

**CONDITION ASSESSMENT REPORT OF EXISTING STRUCTURE  
USING NON DESTRUCTIVE TECHNIQUE  
AT  
ANSAL KIRTI SHIKHAR TOWER, JANAKPURI WEST, DELHI.**



**Structure is RCC Framed Structure having Basement +  
Upper ground + Ground + 11Floors**

## EXECUTIVE SUMMARY:

Non Destructive and Semi Destructive Testing of using Non Destructive Technique at **Kirti Shikar, Janakpuri District Center, Janakpuri, Delhi, 110058.**

Duration of Testing:-16/08/2022-20/08/2022

**Table 2**

| <b>NON DESTRUCTIVE AND SEMI-DESTRUCTIVE TEST SUMMARY</b> |                           |                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                   |                       |
|----------------------------------------------------------|---------------------------|-----------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| <b>S.N<br/>O</b>                                         | <b>TEST NAME</b>          | <b>REFERENCE OF<br/>TEST</b>                                                                              | <b>PURPOSE OF TEST ,TEST<br/>RESULT &amp; COMMENT</b>                                                                                                                                                                                                                                                                                                                                                             | <b>REFERENCE</b>      |
| 1                                                        | Rebound Hammer Test       | IS 13311 (Part-2)-<br>1992, ASTM C<br>805-02, BS<br>6089:1981 and<br>BS 1881: Part<br>202, BSEN:13791     | To determining the estimated<br>compressive strength and<br>uniformity of concrete<br><br>Around 106 tests conducted on<br>RCC Column, slab and beams<br>and compressive strength of<br>concrete tested range from M13-<br>M22 Grade of concrete & M8-<br>M12 ON 11th floor and water<br>tank area.<br><br>Which is lower than M20 as per<br>the latest codal provision of IS<br>456:2000                         | Table-9<br>Page-56-66 |
| 2                                                        | Ultrasonic Pulse Velocity | IS 13311 (Part-1)-<br>1992, ASTM:<br>C597-83, BS<br>6089: 1981 and<br>BS 1881: Part 203<br>and BSEN:13791 | To determine the quality of<br>concrete, soundness and density<br>of concrete.<br><br>Around 90 tests conducted on<br>RCC Column, slab and beam and<br>its quality is found to be Good-<br>Doubtful Concrete.<br><br>Which clearly indicates that there<br>is presence of voids/minor cracks<br>inside the concrete. Some of<br>which is exposed on surface and<br>some is not exposed on the<br>surface till now | Table-9<br>Page-56-66 |

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|   |                          |                                    |                                                                                                                                                                                                                                                                                                                                                                                               |                        |
|---|--------------------------|------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|
| 3 | Half Cell Potential Test | ASTM C876-1980 ,ASTM C876 [6]-1991 | <p>To determine the percentage of risk of corrosion in reinforcement</p> <p>10 test have been performed on RCC members. It is found out that chances of corrosion is 0%-10% in reinforcement bars but on 11th floor and water tank area corrosion is high.</p> <p>As per testing its, clear that the existing reinforcement in members are rusted about 10% of existing diameter of steel</p> | Table-12<br>Page-72    |
| 4 | Cover Depth Measurement  | IS:456:2000                        | <p>To see the adequacy of concrete cover to Rebars and creation of Contour Mapping of cover depth in RCC Structure.</p> <p>50 Test were performed on RCC Column, slab &amp; beam &amp; Sufficient Cover is found to be there to all structural members.</p> <p>It is sufficient as per the Indian Codal provision IS 456:2000</p>                                                             | Table-13<br>Page-76-78 |
| 5 | Carbonation Test         | BS EN: 14630                       | <p>If depth of carbonation is greater than cover, then incubation period is over; degradation rate will be accelerated.</p> <p>2 Samples are extracted and its average carbonation depth is found to be more than effective cover.</p> <p>It is not in the permissible limits as per Indian Codal provision</p>                                                                               | Table-14<br>Page-81    |
| 6 | Core Testing             | As per IS 516                      | <p>To determine the grade of concrete.</p> <p>3 test have been performed on RCC columns. It is found to be in range of M17-M18 Which is lower than M20 as per the latest codal provision of IS 456:2000</p>                                                                                                                                                                                   | Table-15<br>Page-84    |

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|   |                                                 |                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                     |
|---|-------------------------------------------------|------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
| 8 | Brick compression Test                          | IS 3495 :1992<br>part I, IS 1077 :<br>1992                       | <p>To check the compressive strength of burnt brick</p> <p>2 brick were extracted for testing and it's average compressive strength found to be is 8.03-8.2 Kn/mm<sup>2</sup></p> <p>The existing strength of the brick lies under second class brick as per strength achieve during brick testing as per Indian Codal provisions</p>                                                                                                                           | Table-16<br>Page-86 |
| 9 | Chemical Analysis of Binding Material of Mortar | IS 1905:1984<br>Clause 3.2.1<br>Table-1, Clause<br>5.4.1 Table-8 | <p>To determine the binding material properties, Percentage of constituent elements and source of materials, composition details of materials, its compressive strength, type of mortar and its composition.</p> <p>2 Sample were tested and its found that M2 Grade of Mortar used for binding of Bricks.</p> <p>As per the testing the mortar ratio is found to be M2 grade range as per Indian code which is sufficient for binding two bricks together.</p> | Table-17<br>Page-91 |

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## **FINAL CONCLUSION: -**

**REBOUND HAMMER :-** From the Rebound Hammer tests, it is clear that the strength of concrete is in the range of M13 to M22 (Which is below the Standard practice of Design ) & 11<sup>th</sup> Floor & water tank area is in range of M8-M12 which is under doubtful condition and is alarming (Either Needs Repair or Dismantle with some Standby arrangements)

**UPV RESULTS :-** Most of the Concrete behaviour lies in the range of Medium except 11<sup>th</sup> floor/ Watertank/UGF- which is under doubtful situations, which needs immediate repair to avoid any structural Fatigue., UPV Results for Structural elements at every level is medium but needs Repair on Priority to avoid any further stresses .

**CORROSION/CARBONATION :-** Entire structure is experiencing Corrosion and the impact of it on the structural elements, To avoid any further corrosion and loss in section of the reinforcement, It has to go under Significant repair and Mapping of Corrosion with Impressed or Sacrificial Cathodic Protection. At 11th floor and water tank area reinforcement is suffering from high risk of corrosion which is indicative of onset of active corrosion and may result in reduction of X-section of reinforcement (approx. 30% of diameter reduction). High risk of corrosion may be due to presence (sub structure) of air voids and or honeycombing in RCC structural members. Cracks at few locations are visible along the reinforcement length due to undergoing active corrosion (high risk of corrosion). The cover provided to protect the reinforcement is fully carbonated and may not remain effective to protect the reinforcement.

**CORE RESULTS :-** Random core extracted result showed the deficiency in compressive strength, which needs to be addressed to reach present Codal Practices against structural Integrity .

**STAD RESULTS :-** Most of the steel has undergone corrosion and lies under Deficient/ Failure stage, Required Flexural/tensile Properties to be increased level wise.

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**FINAL CONCLUSION :-** The structure has to undergo significant repair against the structural stability, specially the TANK/11<sup>TH</sup> FLOOR, Columns and Beams at the periphery.

**Team Involve In Audit Work:**

**Table 3**

| S.No | Name              | Qualification   | Role                   |
|------|-------------------|-----------------|------------------------|
| 1.   | Mr Brijesh Mishra | Civil engineer  | Checked & Approved By  |
| 2.   | Mr. Rakesh        | MTech (Civil)   | Stad Partner & auditor |
| 3.   | Mr. Karan Nagar   | B Tech (Civil)  | Compiled by            |
| 4.   | Mr Bilal Khan     | B. Tech (Civil) | Test & Prepared By     |

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# 1. INTRODUCTION

## 1. INTRODUCTION:

### 1.1 Site

The existing structure **JANAKPURI** Using Non Destructive Test At **Kirti Shikar, Janakpuri District Center, Janakpuri, Delhi, 110058**.has requested to **M/s Zeichenburo** for Health Assessment of superstructure through conditions survey using Non-destructive testing. This report pertains to the stated safety appraisal, health assessments. Objectives of the investigation and survey, general methodology and test procedures, etc. are given followed by details of the observations recorded at site and results of in-situ and laboratory tests.

### 1.2 Evaluation of the Structure

In order to assess the condition of the RCC structure, a thorough evaluation was performed. The testing consisted of:

- A visual inspection of the exterior exposed elements to determine if there were any obvious signs of distress, deflection or deterioration in the structure.
- A thorough inspection of the structure to determine the condition of the structure. This is essential as we found that the structure can appear to be in a very good condition from outside, but could be suffering from extreme structural distress from inside.
- Selective concrete removal to examine the condition of the underlying reinforcing steel.
- Materials testing to determine concrete compressive strength, carbonation, cover depth.

### 1.3. Objectives of the overall investigation:

The overall objective of the investigation carried out for the structure is to obtain an up to date account of the health condition of the structure so that appropriate repair measures can be taken up to make up for the damages sustained. Keeping this in view the basic objectives of the investigation formulated are as given below.

1. To assess the existing condition of the structural elements.
2. To determine the extent of damages in the structure, so as to undertake suitable remedial measures for rehabilitation of the structure.

### 1.4. Planning of Investigation and Methodology

#### 1.4.1 Walk over survey:

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First and foremost activity in a condition survey and structural investigation, especially in distressed superstructure, is a walk over survey or systematic visual inspection so as to gather readily available information about the structure in question. Further, careful visual observation of typical crack pattern and the nature of the spalling can furnish valuable information regarding the distresses. This in turn provides an idea about the degree of damage encountered in the concrete and hence the extent of repair required. A systematic visual observation has been recorded in this investigation and the findings are presented in later part of this report.

#### **1.4.2 Selection of tests:**

Tests are selected on the basis of the requirements of the overall objectives of the investigation and the observations made during a quick walk over survey. In this investigation, following in-situ and laboratory tests were considered necessary for achieving the overall objectives stated earlier for the structure.

#### **Various Test were Conducted for the evaluation of the Structure:**

The various Non-Destructive Tests proposed to be carried out for condition survey of the structure are listed below:

1. **Ultrasonic Pulse Velocity Test** as per IS: 13311 (Part-1)-1992 for ascertaining the quality of concrete, soundness and density of concrete.
2. **Rebound Hammer Test:** For determining the estimated compressive strength of concrete and uniformity of concrete in terms of surface hardness as per IS 13311 (Part-2)-1992.
3. **Half Cell Potential Test** as per ASTM C876-1991 for assessing the percentage risk of corrosion in reinforcement. Measuring the half-cell / surface potentials at selected locations on RCC members of the structures covered under the study to understand the extent of reinforcement corrosion. (Risk of corrosion of steel).
4. **Carbonation Test** as per BS EN: 14630 Measurement of carbonation depth by phenolphthalein spray test at selected locations on RCC members of the structures covered under the study to see the depth of carbonation.
5. **Core Extraction** IS: 516, concrete extraction for exact in-situ compressive strength evaluation of concrete, grade and fck value of concrete.
6. **Brick Compressive Strength:-** To check the compressive strength of burnt brick as per IS 3495 :1992 part I, IS 1077: 1992
7. **Chemical analysis for binding material Mortar:-** Binding material properties; Percentage of constituent elements and source of materials, composition details of materials, its compressive strength of binding materials, type of mortar

### 1.5 Sample and Site Data Collection:-

The four instruments i.e. Ultrasonic Pulse velocity meter, Rebound Hammer, Half-Cell Potential meter & Cover Meter, Core Cutter were used to collect the data from the structure. Carbonation test has been done on extracted concrete core sample as well as through the drilling the concrete surface test locations were selected after visual survey and data was collected from below mentioned test locations in the structure. As per surface condition required numbers of tests on different concrete surface have been decided to get the overall idea of concrete quality.

### 1.6 Table 5-Number Of Tests To Be Conducted:-

| S.No | Location             | Rebound Hammer | Ultrasonic Pulse Velocity Test | Carbonation Test | Core Test | Cover Test | Half Cell Potential test |
|------|----------------------|----------------|--------------------------------|------------------|-----------|------------|--------------------------|
| 1    | Basement             | 50             | 34                             | 2                | 3         | 24         | 4                        |
| 2    | ground floor         | 4              | 4                              | .                | .         | 2          | .                        |
| 3    | Upper ground floor   | 4              | 4                              | .                | .         | 2          | .                        |
| 4    | First Floor          | 4              | 4                              | .                | .         | 2          | .                        |
| 5    | Second Floor         | 4              | 4                              | .                | .         | 2          | .                        |
| 6    | Third floor          | 3              | 3                              | .                | .         | 2          | .                        |
| 7    | Fourth floor         | 4              | 4                              | .                | .         | 2          | .                        |
| 8    | Fifth floor          | 3              | 3                              | .                | .         | 2          | .                        |
| 9    | Sixth floor          | 5              | 5                              | .                | .         | 2          | .                        |
| 10   | Seventh floor        | 5              | 5                              | .                | .         | 2          | .                        |
| 11   | Eighth floor         | 4              | 4                              | .                | .         | 2          | .                        |
| 12   | Ninth floor          | 3              | 3                              | .                | .         | 2          | .                        |
| 13   | Tenth floor          | 3              | 3                              | .                | .         | 2          | .                        |
| 14   | Eleventh floor       | 5              | 5                              | .                | .         | 2          | 3                        |
| 15   | Terrace (water tank) | 5              | 5                              | .                | .         | .          | 3                        |

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## 2. VISUAL SURVEY

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TABLE:-6

| S.NO.   | PARTICULAR                    | IMAGE                                                                               | LOCATION           | TYPE OF DEFECT                                        |
|---------|-------------------------------|-------------------------------------------------------------------------------------|--------------------|-------------------------------------------------------|
| TERRACE |                               |                                                                                     |                    |                                                       |
| 1       | WATER TANK -1<br>NEAR E-F/5-6 |    | SLAB<br>(7.5X7.5m) | CONCRETE SPALLING<br>REINFORCEMENT<br>EXPOSED SEEPAGE |
| 2       | WATER TANK -1<br>NEAR E-F/6   |   | COLUMN             | CONCRETE SPALLING<br>& REINFORCEMENT<br>EXPOSED       |
| 3       | WATER TANK -2<br>NEAR E-F/6   |  | COLUMN             | CONCRETE SPALLING<br>& REINFORCEMENT<br>EXPOSED       |

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|   |                              |                                                                                     |        |                                                        |
|---|------------------------------|-------------------------------------------------------------------------------------|--------|--------------------------------------------------------|
| 4 | WATER TANK -2<br>NEAR E-F/-6 |    | COLUMN | CONCRETE SPALLING<br>& REINFORCEMENT<br>EXPOSED        |
| 5 | WATER TANK<br>NEAR E-F/14    |   | SLAB   | CRACK+REINFORCEMENT<br>EXPOSED+CONCRETE<br>SPALLING    |
| 6 | WATER TANK<br>NEAR E-F/14    |  | SLAB   | CRACK<br>REINFORCEMENT<br>EXPOSED<br>CONCRETE SPALLING |

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|   |                              |                                                                                    |        |                                                                     |
|---|------------------------------|------------------------------------------------------------------------------------|--------|---------------------------------------------------------------------|
| 7 | WATER TANK -2<br>NEAR E-F/14 |   | COLUMN | CRACK<br>REINFORCEMENT EXPOSED<br>CONCRETE SPALLING<br><br>( MAJOR) |
| 8 | WATER TANK -2<br>NEAR E-F/14 |  | COLUMN | REINFORCEMENT<br>EXPOSED                                            |

11<sup>TH</sup> FLOOR

|   |                                               |                                                                                     |      |                                                   |
|---|-----------------------------------------------|-------------------------------------------------------------------------------------|------|---------------------------------------------------|
| 9 | C-I-7-1 ALL<br>AREA<br>DAMAGED DUE<br>TO FIRE |  | SLAB | REINFORCEMENT<br>EXPOSED<br><br>CONCRETE SPALLING |
|---|-----------------------------------------------|-------------------------------------------------------------------------------------|------|---------------------------------------------------|

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|    |                         |                                                                                     |             |                                                          |
|----|-------------------------|-------------------------------------------------------------------------------------|-------------|----------------------------------------------------------|
| 10 |                         |    | CORRIDOR    | PLASTER SPALLING                                         |
| 11 | G-F-11-12<br>TOILET     |    | SLAB & BEAM | SEEPAGE<br>REINFORCEMENT<br>EXPOSED<br>CONCRETE SPALLING |
| 12 | 17-18-E-F NEAR<br>STAIR |   | WALL        | SEEPAGE(3X3m)                                            |
| 13 | E-F STAIR               |  | SLAB        | CRACK(4x1m)                                              |

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10<sup>TH</sup> FLOOR

|    |           |                                                                                     |      |                         |
|----|-----------|-------------------------------------------------------------------------------------|------|-------------------------|
| 14 | F-17-18   |    | WALL | SEEPAGE(3X1)            |
| 15 | F-16-17   |   | WALL | CRACK(2.5X2)            |
| 16 | 13-14-E-F |  | SLAB | CONCRETE<br>POPOUT(1X1) |

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|                       |                |                                                                                     |      |                                  |
|-----------------------|----------------|-------------------------------------------------------------------------------------|------|----------------------------------|
| 17                    | MAN'S TOILET   |    | SLAB | SEEPAGE<br>PAINT<br>PEELOFF(2X2) |
| 18                    | LADIES TOILETS |   | SLAB | SEEPAGE<br>PAINT<br>PEELOFF(3X3) |
| 9 <sup>TH</sup> FLOOR |                |                                                                                     |      |                                  |
| 19                    | LADIES TOILETS |  | SLAB | PAINT PEELOFF(1X1)               |

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|                       |                                        |                                                                                     |            |                                             |
|-----------------------|----------------------------------------|-------------------------------------------------------------------------------------|------------|---------------------------------------------|
| 20                    | F-16-17                                |    | WALL& BEAM | PAINT PEELOFF<br>CRACK SEEPAGE<br>(2.5X2.5) |
| 21                    | 18-E-F<br>CANTILEVER PART<br>STAIRCASE |   | BEAM       | CRACK<br>CONCRETE POPOUT(<br>3m)            |
| 8 <sup>TH</sup> FLOOR |                                        |                                                                                     |            |                                             |
| 22                    | F-17-18+E-17-18                        |  | WALL 2NOS  | SEEPAGE<br>(2X2m)                           |

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|    |                             |                                                                                     |      |                                |
|----|-----------------------------|-------------------------------------------------------------------------------------|------|--------------------------------|
| 23 | CANTILEVER<br>PART STAIRCAS |    | BEAM | SEEPAGE (3m)<br>CRACK(4m)      |
| 24 | MAN'S TOILET                |    | SLAB | CRACK &<br>SEEPAGE(3mx3m)      |
| 25 | LADIES TOILET               |  | SLAB | MINOR CRACK &<br>PAINT PEELOFF |

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|    |            |                                                                                    |        |                                     |
|----|------------|------------------------------------------------------------------------------------|--------|-------------------------------------|
| 26 | 10-11-H-I  |   | SLAB   | CRACK &<br>PAINT PEELOFF<br>SEEPAGE |
| 27 | 805 OFFICE |  | COLUMN | CRACK (1m)                          |

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7<sup>TH</sup> FLOOR

|    |                               |                                                                                     |      |                              |
|----|-------------------------------|-------------------------------------------------------------------------------------|------|------------------------------|
| 28 | STAIRCASE IN<br>FRONT OF GATE |    | SLAB | CRACK(2m)                    |
| 29 | IN FRONT OF<br>LIFT           |    | SLAB | CONCRETE POPOUT<br>(1.5X1.5) |
| 30 | IN FRONT OF<br>MAN'S TOILET   |  | SLAB | SEEPAGE(2X2)                 |

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|    |                      |                                                                                    |      |                                   |
|----|----------------------|------------------------------------------------------------------------------------|------|-----------------------------------|
| 31 | MAN'S TOILET         |   | SLAB | WHOLE SEEPAGE                     |
| 32 | E-F-17-18            |   | SLAB | CRACK(3m)                         |
| 33 | STAIRCASE CANTILEVER |  | BEAM | REINFORCEMENT EXPOSE<br>CRACK(3m) |

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6<sup>TH</sup> FLOOR

|    |                     |                                                                                   |      |                 |
|----|---------------------|-----------------------------------------------------------------------------------|------|-----------------|
| 34 | E-F-17-18 staircase |  | SLAB | Crack(3m)       |
| 35 | F-17-18 staircase   |  | WALL | SEEPAGE (3mx5m) |

5<sup>TH</sup> FLOOR

|    |                     |                                                                                     |      |                    |
|----|---------------------|-------------------------------------------------------------------------------------|------|--------------------|
| 36 | STAIRCASE NEAR LIFT |  | WALL | SEEPAGE (2.5X2.5m) |
|----|---------------------|-------------------------------------------------------------------------------------|------|--------------------|

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|    |              |                                                                                    |           |                                      |
|----|--------------|------------------------------------------------------------------------------------|-----------|--------------------------------------|
| 37 | K-G-5-6      |   | SLAB      | CONCRETE POPOUT<br>(1X1m)            |
| 38 | MAN'S TOILET |  | WALL&SLAB | PAINT PEEL OFF<br>SEEPAGE<br>(4mx3m) |

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|    |                                        |                                                                                                                                                                           |             |                        |
|----|----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|------------------------|
| 39 | E-F-17-18<br>STAIRCASE                 |                                                                                          | SLAB        | CRACK(3m)              |
| 40 | STAIRCASE<br>CANTILEVER<br>NEAR E-F-18 | <br> | SLAB & BEAM | SEEPAGE-3m<br>CRACK-3m |

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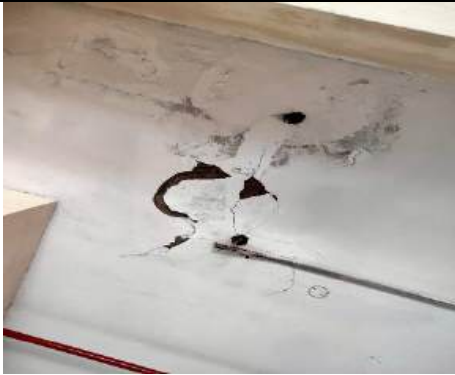
4<sup>TH</sup> FLOOR

|    |                         |                                                                                     |      |                                      |
|----|-------------------------|-------------------------------------------------------------------------------------|------|--------------------------------------|
| 41 | STAIRCASE<br>F-17-18    |    | SLAB | PAINT PEELOFF<br>(3mx2m)<br>CRACK 3m |
| 42 | STAIRCASE<br>CANTILEVER |   | BEAM | SEEPAGE &<br>CRACK                   |
| 43 | MAN'S TOILET            |  | SLAB | SEEPAGE (3X2m)                       |

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|    |                    |                                                                                     |      |                                            |
|----|--------------------|-------------------------------------------------------------------------------------|------|--------------------------------------------|
| 44 | LADIES TOILET      |    | SLAB | SEEPAGE<br>(3X2m)<br>MINOR CRACK<br>(0.5m) |
| 45 | STAIRCASE-<br>2NOS |    | WALL | SEEPAGE                                    |
| 46 | STAIRCASE<br>SLAB  |   | SLAB | CRACK 3m                                   |
| 47 | LADIES TOILET      |  | SLAB | SEEPAGE PAINT<br>PEELOFF                   |

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|    |                                |                                                                                    |      |                                       |
|----|--------------------------------|------------------------------------------------------------------------------------|------|---------------------------------------|
| 48 | MAN'S TOILET                   |   | SLAB | SEEPAGE (3mx3m)                       |
| 49 | E-F-17                         |   | SLAB | CONCRETE<br>POPOUT<br>SEEPAGE (2mx2m) |
| 50 | E-F-17-18<br>STAIRCASE<br>2NOS |  | SLAB | CRACK 3m                              |

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|                       |            |                                                                                    |               |                    |
|-----------------------|------------|------------------------------------------------------------------------------------|---------------|--------------------|
| 51                    | 419 OFFICE |   | COLUMN & SLAB | SEEPAGE<br>(2mx2m) |
| 52                    | 411 OFFICE |  | COLUMN        | SEEPAGE            |
| 3 <sup>RD</sup> FLOOR |            |                                                                                    |               |                    |

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|                       |                         |                                                                                     |      |                                                                                     |
|-----------------------|-------------------------|-------------------------------------------------------------------------------------|------|-------------------------------------------------------------------------------------|
| 53                    | STAIRCASE<br>CANTILEVER |    | BEAM | SEEPAGE<br>(3mx3m)<br>CRACK 3m                                                      |
| 54                    | 10-11-G-H               |    | SLAB | REINFORCEMENT<br>EXPOSED<br><br>CONCRETE<br>SPALLING<br><br>(3mx3m)<br><br>CRACK-3m |
| 2 <sup>ND</sup> FLOOR |                         |                                                                                     |      |                                                                                     |
| 55                    | MAN'S TOILET            |  | SLAB | CONCRETE<br>POPOUT<br><br>SEEPAGE (2X2m)                                            |

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|    |               |                                                                                    |      |                    |
|----|---------------|------------------------------------------------------------------------------------|------|--------------------|
| 56 | LADIES TOILET |   | SLAB | SEEPAGE (3mx3m)    |
| 57 | 5-6-A-B       |  | WALL | SEEPAGE<br>(2mx2m) |

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|    |            |                                                                                   |        |                       |
|----|------------|-----------------------------------------------------------------------------------|--------|-----------------------|
| 58 | 217 OFFICE |  | COLUMN | CRACK<br>(2m)<br>3Nos |
|----|------------|-----------------------------------------------------------------------------------|--------|-----------------------|

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1<sup>ST</sup> FLOOR

|    |               |                                                                                     |      |                                     |
|----|---------------|-------------------------------------------------------------------------------------|------|-------------------------------------|
| 59 | LADIES TOILET |    | SLAB | SEEPAGE (3mx2m)                     |
| 60 | STAIRCASE     |   | WALL | CRACK -2m<br>SEEPAGE-2x1.5m<br>2nos |
| 61 | MAN'S TOILET  |  | SLAB | SEEPAGE<br>PAINT PEELOFF<br>(2mx3m) |

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|    |                         |                                                                                   |      |                     |
|----|-------------------------|-----------------------------------------------------------------------------------|------|---------------------|
| 62 | STAIRCASE<br>CANTILEVER |  | BEAM | SEEPAGE<br>CRACK 3m |
|----|-------------------------|-----------------------------------------------------------------------------------|------|---------------------|

## UPPER GROUND FLOOR

|    |                         |                                                                                     |      |                                                            |
|----|-------------------------|-------------------------------------------------------------------------------------|------|------------------------------------------------------------|
| 63 | STAIRCASE<br>CANTILEVER |    | BEAM | SEEPAGE<br>CRACK 3m                                        |
| 64 | LIFT RCC WALL           |   | WALL | REINFORCEMENT<br>EXPOSED<br><br>CONCRETE<br>POPOUT (2mx1m) |
| 65 | STAIRCASE<br>NEAR LIFT  |  | SLAB | CRACK 2m                                                   |

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|              |                  |                                                                                     |      |                                                                                |
|--------------|------------------|-------------------------------------------------------------------------------------|------|--------------------------------------------------------------------------------|
| 66           | H-I-8-11<br>5nos |    | BEAM | CRACK-3m                                                                       |
| 67           | 9-10-G-H         |   | SLAB | SEEPAGE (3mx5m)                                                                |
| GROUND FLOOR |                  |                                                                                     |      |                                                                                |
| 68           | 5-6-I            |  | BEAM | REINFORCEMENT<br>EXPOSED<br><br>CONCRETE<br>SPALLING<br><br>(1.5m)<br><br>3Nos |

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## BASEMENT

|    |                |                                                                                     |      |                                                        |
|----|----------------|-------------------------------------------------------------------------------------|------|--------------------------------------------------------|
| 69 | NEAR 11-12-I-J |    | SLAB | SEEPAGE<br>REINFORCEMENT<br>EXPOSED (4mx4m)            |
| 70 |                |   | SLAB | SEEPAGE                                                |
| 71 | E-F-16-17      |  | SLAB | CONCRETE<br>POPOUT<br>REINFORCEMENT<br>EXPOSED (2mx2m) |

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|    |                   |                                                                                     |      |                                                                    |
|----|-------------------|-------------------------------------------------------------------------------------|------|--------------------------------------------------------------------|
| 72 | 15-17-A-C         |    | SLAB | SEEPAGE (3X5m)<br>PAINT PEELOFF<br>(3X3m)                          |
| 73 | 16-A-C<br>(MAJOR) |   | BEAM | CRACK<br>CONCRETE<br>POPOUT<br>REINFORCEMENT<br>EXPOSED<br>(2mx2m) |
| 74 | 13-14-C-D         |  | SLAB | SEEPAGE (3mx3m)<br>CRACK                                           |

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|    |                      |                                                                                     |      |                                                                                   |
|----|----------------------|-------------------------------------------------------------------------------------|------|-----------------------------------------------------------------------------------|
| 75 | RCC WALL<br>LIFT     |    | WALL | SEEPAGE (3X2m)<br><br>CRACK<br><br>PAINT PEELOFF                                  |
| 76 | 8-9-F-G<br>RCC WALL  |    | WALL | REINFORCEMENT<br>EXPOSED<br><br>CONCRETE<br>SPALLING<br><br>(3X2m)<br><br>SEEPAGE |
| 77 | 8-10-E-D RCC<br>WALL |  | WALL | SEEPAGE (3X3m)<br><br>PLASTER<br>PEELOFF                                          |

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|    |                   |                                                                                     |                   |                                 |
|----|-------------------|-------------------------------------------------------------------------------------|-------------------|---------------------------------|
| 78 | 8-10-E-D RCC WALL |    | SHAFT             | CRACK (1.5m)<br>SEEPAGE (3mx2m) |
| 79 | B-C-4             |   | BEAM              | CRACK 2m<br>3nos                |
| 80 | 1-2-E-F           |  | SLAB & BRICK WALL | SEEPAGE<br>(5mx5m)              |

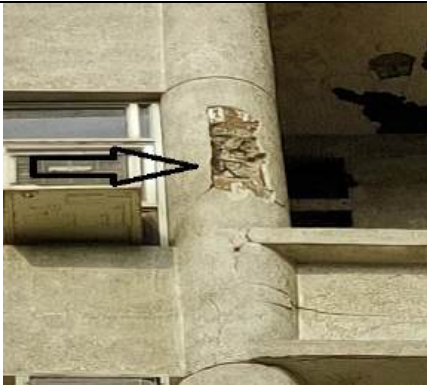
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|    |          |                                                                                    |              |                                                                             |
|----|----------|------------------------------------------------------------------------------------|--------------|-----------------------------------------------------------------------------|
| 81 | NEAR G-4 |   | SLAB         | CONCRETE<br>SPALLING<br>(1mx1m)<br>REINFORCEMENT<br>EXPOSED<br>CRACK        |
| 82 | I-9-11   |   | BEAM         | CONCRETE<br>SPALLING<br>(1mx1m)<br>REINFORCEMENT<br>EXPOSED<br>CRACK(3X.3m) |
| 83 | 5-6-I    |  | BEAM<br>3NOS | CONCRETE<br>SPALLING<br>REINFORCEMENT<br>EXPOSED                            |

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## OUTER VISUAL

|    |                           |                                                                                     |        |                                                 |
|----|---------------------------|-------------------------------------------------------------------------------------|--------|-------------------------------------------------|
| 84 | I-7 5 <sup>TH</sup> FLOOR |    | COLUMN | CRACK-1m                                        |
| 85 | H-11                      |   | COLUMN | REINFORCEMENT<br>EXPOSED<br>SPALLING-(0.5X0.5m) |
| 86 | 14-J GROUND FLOOR         |  | COLUMN | CRACK-2m                                        |

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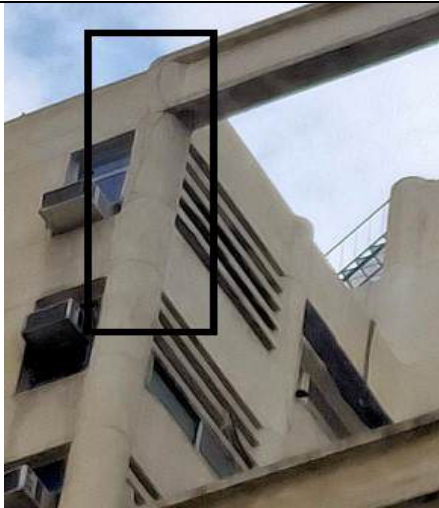
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|    |                    |                                                                                     |        |                                                         |
|----|--------------------|-------------------------------------------------------------------------------------|--------|---------------------------------------------------------|
| 87 | 17-H               |    | COLUMN | CRACK-3m                                                |
| 88 | 16-17-C            |   | BEAM   | CRACK-2m                                                |
| 89 | 15-A-B FIRST FLOOR |  | BEAM   | CONCRETE SPALLING &<br>REINFORCEMENT<br>EXPOSED-(3mX3m) |

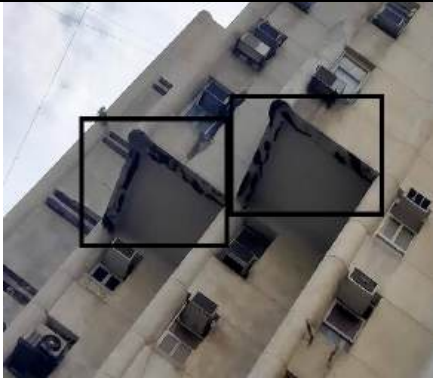
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|    |                               |                                                                                     |               |                                                                                        |
|----|-------------------------------|-------------------------------------------------------------------------------------|---------------|----------------------------------------------------------------------------------------|
| 90 | A-13-14 GROUND FLOOR          |    | BEAM&<br>SLAB | CRACK<br>REINFORCEMENT<br>EXPOSE(3X5m)                                                 |
| 91 | A-13-14 upper<br>GROUND FLOOR |   | SLAB          | CONCRETE POP OUT<br>(2x2m)                                                             |
| 92 | B-8                           |  | COLUMN        | CONCRETE SPALLING –<br>(1mX3m)<br><br>REINFORCEMENT<br>EXPOSED-(3mX3m)<br><br>CRACK-9m |

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|    |                                                   |                                                                                     |                |                                                         |
|----|---------------------------------------------------|-------------------------------------------------------------------------------------|----------------|---------------------------------------------------------|
| 93 | B-9,10 <sup>TH</sup> TO 11 <sup>TH</sup><br>FLOOR |    | COLUMN         | CRACK -6m                                               |
| 94 | B-11-12 11 <sup>TH</sup><br>FLOOR                 |   | BEAM           | CONCRETE SPALLING<br>(1X3)m<br>REINFORCEMENT<br>EXPOSED |
| 95 | B-8-11<br>8 <sup>TH</sup> FLOOR                   |  | SLAB &<br>SLAB | CRACK-6m<br>POPOUT-1x1m                                 |

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|    |                                                         |                                                                                     |                |                       |
|----|---------------------------------------------------------|-------------------------------------------------------------------------------------|----------------|-----------------------|
| 96 | A-5-6<br>STAIRCASE                                      |    | COLUMN         | PLANTATION<br>SEEPAGE |
| 97 | 4-2-B-C 8 <sup>th</sup> floor                           |    | BEAM<br>4nos   | SEEPAGE -3mx3m        |
| 98 | E-I<br>UP GROUND &<br>2 <sup>ND</sup> FLOOR             |   | COLUMN<br>2NOS | CRACK-2m              |
| 99 | E-F-I<br>GROUND,UP<br>GROUND & 1 <sup>ST</sup><br>FLOOR |  | BRICK<br>WALL  | SEEPAGE-9X5m          |

**PREPARED BY:****ZEICHENBURO INDIA PRIVATE LIMITED****BH-1012, 10<sup>TH</sup> FLOOR, PURI BUSSINESS HUB****SECTOR-81, FARIDABAD, HARYANA**

**PREPARED BY:**

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***SECTOR-81, FARIDABAD, HARYANA***

### **3. METHODOLOGY FOR PERFORMING VARIOUS NON DESTRUCTIVE AND SEMI DESTRUCTIVE TESTS& TEST RESULTS SUMMARY**

**PREPARED BY:**

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### 3.1.1 REBOUND HAMMER TEST:-

#### Purpose:-

This test gives a measure of the surface hardness of the concrete surface. Although there is no direct relationship between this measurement of surface hardness and strength, an empirical relationship exists.

Rebound hammer is the best known methods of comparing the concrete in different parts of a structure and indirectly assessing concrete strength. The rebound hammer should be considered as a means of assessing variations of strength within a structure rather than an accurate means of assessing the strength.

#### Objective of testing:-

Rebound hammer test is performed to determine the following:

- ✓ Surface hardness
- ✓ Uniformity of concrete over the structure
- ✓ Grade of concrete
- ✓ Estimated strength which is derived from establishing a relationship between in-situ core strength and rebound number.

#### References:-

- ✓ BS 6089:1981 and BS 1881:Part 202,
- ✓ IS13311(Part2):1992
- ✓ ASTM C 805-02

#### Influencing factors:-

Rebound hammer test results are considerably influenced by these factors:

- ✓ Size, shape and rigidity of the specimen
- ✓ Age of test specimen
- ✓ Smoothness of surface and internal moisture condition of the concrete
- ✓ Carbonation of concrete surface

#### Testing Method:-

According to ASTM C 805-02 clause 7.1 the concrete members to be tested shall be at least 100mm thick and fixed within a structure. Towelled surfaces generally exhibit high rebound numbers than screed or formed finishes. Do not compare the test results if the form material against which the concrete is placed is not similar.

Heavily textured, soft or surfaces with loose mortar shall be ground flat with abrasive stone. Smooth formed or towelled surfaces do not have to be ground prior to testing.

Also this test is not conducted directly over the reinforcing bars having cover less than 20mm. The surface under test should be clean and smooth because rough surfaces cannot be tested as they do not give reliable results. Dirt or other loose material on the surface can be removed using a grinding stone prior to test.

### 3.1.2ULTRASONIC PULSE VELOCITY:-

**PREPARED BY:**

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**Purpose:-**

Although there is no fundamental relationship between pulse velocity and strength, an estimation of strength can be obtained by correlation. The method has perhaps a greater potential for comparing known sound concrete with affected concrete.

Ultrasonic pulse velocity is a means of assessing variations in the apparent strength of concrete.

The quality gradation of concrete can be appraised at best qualitatively as 'excellent', 'good', 'medium' or 'doubtful'. The meanings of the term 'excellent', 'good', 'medium' and 'doubtful' are based on ultra-sonic pulse velocity measured at site and are as per the nomenclature of IS 13311(part-1): 1992. To strike balance between the reliability, speed and damage to structure, core test have to be used to establish a correlation between rebound number index and the estimated in-situ strength with the USPV test results in the investigation.

**Objective of testing:-**

Ultrasonic pulse velocity test is used to establish the following:

- ✓ Homogeneity of concrete
- ✓ Presence of cracks voids, honeycombing and other imperfections
- ✓ Changes in the structure of concrete which may occur with time.
- ✓ Quality of one element of concrete in relation to another i.e. comparative quality analysis and gradation of concrete.
- ✓ The values of dynamic elastic modulus of the concrete.

**References:-**

- ✓ BS 6089:1981 and BS 1881:Part203
- ✓ IS 13311:Part1:1992
- ✓ ASTM: C597-83.

**Influencing factors:-**

The velocity of a pulse of ultrasonic energy in concrete is influenced by the stiffness and mechanical strength of the concrete

- ✓ Moisture content: The moisture content of the concrete have a small effect in the velocity and can increase the pulse velocity by 2%.
- ✓ Surface condition: The testing surface should be smooth any roughness cannot provide reliable readings because of gap between transducers and testing surface.

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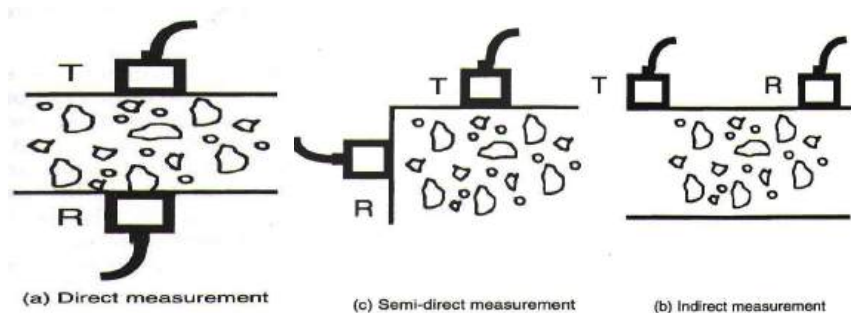
- ✓ Stress: When concrete is subjected to a stress which is abnormally high for a quality of concrete, the pulse velocity may be reduced due to development of micro-cracks.
- ✓ Reinforcing bars: The velocity measured in reinforced concrete in the vicinity of reinforcing bars is usually higher than in plain concrete because pulse velocity in steel is 1.2-1.9 times the velocity in plain concrete. Wherever possible, measurements should be made in such a way that steel does not lie in the path of the pulse.

#### Testing method:-

According to IS 13311(Part1):1992 clause 5.2 transducers with a frequency of 50 to 60 kHz are useful for most all round applications, and as per IS 13311(Part1):1992 clause 6.2 the path length should be long enough not to be significantly influenced by the heterogeneous nature of concrete. This test requires a flat surface generally only appropriate for unspalled surfaces.

In view of inherent variability in the test results, sufficient number of readings should be taken by dividing the entire structure in suitable grid of markings 30x30 cm or even smaller. Each junction point of the grid becomes a point of observation.

There are three possible methods of testing according to the type of surface:



**Table:-7**

**Velocity Criterion for Concrete Quality Grading** [Ref: IS13311 (part-1)]

| Sr. No. | USPV by Cross Probing (km/sec) | Concrete Quality Grading. |
|---------|--------------------------------|---------------------------|
| 1       | Above 4.5                      | Excellent                 |
| 2       | 3.5 - 4.5                      | Good                      |
| 3       | 3.0 - 3.5                      | Medium                    |
| 4       | Below 3.0                      | * Doubtful                |

#### 3.1.3 GENERAL INTRODUCTION:-

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To assess the condition of concrete in terms of its existing quality and acceptability of its strength, the tests are usually chosen considering the economy, damage to structure, speed and reliability. Core tests provide the most reliable in-situ strength assessment, but causes damage to structure. The non-destructive tests (NDT) such as Ultrasonic Pulse Velocity test provide indirect measure of quality of concrete through specified indices namely, ultra sonic pulse velocity (USPV) respectively. In absence of such correlation, the concrete can be appraised at best qualitatively as 'excellent', 'good', 'medium' or 'doubtful'. The meanings of the term 'excellent', 'good', 'medium' and 'doubtful' are based on ultra-sonic pulse velocity measured at site and are as per the nomenclature of IS 13311(part-1): 1992.

### 3.1.3.1 ULTRASONIC PULSE VELOCITY TEST:-

USPV test makes possible the examination of homogeneity of material. Analysing the ultrasonic velocity wave propagation variations, it is possible to verify the compactness of the structure or detect heterogeneous regions. The ultrasonic test methodology in concrete is based on the fact that the propagation time expresses the density of the material. The main idea is to explore the fact that ultrasonic velocity waves are a function of the material density and quality of concrete based on density of existing concrete. USPV results also give idea about quality of original concrete (used in construction), air-pockets and voids as per IS 13311 (Part-1)-1992. We have converted indirect UPSV reading into equivalent direct proportionate USPV readings per IS13311 part 1, Clause 5.4.1. Histogram of USPV test results is analysed in same pattern as rebound hammer is done but basic difference is that USPV results are interrelated in terms of density and rebound hammer results are interrelated in terms of surface hardness. Detailed density pattern of concrete in terms of USPV test results is given in the **Table 8**.

|   | <b>For USPV Test in Table</b> |                                                                                  |
|---|-------------------------------|----------------------------------------------------------------------------------|
| 1 | Type of surface               | Possible methods of testing (Direct, Indirect & Semi Direct)                     |
| 2 | Distance (mm)                 | Distance between sonic transducer and receiver                                   |
| 3 | Travel Time ( $\mu$ s)        | Travelled time between transducer to receiver                                    |
| 4 | Av. Velocity (km/sec)         | Velocity of Ultrasonic Wave                                                      |
| 5 | Direct Proportionate Velocity | Direct Proportionate of Avg. Velocity (IS: 5.4.1 13311 part 1)                   |
| 6 | Concrete Quality              | Velocity Criterion for Concrete Quality Grading as per IS 13311 (part-1) Table 2 |

### 3.1.4 REBOUND HAMMER TEST:-

**PREPARED BY:**

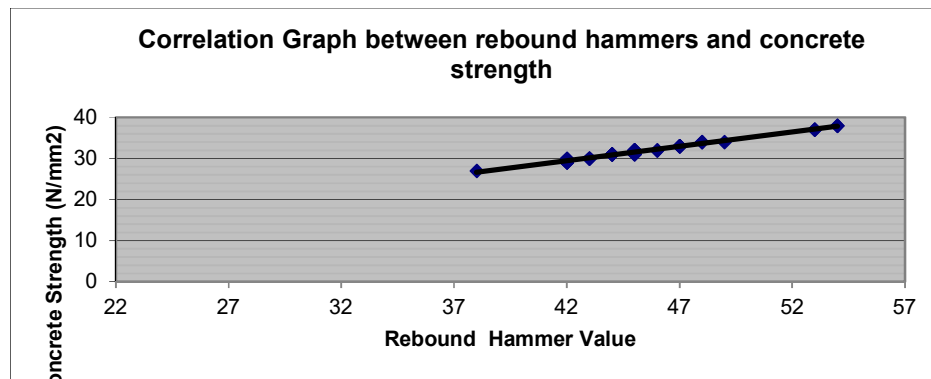
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**SECTOR-81, FARIDABAD, HARYANA**

Test results analysis of the Rebound Number values is based on test results conducted over concrete surfaces. Obtained test results explain about pattern of concrete strength of whole structure sections in terms of surface hardness. Estimated strength of concrete calculated from rebound hammer number is based on correlation graph between concrete strength of similar type of concrete in earlier projects v/s corresponding rebound hammer values. Rebound hammer has been carried out in all three directions horizontal, vertical down and vertical up. By using manufacturer graph, all vertical up/vertical down rebound hammer readings has been converted into the equivalent horizontal readings. Histogram plot of the Rebound Number values is based on test results conducted over concrete surfaces. Histogram plot explains about pattern of concrete quality of whole structure sections in terms of surface hardness. Rebound number helps to obtained Estimation of Strength of concrete from correlation between Rebound Hammer V/S Concrete strength of similar type of concrete in earlier projects.

**Rebound hammer and corresponding Core strength for correlation to estimate strength of concrete**



**Figure.**

\*The linear trendline equation uses the least squares methods to seek the slope and intercept coefficients such that:

$$y = bx + a$$

Where:

b is the slope of a trendline.

a is the y-intercept, which is the expected mean value of y when all x variables are equal to 0. On a chart, it's the point where the trendline crosses the y axis.

The Estimated Concrete strength can be find using Rebound Number:-

## Quality Assurance in Concrete using Non Destructive Testing

TABLE:-9

| Client:- ANSAL HOUSING LTD                                             |                                    |        |                     |             |    |    |    |                  |                           | Consultant :- M/S Zeichenburo India Pvt Ltd |                 |               |                          |                       |                                                      |                  |      |        |
|------------------------------------------------------------------------|------------------------------------|--------|---------------------|-------------|----|----|----|------------------|---------------------------|---------------------------------------------|-----------------|---------------|--------------------------|-----------------------|------------------------------------------------------|------------------|------|--------|
| Non Destructive Testing of At Kirti Shikhar Tower,Janakpuri West,Delhi |                                    |        |                     |             |    |    |    |                  |                           |                                             |                 |               |                          |                       |                                                      |                  |      |        |
| S. No./Location                                                        |                                    |        | Rebound Hammer Test |             |    |    |    |                  | Ultrasonic Pulse Velocity |                                             |                 |               |                          |                       |                                                      |                  |      |        |
| S.No                                                                   | Sample Identification/<br>Location |        | Hammer Alignment    | Rebound No. |    |    |    | Avg. Rebound No. | Quality Of Concrete       | Estimated Strength (MPa)                    | Type of surface | Distance (mm) | Travel Time (micro sec.) | Av. Velocity (km/sec) | Direct Proportionate Velocity (IS, 5.4.113311part 1) | Concrete Quality |      |        |
| BASEMENT                                                               |                                    |        |                     |             |    |    |    |                  |                           |                                             |                 |               |                          |                       |                                                      |                  |      |        |
| 1                                                                      | 11-I                               | Column | Horizontal          | 48          | 50 | 56 | 50 | 52               | 50                        | 51                                          | Very Good Layer | 20            | Indirect                 | 300                   | 114.70                                               | 2.62             | 3.62 | Good   |
| 2                                                                      | 12-I                               | Column | Horizontal          | 48          | 56 | 54 | 54 | 50               | 50                        | 52                                          | Very Good Layer | 21            | Indirect                 | 300                   | 125.40                                               | 2.39             | 3.39 | Medium |
| 3                                                                      | 13-J                               | Column | Horizontal          | 36          | 36 | 34 | 34 | 36               | 36                        | 35                                          | Good Layer      | 14            | Indirect                 | 300                   | 112.30                                               | 2.67             | 3.67 | Good   |
| 4                                                                      | 15-I                               | Column | Horizontal          | 54          | 56 | 48 | 48 | 50               | 48                        | 51                                          | Very Good Layer | 20            | Indirect                 | 300                   | 109.80                                               | 2.73             | 3.73 | Good   |
| 5                                                                      | H-16                               | Column | Horizontal          | 48          | 50 | 52 | 54 | 50               | 52                        | 51                                          | Very Good Layer | 20            |                          |                       |                                                      |                  |      |        |

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|    |      |        |            |    |    |    |    |    |    |    |                 |    |          |     |        |      |      |          |
|----|------|--------|------------|----|----|----|----|----|----|----|-----------------|----|----------|-----|--------|------|------|----------|
| 6  | G-15 | Column | Horizontal | 50 | 56 | 54 | 48 | 48 | 50 | 51 | Very Good Layer | 20 | Indirect | 300 | 124.60 | 2.41 | 3.41 | Medium   |
| 7  | G-13 | Column | Horizontal | 52 | 54 | 56 | 56 | 54 | 50 | 54 | Very Good Layer | 21 |          |     |        |      |      |          |
| 8  | E-17 | Column | Horizontal | 42 | 46 | 46 | 40 | 42 | 46 | 44 | Very Good Layer | 17 | Indirect | 300 | 119.70 | 2.51 | 3.51 | Good     |
| 9  | C-16 | Column | Horizontal | 44 | 46 | 46 | 40 | 42 | 46 | 44 | Very Good Layer | 18 | Indirect | 300 | 104.30 | 2.88 | 3.88 | Good     |
| 10 | B-15 | Column | Horizontal | 44 | 50 | 52 | 52 | 44 | 48 | 48 | Very Good Layer | 19 |          |     |        |      |      |          |
| 11 | A-13 | Column | Horizontal | 38 | 40 | 42 | 44 | 44 | 38 | 41 | Very Good Layer | 16 |          |     |        |      |      |          |
| 12 | B-12 | Column | Horizontal | 50 | 50 | 48 | 44 | 48 | 48 | 48 | Very Good Layer | 19 | Indirect | 300 | 101.60 | 2.95 | 3.95 | Good     |
| 13 | D-13 | Column | Horizontal | 48 | 48 | 44 | 46 | 52 | 52 | 48 | Very Good Layer | 19 | Indirect | 300 | 96.70  | 3.10 | 4.10 | Good     |
| 14 | G-11 | Column | Horizontal | 50 | 56 | 52 | 52 | 54 | 54 | 53 | Very Good Layer | 21 | Indirect | 300 | 107.40 | 2.79 | 3.79 | Good     |
| 15 | G-10 | Column | Horizontal | 48 | 54 | 54 | 54 | 50 | 50 | 52 | Very Good Layer | 21 | Indirect | 300 | 155.70 | 1.93 | 2.93 | Doubtful |

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|----|------|--------|------------|----|----|----|----|----|----|----|-----------------|----|----------|-----|--------|------|------|------|
| 16 | G-9  | Column | Horizontal | 48 | 50 | 50 | 54 | 54 | 54 | 52 | Very Good Layer | 21 | Indirect | 300 | 109.80 | 2.73 | 3.73 | Good |
| 17 | G-8  | Column | Horizontal | 54 | 54 | 50 | 48 | 50 | 50 | 51 | Very Good Layer | 20 | Indirect | 300 | 119.70 | 2.51 | 3.51 | Good |
| 18 | I-8  | Column | Horizontal | 48 | 50 | 50 | 50 | 52 | 48 | 50 | Very Good Layer | 20 |          |     |        |      |      |      |
| 19 | H-9  | Column | Horizontal | 48 | 46 | 58 | 58 | 54 | 52 | 53 | Very Good Layer | 21 | Indirect | 300 | 115.70 | 2.59 | 3.59 | Good |
| 20 | H-10 | Column | Horizontal | 50 | 48 | 50 | 46 | 46 | 50 | 48 | Very Good Layer | 19 |          |     |        |      |      |      |
| 21 | H-11 | Column | Horizontal | 50 | 46 | 46 | 50 | 50 | 46 | 48 | Very Good Layer | 19 | Indirect | 300 | 105.70 | 2.84 | 3.84 | Good |
| 22 | D-8  | Column | Horizontal | 44 | 46 | 52 | 44 | 46 | 52 | 47 | Very Good Layer | 19 | Indirect | 300 | 96.40  | 3.11 | 4.11 | Good |
| 23 | C-8  | Column | Horizontal | 54 | 56 | 58 | 58 | 56 | 54 | 56 | Very Good Layer | 22 | Indirect | 300 | 105.70 | 2.84 | 3.84 | Good |
| 24 | A-9  | Column | Horizontal | 42 | 44 | 46 | 44 | 44 | 42 | 44 | Very Good Layer | 17 |          |     |        |      |      |      |
| 25 | D-6  | Column | Horizontal | 52 | 46 | 46 | 52 | 46 | 48 | 48 | Very Good Layer | 19 | Indirect | 300 | 98.30  | 3.05 | 4.05 | Good |

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|                     |                                                                                                                                               |
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|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|

|    |           |      |             |    |    |    |    |    |    |    |                 |    |          |     |        |      |      |        |
|----|-----------|------|-------------|----|----|----|----|----|----|----|-----------------|----|----------|-----|--------|------|------|--------|
| 36 | GH-15-16  | Slab | Vertical up | 50 | 52 | 48 | 48 | 50 | 50 | 50 | Very Good Layer | 20 | Indirect | 300 | 121.70 | 2.47 | 3.47 | Medium |
| 37 | D-14-15   | Beam | Vertical up | 48 | 44 | 46 | 50 | 44 | 50 | 47 | Very Good Layer | 19 | Indirect | 300 | 125.40 | 2.39 | 3.39 | Medium |
| 38 | C-D-14-15 | Slab | Vertical up | 48 | 50 | 52 | 52 | 46 | 46 | 49 | Very Good Layer | 20 | Indirect | 300 | 129.20 | 2.32 | 3.32 | Medium |
| 39 | B-12-13   | Beam | Vertical up | 44 | 42 | 44 | 42 | 42 | 46 | 43 | Very Good Layer | 17 | Indirect | 300 | 119.70 | 2.51 | 3.51 | Good   |
| 40 | B-C-12-13 | Slab | Vertical up | 50 | 50 | 48 | 44 | 44 | 46 | 47 | Very Good Layer | 19 | Indirect | 300 | 137.70 | 2.18 | 3.18 | Medium |
| 41 | B-C-8     | Beam | Vertical up | 44 | 46 | 46 | 40 | 42 | 44 | 44 | Very Good Layer | 17 | Indirect | 300 | 127.70 | 2.35 | 3.35 | Medium |
| 42 | BC-8-9    | Slab | Vertical up | 44 | 48 | 50 | 50 | 44 | 46 | 47 | Very Good Layer | 19 | Indirect | 300 | 132.40 | 2.27 | 3.27 | Medium |
| 43 | GH-4      | Beam | Vertical up | 42 | 44 | 44 | 42 | 46 | 40 | 43 | Very Good Layer | 17 | Indirect | 300 | 117.10 | 2.56 | 3.56 | Good   |
| 44 | GH-45     | Slab | Vertical up | 40 | 44 | 46 | 46 | 48 | 46 | 45 | Very Good Layer | 18 | Indirect | 300 | 147.70 | 2.03 | 3.03 | Medium |
| 45 | G-14-15   | Beam | Vertical up | 42 | 42 | 44 | 44 | 42 | 44 | 43 | Very Good Layer | 17 |          |     |        |      |      |        |

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|    |          |      |             |    |    |    |    |    |    |    |                 |    |
|----|----------|------|-------------|----|----|----|----|----|----|----|-----------------|----|
| 46 | GH-14-15 | Slab | Vertical up | 48 | 44 | 46 | 44 | 46 | 44 | 45 | Very Good Layer | 18 |
| 47 | BC-16    | Beam | Vertical up | 42 | 44 | 46 | 46 | 40 | 42 | 43 | Very Good Layer | 17 |
| 48 | BC-15-16 | Slab | Vertical up | 46 | 48 | 50 | 46 | 46 | 46 | 47 | Very Good Layer | 19 |
| 49 | BC-3     | Beam | Vertical up | 40 | 42 | 44 | 44 | 46 | 42 | 43 | Very Good Layer | 17 |
| 50 | 3-4-BC   | Slab | Vertical up | 46 | 44 | 46 | 44 | 48 | 46 | 46 | Very Good Layer | 18 |

**GROUND FLOOR**

|   |          |      |             |    |    |    |    |    |    |    |            |    |          |     |        |      |      |        |
|---|----------|------|-------------|----|----|----|----|----|----|----|------------|----|----------|-----|--------|------|------|--------|
| 1 | H-I-8    | Beam | Vertical up | 34 | 32 | 36 | 36 | 34 | 34 | 34 | Good Layer | 14 | Indirect | 300 | 135.60 | 2.21 | 3.21 | Medium |
| 2 | HI-7-8   | Slab | Vertical up | 32 | 30 | 34 | 32 | 34 | 30 | 32 | Good Layer | 13 | Indirect | 300 | 113.30 | 2.65 | 3.65 | Good   |
| 3 | EF-13    | Beam | Vertical up | 36 | 38 | 34 | 34 | 36 | 36 | 36 | Good Layer | 14 | Indirect | 300 | 127.50 | 2.35 | 3.35 | Medium |
| 4 | EF-12-13 | Slab | Vertical up | 36 | 36 | 38 | 38 | 34 | 36 | 36 | Good Layer | 15 | Indirect | 300 | 122.80 | 2.44 | 3.44 | Medium |

**UPPER GROUND FLOOR**

|   |      |        |            |    |    |    |    |    |    |    |                 |    |          |     |        |      |      |        |
|---|------|--------|------------|----|----|----|----|----|----|----|-----------------|----|----------|-----|--------|------|------|--------|
| 1 | H-8  | Column | Horizontal | 36 | 32 | 32 | 32 | 38 | 36 | 34 | Good Layer      | 14 | Indirect | 300 | 142.00 | 2.11 | 3.11 | Medium |
| 2 | F-17 | Column | Horizontal | 40 | 42 | 44 | 36 | 44 | 44 | 42 | Very Good Layer | 17 | Indirect | 300 | 132.60 | 2.26 | 3.26 | Medium |

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|                     |          |        |             |    |    |    |    |    |    |    |                 |    |          |     |        |      |      |          |
|---------------------|----------|--------|-------------|----|----|----|----|----|----|----|-----------------|----|----------|-----|--------|------|------|----------|
| 3                   | GH-10    | Beam   | Vertical up | 38 | 38 | 36 | 40 | 38 | 36 | 38 | Good Layer      | 15 | Indirect | 300 | 227.30 | 1.32 | 2.32 | Doubtful |
| 4                   | GH 9-10  | Slab   | Vertical up | 38 | 36 | 34 | 38 | 34 | 34 | 36 | Good Layer      | 14 | Indirect | 300 | 345.40 | 0.87 | 1.87 | Doubtful |
| <b>FIRST FLOOR</b>  |          |        |             |    |    |    |    |    |    |    |                 |    |          |     |        |      |      |          |
| 1                   | G-9      | Column | Horizontal  | 56 | 56 | 50 | 48 | 48 | 44 | 50 | Very Good Layer | 20 | Indirect | 300 | 129.60 | 2.31 | 3.31 | Medium   |
| 2                   | G-10     | Column | Horizontal  | 54 | 52 | 48 | 48 | 52 | 48 | 50 | Very Good Layer | 20 | Indirect | 300 | 144.50 | 2.08 | 3.08 | Medium   |
| 3                   | EF-12    | Beam   | Vertical up | 34 | 36 | 32 | 34 | 36 | 34 | 34 | Good Layer      | 14 | Indirect | 300 | 125.40 | 2.39 | 3.39 | Medium   |
| 4                   | EF-12-11 | Slab   | Vertical up | 34 | 36 | 36 | 38 | 34 | 36 | 36 | Good Layer      | 14 | Indirect | 300 | 147.70 | 2.03 | 3.03 | Medium   |
| <b>SECOND FLOOR</b> |          |        |             |    |    |    |    |    |    |    |                 |    |          |     |        |      |      |          |
| 1                   | B-5      | Column | Horizontal  | 40 | 42 | 40 | 46 | 40 | 42 | 42 | Very Good Layer | 17 | Indirect | 300 | 113.00 | 2.65 | 3.65 | Good     |
| 2                   | A-5      | Column | Horizontal  | 42 | 46 | 42 | 40 | 48 | 46 | 44 | Very Good Layer | 18 | Indirect | 300 | 135.40 | 2.22 | 3.22 | Medium   |
| 3                   | EF-7     | Beam   | Vertical up | 36 | 38 | 34 | 34 | 36 | 36 | 36 | Good Layer      | 14 | Indirect | 300 | 123.40 | 2.43 | 3.43 | Medium   |
| 4                   | EF-1     | Slab   | Vertical up | 36 | 36 | 38 | 38 | 34 | 36 | 36 | Good Layer      | 15 | Indirect | 300 | 145.70 | 2.06 | 3.06 | Medium   |
| <b>THIRD FLOOR</b>  |          |        |             |    |    |    |    |    |    |    |                 |    |          |     |        |      |      |          |
| 1                   | F-17     | Column | Horizontal  | 40 | 42 | 46 | 46 | 48 | 44 | 44 | Very Good Layer | 18 | Indirect | 300 | 145.30 | 2.06 | 3.06 | Medium   |

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|              |          |        |             |    |    |    |    |    |    |    |                 |    |          |     |        |      |      |        |
|--------------|----------|--------|-------------|----|----|----|----|----|----|----|-----------------|----|----------|-----|--------|------|------|--------|
| 2            | G-13-14  | Beam   | Vertical up | 36 | 38 | 36 | 34 | 34 | 36 | 36 | Good Layer      | 14 | Indirect | 300 | 125.30 | 2.39 | 3.39 | Medium |
| 3            | GF-13-14 | Slab   | Vertical up | 38 | 36 | 34 | 34 | 34 | 36 | 35 | Good Layer      | 14 | Indirect | 300 | 129.50 | 2.32 | 3.32 | Medium |
| FOURTH FLOOR |          |        |             |    |    |    |    |    |    |    |                 |    |          |     |        |      |      |        |
| 1            | G-9      | Column | Horizontal  | 42 | 42 | 40 | 44 | 46 | 40 | 42 | Very Good Layer | 17 | Indirect | 300 | 145.30 | 2.06 | 3.06 | Medium |
| 2            | G-10     | Column | Horizontal  | 42 | 42 | 40 | 44 | 48 | 40 | 43 | Very Good Layer | 17 | Indirect | 300 | 145.30 | 2.06 | 3.06 | Medium |
| 3            | EF-6     | Beam   | Vertical up | 36 | 38 | 36 | 34 | 36 | 36 | 36 | Good Layer      | 14 | Indirect | 300 | 145.30 | 2.06 | 3.06 | Medium |
| 4            | EF-6     | Slab   | Vertical up | 38 | 36 | 34 | 34 | 34 | 36 | 35 | Good Layer      | 14 | Indirect | 300 | 145.30 | 2.06 | 3.06 | Medium |
| FIFTH FLOOR  |          |        |             |    |    |    |    |    |    |    |                 |    |          |     |        |      |      |        |
| 1            | A-5      | Column | Horizontal  | 42 | 40 | 40 | 44 | 46 | 42 | 42 | Very Good Layer | 17 | Indirect | 300 | 135.70 | 2.21 | 3.21 | Medium |
| 2            | EF-15    | Beam   | Vertical up | 34 | 32 | 36 | 36 | 34 | 34 | 34 | Good Layer      | 14 | Indirect | 300 | 113.70 | 2.64 | 3.64 | Good   |
| 3            | EF-14-15 | Slab   | Vertical up | 34 | 30 | 34 | 36 | 36 | 34 | 34 | Good Layer      | 14 | Indirect | 300 | 119.40 | 2.51 | 3.51 | Good   |
| SIXTH FLOOR  |          |        |             |    |    |    |    |    |    |    |                 |    |          |     |        |      |      |        |
| 1            | A-6      | Column | Horizontal  | 48 | 44 | 46 | 44 | 44 | 42 | 45 | Very Good Layer | 18 | Indirect | 300 | 143.20 | 2.09 | 3.09 | Medium |
| 2            | EF-17    | Beam   | Vertical up | 34 | 32 | 36 | 36 | 34 | 34 | 34 | Good Layer      | 14 | Indirect | 300 | 109.40 | 2.74 | 3.74 | Good   |

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|   |          |      |             |    |    |    |    |    |    |    |            |    |          |     |        |      |      |        |
|---|----------|------|-------------|----|----|----|----|----|----|----|------------|----|----------|-----|--------|------|------|--------|
| 3 | EF-16-17 | Slab | Vertical up | 32 | 30 | 34 | 32 | 34 | 30 | 32 | Good Layer | 13 | Indirect | 300 | 123.70 | 2.43 | 3.43 | Medium |
| 4 | G-13-14  | Beam | Vertical up | 30 | 30 | 32 | 36 | 34 | 34 | 33 | Good Layer | 13 | Indirect | 300 | 139.90 | 2.14 | 3.14 | Medium |
| 5 | FG-13-14 | Slab | Vertical up | 34 | 30 | 34 | 32 | 32 | 34 | 33 | Good Layer | 13 | Indirect | 300 | 135.70 | 2.21 | 3.21 | Medium |

## SEVENTH FLOOR

|   |        |        |             |    |    |    |    |    |    |    |                 |    |          |     |        |      |      |        |
|---|--------|--------|-------------|----|----|----|----|----|----|----|-----------------|----|----------|-----|--------|------|------|--------|
| 1 | F-17   | Column | Horizontal  | 48 | 46 | 46 | 42 | 48 | 44 | 46 | Very Good Layer | 18 | Indirect | 300 | 136.20 | 2.20 | 3.20 | Medium |
| 2 | EF-6   | Beam   | Vertical up | 32 | 34 | 30 | 34 | 36 | 36 | 34 | Good Layer      | 13 | Indirect | 300 | 135.60 | 2.21 | 3.21 | Medium |
| 3 | EF-5-6 | Slab   | Vertical up | 36 | 34 | 32 | 30 | 30 | 32 | 32 | Good Layer      | 13 | Indirect | 300 | 144.70 | 2.07 | 3.07 | Medium |
| 4 | EF-7   | Beam   | Vertical up | 32 | 34 | 36 | 36 | 32 | 32 | 34 | Good Layer      | 13 | Indirect | 300 | 125.70 | 2.39 | 3.39 | Medium |
| 5 | EF-7-8 | Slab   | Vertical up | 32 | 34 | 34 | 32 | 30 | 30 | 32 | Good Layer      | 13 | Indirect | 300 | 135.30 | 2.22 | 3.22 | Medium |

## EIGHTH FLOOR

|   |          |        |             |    |    |    |    |    |    |    |                 |    |          |     |        |      |      |        |
|---|----------|--------|-------------|----|----|----|----|----|----|----|-----------------|----|----------|-----|--------|------|------|--------|
| 1 | G-9      | Column | Horizontal  | 40 | 38 | 40 | 44 | 44 | 42 | 41 | Very Good Layer | 17 | Indirect | 300 | 86.30  | 3.48 | 4.48 | Good   |
| 2 | G-10     | Column | Vertical up | 48 | 54 | 50 | 54 | 50 | 48 | 51 | Very Good Layer | 20 | Indirect | 300 | 131.00 | 2.29 | 3.29 | Medium |
| 3 | EF-12    | Beam   | Vertical up | 34 | 36 | 32 | 34 | 36 | 34 | 34 | Good Layer      | 14 | Indirect | 300 | 126.90 | 2.36 | 3.36 | Medium |
| 4 | EF-12-11 | Slab   | Vertical up | 34 | 36 | 36 | 38 | 34 | 36 | 36 | Good Layer      | 14 | Indirect | 300 | 141.70 | 2.12 | 3.12 | Medium |

## NINTH FLOOR

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|                     |                                                                                                                                               |
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|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|

|   |             |        |             |    |    |    |    |    |    |    |      |    |          |     |        |      |      |          |
|---|-------------|--------|-------------|----|----|----|----|----|----|----|------|----|----------|-----|--------|------|------|----------|
| 2 | 5-B         | Column | Horizontal  | 20 | 22 | 18 | 22 | 28 | 28 | 23 | Fair | 9  | Indirect | 300 | 584.30 | 0.51 | 1.51 | Doubtful |
| 3 | C-4         | Column | Horizontal  | 22 | 22 | 24 | 20 | 20 | 18 | 21 | Fair | 8  | Indirect | 300 | 487.10 | 0.62 | 1.62 | Doubtful |
| 4 | EF-5-6 Slab | Slab   | Vertical up | 24 | 26 | 24 | 26 | 26 | 26 | 25 | Fair | 10 | Indirect | 300 | 254.10 | 1.18 | 2.18 | Doubtful |
| 5 | D-8         | Column | Vertical up | 24 | 24 | 22 | 22 | 24 | 26 | 24 | Fair | 9  | Indirect | 300 | 561.30 | 0.53 | 1.53 | Doubtful |

**Rebound Hammer(ASTM C 805- 85):-** Surface Hardness indices value should be more than 28 to get correlation with estimated strength , uniformity of concrete

**USPV(IS:13311 part 1):-** Concrete Quality Grading(km/sec) Above 4.5 – Excellent, 3.5 - 4.5 - Good , 3.0 - 3.5- Medium & Below 3.0- Doubtful

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**A. Analysis of uniformity and imperviousness of concrete on the basis of USPV test results:-**

The ultrasonic test methodology in concrete is based on the fact that the propagation time expresses the density of the material. It has uniform concrete quality in terms of density. There are indications of air-pockets and voids as significant from USPV test results as per IS:13311 part 1.

**Table 10**

|                      |                 |
|----------------------|-----------------|
| Basement             | Good-Doubtful   |
| Ground floor         | Good-Medium     |
| Upper ground floor   | Medium-Doubtful |
| First Floor          | Medium          |
| Second Floor         | Good-Medium     |
| Third Floor          | Medium          |
| Fourth floor         | Medium          |
| Fifth floor          | Good-Medium     |
| Sixth floor          | Good-Medium     |
| Seventh floor        | Medium          |
| Eighth floor         | Good-Medium     |
| Ninth floor          | Medium          |
| Tenth floor          | Medium-Doubtful |
| Eleventh floor       | Medium-Doubtful |
| Terrace (water tank) | Doubtful        |

Test was performed under the room temperature varies between 22degree to 30 degree.

**B. Interpretation of RCC Surface condition, uniformity of concrete and  $f_{ck}$  value of concrete obtained from Rebound hammer:-**

**Test results analysis** of the Rebound Number values is based on test results conducted over concrete surfaces. Obtained test results explain about pattern of concrete quality of whole structure sections in terms of surface hardness.

**Table 11**

|                    |                             |
|--------------------|-----------------------------|
| Basement           | Very good layer of concrete |
| Ground floor       | Good layer of concrete      |
| Upper ground floor | Good layer of concrete      |
| First Floor        | Good layer of concrete      |
| Second Floor       | Good layer of concrete      |
| Third Floor        | Good layer of concrete      |
| Fourth floor       | Good layer of concrete      |
| Fifth floor        | Good layer of concrete      |
| Sixth floor        | Good layer of concrete      |
| Seventh floor      | Good layer of concrete      |
| Eighth floor       | Good layer of concrete      |
| Ninth floor        | Good layer of concrete      |
| Tenth floor        | Good-fair layer of concrete |

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|                      |                             |
|----------------------|-----------------------------|
| Eleventh floor       | Good-fair layer of concrete |
| Terrace (water tank) | Good-fair layer of concrete |

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## Relevant Testing Codes For Rebound Hammer & Ultra Sonic Pulse Velocity Test

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>IS 13311 ( Part 2 ) : 1992</p> <p>भारतीय मानक</p> <p>कंकरीट का अविनाशी परीक्षण—परीक्षण पद्धतियां</p> <p>भाग 2 प्रतिक्षेप हथौड़ा</p> <p><i>Indian Standard</i></p> <p>NON-DESTRUCTIVE TESTING OF<br/>CONCRETE—METHODS OF TEST</p> <p><b>PART 2 REBOUND HAMMER</b><br/>( First Reprint JUNE 1995 )</p> <p>UDC 666-972 : 620-179-1</p> <p>© BIS 1992</p> <p><b>BUREAU OF INDIAN STANDARDS</b><br/>MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG<br/>NEW DELHI 110002</p> <p>April 1992</p> <p>Price Group 3</p> | <p>IS 13311 ( Part 1 ) : 1992<br/>( Reaffirmed 1999 )</p> <p>भारतीय मानक</p> <p>कंकरीट का अविनाशी परीक्षण – परीक्षण पद्धतियां</p> <p>भाग 1 पराश्रव्यी स्पन्द वेग</p> <p><i>Indian Standard</i></p> <p>NON-DESTRUCTIVE TESTING OF CONCRETE –<br/>METHODS OF TEST</p> <p><b>PART 1 ULTRASONIC PULSE VELOCITY</b><br/>First Reprint SEPTEMBER 1996</p> <p>UDC 666-972-620-179-16</p> <p>© BIS 1992</p> <p><b>BUREAU OF INDIAN STANDARDS</b><br/>MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG<br/>NEW DELHI 110002</p> <p>January 1992</p> <p>Price Group 4</p> |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

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### 3.2 HALF-CELL POTENTIAL DIFFERENCE TEST:-

#### Purpose:-

It is a non-destructive test that collects an enormous quantity of data from a large structural area. Establishing structures potential map, according to ASTM C876-91, is the most commonly applied electrochemical technique for diagnosing the corrosion risk of reinforced concrete structures.

#### Objective of testing:-

Half-Cell Potential test is performed to determine the following:

- ✓ Electrochemical behaviour of steel
- ✓ Probability of corrosion risk

#### References:-

- ✓ Broom Field, BRE Digest 434,
- ✓ As per ASTM C 876 [6]

#### Influencing factors:-

Half-Cell Potential test results are considerably influenced by these factors:

- ✓ Surface Layer and contamination: - dry, carbonated high-resistivity increase the (+)ve potential
- ✓ Cracked and delaminated surface:- increase ( – )ve Potential
- ✓ Saturated surface:- More (-)ve potential

#### Testing Method:-

The principle involved in this technique is essentially measurement of corrosion potential of rebar with respect to a standard reference electrode, such as saturated calomel electrode (SCE), copper/copper sulphate electrode (CSE), silver/ silver chloride electrode etc. standards, the probability of reinforcement corrosion is as follows in Table

- ✓ Select the area for measurement, usually the whole element such as a bridge deck or cross-head beam, or representative areas of an element or the structure several square meters in area, preferably at least 5 m<sup>2</sup>. Care must be taken to avoid possible sources of error.
- ✓ Use a cover meter to locate the steel and determine the bar spacing.
- ✓ Make an electrical connection to the steel either by exposing it or using already exposed steel.
  - Use a cover meter to locate a suitable reinforcing bar.
  - Locally expose the bar, e.g. by drilling through the cover with a large diameter percussion drill.
  - Drill a small-diameter hole into the reinforcing bar and attach the cable with a self-tapping screw or by hammering in a lead plug.

- ✓ Check that the steel is electrically continuous by testing with a DC resistivity meter between two well-separated points on well-separated bars. Measurements should be made in both forward and reverse directions (i.e. with the connections reversed). A resistance of less than  $1\Omega$  indicates that the steel is continuous.
- ✓ Make out a grid or matrix on the surface of the concrete using a chalk line, adhesive tape or paint. The choice of grid dimension will depend on the type of corrosion taking place. If general corrosion is suspected a grid size of 1x1 m may be adequate as the potential gradients will be low. If localized corrosion is suspected a grid size suitable for detecting all corroding sites is 0.2x0.2 m. If half-cell potentials at adjacent positions differ by more than 100 mV it is advisable to reduce the grid size locally.
- ✓ If necessary, use tap water or detergent solution to wet the whole area or the area where each measurement is to be taken to ensure good electrical contact. Saline solutions should not be used. For a reading to be made, ionic contact is required from the steel to the half-cell, and the concrete must be damp enough for an ionic path. Direct contact to the steel must not occur, and the current must flow as ions not electrons.
- ✓ Make the connections to the voltmeter: connect the reference electrode to the negative terminal of the voltmeter and the reinforcing steel to the positive terminal
- ✓ A fuller understanding of the corrosion condition is given by a drawing a potential map of the area surveyed. The greater the potential difference between the anodic and cathodic areas, the steeper the gradient of potential lines and the greater the possibility of significant corrosion in the anodic area.

**AS PER ASTM C 876-09 (APPENDIX):-**

1. If potentials over an area are more positive than  $-200$  mV CSE, there is a greater than 70 % probability that no reinforcing steel corrosion is occurring in that area at the time of measurement.
2. If potentials over an area are in the range of  $-200$  to  $-350$  mV CSE, corrosion activity of the reinforcing steel in that area is uncertain.
3. If potentials over an area are more negative than  $-350$  mV CSE, there is a greater than 90% probability that reinforcing steel corrosion is occurring in that area at the time of measurement

**Permeability of concrete has an inverse relationship with the concrete cover depth and is directly related to the corrosion of the reinforcement.** The tendency of any metal to react with an environment is indicated by the potential it develops in contact with the environment. In reinforced concrete structures, concrete acts, as an electrolyte and the reinforcement will develop a potential depending on the concrete environment, which may vary from place to place. The schematic diagram for reinforcement corrosion mechanism is shown below:

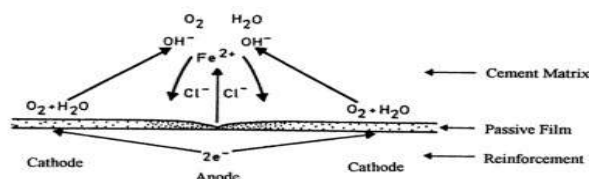


Figure 1 Corrosion Mechanism of Concrete Reinforcement

ASTM C876 standard provides information on the probability of reinforcement corrosion based on measured HCP values. The difference in voltage between the reinforcing steel and the current source can be correlated to the amount of corrosion.

Table:-12

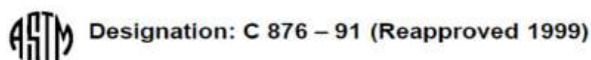
| Quality Assurance in Concrete using Non Destructive Testing          |                       |                             |                            |
|----------------------------------------------------------------------|-----------------------|-----------------------------|----------------------------|
| Client:-M/S ZEICHENBURO                                              |                       | Consultant :- OB Developers |                            |
| Non Destructive Testing of KirtiShikhar Tower, Janakpuri West, Delhi |                       |                             |                            |
| SL. No.                                                              | Sample Identification | Mean Value (mV)             | Risk to Corrosion of Steel |
| BASEMENT                                                             |                       |                             |                            |
| 1                                                                    | I-12-11 Slab          | -287.3                      | Uncertain                  |
| 2                                                                    | G-11 Column           | -209.7                      | Uncertain                  |
| 3                                                                    | B-12 Column           | -195.3                      | Low                        |
| 4                                                                    | C-3 Column            | -221.7                      | Uncertain                  |
| ELEVENTH FLOOR                                                       |                       |                             |                            |
| 5                                                                    | EF-6-5 Slab           | -361.7                      | High                       |
| 6                                                                    | EF-6-7 Slab           | -410.3                      | High                       |
| 7                                                                    | FG-5-6 Slab           | -374.3                      | High                       |
| TERRACE                                                              |                       |                             |                            |
| 8                                                                    | D-8 Column            | -357.1                      | High                       |
| 9                                                                    | DE-6 Slab             | -364.1                      | High                       |
| 10                                                                   | EF-14 Slab            | -374.1                      | High                       |

### 3.4.1 Half-Cell Potential Test Results Interpretation: -

Permeability of concrete has an inverse relationship with the concrete cover depth and is directly related to the corrosion of the reinforcement.

At most locations of basement steel are suffering from 0-10% risk of corrosion which clearly shows that risk of active corrosion is low which is under permissible range but on 11th floor and terrace risk of corrosion is high . So we can say that 11th floor and terrace reinforcement has lost its tensile strength due to corrosion.

# Relevant Testing Code For Half Cell Potential Test



## Standard Test Method for Half-Cell Potentials of Uncoated Reinforcing Steel in Concrete<sup>1</sup>

This standard is issued under the fixed designation C 876; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This test method covers the estimation of the electrical half-cell potential of uncoated reinforcing steel in field and laboratory concrete, for the purpose of determining the corrosion activity of the reinforcing steel.

1.2 This test method is limited by electrical circuitry. A concrete surface that has dried to the extent that it is a dielectric and surfaces that are coated with a dielectric material will not provide an acceptable electrical circuit. The basic configuration of the electrical circuit is shown in Fig. 1.

1.3 The values stated in inch-pound units are to be regarded as the standard.

1.4 *This standard does not purport to address the safety-concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

- 2.1 *ASTM Standards:*  
G 3 Practice for Conventions Applicable to Electrochemical Measurements in Corrosion Testing<sup>2</sup>

### 3. Significance and Use

3.1 This test method is suitable for in-service evaluation and for use in research and development work.

3.2 This test method is applicable to members regardless of their size or the depth of concrete cover over the reinforcing steel.

3.3 This test method may be used at any time during the life of a concrete member.

3.4 The results obtained by the use of this test method shall not be considered as a means for estimating the structural properties of the steel or of the reinforced concrete member.

3.5 The potential measurements should be interpreted by engineers or technical specialists experienced in the fields of concrete materials and corrosion testing. It is often necessary to

use other data such as chloride contents, depth of carbonation, delamination survey findings, rate of corrosion results, and environmental exposure conditions, in addition to half-cell potential measurements, to formulate conclusions concerning corrosion activity of embedded steel and its probable effect on the service life of a structure.

### 4. Apparatus

4.1 The testing apparatus consists of the following:

#### 4.1.1 *Half Cell:*

4.1.1.1 A copper-copper sulfate half cell (Note 1) is shown in Fig. 2. It consists of a rigid tube or container composed of a dielectric material that is nonreactive with copper or copper sulfate, a porous wooden or plastic plug that remains wet by capillary action, and a copper rod that is immersed within the tube in a saturated solution of copper sulfate. The solution shall be prepared with reagent grade copper sulfate crystals dissolved in distilled or deionized water. The solution may be considered saturated when an excess of crystals (undissolved) lies at the bottom of the solution.

4.1.1.2 The rigid tube or container shall have an inside diameter of not less than 1 in. (25 mm); the diameter of the porous plug shall not be less than 1/2 in. (13 mm); the diameter of the immersed copper rod shall not be less than 1/4 in. (6 mm), and the length shall not be less than 2 in. (50 mm).

4.1.1.3 Present criteria based upon the half-cell reaction of  $\text{Cu} \rightarrow \text{Cu}^{++} + 2\text{e}$  indicate that the potential of the saturated copper-copper sulfate half cell as referenced to the hydrogen electrode is  $-0.316 \text{ V}$  at  $72^\circ\text{F}$  ( $22.2^\circ\text{C}$ ). The cell has a temperature coefficient of about  $0.0005 \text{ V}$  more negative per  $^\circ\text{F}$  for the temperature range from  $32$  to  $120^\circ\text{F}$  ( $0$  to  $49^\circ\text{C}$ ).

NOTE 1—While this test method specifies only one type of half cell, that is, the copper-copper sulfate half cell, others having similar measurement range, accuracy, and precision characteristics may also be used. In addition to copper-copper sulfate cells, calomel cells have been used in laboratory studies. Potentials measured by other than copper-copper sulfate half cells should be converted to the copper-copper sulfate equivalent potential. The conversion technique can be found in Practice G 3 and it is also described in most physical chemistry or half-cell technology text books.

4.1.2 *Electrical Junction Device*—An electrical junction device shall be used to provide a low electrical resistance liquid bridge between the surface of the concrete and the half cell. It shall consist of a sponge or several sponges pre-wetted with a

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee G01 on Corrosion of Metals and is the direct responsibility of Subcommittee G01.14 on Corrosion of Reinforcing Steel.

Current edition approved March 11, 1991. Published May 1991. Originally published as C 876 – 77. Last previous edition C 876 – 87.

<sup>2</sup> *Annual Book of ASTM Standards*, Vol 03.02.

### 3.3 COVER DEPTH IN RCC STRUCTURE BY USING PROFOMETER: AN IN-SITU TEST

The Profometer has been used for the non destructive location of steel bar and for the measurement of concrete cover, using the eddy current principle with pulse induction as the measuring method. This machine works on magnetic field generation and by creating a full current circle with help of hidden steel bar machine maps the cover depth and diameter of steel bar.

#### *Application*

- ✓ Quality control, to ensure correct location and cover to reinforcing bars after concrete placement or in existing RCC structures,
- ✓ Investigation of concrete members and locating reinforcement as a preliminary to some form of testing, such as, core extraction or UPV.

#### *Objective of testing*

Test is performed to determine the following:

- ✓ Cover depth
- ✓ Relation between Protective Layer/cover depth V/S penetration depth of deleterious agent

#### *References*

- ✓ BS 1881 Part 204
- ✓ B5707-2003

**3.3.1 TABLE 13:-COVER DEPTH TEST RESULTS:-**

| Quality Assurance in Concrete using Non Destructive Testing           |                       |                                               |                       |
|-----------------------------------------------------------------------|-----------------------|-----------------------------------------------|-----------------------|
| Client:-ANSAL HOUSING                                                 |                       | Consultant :-M/S ZEICHENBURO<br>INDIA PVT LTD |                       |
| Non Destructive Testing At Kirti Shikhar Tower, Janakpuri West, Delhi |                       |                                               |                       |
| SL. No.                                                               | Sample Identification | Cover Value (IN mm)                           | Conclusion            |
| BASEMENT                                                              |                       |                                               |                       |
| 1                                                                     | 11-I Column.          | 45-47                                         | Sufficent Cover Depth |
| 2                                                                     | 12-I Column           | 44-46                                         | Sufficent Cover Depth |
| 3                                                                     | 13-J Column           | 46-48                                         | Sufficent Cover Depth |
| 4                                                                     | 15-I Column           | 45-48                                         | Sufficent Cover Depth |
| 5                                                                     | H-16 Column           | 47-49                                         | Sufficent Cover Depth |
| 6                                                                     | G-15 Column           | 44-47                                         | Sufficent Cover Depth |
| 7                                                                     | G-13 Column           | 46-48                                         | Sufficent Cover Depth |
| 8                                                                     | E-17 Column           | 45-46                                         | Sufficent Cover Depth |
| 9                                                                     | C-16 Column           | 47-49                                         | Sufficent Cover Depth |
| 10                                                                    | B-15 Column           | 48-50                                         | Sufficent Cover Depth |
| 11                                                                    | H-10-11 Beam          | 26-28                                         | Sufficent Cover Depth |
| 12                                                                    | H-10-11 Slab          | 18-20                                         | Sufficent Cover Depth |
| 13                                                                    | H-I-12 Beam           | 27-29                                         | Sufficent Cover Depth |
| 14                                                                    | H-I-12-13 Slab        | 20-22                                         | Sufficent Cover Depth |
| 15                                                                    | G-15-16 Beam          | 25-27                                         | Sufficent Cover Depth |
| 16                                                                    | GH-15-16 Slab         | 19-21                                         | Sufficent Cover Depth |
| 17                                                                    | D-14-15 Beam          | 27-29                                         | Sufficent Cover Depth |
| 18                                                                    | C-D-14-15 Slab        | 18-20                                         | Sufficent Cover Depth |
| 19                                                                    | B-12-13 Beam          | 25-27                                         | Sufficent Cover Depth |

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|                           |                |       |                        |
|---------------------------|----------------|-------|------------------------|
| 20                        | B-C-12-13 Slab | 19-21 | Sufficient Cover Depth |
| 21                        | B-C-8 Beam     | 26-28 | Sufficient Cover Depth |
| 22                        | BC-8-9 Slab    | 20-22 | Sufficient Cover Depth |
| 23                        | GH-4 Beam      | 28-30 | Sufficient Cover Depth |
| 24                        | GH-45 Slab     | 19-21 | Sufficient Cover Depth |
| <b>GROUND FLOOR</b>       |                |       |                        |
| 25                        | H-I-8 Beam     | 25-27 | Sufficient Cover Depth |
| 26                        | HI-7-8 Slab    | 19-21 | Sufficient Cover Depth |
| <b>UPPER GROUND FLOOR</b> |                |       |                        |
| 27                        | H-8 Column     | 45-47 | Sufficient Cover Depth |
| 28                        | GH-10 Beam     | 27-29 | Sufficient Cover Depth |
| <b>FIRST FLOOR</b>        |                |       |                        |
| 29                        | G-9 Column     | 44-46 | Sufficient Cover Depth |
| 30                        | EF-12-11 Slab  | 18-20 | Sufficient Cover Depth |
| <b>SECOND FLOOR</b>       |                |       |                        |
| 31                        | B-5 Column     | 45-47 | Sufficient Cover Depth |
| 32                        | EF-7 Beam      | 27-29 | Sufficient Cover Depth |
| <b>THIRD FLOOR</b>        |                |       |                        |
| 33                        | F-17 Column    | 47-49 | Sufficient Cover Depth |
| 34                        | GF-13-14 Slab  | 18-20 | Sufficient Cover Depth |
| <b>FOURTH FLOOR</b>       |                |       |                        |
| 35                        | G-9 Column     | 44-46 | Sufficient Cover Depth |
| 36                        | EF-6 Beam      | 25-27 | Sufficient Cover Depth |
| <b>FIFTH FLOOR</b>        |                |       |                        |
| 37                        | A-5 Column     | 45-47 | Sufficient Cover Depth |
| 38                        | EF-14-15 Slab  | 19-21 | Sufficient Cover Depth |
| <b>SIXTH FLOOR</b>        |                |       |                        |

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|                       |                 |       |                        |
|-----------------------|-----------------|-------|------------------------|
| 39                    | A-6 Column      | 44-46 | Sufficient Cover Depth |
| 40                    | EF-17 Beam      | 26-28 | Sufficient Cover Depth |
| <b>SEVENTH FLOOR</b>  |                 |       |                        |
| 41                    | F-17 Column     | 46-48 | Sufficient Cover Depth |
| 42                    | EF-7-8 Slab     | 20-22 | Sufficient Cover Depth |
| <b>EIGHTH FLOOR</b>   |                 |       |                        |
| 43                    | G-10 Column     | 45-47 | Sufficient Cover Depth |
| 44                    | EF-12 Beam      | 26-28 | Sufficient Cover Depth |
| <b>NINETH FLOOR</b>   |                 |       |                        |
| 45                    | B-5 Column      | 47-49 | Sufficient Cover Depth |
| 46                    | EF-6-7 Slab     | 19-21 | Sufficient Cover Depth |
| <b>TENTH FLOOR</b>    |                 |       |                        |
| 47                    | F-17 Column     | 44-46 | Sufficient Cover Depth |
| 48                    | Near EF-18 Slab | 18-20 | Sufficient Cover Depth |
| <b>ELEVENTH FLOOR</b> |                 |       |                        |
| 49                    | G-10 Column     | 45-47 | Sufficient Cover Depth |
| 50                    | EF-6 Beam       | 26-28 | Sufficient Cover Depth |

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Relevant Code for Contour/Cover Mapping

IS 456 : 2000  
(Reaffirmed 2005)

भारतीय मानक  
सामान्य एवं प्रबलित कंक्रीट — रीति संहिता  
( चौथा पुनरीक्षण )

*Indian Standard*  
PLAIN AND REINFORCED CONCRETE —  
CODE OF PRACTICE  
( *Fourth Revision* )

Tenth Reprint APRIL 2007  
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ICS 91.100.30

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BUREAU OF INDIAN STANDARDS  
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG  
NEW DELHI 110002

July 2000

Price Rs. 850.00 + Rs. 120.00

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### 3.4 CARBONATION & pH VALUE TEST:-

#### Purpose:-

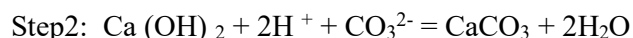
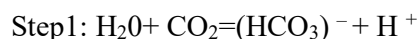
This test involves analysis of hardened concrete on the basis of carbonation depth, chloride content, pH value as well as sulphate content of the concrete in the structural element.

#### Objective:-

The carbonation depth gives an idea about the deterioration of the concrete and further gives an idea about the corrosion of the reinforcement and bonding nature of the concrete.

#### A. Carbonation:-

The relative humidity has been shown as a deciding factor of carbonation rate, which is at a maximum with a range in between 50% and 70% of relative humidity.  $\text{Ca(OH)}_2 + \text{CO}_2 = \text{CaCO}_3 + \text{H}_2\text{O}$  involve a physiochemical reaction between atmospheric  $\text{CO}_2$  and  $\text{Ca(OH)}_2$  generated in cement hydration. The precipitation of  $\text{CaCO}_3$  as shown in following equation reduces the PH value level of concrete.



The neutralization products penetrate gradually into concrete surface. The atmospheric  $\text{CO}_2$  diffuses into hardened concrete through pores and when carbonation occurs, the alkalinity of concrete reduces from 10 to below 9. Penetration rate =  $K (\text{time})^{1/2}$

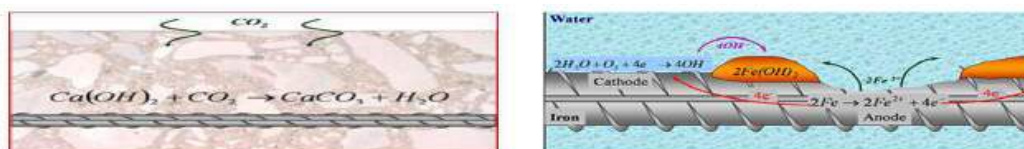
When pH value reduces down to 9 the system becomes acidic, in this new environment  $\text{Fe(OH)}_2$  converts to  $\text{Fe(OH)}_3$  which is known as red rust and the passivity of the steel reinforcement is lost. It reveals that level at which the pH of the concrete is above the 9 sufficiently alkaline to provide passivity of steel. Carbonation test is done to establish whether there is sufficient thickness of un-carbonated concrete to protect the reinforcement for the reminder of design life of the structure. Depth of carbonation and the cover to the reinforcement must be determined. It is important that, even if concrete is carbonated deeper than the reinforcement, the reinforcement will only corrode if there is enough moisture in the concrete.

#### Test Procedure for Carbonation Test:-

- ✓ Pour phenolphthalein indicator solutions in 1% quantity into spray bottle
- ✓ Drill the concrete block using a drilling machine
- ✓ Spray the Phenolphthalein indicator on the exposed drilled surface of concrete

- ✓ Observe the colour and the depth up to which no colour is marked, and note it down. This depth is carbonation dept.
- ✓ The Phenolphthalein test method is based on a new British standard, BS Standard BS EN 14630

**Carbonation Depth:-**Concrete cover layer acts as a good protective layer for the reinforcement. When whole Protective layer/cover depth is carbonated as per carbonation (B.S 4248) deterioration of structure will fall in deterioration period with linear rate. So full carbonated cover depth removal is mandatory to protect the steel bar from further corrosion and we have to increase the thickness of cover depth to protect the steel from futuristic corrosion.



### Process of carbonation and rusting of concrete

#### 3.4.1 CARBONATION TEST RESULTS INTREPRETATION:-

TABLE:-14

| Quality Assurance in Concrete using Non Destructive Testing              |                                |                             |          |
|--------------------------------------------------------------------------|--------------------------------|-----------------------------|----------|
| Client:-M/S ZEICHENBURO                                                  |                                | Consultant :- OB Developers |          |
| Non Destructive Testing of At Kirti Shikhar Tower, Janakpuri West, Delhi |                                |                             |          |
| Sr. No.                                                                  | Sample Identification/Location | Carbonation Depth           | pH Value |
| BASEMENT                                                                 |                                |                             |          |
| 1                                                                        | 12-I                           | 50-52mm                     | 9.6      |
| 2                                                                        | D-13                           | 54-56mm                     | 10.45    |

Whole Protective layer is carbonated in present case. Carbonation depth is heigher than the depth of cover so structure is in deterioration period.

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Relevant Testing Code For Carbonation Test

BRITISH STANDARD

BS EN  
14630:2006

**Products and systems  
for the protection and  
repair of concrete  
structures — Test  
methods —  
Determination of  
carbonation depth in  
hardened concrete by  
the phenolphthalein  
method**

The European Standard EN 14630:2006 has the status of a  
British Standard

**PREPARED BY:**

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SECTOR-81, FARIDABAD, HARYANA**

### 3.5 CORE DRILLING METHOD FOR IN-SITU COMPRESSIVE STRENGTH ANALYSIS OF CONCRETE CORE IN LAB

#### Purpose

This test is done to exactly measure the compressive strength of the concrete

#### References

- i. IS 456:2000
- ii. IS 516:1959
- iii. IS 1199-1959: Part 4
- iv. BS 1881: Part 4: 1970
- v. ASTM C: 42 – 77
- vi. BS EN 13791:2007

#### Sampling

**1. Diameter of core size:** - The general rule adopted for fixing the core size, besides the H/D ratio, is the nominal size of stone aggregate and the diameter should be not less than 3 times the maximum size of stone aggregate. **Reference ASTM C-42 article clause number 6.1 and part 4 of IS: 1199-1959.**

**2. L/d ratio:** Its value should be minimum 0.95 and maximum 2 (without capping but after trimming). Higher ratio would cause a reduction in strength. L/d of extracted core after capping should be  $1 < L/d < 2$ . Capping size should be 0.5% of core diameter. Capping thickness can't be fixed it depends upon diameter of core. **Reference: IS 516: 1959 Article clause number 4.3 and ASTM C-42 article clause number 6.1 and 6.5**

#### Procedure

**1. Drilling operations:** The strength of cores is generally less than that of standard cylinders, partly as a consequence of disturbance due to vibrations during drilling operations. It disturbs the micro-structure of concrete core so it affects the bonding between aggregate to aggregate (directly strength of concrete). Whatever best precautions are taken during drilling; there is always a risk of slight damage. Machine should be installed on separate platform to avoid vibration. **Reference code:- ASTM C-42 Article clause number:- 4.1.1**

**2. Position of sample:** - Core sample should be taken from near the middle of a unit of RCC section. It should not be taken near fronted joint or obvious edge of a unit of deposit. Concrete core taken from cover depth gives very lower strength because it mainly contains cement slurry. **Reference code: - ASTM C- 42 article clause number 4.2**

#### Interpretation

**Method of strength calculation:** - Apply the compression load over the core sample at 140 kg/sq cm/min rate of loading.

A. Cylindrical compressive strength (MPa) = Failure load (kN)/ Loading surface area ( $m^2 = \pi.d^2/4$ )

B. Correction factor = IS Code 516:1959 Page no 12 fig 1

C. Equivalent cube strength (MPa) = Cylindrical compressive strength \* 1.25

D. **Interpretation Methodology and acceptance criteria:** Concrete construction should be considered structurally adequate if average of three cores from questionable region is equal to or exceed the 85% of specified strength as per ACI 318. IS 456: 2000 Sec 17.4.3 provides the below following acceptance criteria for core strength:

Average equivalent cube strength of the core > 85% of Grade of concrete

The least value of individual equivalent cube strength of the core > 75% of Grade of concrete

| Compressive Strength of Concrete: Concrete Core (IS516: 1959/1991)                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                       |                       |           |                             |                   |                                        |                   |                                |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|-----------------------|-----------------------|-----------|-----------------------------|-------------------|----------------------------------------|-------------------|--------------------------------|
| Client:- M/S ZEICHENBURO                                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                       |                       |           | Consultant :- OB Developers |                   |                                        |                   |                                |
| Non Destructive Testing of kirti shikhar tower, janakpuri west, delhi.                                                                                                                                                                                                                                                                                                                                                                                             |                               |                       |                       |           |                             |                   |                                        |                   |                                |
| Sr.No                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Identification mark/Serial No | Dia of core (d in mm) | Core Length (l in mm) | l/d ratio | Loading surface area (m2)   | Failure load (kN) | Cylindrical compressive strength (MPa) | Correction factor | Equivalent cube strength (MPa) |
| BASEMENT                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                       |                       |           |                             |                   |                                        |                   |                                |
| 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | G11                           | 55                    | 110                   | 2.00      | 0.00238                     | 32.50             | 13.67                                  | 1.0000            | 17                             |
| 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | B12                           | 55                    | 105                   | 1.91      | 0.00238                     | 33.10             | 13.93                                  | 0.9909            | 17                             |
| 3                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | C3                            | 55                    | 110                   | 2.00      | 0.00238                     | 34.60             | 14.56                                  | 1.0000            | 18                             |
| <b>Codal Procedure :</b> Cylindrical compressive strength (MPa) = Failure load (kN)/ Loading surface area (m2 = $\Pi.d^2/4$ )<br>Correction factor = IS Code 516:1959 Page no 12 fig 1, Equivalent cube strength (MPa) = Cylindrical compressive strength * 1.25, Concrete construction should be considered structurally adequate if average of three cores from questionable region/sections is equal to or exceed the 85% of specified strength as per ACI 318. |                               |                       |                       |           |                             |                   |                                        |                   |                                |
| <b>Interpretation of concrete core test results :-</b> The Equivalent cube compressive strength obtained for the cores ranges from 17 MPa to 18 MPa, Average 17 MPa and in-situ strength of concrete is in the range of                                                                                                                                                                                                                                            |                               |                       |                       |           |                             |                   |                                        |                   |                                |
| M17                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                               |                       |                       |           |                             |                   |                                        |                   |                                |
| Grade of Concrete: M17                                                                                                                                                                                                                                                                                                                                                                                                                                             |                               |                       |                       |           |                             |                   |                                        |                   |                                |

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### 3.6 COMPRESSION TESTING OF BRICK

Compressive strength test on bricks are carried out to determine the load carrying capacity of bricks under compression with the help of compression testing machine.

Bricks are generally used for construction of load bearing masonry walls, columns and footings. These load bearing masonry structures experiences mostly the compressive loads. Thus, it is important to know the compressive strength of bricks to check for its suitability for construction

#### Apparatus

Compression testing machine, the compression plate of which shall have ball seating in the form of portion of a sphere centre of which coincides with the centre of the plate.

#### Specimen

Three numbers of whole bricks from sample collected should be taken. The dimensions should be measured to the nearest 1mm.

#### Sampling of Bricks

Remove unevenness observed the bed faces of bricks to provide two smooth parallel faces by grinding. Immerse the bricks in water at room temperature for 24 hours, then remove the specimen and drain out any surplus moisture at room temperature.

Fill the frog and all voids in the bed faces flush with cement mortar (1 cement, 1 clean coarse sand of grade 3mm and down). Store it under the damp jute bags for 24 hours filled by immersion in clean water for 3 days. Remove and wipe out any traces of moisture.

#### Procedure of Compressive Strength Test on Bricks

1. Place the specimen with flat faces horizontal and mortar filled face facing upwards between plates of the testing machine.
2. Apply load axially at a uniform rate of 14 N/mm<sup>2</sup> (140 kg/cm<sup>2</sup>) per minute till failure occurs and note maximum load at failure.

3. The load at failure is maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine.

### Calculation of compressive strength

Compressive Strength of Bricks = Maximum Load at Failure (N)/Average area of bed face (mm<sup>2</sup>)

### 3.6.1 BRICK COMPRESSIVE STRENGTH

#### Range Calculation

Maximum compressive strength = 207.4 KN

Contact area = 0.0253 m<sup>2</sup>

### Result

Average compressive strength of the given bricks = 8.2 N/mm<sup>2</sup>

| TABLE-16                                                           |          |                     |                             |                         |                 |                                                            |
|--------------------------------------------------------------------|----------|---------------------|-----------------------------|-------------------------|-----------------|------------------------------------------------------------|
| Test as per : IS 3495 :1992 part I, IS 1077 : 1992 , ASTM C 67     |          |                     |                             |                         |                 |                                                            |
| NON DESTRUCTIVE TESTING OFKIRTI SHIKHAR TOWER,JANAKPURI WEST,DELHI |          |                     |                             |                         |                 |                                                            |
| CLIENT: M/s ZEICHENBURO                                            |          |                     | CONSULTANT :- OB DEVELOPERS |                         |                 |                                                            |
| COMPRESSIVE STRENGHT OF BRICK                                      |          |                     |                             |                         |                 |                                                            |
| Sr. No.                                                            | Brick No | Location OF Brick   | Dimension mm/mm             | Loading surface area m² | Failure load kN | Result MPa (As per : IS 3495 :1992 part I, IS 1077 : 1992) |
| 1                                                                  | 1        | Near Column G4 Wall | 230X110X70                  | 0.0253                  | 207.4           | 8.2                                                        |
| 2                                                                  | 2        | Wall Near D6 Column | 230X110X70                  | 0.0253                  | 203.1           | 8.03                                                       |

### Representing Result of Brick compression Test

Specifications of Bricks

### Speciation of Common Clay Building Bricks

**Dimensions:** The standard size of clay bricks shall be as follows

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### Classification of Bricks based on Compressive Strength

The common burnt clay shall be classified on the basis of average compressive strength as given in

| Bricks Class Designation | Average compressive strength of Bricks |                                |
|--------------------------|----------------------------------------|--------------------------------|
|                          | Not less than (N/mm <sup>2</sup> )     | Less than (N/mm <sup>2</sup> ) |
| 350                      | 35                                     | 40                             |
| 300                      | 30                                     | 35                             |
| 250                      | 25                                     | 30                             |
| 200                      | 20                                     | 25                             |
| 175                      | 17.5                                   | 20                             |
| 150                      | 15                                     | 17.5                           |
| 125                      | 12.5                                   | 15                             |
| 100                      | 10                                     | 12.5                           |
| 75                       | 7.5                                    | 10                             |
| 50                       | 5                                      | 7.5                            |
| 35                       | 3.5                                    | 5                              |

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# Indian Standard

## METHODS OF TESTS OF BURNT CLAY BUILDING BRICKS

### PART 1 DETERMINATION OF COMPRESSIVE STRENGTH

#### ( Third Revision )

#### 1 SCOPE

1.1 This standard ( Part 1 ) covers the method of determination of compressive strength of burnt clay building bricks.

#### 2 REFERENCE

2.1 The Indian Standard IS 5454 : 1976 'Method for sampling of clay building bricks ( first revision )' is a necessary adjunct to this standard.

#### 3 GENERAL

3.1 The dimensions shall be measured to the nearest 1 mm.

3.2 All apparatus and testing equipment shall be calibrated at frequent intervals.

3.3 The number of specimens for the test shall be selected according to IS 5454 : 1976.

#### 4 METHODS

##### 4.1 For Solid Bricks

###### 4.1.1 Apparatus

A compression testing machine, the compression plate of which shall have a ball seating in the form of portion of a sphere the centre of which coincides with the centre of the plate, shall be used.

###### 4.1.2 Preconditioning

Remove unevenness observed in the bed faces to provide two smooth and parallel faces by grinding. Immerse in water at room temperature for 24 hours. Remove the specimen and drain out any surplus moisture at room temperature. Fill the frog ( where provided ) and all voids in the bed face flush with cement mortar ( 1 cement, clean coarse sand of grade 3 mm and down ). Store under the damp jute bags for 24 hours followed by immersion in clean water for 3 days. Remove, and wipe out any traces of moisture.

###### 4.1.3 Procedure

Place the specimen with flat faces horizontal, and mortar filled face facing upwards between two 3-ply plywood sheets each of 3 mm thickness and carefully centred between plates of the testing machine. Apply load axially at a uniform rate of 14 N/mm<sup>2</sup> ( 140 kgf/cm<sup>2</sup> ) per minute till failure occurs and note the maximum load at failure. The load at failure shall be the maximum load at which the specimen fails to produce any

further increase in the indicator reading on the testing machine.

NOTE — In place of plywood sheets plaster of Paris may be used to ensure a uniform surface for application of load.

###### 4.1.4 Report

The report shall be as given below:

Compressive strength in N/mm<sup>2</sup>  

$$(\text{kgf/cm}^2) = \frac{\text{Maximum load at failure in N(kgf)}}{\text{Average area of the bed faces in mm}^2 (\text{cm}^2)}$$

4.1.4.1 The average of results shall be reported.

##### 4.2 For Perforated Bricks

###### 4.2.1 Apparatus

See 4.1.1.

###### 4.2.2 Preconditioning

Immerse the specimen in water at room temperature for 24 hours. Remove the specimen from water and drain out any surplus water. No mortar shall be filled in perforations and no mortar capping shall be provided.

###### 4.2.3 Procedure

Place the perforated faces of the brick between two 3-ply plywood sheets each of 3 mm thickness and carefully centred between the plates of the testing machine. Apply the load axially at uniform rate of 14 N/mm<sup>2</sup> ( 140 kgf/cm<sup>2</sup> ) per minute till the failure occurs and note the maximum load at failure. The load at failure shall be the maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine.

NOTE — In place of plywood sheets plaster of Paris may be used to ensure a uniform surface for application of load.

###### 4.2.4 Report

The report shall be as given below:

Compressive strength in N/mm<sup>2</sup>  

$$(\text{kgf/cm}^2) = \frac{\text{Maximum load at failure in N (kgf)}}{\text{Average net area of the two faces under compression in mm}^2 (\text{cm}^2)}$$

4.2.4.1 The average of results shall be reported.

1

Representing Brick compression Reference code Fig-13

## 3.7 Chemical Analysis of binding Material Mortar

| TABLE-17                                                            |                     |                                                           |                                        |                                                              |                                                                                         |                                                                                                                           |
|---------------------------------------------------------------------|---------------------|-----------------------------------------------------------|----------------------------------------|--------------------------------------------------------------|-----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|
| NON DESTRUCTIVE TESTING OF KIRTI SHIKHAR TOWER,JANAKPURI WEST,DELHI |                     |                                                           |                                        |                                                              |                                                                                         |                                                                                                                           |
| CLIENT:- M/s ZEICHENBURO                                            |                     |                                                           |                                        | CONSULTANT :-OB DEVELOPERS                                   |                                                                                         |                                                                                                                           |
| CHEMICAL ANALYSIS OF BINDING MATERIAL MORTAR                        |                     |                                                           |                                        |                                                              |                                                                                         |                                                                                                                           |
| S.No                                                                | LOCATION            | Mortar ratio<br>(on average)<br>from chemical<br>analysis | Type of<br>mortar<br>table 1<br>IS1905 | Compressive<br>strength of<br>mortar N/mm2<br>table 1 IS1905 | Compressive<br>strength of<br>brick N/mm2<br>From brick<br>compressive<br>strength test | Basic<br>compressive<br>Stresses in<br>N/mm <sup>2</sup><br>corresponding<br>to masonry<br>unites from<br>table 8 IS:1905 |
| 1                                                                   | Near Column G4 Wall | 0.98:6.5                                                  | M2                                     | 3                                                            | 8.2                                                                                     | 0.59                                                                                                                      |
| 2                                                                   | Wall Near D6 Column | 1.4:5.6                                                   | M2                                     | 3                                                            | 8.03                                                                                    | 0.59                                                                                                                      |

Representing result of Mortar, Brick & Combination of compressive strength

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Designation: C 1152/C 1152M – 03

## Standard Test Method for Acid-Soluble Chloride in Mortar and Concrete<sup>1</sup>

This standard is issued under the fixed designation C 1152/C 1152M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last reapproval.

### 1. Scope

1.1 This test method<sup>2</sup> provides procedures for the sampling and analysis of hydraulic-cement mortar or concrete for chloride that is acid soluble under the conditions of test. In most cases, acid-soluble chloride is equivalent to total chloride.

1.2 The text of this standard references notes and footnotes that provide explanatory information. These notes and footnotes shall not be considered as requirements of this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other.

### 2. Referenced Documents

#### 2.1 ASTM Standards:<sup>3</sup>

- C 42/C 42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
- C 114 Test Methods for Chemical Analysis of Hydraulic Cement
- C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
- C 702 Practice for Reducing Field Samples of Aggregate to Testing Size
- C 823 Practice for Examination and Sampling of Hardened Concrete in Constructions

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.09 on Miscellaneous Tests.

Current edition approved Dec. 1, 2003. Published January 2004. Originally approved in 1990. Last previous edition approved in 1997 as C 1152 – 97.

<sup>2</sup> This test method is based on a report by Clear, K. C., and Harrigan, E. T., "Sampling and Testing for Chloride Ion in Concrete," Report No. FHWA-RD77-85, Federal Highway Administration, Washington, DC, Aug. 1977 (Available as PB 275-428/AS National Technical Information Services).

<sup>3</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

Test Method for Portland-Cement Content of Hard-

ened Hydraulic-Cement Concrete

D 1193 Specification for Reagent Water

E 11 Specification for Wire-Cloth Sieves for Testing Purposes

### 3. Significance and Use

3.1 The amount of acid-soluble chloride in most hydraulic-cement systems is equal to the total amount of chloride in the system. However, some organic substances that may be introduced into mortar or concrete contain chloride that is initially acid-insoluble that can eventually ionize and thus become acid-soluble or water-soluble after a period of exposure in the very alkaline cement system.

3.2 Sulfides are known to interfere with the determination of chloride content. Blast-furnace slag aggregates and cements contain sulfide sulfur in concentrations that can cause such interference and produce erroneously high test results. Treatment with hydrogen peroxide, as discussed in Test Methods C 114, is used to eliminate such interference.

### 4. Apparatus

#### 4.1 Sampling Equipment

4.1.1 The apparatus required for obtaining samples by coring or sawing is described in Test Method C 42/C 42M.

4.1.2 Use the following apparatus for sampling by drilling (pulverization):

4.1.2.1 *Rotary Impact Drill* and drill or pulverizing bits of sufficient diameter to provide a representative sample of sufficient size for testing.

4.1.2.2 *Spoon* or other suitable means to remove pulverized sample material from drill hole without contamination.

4.1.2.3 *Sample Containers* capable of maintaining samples in an uncontaminated state.

4.2 *Sample Processing Apparatus*—The apparatus required for processing samples shall be chosen for its suitability for the purposes of the investigation, and frequently includes a concrete saw and one or more pulverizers.

4.2.1 Samples more than 25 mm (1 in.) in maximum dimension shall be reduced in size by use of a jaw crusher or broken into smaller pieces by hammering carefully to avoid loss of smaller pieces.

Representing Mortar Reference code Fig-12

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## **ANNEXURE: - 1**

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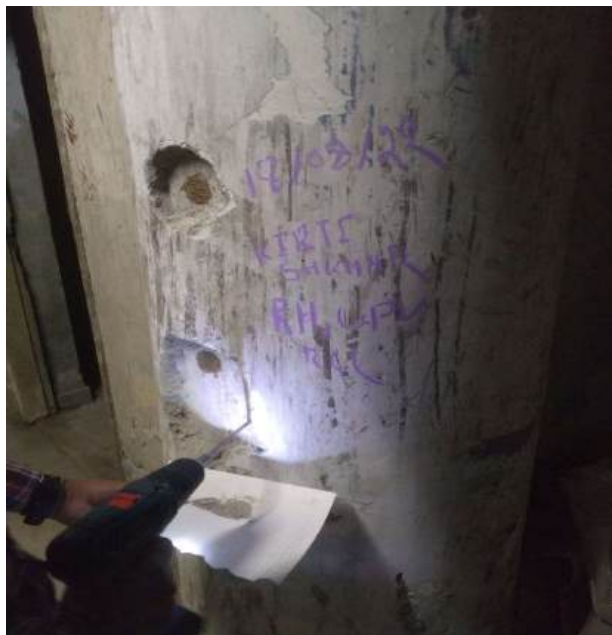
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# TESTING PHOTOGRAPHS

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### CARBONATION & PH TEST



### ULTRA SONIC PULSE VELOCITY TEST



### COVER METER TEST



### REBOUND HAMMER TEST



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**HALF CELL POTENTIAL TEST**



**BRICK EXTRACTION**



**CORE CUTTING**



## **STRUCTURE ADEQUACY ANALYSIS**

**OF  
KIRTI SHIKHAR TOWER, JANAKPURI WEST, DELHI.**

91

**PREPARED BY:**

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**FOR  
ANSAL HOUSING KIRTI SHIKHAR TOWER JANAK PURI NEW DELHI**



**PREPARED BY:**

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**FINAL CONCLUSION: -****KIRTI SHIKHAR****Specification Used in Designing Process****CALCULATIONS**

| S.NO | PARTICULAR                | SIZE OF (M) |      | GRADE OF CONCRETE | GRADE OF STEEL       | STEEL AS PER SITE<br>SQ.MM | STEEL AFTER 15% RUST REDUCTION<br>SQ.MM | STEEL AS PER STAAD<br>SQ.MM | RESULT |
|------|---------------------------|-------------|------|-------------------|----------------------|----------------------------|-----------------------------------------|-----------------------------|--------|
| 1    | COLUMN (CENTER )          | 0.6         |      | 18N/mm2           | 415N/mm <sup>2</sup> | 3920                       | 3332                                    | 8160                        | FAIL   |
| 2    | COLUMN (CENTER)           | 0.6         |      | 18N/mm2           | 415N/mm <sup>2</sup> | 3920                       | 3332                                    | -                           | FAIL   |
| 3    | COLUMN (CENTER NEAR LIFT) | 0.6         |      | 18N/mm2           | 415N/mm <sup>2</sup> | 3920                       | 3332                                    | 8403                        | FAIL   |
| 4    | COLUMN (PERIPHERY)        | 0.6         |      | 18N/mm2           | 415N/mm <sup>2</sup> | 3920                       | 3332                                    | 2262                        | SAFE   |
| 5    | COLUMN (PERIPHERY)        | 0.6         |      | 18N/mm2           | 415N/mm <sup>2</sup> | 3920                       | 3332                                    | 3330                        | SAFE   |
| 6    | BEAM (CENTER)             | 0.3         | 0.65 | 18N/mm2           | 415N/mm <sup>2</sup> | 1470                       | 1250                                    | 1795                        | FAIL   |
| 7    | BEAM (CENTER )            | 0.3         | 0.65 | 18N/mm2           | 415N/mm <sup>2</sup> | 1470                       | 1250                                    | 1810                        | FAIL   |
| 8    | BEAM (PERIPHERY )         | 0.3         | 0.65 | 18N/mm2           | 415N/mm <sup>2</sup> | 1470                       | 1250                                    | 612                         | SAFE   |
| 9    | BEAM (PERIPHERY)          | 0.3         | 0.65 | 18N/mm2           | 415N/mm <sup>2</sup> | 1470                       | 1250                                    | 406                         | SAFE   |

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## 1. Method of structural adequacy analysis and design parameters: -

The seismic safety of a reinforced concrete building will depend upon the initial architectural and structural configuration of the total building, the quality of the Structural analysis, design and reinforcement detailing of the building frame to achieve stability of elements and their ductile performance under severe seismic loading. Proper quality of construction and stability of the infill walls and partitions are additional safety requirements of the structure as a whole. Any weakness left in the structure, whether in design or in construction will be fully revealed during the postulated maximum considered earthquake for the seismic zone 4 in the earthquake code IS: 1893.

### Assumptions in static analysis

The basic assumptions in static analysis methodology are as follows:-

- 1) The behaviour of the structure is assumed to be perfectly linear and deformations are small
- 2) All joints are rigid
- 3) The members are subjected to axial, flexural and shear deformations
- 4) The force deformation relationship remains linear during the entire load regime.
- 5) Plinth beams are assumed

### Mathematical Modelling

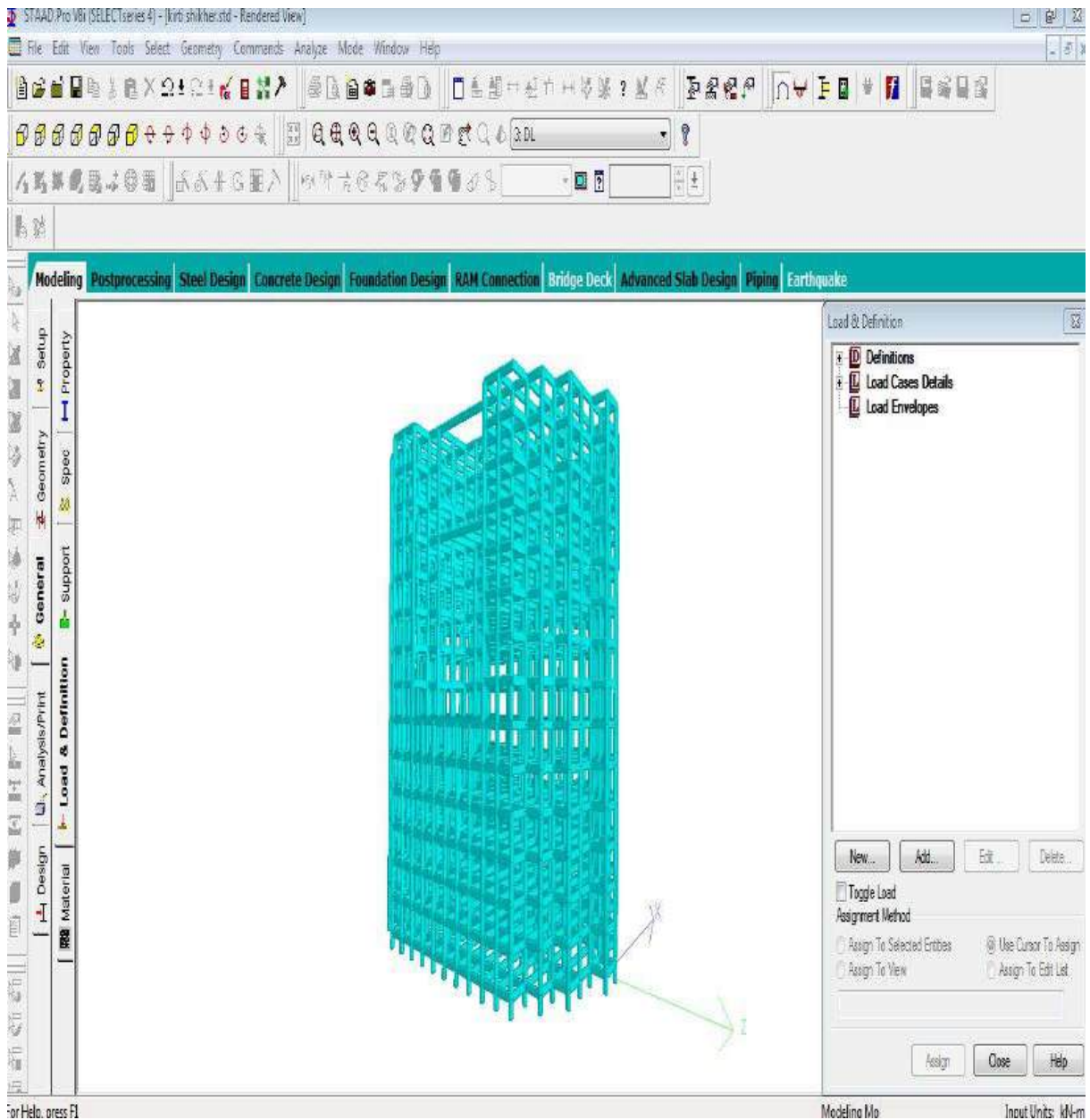
The structure is idealized as a 3-D space frame model. The beams and columns are considered as members. The floor slab load is given on beam members. The brick wall is used as a filler wall and is not casted monolithically with structure; hence this load is also given on beam members. The columns are assumed to be fixed at the foundation level.

## 2. Loads for Superstructure and Sub structural elements:

1. Grade of Concrete: M18
2. Steel: Fe415
3. Slab thickness: 150mm
4. Density of Concrete: 25kN/m<sup>3</sup>
5. Density of Brick: 20kN/m<sup>3</sup>
6. Live load on other floors: 2.5kN/m<sup>2</sup>,
7. Live load on roof : 1.5kN/m<sup>2</sup>,
8. Floor Dead load: 4.75kN/m<sup>2</sup> (all dead load included in it like Tiles, False ceiling and others)

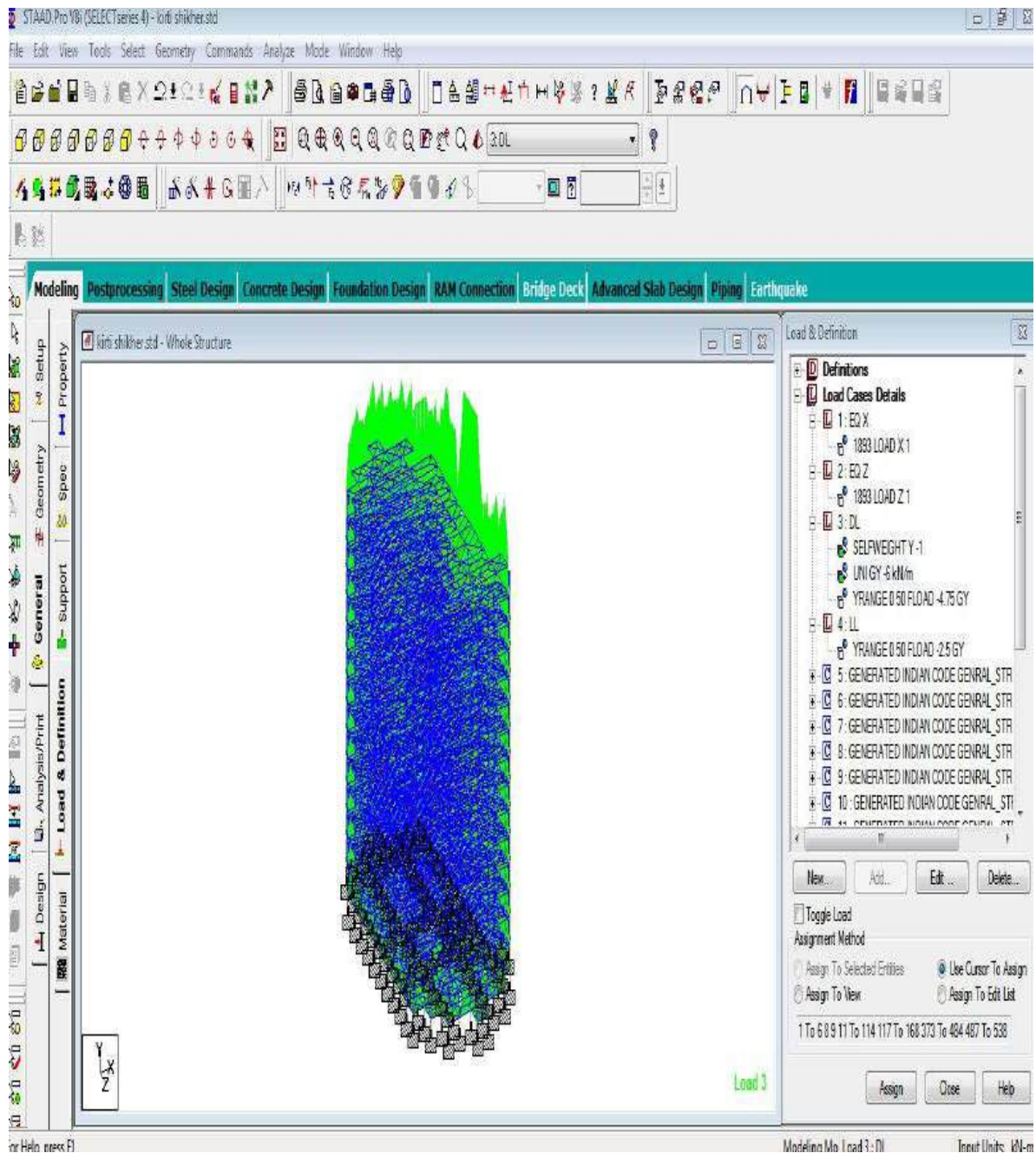
9. Floor Dead Wall Load: 6KN/M(Excluding windows opening)

## LOADING AND FRAME ARRANGEMENT



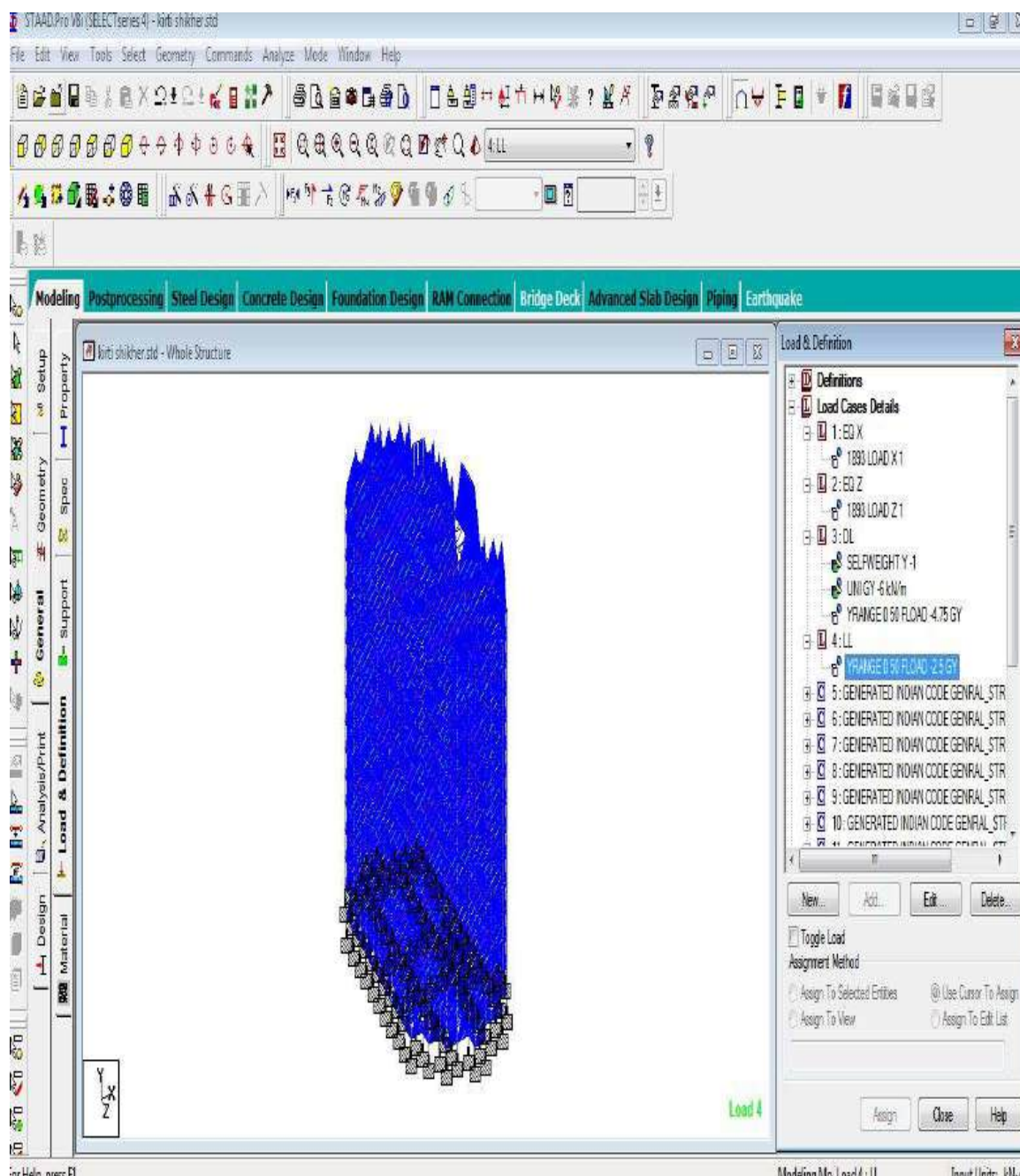
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#### 4. Materials properties data for static analysis: (as given in test certificates of reports; clause no 4.1)

- 1) Concrete
  - a) Concrete grade : Grade of concrete: M 18
  - b) Static modulus of elasticity  $E_c$  :  $5000v_{f_{ck}}$
  - c) Poisson's ratio : 0.17

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- d) Unit weight of R.C.C : 25 kN/m<sup>3</sup>
- e) P.C.C : nominal mix of 1:4:8
- 2) Reinforcement Steel
- Yield strength  $F_y$  : 415 N/mm<sup>2</sup>
- Conforming to IS 1786 -1985
- Static modulus of elasticity  $E_s$  :  $2 \times 10^5$  N/mm<sup>2</sup>

## 5. Load combinations

**Combination of Loads considered in analysis:** The structural design has been carried out in accordance with the provisions of the codes IS 456 – 2000 and IS 1893 – 2002 for **Normal design conditions**

Table of Load combinations and load factors as per (Ref. IS: 456 – 2000, Cl.18.2.3.1, 36.4.1, and B4.3)

**Table 18 Values of Partial Safety Factor  $\gamma_f$  for Loads**  
(Clauses 18.2.3.1, 36.4.1 and B-4.3)

| Load Combination | Limit State of Collapse     |           |           | Limit States of Serviceability |           |           |
|------------------|-----------------------------|-----------|-----------|--------------------------------|-----------|-----------|
|                  | DL<br>(2)                   | IL<br>(3) | WL<br>(4) | DL<br>(5)                      | IL<br>(6) | WL<br>(7) |
| (1)<br>DL + IL   | 1.5                         |           | 1.0       | 1.0                            | 1.0       | –         |
| DL + WL          | 1.5 or<br>0.9 <sup>1)</sup> | –         | 1.5       | 1.0                            | –         | 1.0       |
| DL + IL + WL     | 1.2                         |           |           | 1.0                            | 0.8       | 0.8       |

NOTES

1 While considering earthquake effects, substitute *EL* for *WL*.

2 For the limit states of serviceability, the values of  $\gamma_f$  given in this table are applicable for short term effects. While assessing the long term effects due to creep the dead load and that part of the live load likely to be permanent may only be considered.

1) This value is to be considered when stability against overturning or stress reversal is critical.

Note: **DL** = Dead Load, **LL** = Live Load/ Superimposed Load, **WL** = Wind Load, **EL** = Earthquake load But in Analysis only working load 1.0 (DL+LL) is taken also material safety factor is removed from the analysis part

## LOAD ARRANGEMENT ON FLOORS

| LOAD ON FLOORS |              |                   |                       |
|----------------|--------------|-------------------|-----------------------|
| SR NO          | FLOOR        | TYPE OF OCCUPANCY | APPROX. LOAD IN KN/M2 |
| 1              | BASMENT      | OFFICE            | 2.5 KN/M2             |
| 2              | GROUND       | OFFICE            | 2.5 KN/M2             |
| 3              | UPPER GROUND | OFFICE            | 2.5 KN/M2             |
| 4              | 1ST          | OFFICE            | 2.5 KN/M2             |
| 5              | 2ND          | OFFICE            | 2.5 KN/M2             |
| 6              | 3RD          | OFFICE            | 2.5 KN/M2             |
| 7              | 4TH          | OFFICE            | 2.5 KN/M2             |
| 8              | 5TH          | OFFICE            | 2.5 KN/M2             |
| 9              | 6TH          | OFFICE            | 2.5 KN/M2             |
| 10             | 7TH          | OFFICE            | 2.5 KN/M2             |
| 11             | 8TH          | OFFICE            | 2.5 KN/M2             |
| 12             | 9TH          | OFFICE            | 2.5 KN/M2             |
| 13             | 10TH         | OFFICE            | 2.5 KN/M2             |
| 14             | 11TH         | OFFICE            | 2.5 KN/M2             |

**PREPARED BY:**

**ZEICHENBURO INDIA PRIVATE LIMITED**  
**BH-1012, 10<sup>TH</sup> FLOOR, PURI BUSSINESS HUB**  
**SECTOR-81, FARIDABAD, HARYANA**

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