrete with a reference, in terms of specific requirement;
- Determining the properties of the surface of the concrete which have a direct influence on its performance; and
- Estimation of strength of concrete in structures.

This method is quick and easy to perform, but might cause surface mark and results are influenced by many factors. Besides that, the test is sensitive to local variation in the concrete quality, for instance the presence of aggregate just under the plunger. For this reason, BS 1881: Part 202 recommended that at least 12 readings be taken in an area smaller than 300 mm by 300 mm (i.e. 1 ft^2). A number of different types of hammer are available to suit particular concrete types. Each hammer is supplied with a calibration chart by the manufacturer.

6.2 EQUIPMENT

The components of rebound hammer test equipment used for the hardened concrete are described below, and illustrated in **Figure 6.1**:

1. Rebound Hammer – consisting of a spring-loaded steel hammer which when released strikes a steel plunger in contact with the concrete surface

2. Abrasive stone – consisting of medium-grain texture silicon carbide

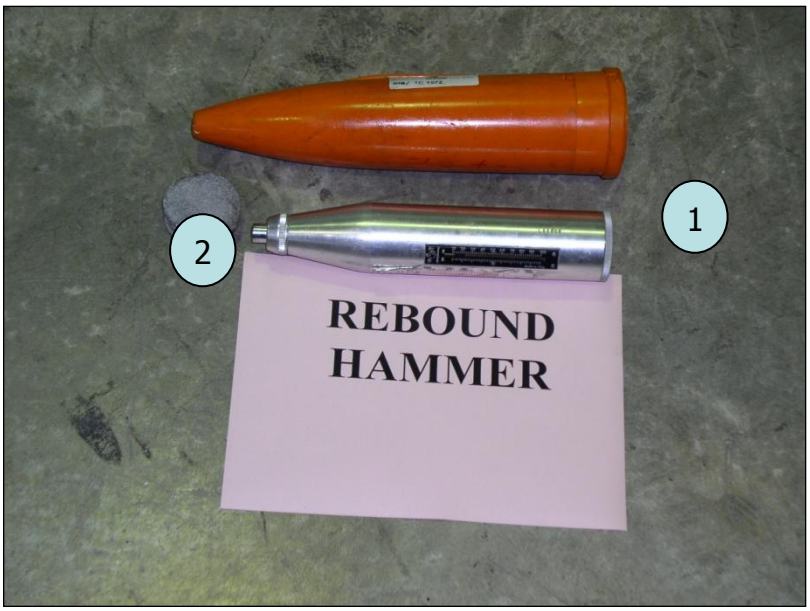

Figure 6.1: Rebound hammer apparatus

6.3 PROCEDURE

a) Before performing this test, remove any plaster or coating covering, serious roughness and small voids by brushing with abrasive stone, as shown in **Figure 6.2**. Avoid testing at areas exhibiting honeycombing, scaling, or high porosity.

Figure 6.2: Brushing concrete surface to remove roughness and loose materials before test

b) After brushing, mark the test points according to a grid of 20-50 mm apart, as illustrated in **Figure 6.3**. Twelve (12) points for an area of 300 x 300 mm are recommended.

Figure 6.3: Marking test points according to grid

c) Hold the hammer firmly so that the plunger is perpendicular to the surface, as shown in **Figure 6.4**.

Figure 6.4: Holding the hammer perpendicularly to the test surface

d) Gradually push the hammer strongly and steadily toward the test surface until the hammer impacts, i.e. the spring-loaded mass is triggered from its locked position, as in **Figure 6.5**.

Figure 6.5: Pushing the hammer towards the test surface

e) After the impact, maintain the hammer on its location and, if necessary, lock the plunger in its retracted position by depressing the button on the side of the hammer.

f) Read and record the scale index from the hammer, which is known as the rebound number.

g) Convert rebound number to compressive strength value using calibration chart established for a particular device.

6.4 COMPLIANCE

The average rebound number of a particular place is recorded. This number indicates the surface hardness of the concrete. A typical relation between rebound number and cube compressive strength is shown in **Figure 6.6**.

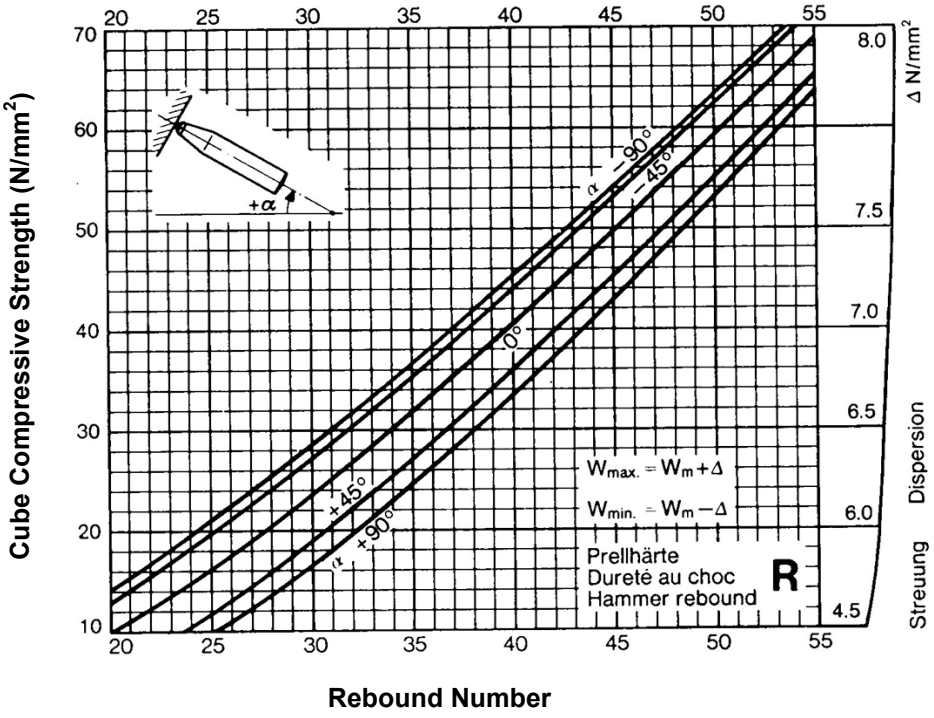

Figure 6.6: Typical relationship between rebound number and cube compressive strength

REFERENCES

1) British Standard, BS 1881: Part 202 "*Recommendation for surface hardness testing by rebound hammer"*. British Standard Institute, London, 1983.

2) ASTM C 805 "*Rebound Hammer of Hardened Concrete*". American Society for Testing and Materials, Philadelphia, 1997.

7.0 ULTRASONIC PULSE VELOCITY TEST

7.1 INTRODUCTION

Ultrasonic Pulse Velocity (UPV) test is a well established non-destructive method to access the modulus of elasticity and correlated strength of concrete. This method is quick to use and does not damage the concrete, but requires access to opposite faces of the member under test for best results.

Pulses of compressional waves are generated by an electro-acoustical transducer that is held in contact with one surface of the concrete under test. After traversing through the concrete, the pulses are received and converted into electrical energy by a second transducer located at a measured distance between transmitting and receiving transducers placed on the concrete surface. The transit time is measured electronically and the pulse velocity is calculated by dividing the distance by transit time. This provides a measurement of the mean ratio of elastic stiffness to density along the path and has been found to be a useful index of concrete quality.

7.2 EQUIPMENT

The components of ultrasonic pulse velocity (UPV) test equipment used for the hardened concrete are described below, and illustrated in **Figure 7.1.**

1. Voltmeter – digital direct-reading display with an interval timer
2. Calibrator block – to check the proper operation of the time-measuring circuit
3. Transmitter and Receiving Transducer – generate and receive pulses of voltage
4. Grease oil – as a coupling agent for the transmission of pulses
5. Connecting wire – connecting the transducers with voltmeter
6. Battery charger

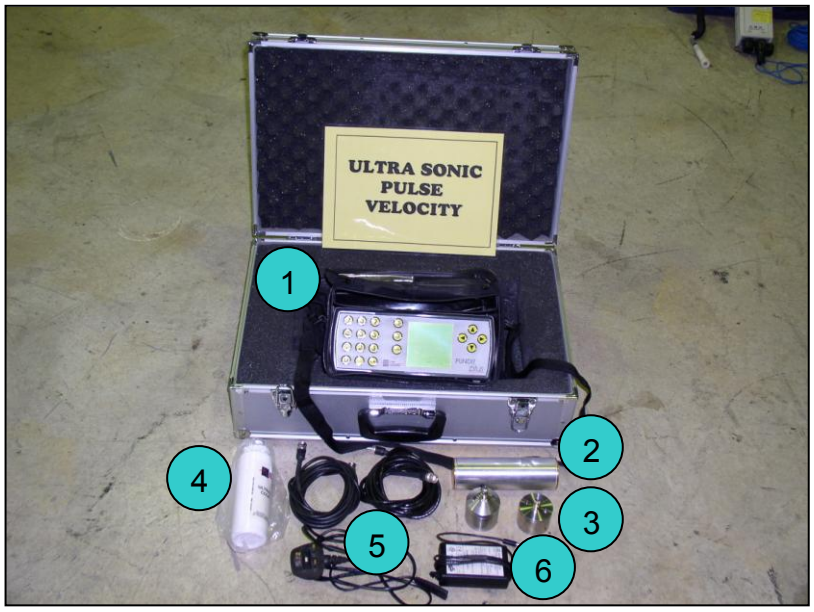

Figure 7.1: UPV test components

7.3 PROCEDURE

The procedure for carrying out ultrasonic pulse velocity (UPV) test is described in the following sub-sections. The procedures described below assume that the setting out of location for test is in place and that all safety procedures are strictly adhered to.

a) After defining test location, chip off plaster (if any) and clean the surface of test location by brushing to remove unsuitable surface condition such as serious roughness and small voids. The structure surface shall be in dry condition.

b) Apply coupling agent (grease or lubricant) to the transducer diaphragms and structure surface to avoid entrapped air between contact surface of the diaphragms and structure, as shown in **Figure 7.2**.

Figure 7.2: Applying coupling agent to transducers and structure surface

c) Press the transducers against concrete surface. There are three different ways of placing the transducers. They are:

i. Direct Transmission

Transducers are placed on direct opposite faces of concrete, as in **Figure 7.3**, resulting in the receiving-transducer receiving maximum energy from the transmitted pulse.

Figure 7.3: Arrangement of transducers for direct transmission

ii. Semi-direct Transmission

Transducers are placed on adjacent faces, as shown in **Figure 7.4**, thus reducing the accuracy of measurement of path length.

Figure 7.4: Arrangement of transducers for semi-direct transmission

iii. Indirect Transmission

Transducers are placed on same face of concrete, as illustrated in **Figure 7.5.** It is used where only one face of the concrete is accessible.

Figure 7.5: Arrangement of transducers for indirect transmission

d) Turn on the power supply, and the ultrasonic waves travel from the emitter transducer through the structure to the receiving transducer.

e) The time taken by the waves to travel between the two transducers is displayed on the recording device. The transit time is measured and the ultrasonic pulse velocity is calculated from the following formula:

$$UPV = \frac{\text{PATH LENGTH}}{\text{TRANSIT TIME}} \quad \text{(km/s)}$$

f) The UPV value is applicable to determine the uniformity of concrete in or between members; detection of the presence and approximate extent of cracks, voids and other defects; correlation of pulse velocity and strength to measure concrete quality; and determination of dynamic modulus and Poisson ratio, using specific formula.

7.4 COMPLIANCE

High pulse velocity readings are generally indicative of good quality concrete. A general relation between compressive strength and ultrasonic pulse velocity for hardened cement paste, mortar, and concrete, in a dry and a moist condition is shown in **Figure 7.6**.

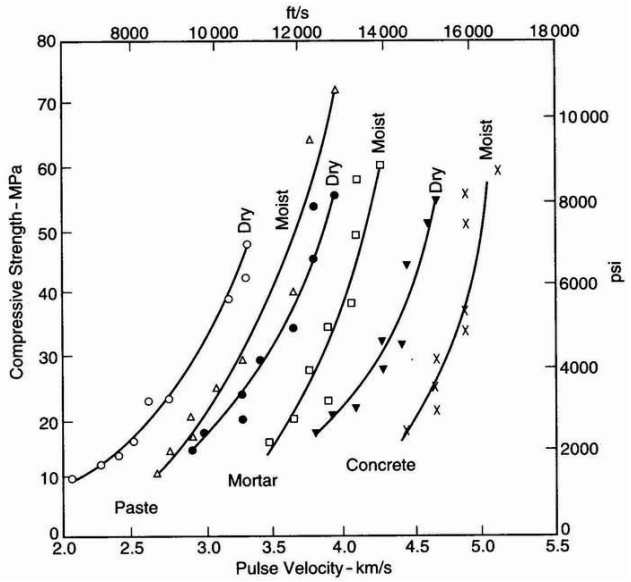

Figure 7.6: Typical relation between concrete quality and pulse velocity (Sturrup *et. Al*, 1984)

REFERENCES

1) Malaysia Standard, MS 26: Part 3 "*Recommendations for Measurement of Velocity of Ultrasonic Pulses in Concrete",* Malaysia Standard Institute, 1992.

2) British Standard, BS 1881: Part 203 "*Recommendation for Measurement of Velocity of Ultrasonic Pulses in Concrete".* British Standard Institute, London, 1986.

3) ASTM C 597-09 "*Standard test method for pulse velocity through concrete"*. America Society for Testing and Materials. Philadelphia, 1997.

4) Sturrup, V.R., Vecchio, F.J. and Caratin, H. " *Pulse Velocity as a measure of concrete compressive strength*", In Situ/Non-destructive Testing of Concrete, Ed. V.M., Malhotra, ACI SP-82, pp.201-27, Detroit, Michigan, 1984.

8.0 PENETRATION RESISTANCE TEST (WINDSOR PROBE)

8.1 INTRODUCTION

This technique is commercially known as the Windsor Probe test. It determines the concrete strength by testing the resistance of concrete to penetration by a steel rod, or probe, driven by a fixed amount of energy. This test method may be used to:

- assess the uniformity of concrete and to delineate zones of poor quality or deteriorated concrete in structures; and
- estimate in-situ strength, provided that a relation has been experimentally established between penetration resistance and concrete strength

The underlying principle is that, for standard test conditions, a hardened steel alloy probe is fired into the concrete surface using a standardized powder cartridge. The exposed length is measured to derive the depth of penetration which is usually between 20-40 mm. The test is essentially non-destructive, since concrete and structural members can be tested in-situ, with only minor patching of holes on exposed faces.

8.2 EQUIPMENT

The components of Windsor Probe test equipment used for the hardened concrete are described below, and illustrated in **Figure 8.1**:

1. Driver Unit – e.g. powder-actuated device that capable of driving the probe
   into the concrete with an accurately controlled energy

2. Probe – or bolt of hardened steel alloy. Generally 6.35 mm in diameter and 79.5mm in length and can penetrate up to 40 mm into the concrete

3. Measuring unit – to measure and record the exposed length (above original surface) of probe to the nearest 0.5 mm

Figure 8.1: Windsor Probe test apparatus

8.3 PROCEDURE

a) Set the test position to be at least 200 mm apart and a minimum distance of 150mm from the edge of the concrete surface.

b) Place the positioning device on the surface of test location.

c) Mount the probe in the driving unit, position the driver in the positioning device, as illustrated in **Figure 8.2**, and then fire the probe into the concrete.

Figure 8.2: Positioning the driving unit with probe before fire into the concrete

d) Remove the positioning device and tap the probe on the exposed end with a small hammer to firmly embed it. The partly exposed probe embedded in concrete structure to be measured is shown in **Figure 8.3**.

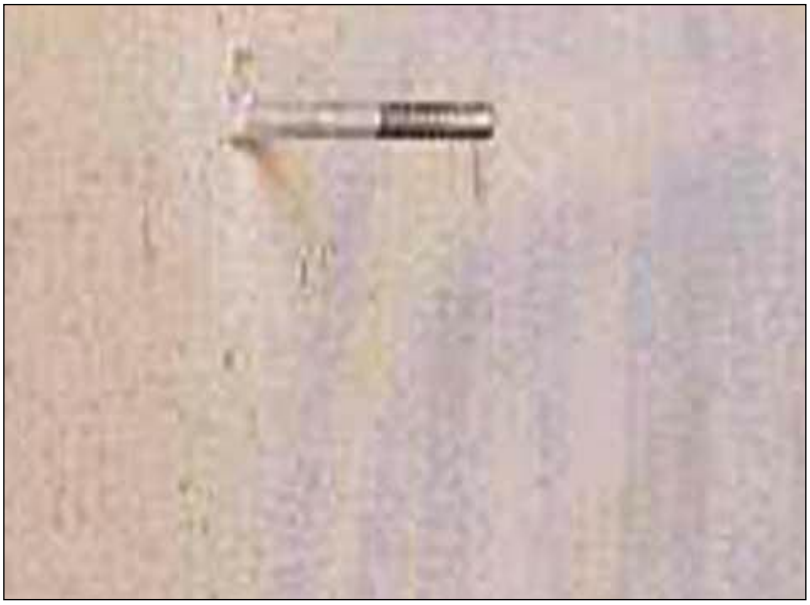

Figure 8.3: Exposed probe embedded in concrete structure

e) Eject the loose probe and place the measuring baseplate over the probe. Position it to bear firmly on the surface of the concrete without movement.

f) Install probe-measuring cap and the measuring device, as illustrated in **Figure 8.4**. The measuring device will measure the distance from the reference plate to the end of the probe, to the nearest 0.5mm.

Figure 8.4: Measuring the exposed probe length

8.4 COMPLIANCE

In-situ concrete strength is given by a linear relationship with exposed probe length as shown in **Figure 8.5**.

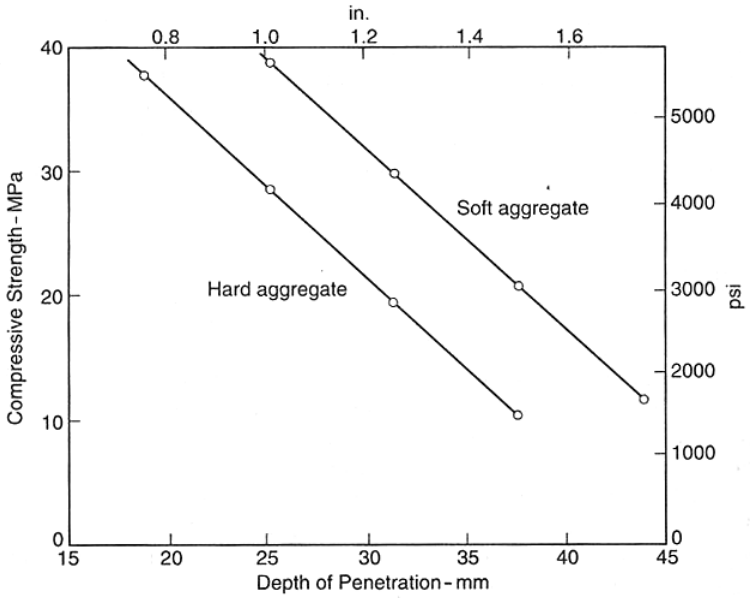

Figure 8.5: Typical Windsor probe correlation

REFERENCES

1) British Standard Institute, BS 1881: Part 207 "*Near to surface test methods for strength"*. British Standard Institute, London, 1992.

2) ASTM C 803 – 03 *Standard Method for Penetration Resistance of Hardened Concrete.* American Society of Testing and Materials, Philadelphia, 1997.

3) ACI 228.1 R-89, *In-place methods for determination of strength of concrete, ACI Manual of Concrete Practice, Part 2: Construction Practices and Inspection Pavements*, American Concrete Institute, Michigan, 1994.

9.0 CARBONATION TEST

9.1 INTRODUCTION

Carbonation may be simply identified by spraying a core‟s surface with a suitable indicator to detect the loss of alkalinity, which is related to the protection of the steel reinforcement bars in the concrete structure.

Knowledge of the depth of penetration of carbonation below the surface of the member may be useful when assessing the risk of reinforcement corrosion. Future progression of carbonation may also be predicted. Phenolphthalein solution indicator locate carbonation front based on boundary between alkaline/acid zones. Phenolphthalein simply gives purple colour when reacts with alkaline or remain colorless if not encounter with alkaline. For more detail, „multicoloured‟ indicator can identify range of alkalinity/acidity by pH number.

9.2 EQUIPMENT

Apparatus and materials used for carbonation test in accordance to BRE IP 6/81 are described below and shown in **Figure 9.1**:

1. Phenolphthalein (1% solution in diluted ethyl alcohol) (*LABCHEM*-100g) – as an indicator to detect the presence of alkali i.e. $Ca(OH)_2$

2. Methylated spirit – mix with phenolphthalein to form a chemical indicator

3. 1 litre spray bottle – for spraying the indicator solution to concrete surface

4. Distilled water – mix with phenolphthalein to form a chemical indicator

5. Beakers – for measuring and mixing phenolphthalein solution

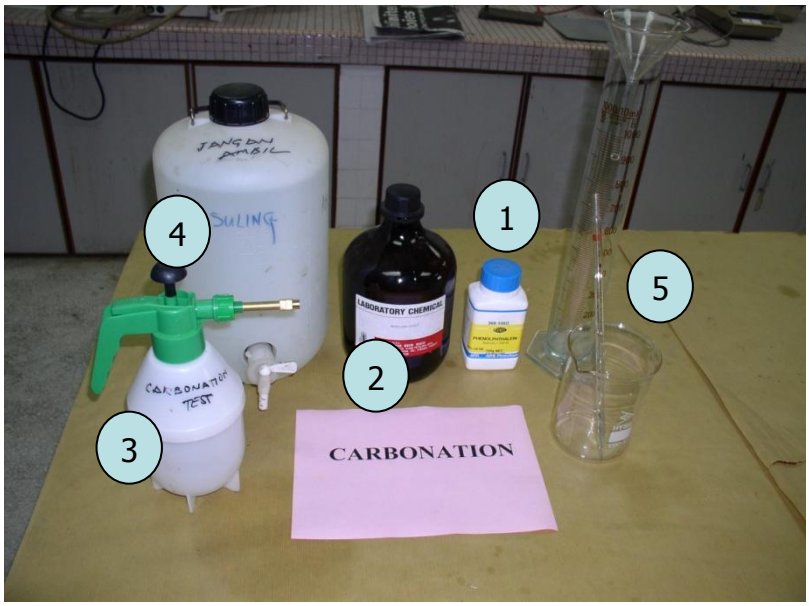

Figure 9.1: Carbonation test apparatus

9.3 PROCEDURE

a) Measure and mix 1 gram phenolphthalein with 300 ml distilled water and 700 ml methylated spirit in the beaker to make 1 litre of carbonation solution (adequate for ±20 core samples) and put into spray bottle.

b) Clean the core sample by rinsing with clean water to wash away core dust at the surface immediately upon extraction or receipt.

c) Air-dry the core specimen in accordance to BRE IP6/81. One typical concrete specimen for carbonation test is shown in **Figure 9.2**.

Figure 9.2: Core specimen ready for carbonation test

d) Using the spray bottle, spray the indicator solution on the surface of the core sample after air-dried, as illustrated in **Figure 9.3.**

Figure 9.3: Spraying phenolphthalein solution on a core sample

e) Visually observe the color changes of core surface. If core surface immediately undergoes colour change to purple red (red violet), this indicates the presence of alkaline, i.e. $Ca(OH)_2$, hence no carbonation. If

portion of the core is not experiencing colour change it means the loss of alkalinity caused by the presence of carbonation.

f) Measure the length of colourless portion on sample surface, as shown in **Figure 9.4**, preferably on both sides of the core-through concrete sample. The dimension measured is also equivalent to the carbonation penetration at the sample element.

Figure 9.4: Measuring the carbonation depth of a core sample

REFERENCES

1) BRE "*Determination of Carbonation Depth'*, Information Paper IP6/81. Building Research Establishment, London, 1981.

10.0 HALF-CELL POTENTIAL MEASUREMENT

10.1 INTRODUCTION

Half-cell potential measurements are conducted to measure the probability of corrosion of steel bars in the concrete elements. By measuring concrete surface electrical potentials relative to a standard reference electrode on a pre-determined grid, the probability of future corrosion can be assessed. Such diagnosis identifies areas where corrosion is occurring or about to proceed long before any physical damage is visible.

This test traditionally consists of a copper/copper sulphate half-cell connected through a high impendence voltmeter into the steel reinforcement. The half-cell is then contacted to the surface of the concrete via a sponge or porous plug and contact fluid (water with detergent or alcohol). Electrical potential of embedded reinforcement relative to a half-cell placed on the concrete surface is measured by the voltmeter.

10.2 EQUIPMENT

Half-cell potential test for the hardened concrete comprises of a few equipments described below, and illustrated in **Figure 10.1**:

1. Half-cell voltmeter – measure and record electrical potential
2. Crocodile clip – to connect the reinforcement steel to voltmeter
3. Half-cell probe – move about on surface to measure potential of reinforcing steel at various location
4. Rod – to support half-cell probe for testing on soffit at high level e.g. slab.

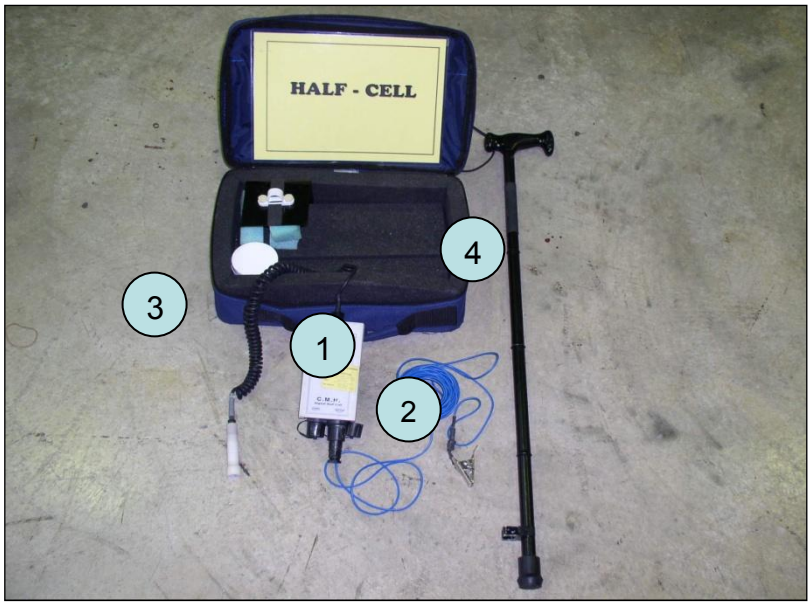

Figure 10.1: Half-cell potential test equipments

10.3 PROCEDURE

a) Hack and remove a small portion of concrete to expose reinforcing steel and make direct connection between steel bar and positive terminal of the voltmeter with a crocodile clip, as illustrated in **Figure 10.2.**

Figure 10.2: Connecting reinforcing steel with crocodile clip

b) Connect one end of the lead wire to the half-cell and the other end of the same wire to the negative (ground) terminal of the voltmeter.

c) Determine whether pre-wetting of the concrete surface is required by place the half-cell on the concrete surface without moving it and observe the voltmeter for one of the following conditions (**Figure 10.3**):

i. If the measured value of half-cell does not change or fluctuate with time, pre-wetting process is not necessary; or

ii. If the measured value of half-cell changes or fluctuates with time, pre-wetting process is required by either:

a. spraying the entire concrete surface with an electrical contact solution, composed of a mixture of 95 *ml* wetting agent or a liquid household detergent thoroughly mixed with 5 gal (19*l*) of portable water; or

b. saturating the sponge with the electrical solution described above and place it on the concrete surface until condition in (c)i above is achieved and continue maintain it on the surface until half-cell reading is made.

Figure 10.3: Placing the half-cell probe on the concrete surface

d) Perform horizontal and vertically upward measurements exactly as vertically downward measurement. However, additionally ensure that the copper/copper sulphate solution in the half-cell makes simultaneous electrical contact with the porous plug and the rod at all times.

e) Record the electrical half-cell potentials to the nearest 10 mV.

f) Report all half-cell potential values in millivolts (mV).

10.4 COMPLIANCE

Referring to ASTM C876, the probability of steel corrosion according to volt relative to copper/copper sulphate half-cell is presented in **Table 10.1**.

Table 10.1: Probability of steel corrosion as referring to copper / copper sulphate half-cell voltage

Volts relative to copper/copper sulphate reference electrode (mV)	Probability of active corrosion of steel
< -350	90%
-200 to -350	50%
> -200	10%

REFERENCE

1) ASTM C 876 "*Standard Test Method for Half-Cell Potential of Uncoated Reinforcing Steel in Concrete".* American Society of Testing and Materials, Philadelphia, 1997.

11.0 INITIAL SURFACE ABSORPTION TEST (ISAT)

11.1 INTRODUCTION

Initial surface absorption is defined as the rate of flow of water into concrete per unit area at a stated interval from the start of the test at a constant applied head and temperature. The application of this method is usually as a quality control test for precast concrete unit, where the results obtained may be compared with predetermined acceptance limit; to assess the compliance of in-situ concrete with specification for weathering performance; and as a mean of comparative assessment of surface finishes and quality of the concrete in the surface zone. Results are expressed as milliliter per square meter per second (ml/m^2/s) at a stated time from the start of test.

In this method, the rate of flow of water per unit area into a concrete surface when subjected to a constant head of 200 mm is measured. A watertight cap is sealed to the concrete surface to provide a water contact area of at least 5000 mm^2 (> 71 mm x 71 mm) and connected to a reservoir and calibrated horizontal capillary tube and scale. At specified intervals from the start of test (10 mins, 30 mins, 1 hour) the tap between cap and reservoir is closed and movement of water in the capillary caused by surface absorption is measured over a specified period of time.

11.2 EQUIPMENT

Testing for Initial Surface Absorption involves a few apparatus as described below and illustrated in **Figure 11.1**:

1. Cap – of impermeable material with a minimum contact area of 5000 mm^2 and complete with inlet and outlet connection
2. Reservoir (with connection to the cap) – a funnel made of glass or plastic of about 100 mm diameter with a connection to the inlet to the cap by flexible tube

3. Capillary tube and scale – a length of precision bore glass capillary tubing, 100 - 1000 mm long with a bore of 0.4 - 1.0 mm radius and fixed to a calibrated scale
4. Sealant – for sealing cap onto concrete surface
5. De-aerated water
6. Stopwatch – for recording time during observation of movement in scale
7. Reservoir holder/stand – for holding reservoir on a height of 200 mm from concrete surface

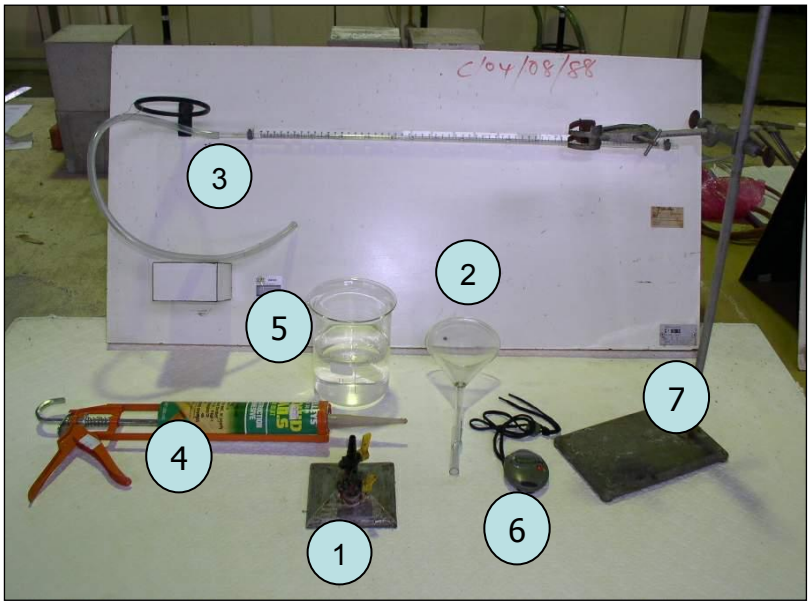

Figure 11.1: Initial surface absorption test apparatus

11.3 PROCEDURE

a) Prepare one concrete cube specimen to be tested.

b) Fix or clamp the cap into position on test location. Apply modelling clay or other suitable materials to seal the connection between concrete surface

and the edges of the cap to provide a watertight assembly, as illustrated in **Figure 11.2**.

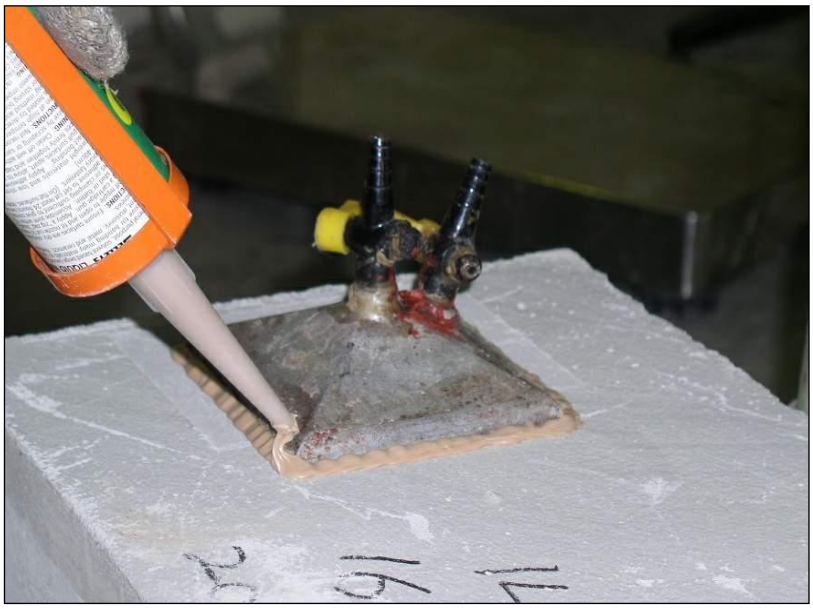

Figure 11.2: Fixing the cap onto concrete surface

c) Set the reservoir and capillary at a head of 200mm ± 20mm above surface, with the reservoir connected to the inlet of the cap while capillary connected to the outlet. A complete set-up of the test is shown in **Figure 11.3**.

Figure 11.3: Complete set-up of ISAT test

d) Close the tap from reservoir and fill the reservoir with water maintained at 27ºC± 2ºC.

e) Start recording the time and open the reservoir tap to allow the water to flow into the cap until no more air escapes.

f) Connect the outlet tube to the capillary tube and flush out any trapped air by allowing the capillary to overflow.

g) At the intervals of 10 minutes, 30 minutes, 1 hour and 2 hours, close the inlet tap and start recording time when water starts to flow along the capillary tube.

h) Record the number of scale division moved during the period selected from **Table 11.1**. Note the number of scale unit"s move in the first five seconds. If the movement is less than 3 divisions, measurements are continue for two minutes; if 3-9 divisions, continue for one minute; or if 10-30 divisions, continue for 30 seconds. If the movement is more than 30 divisions in five seconds, the result can be quoted as more than 3.60 ml/m^2/s.

Table 11.1: Determination of period of movement

Number of scale units moved in 5 seconds	Period during which movement is noted
Less than 3	2 minutes
3 – 9	1 minute
10 – 30	30 seconds
More than 30	Record initial surface absorption as 3.60 ml/m^2/s

i) Just before each specific interval, adjust the position of the capillary tube to completely fill it with water. Between test intervals leave the tap open and maintain the level of water in the reservoir at the specific head.

j) If the reading taken 10 minutes after the start of the test is below 0.05 ml/m^2/s, stop the test and record the result with the comment „concrete too impermeable to be sensitive to a longer term test". Similarly, where the 10 minutes reading is above 3.60 ml/m^2/s, stop the test and record the result with the comment „concrete too permeable to be within the sensitivity of the test method".

11.4 COMPLIANCE

Values for 10 minutes of surface absorption of low, average and high concrete permeability/absorption are given by Concrete Society, London are as follows (A.M.Neville, 1995):

Low concrete permeability	< 0.25	ml/m^2/s
Average concrete permeability	0.25-0.50	ml/m^2/s
High concrete permeability	>0.50	ml/m^2/s

REFERENCES

1) Malaysia Standard, MS 7.1: Part 5 "*METHOD for DETERMINATION of INITIAL SURFACE ABSORPTION"*. Malaysia Standard Institute, 1971.

2) British Standard, BS 1881: Part 208 "*Test for determination of the Initial Surface Absorption of Concrete*". British Standard Institute, 1996.

3) Neville, A.M. "*Properties of Concrete*", Fourth Edition, Addison Wesley Longman Limited, 1995, England.

12.0 RAPID CHLORIDE PENETRABILITY TEST

12.1 INTRODUCTION

This test method is carried out to determine the resistance of concrete to the penetration of the chloride ions by evaluating the electrical conductance of concrete samples. This property is important to determine the concrete's resistance to chloride ingress, which leads to corrosion of the reinforcing steel and a subsequent reduction in strength, serviceability, and esthetic of the structure.

There are currently two test methods to carry out the test. One of them is ASTM C1202, which is developed by American Society of Testing and Materials. The other one is a modified ASTM C1202 method, which is developed by Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia.

The ASTM C1202 test method consists of monitoring the amount of electrical current passed through a 2 inches (51 mm) thick and 4 inches (102 mm) diameter cores or cylinders during a 6 hours period. A potential difference of 60 V dc is maintained across the ends of the specimen, one of which immersed in a sodium chloride solution, the other in a sodium hydroxide solution. The total charge passed, in coulombs, is recorded as the chloride ion penetrability of the concrete sample.

The modified ASTM C1202 method involves performing an additional test using curing water as electrolyte, which improves the binder independency of the results. The difference in the total charges passed obtained between standard test and test performed in curing water is used as an indicator of the concrete quality.

12.2 EQUIPMENT

1. Vacuum Saturation Apparatus (desiccators and vacuum pump) – for sample preparation.

2. Applied Voltage Cell – Two symmetric poly (methyl methacrylate) chambers, each containing electrically conductive mesh and external connectors.
3. Voltage application and Data Readout Apparatus – e.g. Voltmeter.
4. Corecase – for coring sample.
5. Diamond saw – for slicing sample.

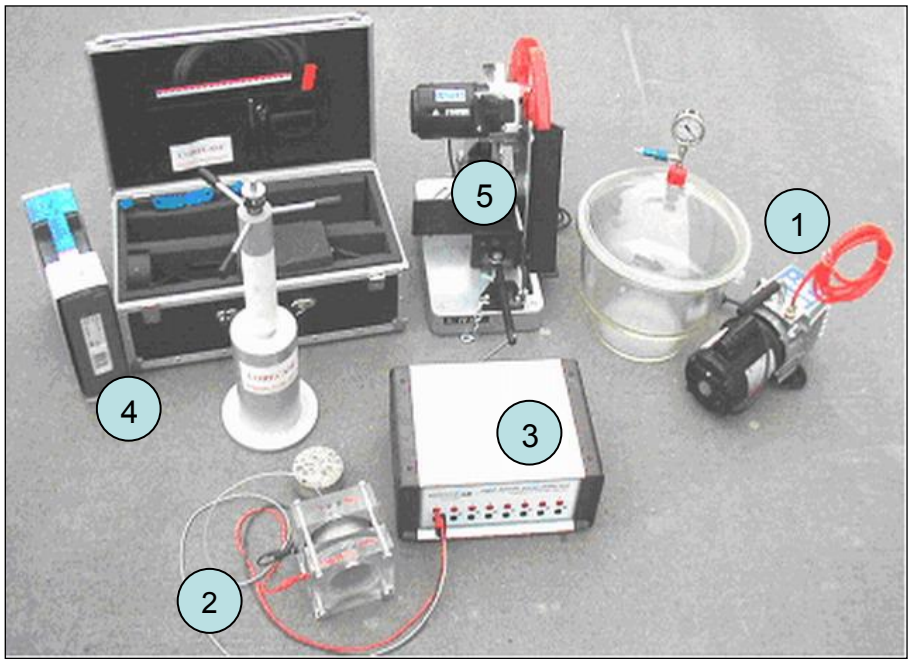

Figure 12.1: A complete set of chloride penetrability test kit

(A) RAPID CHLORIDE PENETRABILITY TEST TO ASTM C1202

12.3 PROCEDURE

a) Prepare cylinder specimen in accordance with ASTM C192 with 4 inches (102 mm) in diameter.

b) Using a water-cooled diamond saw, cut a 2 ± ⅛ inch (51 ± 3 mm) slice from the top of the cylinder. Remove any burrs on the end of the specimen. Allow specimen to surface dry in air for at least 1 hour.

c) Prepare approximately ½ oz (10 g) of rapid setting coating and brush onto the side surface of the specimen. Allow coating to cure according to the manufacturer"s instructions until it is not sticky to the touch.

d) Place the specimen in a beaker with both ends exposed and place it in the vacuum desiccator.

e) Seal the desiccator and start vacuum pump. Maintain vacuum for 3 hours.

f) Fill separatory funnel with de-aerated water. With vacuum pump still running, open water stopcock and drain sufficient water into beaker to cover specimen (do not allow air to enter desiccator through this stopcock).

g) Close stopcock and allow vacuum pump to run for an additional one hour.

h) Close vacuum line stopcock and turn off pump. Turn vacuum line stopcock.

i) Soak the specimen under de-aerated water for 18 ± 2 hours.

j) Remove specimen from water and blot off excess water. Then transfer specimen to a sealed container that maintains the specimen in a 95% or higher humidity.

k) Mount both ends of specimen with either:

   i. *Low viscosity specimen-cell sealant (0.7–1.4 oz (20–40 g))* – if filter paper is necessary, centre filter paper over one screen of the applied voltage cell. Trowel sealant over brass shims adjacent to applied voltage cell body. Carefully remove filter paper. Press specimen onto screen. Remove or smooth excess sealant which has flow out of specimen-cell boundary;

ii. *High viscosity specimen-cell sealant (0.7–1.4 oz (20–40 g))* –set specimen onto screen. Apply sealant around specimen-cell boundary; or

iii. *Rubber gasket* – place a 4-inch outside diameter and 3-inch inside diameter by ¼-inch circular vulcanized rubber gasket in each half of the test cell. Insert specimen and clamp the two halves of the test cell together to seal.

l) Cover exposed face of specimen with impermeable materials such as rubber or plastic sheeting. Place rubber stopper in cell filling hole to restrict moisture movement. Allow sealant to cure according to manufacturer"s instructions.

m) Fill the side of the cell containing the top surface of the specimen with 3.0% NaCl solution and connect to the negative terminal of the power supply.

n) Fill the other side of the cell with 0.3N NaOH solution and connect to the positive terminal of the power supply. The completed cell is shown in **Figure 12.2**.

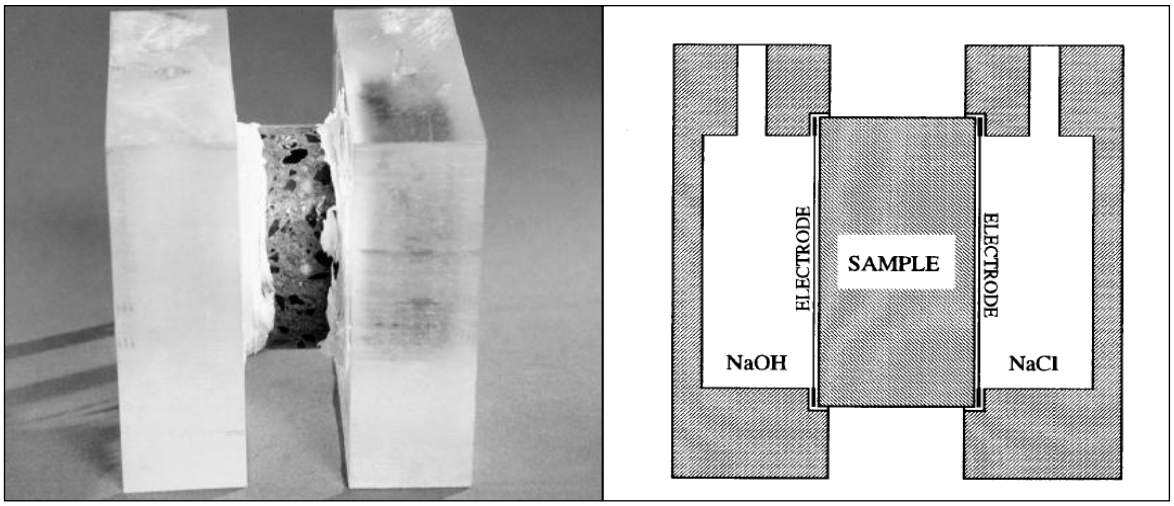

Figure 12.2: Concrete specimen between two halves of the test cell

o) Attach lead wires to cell banana posts. Make electrical connections to voltage application and voltmeter. The complete set-up of test equipment is shown in **Figures 12.3** and **12.4**.

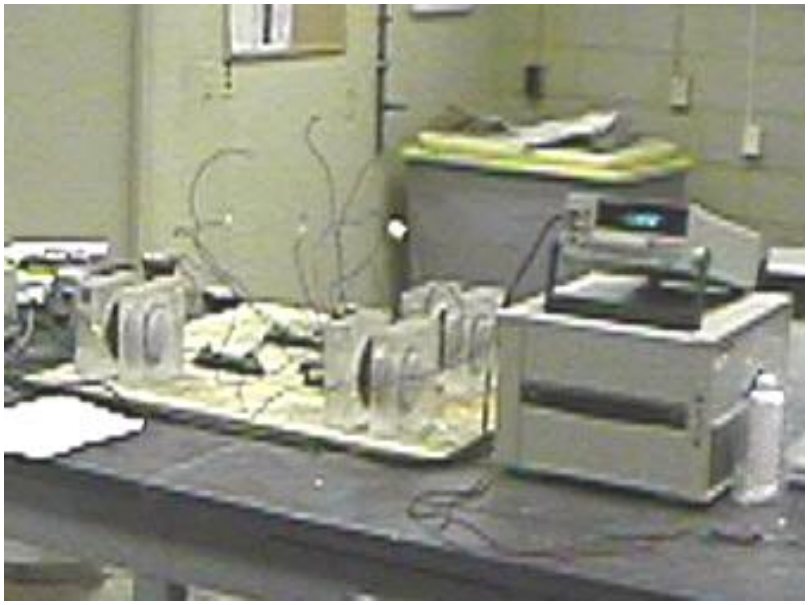

Figure 12.3: Complete set-up of ASTM C1202 Chloride Penetrability Test

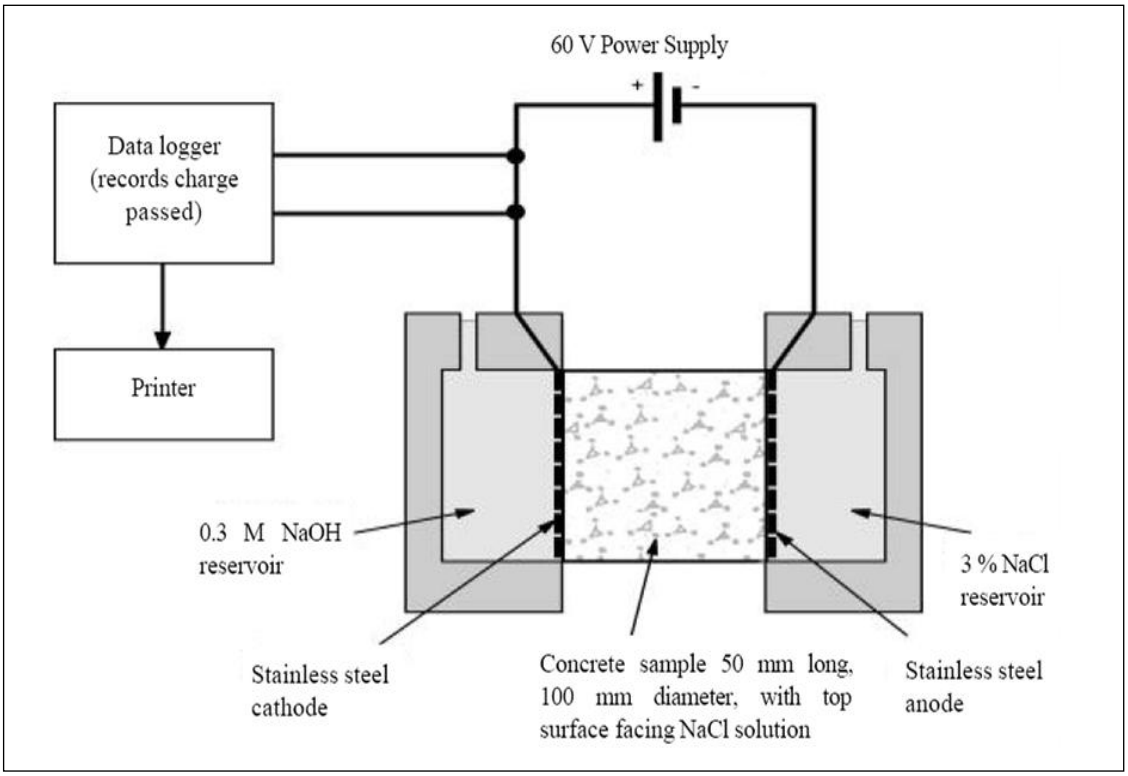

Figure 12.4: A schematic view of the test set-up showing relative position of the sample and the electrodes

p) Turn on power supply and set to 60 ± 0.1 V. Record initial current reading.

q) Read and record current at least every 30 minutes. Each half of the test cell must remain filled with the appropriate solution for the entire period of the test.

r) Terminate test after 6 hours. However, if the temperature of the solution exceeds 190 ºF (90 ºC), terminate the test and the concrete rated as having very high chloride ion penetrability.

s) Remove specimen. Rinse cell thoroughly in tap water; strip out and discard residual sealant.

t) The total charges passed that are recorded are a measure of the electrical conductance of the concrete during the period of the test.

12.4 COMPLIANCE

The chloride penetrability of concrete based on charge passed as referred to ASTM C1202-97 is presented in **Table 12.1.**

Table 12.1: Chloride ion penetrability based on charge passed to ASTM C1202

Charge Passed (coulombs)	Chloride Ion Penetrability
> 4,000	High
2,000 – 4,000	Moderate
1,000 – 2,000	Low
100 – 1,000	Very low
< 100	Negligible

(B) RAPID CHLORIDE PENETRABILITY TEST TO MODIFIED ASTM C1202

12.5 PRINCIPLE

The modified ASTM C1202 test method and its predecessor, ASTM C1202 are accelerated indirect testing method. As compared to ASTM C1202 method, the principles of the modified method are:

- The total charge passed obtained by standard ASTM C1202 procedures contains the contribution by chloride ion movement and contributions by movement of other ions and other effects;

- The total charge passed obtained by the test performed in curing water contains the contributions by the movements of ions other than chloride ions and some contributions by other effects;

- The modified total charge passed, i.e. the difference between the two total charges passed, would reflect more of the contributions of chloride ion movement and would be less dependent on the pore solution chemistry.

12.6 TEST DESCRIPTION

The modified ASTM C1202 test involves the performance of two parallel tests on similar samples, which retains the standard test as an integral part of its procedure. The test procedure can be described as follows:

- Testing is carried out on pair of samples, i.e. from same batch and curing or from same cylinder;

- One sample is tested according to the standard (ASTM C1202) procedures, i.e. using NaCl and NaOH solutions. The total charge

passed is obtained as per standard, TCP_s (*Standard Total Charge Passed*);

- The other sample is tested with curing water as electrolyte in both test chambers, and other items are kept as per ASTM C1202 method. The curing water is referred to the water used in saturation of sample. The total charge passed in this case is termed TCP_w (*Total Charge Passed of Water*) and is less than TCP_s;

- The sample preparation procedures and test variables, i.e. 60V dc and 6 hours are kept according to ASTM C1202 method;

- The difference in the total charge passed between the two tests, i.e. $TCP_s - TCP_w$, represent the movement of chloride ion through the concrete sample, and is used as a criterion for classification of concrete (instead of TCP_s according to ASTM C1202).

12.7 COMPLIANCE (see ref. 2)

Concrete‟s resistance to chloride ion penetration based on modified ASTM C1202 method is presented in **Table 12.2**.

Table 12.2: Limits for chloride ion penetrability based on charge passed to modified ASTM C1202

Charge Passed (coulombs)	Chloride Ion Penetrability
> 3,000	Poor
2,000 – 3,000	Reasonable
1,000 – 2,000	Good
500 – 1,000	Very Good
< 500	Excellent

REFERENCES

1) ASTM C1202, *Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration*. American Society of Testing and Materials, Philadelphia, 1997.

2) Sirivivatnanon, V., Meck, E. and Cao, H.T., „Performance Based specifications in Harmonisation of Durability Standard", 1st Asia/Pacific Conference on Harmonisation of Durability Standards and Performance Tests for Components in Buildings and Infrastructure, Bangkok, Thailand, 8 -10 September, 1999.

13.0 WATER ABSORPTION TEST

13.1 INTRODUCTION

A water absorption test is carried out to determine the water absorption value of concrete, expressed in percentage. This property is particularly important in concrete used for water-retaining structure or watertight basement, as well as being critical for durability.

The test is intended as a durability control of routine quality control of precast products such as paving flags, slabs or kerb (curb) units. Besides that, it is applicable to test concrete quality used in marine environment.

This test is performed on a 75 mm diameter cylindrical specimen prepared in laboratory. Water absorption of the concrete sample is measured by drying the sample to a constant mass and followed by immersing it in water. After immersion in water for 30 minutes, the weight of wet specimen is measured. The absorption of the concrete is the increased weight resulted from the immersion, expressed as a percentage of the mass of the dry specimen.

13.2 EQUIPMENT

Apparatus to carry out water absorption test as refer to MS 26: Part 2 and BS 1881: Part 122 is listed as follows and in **Figures 13.1 - 13.4**:

1. Balance – capable of weighing up to 5 kg with an accuracy of 0.1%
2. Well ventilated drying oven – with temperature controlled at 105±5°C for drying the specimen
3. Tank – to contain water for submersion of sample.
4. Desiccator – sufficient to take three specimens to be tested.

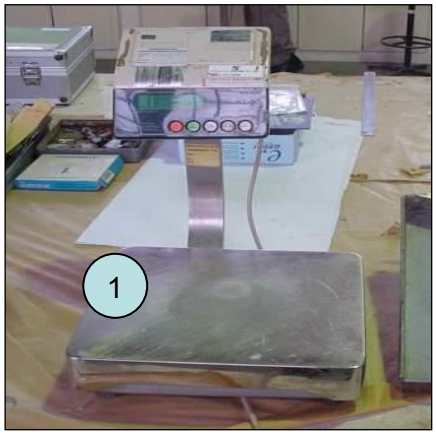

Figure 13.1: Balance

Figure 13.2: Oven

Figure 13.3: Water tank

Figure 13.4: Desiccator

13.3 PROCEDURE

a) Prepare at least three 75 mm diameter cylinder specimens with 75 mm in length as shown in **Figure 13.5**.

b) After preparation, place these three specimens in a drying oven so that each specimen is not less than 25 mm from any heating surface or from each other. Dry the specimens in the oven for 72±2 hours.

Figure 13.5: Cylinder specimens ready for water absorption test

c) On removal from the oven, cool each specimen for 24 ± 0.5 hours in the desiccator, as illustrated in **Figure 13.6**.

Figure 13.6: Storing specimens in a desiccator

d) Remove the specimens from the desiccator and weigh each specimen as in **Figure 13.7** to the nearest 0.001 kg, as W_d.

Figure 13.7: Weighing the specimen on a balance

e) After weighing, immediately immerse the specimens completely in the tank filled with clean water and at a depth such that there is 25 ± 5 mm of water over the top of the specimen, as illustrated in **Figure 13.8.**

Figure 13.8: Immersion of specimen in water

f) Leave the specimen immersed in the water for 30 ± 0.5 minutes.

g) Remove the specimen, shake it to remove the bulk of the water and dry it with a cloth as rapidly as possible until all free water is removed from the specimen surface.

h) After removal of surface water, weigh each specimen again to the nearest 0.001 kg, as W_s.

i) Calculate the absorption of specimens, as the increase in mass resulting from the immersion, expressed as a percentage of the mass of the dry specimen, with the formula:

$$\text{Absorption (\%)} = \frac{W_s - W_d}{W_d} \times 100\% \qquad \text{Equation 1}$$

13.4 COMPLIANCE

Values for 30 minutes absorption of low, average and high absorption concrete as referred to Concrete Society (1988) are as follows:

Low absorption concrete	<	3%
Average absorption concrete		3-5%
High absorption concrete	>	5%

REFERENCES

1) Malaysia Standard, MS 26: Part 2 "*Method for Determination of Water Absorption"*. Malaysia Standard Institute, 1991.

2) British Standard, BS 1881: Part 122 "*Method for Determination of Water Absorption*". British Standard Institute, London, 1983.

3) Concrete Society, "*Permeability of Concrete-a review of testing and experience*". *Technical Report 31*, Concrete Society, London, 1988.

14.0 SORPTION TEST

14.1 INTRODUCTION

The sorption test is carried out to determine the rate of capillary-rise absorption of the outer 50 mm layer of a concrete specimen. This test can be carried out to determine the uniformity of concrete porosity, the effectiveness of waterproofing admixtures or curing systems.

In this test, concrete specimen is oven-dried before put to rest on a tray with water, in a manner such that only the lowest 1-2 mm of the specimen is submerged. The increase in the mass of the prism with time is recorded. In this test, several measurements are taken over a period of up to 4 hours. Upon completion of test, a graph of increase in mass per unit area versus the square root of time is then plotted. The gradient of the best fitted straight line passing through origin is termed the sorptivity of the sample in mm/min^{½}. A typical plot showing the relation between volumes of water absorbed and time used to calculate sorptivity is shown in **Figure 14.1**.

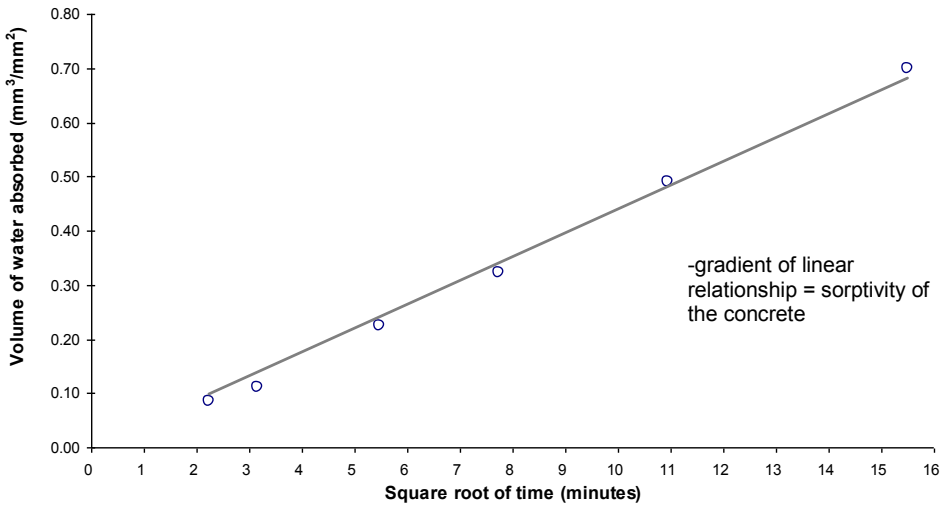

Figure 14.1: Typical relationship between volume of water absorbed and time

14.2 EQUIPMENT

Apparatus used for sorption test for the hardened concrete are described below, and illustrated in **Figures 14.2** and **14.3**:

1. Balance – for weighing the specimen
2. Caliper – for measurement of specimen dimension
3. Tray – as a water container
4. Drying Oven – for drying the specimen before test
5. Desiccator – to maintain specimen temperature before test

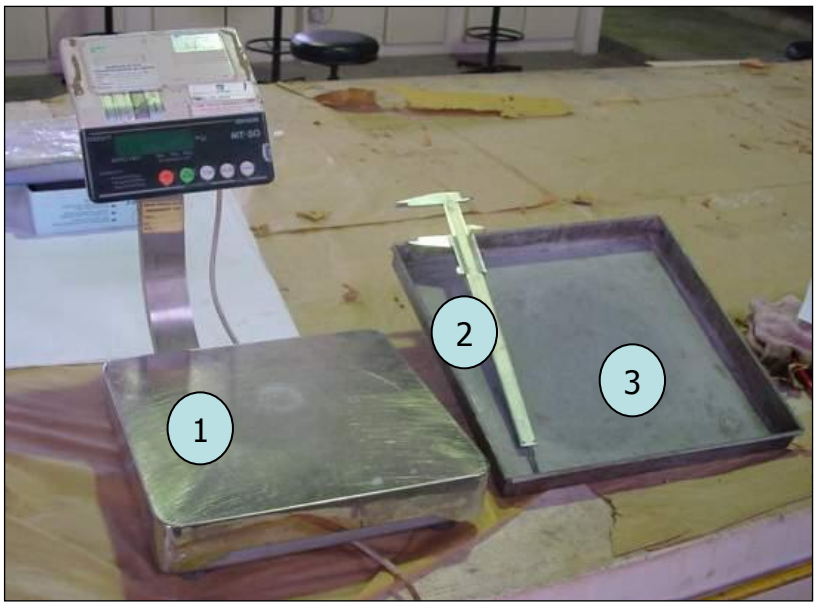

Figure 14.2: Sorption test apparatus

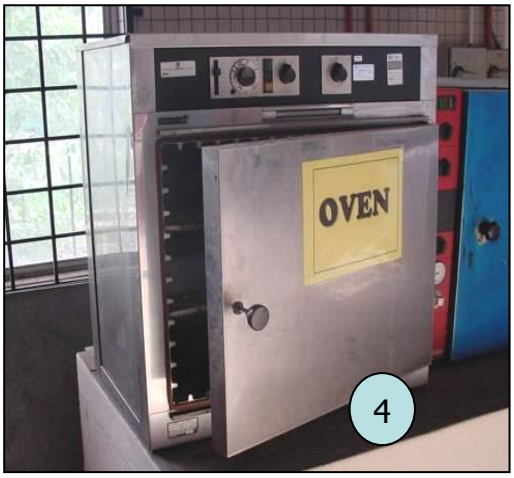

Figure 14.3: Sorption test apparatus

14.3 PROCEDURE

a) Prepare the specimen with the height of at least 100 mm and a minimum weight of 200 g, as shown in **Figure 14.4**. Record the cross-sectional area (*A*) to the nearest 1 mm^2.

b) Clean the specimen surface before weighing.

Figure 14.4: Specimen ready for sorption test

c) Oven dries the specimen at a temperature of 105°C to a constant weight and then allows cooling to 20°C in a desiccator. Measure the specimen weight to the nearest 0.01g as W_d by using a balance as in **Figure 14.5.**

Figure 14.5: Weigh the specimen on a balance

d) Immerse the selected face in a tray of water at 30ºC to a depth of 1-2mm, by resting the specimen on glass rod to permit free water movement, as illustrated in **Figure 14.6**. Record the time of starting of the soaking procedure.

Figure 14.6: Placing specimens on the tray with water at 1-2mm height

e) After 5 minutes, remove the specimen from the tray, dry off surplus water, weigh the specimen as W_t and draw the water profile on the specimen surface, as shown in **Figure 14.7**.

Figure 14.7: Draw water rising profile on specimen surface

f) Repeat step (e) at intervals of 10, 30, 60, 120 and 140 minutes.

g) Calculate the volume of water absorbed per unit cross-section at each intervals time, i_t by using the formula:

$$i_t = \frac{W_t - W_d}{A} \times 10^3 \quad mm^3/mm^2 \qquad \text{Equation 2}$$

h) Plot the graph of i_t vs. $\sqrt{t}$. Determine the gradient of the best fitted straight line passing through the origin.

i) The gradient obtained from the plot is termed the sorptivity of the specimen in $mm/min^{1/2}$.

14.4 COMPLIANCE

Some typical values of sorptivity are: 0.09 mm/min^{½} for concrete with a water/cement ratio of 0.4, and 0.17 mm/min^{½} at a water/cement ratio of 0.6.

REFERENCE

1) T.E. Sorption Test Manual, Taywood Engineering Consult, Taylor Woodrow Group, U.K.