DAMAGE DETECTION BY USING NDT AND ITS REPAIR

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ABSTRACT

Buildings and other structures have a certain useful life, which depends on the specifications adopted. The large numbers of monuments, which are cherished heritage structures have stood well over a period of time. But some of these have shown signs of distress due to age, aggressive natural environment/industrial pollution etc. Further, distress gets aggravated due to overloading and misuse of buildings. A few buildings have also failed due to faulty design or construction. The various causes of structural failure and the principles of rehabilitation of structures are discussed. In the proposed approach we used Damage Detection and It's Repairs and Rehabilitation Techniques in RCC Structures Using NDT 1) Half-cell potential meter 2) Resistivity meter For Corrosion Mapping 3. Ultrasonic Pulse Velocity 4. Rebound Hammer. In the structures, the cracks are generated due to different causes e.g. in some cases cracks are caused after the structure has been completed for a few years which results in shortening of life and strength of structure. The purpose of this paper is damage detection and its repairs and rehabilitation techniques in RCC structures using NDT. For corrosion mapping to justify the latest techniques, advanced materials and various requirements of repairing work to obstruct the deterioration which is necessary and economical than to reconstruct the building.

Keywords - *Building, Rehabilitation, Repair, Retrofitting, Structure, Half-cell potential meter, Resistivity meter, Ultrasonic Pulse Velocity, Rebound Hammer.*

1. INTRODUCTION

Most of structures while in service are subjected to aggressive influences of environment. These corrosive attacks on structures cause damage and lead to failure of the structural element or the whole structure. Corrosion causes deterioration of material and leads to destruction of structures, especially in coastal and industrial areas. Corrosion of steel is an electro-chemical phenomenon. Electro-chemical corrosion results because of the existence of different metals or non-uniformities in steel or non-uniformities in chemical or physical environment, afforded by the surrounding concrete. This thesis is worked with the comparison of three beams(M30(Normal), M30,M20).The experimental results have compared to the half-cell potentiometer readings and the % weight of loss of three beams were casted whose sizes were 750X150X100 mm respectively. The need to improve the ability of an existing building to withstand from weathering action, chemical attack, embedded metals, alkali-aggregate reactivity, fire, due to overload, seismic forces, etc. arises usually from the evidence of damage and poor behavior. These type of structures are deteriorated with use and time and might have passed their design life and require repair and rehabilitation. Therefore the solutions for RCC structure or structural elements are essential and for this different techniques are utilized. Strength assessment of an existing structure or any element of structures is essential to cover all the criteria in which maintenance is required. Thus, some numbers of non-destructive, partially destructive and destructive techniques in the existing structures are used for assessment of concrete structure and to predict the cause of deterioration of the concrete The old buildings in which ancient temples, monuments, heritage buildings and some residential buildings are included and need some maintenance of repair due to which the regain of strength, durability and stability of those buildings should be done. Hence, here some specifications are discussed about repair and rehabilitation of residential buildings. The purpose of this paper is Damage Detection and It's Repairs and Rehabilitation Techniques in RCC Structures Using NDT. In the recent past corrosion in concrete structures has been considered as major durability problems affecting the service life of concrete structures. Corrosion occurs when two different metals or metals in different environments are electrically connected in moist concrete. This paper represents a methodology for a systematic inside testing of corrosion in RCC structures.

1.1. Background

Repair The main purpose of repairs is to bring back the architectural shape of the building so that all services start working and the functioning of building is resumed quickly. Repair does not pretend to improve the structural strength of the building and can be very deceptive for meeting the strength requirements. The objective of any repair should be to produce rehabilitation – which means a repair carried out relatively low cost, with a limited and predictable degree of change with time and without premature deterioration and/or distress throughout its intended life and purpose. To achieve this goal, it is necessary to consider the factors affecting the durability of a repaired structural system as part of a whole, or a component of composite system. B. Rehabilitation Structural rehabilitation involves the upgrading or changing of a building's foundation in support of changes in the building's owners, its use, design goals or regulatory requirements. In every case it is determined that it is cheaper to rehabilitate the structure and make the building improvements instead of demolishing and constructing a new building in the allotted space. Retrofitting is the engineering which involves in modifying the existing buildings for structural behavior without hampering its basic intent of use is termed as retrofitting. It becomes necessary to improve the performance of structures including those facing loss of strength due to deterioration or which have crossed their anticipated lifespan. The realization of retrofitting depends on the authentic cause and measures adopted to prevent its further deterioration. This development includes repair, retrofit, renovation and reconstruction wherever required. A proper load path has to be analyzed by a structural engineer and a decision has to be taken if any additional member like shear walls, etc. needs to be added.

2. METHOD AND PROCESS

2.1 Non Destructive Evaluation (NDE) Methods

The following instruments were used in the project:

1. Half-cell potential meter

2. Resistivity meter

3. Rebound Hammer (Schmidt Hammer) (Impact energy of the hammer is about 2.2 Nm)

4. Ultrasonic Pulse Velocity Tester.

1) Half-cell potential meter: The instrument measures the potential and the electrical resistance between the reinforcement and the surface to evaluate the corrosion activity as well as the actual condition of the cover layer during testing. The electrical activity of the steel reinforcement and the concrete leads them to be considered as one half of weak battery cell with the steel acting as one electrode and the concrete as the electrolyte. The name half-cell surveying derives from the fact that the one half of the battery cell is considered to be the steel reinforcing bar and the surrounding concrete. The electrical potential of a point on the surface of steel reinforcing bar can be measured comparing its potential with that of copper – copper sulphate reference electrode on the surface. Practically this achieved by connecting a wire from one terminal of a voltmeter to the reinforcement and another wire to the copper sulphate reference electrode. Then readings taken are at grid of 1 x 1 m.
Significance and Use: This method may be used to indicate the corrosion activity associated with steel embedded in concrete. This method can be applied to members regardless of their size or the depth of concrete cover. This method can be used at the any time during the life of concrete member.

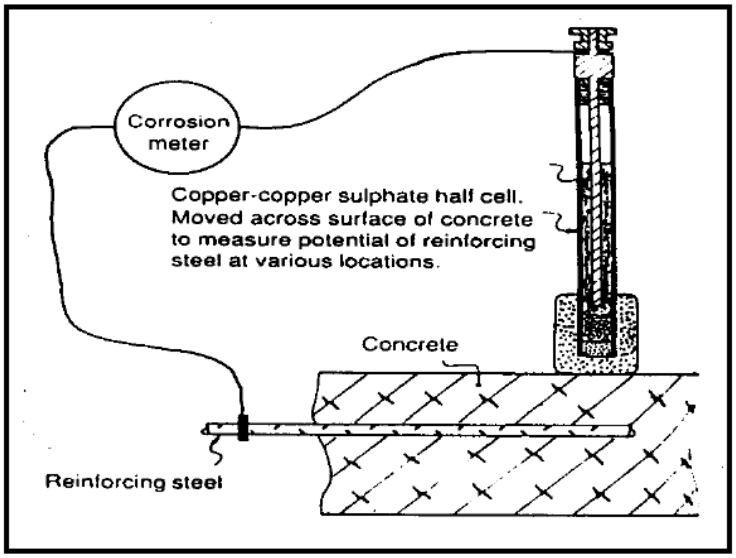


Fig.1: Half-cell Potential Test

The risk of corrosion is evaluated by means of the potential gradient obtained, the higher the gradient, and the higher risk of corrosion. The test results can be interpreted based on the following table.

Table 1: Half Cell Potential Corresponding to Percentage Chance of Corrosion Activity

Half-cell potential (mv) relative to Cu-Cu sulphate Ref. Electrode	% chance of corrosion activity
Less than -200 Between -200 to -350	10% 50% (uncertain)
Above 350	90%

2) Resistivity meter: One of the major problems facing an engineer today is deterioration of concrete member by corrosion of rebars. So it is prime concern to determine the state of corrosion in the bars. For this several commercial Equipments are available, one of these commercial Equipments available is Resistivity Meter (RESI). It is portable equipment and can be easily operated. RESI consists of a display unit and resistivity probe as shown in Fig. Display unit consists of memory of 7200 values and power is supplied to the unit with the help of batteries. Resistivity probe is available with integrated electronics for the measurements by four-point method. In this method resistivity probe is connected with the display unit to obtain brief display. All the functions are tested and checked before starting the measurement process. After checking, unit probe is placed on the area to be measured. Measurement can be done with grid to represent the resistivity value for a large area. The grid of suitable size is marked on the surface and measurements are taken.

Application: It is used to monitor corrosion in the steel bars by measuring the concrete resistivity.

Limitation:
1. It is difficult to measure resistivity in very close reinforcement
2. Carbonation may affect the resistivity
3. It cannot be used where ambient change in temperature is there.
4. Experience operator is required to handle this equipment.

3) Rebound Hammer (Schmidt Hammer):

3.1 Components of a Rebound Hammer

1	Concrete surface	5	Hammer guide	9	Housing
2	Impact spring	6	Release catch	10	Hammer mass
3	Rider on guide rod	7	Compressive spring	11	Plunger
4	Window and scale	8	Locking button		

This is a simple, handy tool, which can be used to provide a convenient and rapid indication of the compressive strength of concrete. It consists of a spring controlled mass that slides on a plunger within a tubular housing.

Principle: The method is based on the principle that the rebound of an elastic mass depends on the hardness of the surface against which mass strikes. When the plunger of rebound hammer is pressed against the surface of the concrete, the spring controlled mass rebounds and the extent of such rebound depends upon the surface hardness of concrete. The surface hardness and therefore the rebound is taken to be related to the compressive strength of the concrete. The rebound value is read off along a graduated scale and is designated as the rebound number or rebound index. The impact energy required for rebound hammer for different applications is given below :- Depending upon the impact energy, the hammers are classified into four types i.e. N, L, M & P. Type N hammer having an impact energy of 2.2 N-m and is suitable for grades of concrete from M-15 to M-45. Type L hammer is suitable for lightweight concrete or small and impact sensitive part of the structure. Type M hammer is generally recommended for heavy structures and mass concrete. Type P is suitable for concrete below M15 grade.

4. Ultrasonic Pulse Velocity Tester

Ultrasonic instrument is a handy, battery operated and portable instrument used for assessing elastic properties or concrete quality. The apparatus for ultrasonic pulse velocity measurement consists of the following (Fig.):-

(a) Electrical pulse generator

(b) Transducer – one pair

(c) Amplifier

(d) Electronic timing device

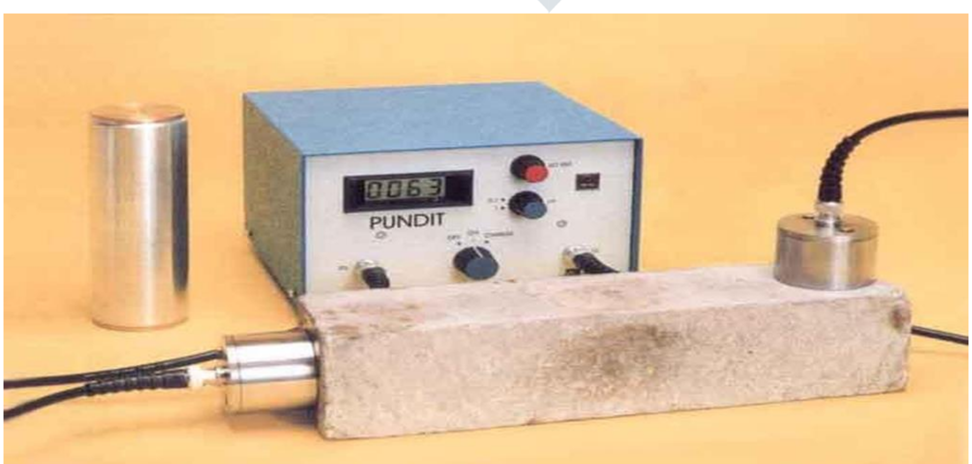


Fig.2 USPV Tester

Principle:-The method is based on the principle that the velocity of an ultrasonic pulse through any material depends upon the density, modulus of elasticity and Poisson's ratio of the material. Comparatively higher velocity is obtained when concrete quality is good in terms of density, uniformity, homogeneity etc. The ultrasonic pulse is generated by an electro acoustical transducer. When the pulse is induced into the concrete from a transducer, it undergoes multiple reflections at the boundaries of the different material phases within the concrete. The receiving transducer detects the onset of longitudinal waves which is the fastest. The actual pulse velocity obtained depends primarily upon the materials and mix proportions of concrete. Density and modulus of elasticity of aggregate also significantly affects the pulse velocity. Any suitable type of transducer operating within the frequency range of 20 KHz to 150 KHz may be used.

The principle of the test is that the velocity of sound in a solid material, V, is a function of the square root of the ratio of its modulus of elasticity, E, to its density, d, as given by the following equation:

$$V = f\left(\frac{gE}{d}\right)^\wedge\left(\frac{1}{2}\right) \quad (1)$$

Where, g is the gravity acceleration. As noted in the previous equation, the velocity is dependent on the modulus of elasticity of concrete. Monitoring modulus of elasticity for concrete through results of pulse velocity is not normally recommended because concrete does not fulfill the physical requirements for the validity of the equation normally used for calculations for homogenous, isotropic and elastic materials

$$V^2 = \frac{Ed(1-\mu)}{p(1+\mu)(1-\mu)} \quad (2)$$

Where V is the wave velocity, ρ is the density, μ is Poisson's ratio and Ed is the dynamic modulus of elasticity. On the other hand, it has been shown that the strength of concrete and its modulus of elasticity are related.

The method starts with the determination of the time required for a pulse of vibrations at an ultrasonic frequency to travel through concrete. Once the velocity is determined, an idea about quality, uniformity, condition and strength of the concrete tested can be attained. In the test, the time the pulses take to travel through concrete is recorded. Then, the velocity is calculated as:

$$V = L/ T$$

Where V=pulse velocity, L=travel length in meters and T=effective time in seconds, which is the measured time minus the zero time correction.

3. SITE DETAILS

The aim of the project was to obtain the Calibration Graphs for Non Destructive Testing Equipment and to study the effect of reinforcement on the obtained results. These Non Destructive Instruments were then used to test the columns, beams and slabs of two double storied buildings viz., Hall No.2 and Hall no.7.

1. Name of the project :Sai Costruction
2. Location : Ambegaon , katraj Pune.
3. Owner : Sagar Gholap
4. Purpose of project: Industrial purpose.
5. Consultant: Mr. Aslam Shaikh.
6. Total Area of construction : 1,68,000 sq.ft.
7. Project highlights: 100% Green energy, STP Plant, Efficient natural light and ventilation.
8. Cost of the project: 25.4 crore.

1. FACTORS INFLUENCING CORROSION

- Inadequate cover thickness
- Quality of concrete in the cover regions

- Environmental conditions
- Chloride level in concrete
- Presence of cracks etc.

2. MATERIALS USED

- CEMENT
- OPC used.(53grade)

- COURSE AGGREGATE
- The sample of crushed aggregate passing through a20mm IS sieve & retaining on a 4.75mm IS sieve issued.

- FINE AGGREGATE
- Locally available sand passing through 4.75mm IS sieve & retaining 150microns sieve.

- STEEL PROVISIONS
- main bars - 10mm bars (Fe-415)stirrups - 8mm bars (Fe-415)

3. MIX DESIGN

- Method of design is Indian standard method
- Design mix ratio of M20 is 1:1.5:3
- Design mix ratio of M30 is 1:2:2.5For all the mixes w/c ratio is 0.55

4. BEAM DESIGN

- Minimum tension reinforcement: (Ast / bd) = (0.85 /fy)>0.34% for mild steel (fy =250N/mm2)>0.20% for HYSD bars (fy =415N/mm2)
- Maximum reinforcement: 0.04 bD for both tension and compression reinforcement.
- Spacing between bars: Diameter of neither larger bar nor less than the normal maximum sizes of coarse aggregate plus 5 mm whichever is greater.
- Nominal cover: 25 mm nor less than the diameter of the bar.
- Curtailment: Refer clause 26.2.3 of IS 456-2000.
- Reinforcement in concrete will not corrode if the protective iron oxide film formed by the high alkaline condition of the concrete pore fluid with a pH around 13 is maintained. This film gets destroyed by chlorides or by carbonation, if moisture and oxygen are present, resulting in corrosion

4. TEST RESULTS AND DISCUSSION

4.1 REBOUND HAMMER TEST

PREPARATION OF SPECIMEN:

6 cubes were cast, targeting at different mean strengths. Further, the cubes were cured for different number of days to ensure availability of a wide range of compressive strength attained by these cubes. Size of each cube was 150×150×150 mm.

TESTING OF SPECIMEN:

1. 10 readings (rebound numbers) were obtained for each cube, at different locations on the surface of the specimen.

2. The cube was divided into grid blocks of equal spacing and 10 points were marked at equal intervals for taking the Rebound Hammer test.

3. The cubes were then given a load of 7 N/mm^2 (as specified by the IS CODE 13311) in the Compression Testing Machine and the Rebound Values were obtained.

4. The cubes were then loaded up to their ultimate stress and the Breaking Load was obtained.

5. The following tables lists the Rebound numbers (rebound index), Mean Rebound Value, Standard Deviation, the Dead Load on the specimen at the time of testing, the Breaking Load, the Predicted Compressive Strength as predicted by the Rebound Hammer and the actual Compressive Strength as obtained by the Compression Testing Machine.

4.2 ULTRASONIC VELOCITY TESTING MACHINE TEST

PREPARATION OF SPECIMEN: 9 cubes were cast, targeting at different mean strengths. Further, the cubes were cured for different number of days to ensure availability of a wide range of compressive strength attained by these cubes. Size of each cube was 150×150×150 mm.

TESTING OF SPECIMEN:
3 readings of Ultrasonic Pulse Velocity (USPV) were obtained for each cube. The cubes were then given a load of 7 N/mm^2 (as specified by the IS CODE 13311) in the Compression Testing Machine and the USPV were obtained. The cubes were then loaded up to their ultimate stress and the Breaking Load was obtained. The following table lists the USPV in each specimen with their mean velocity, the Dead Load, the Breaking Load and the actual Compressive Strength as obtained by the Compression Testing Machine.

4.3 HALF-CELL POTENTIOMETER TEST

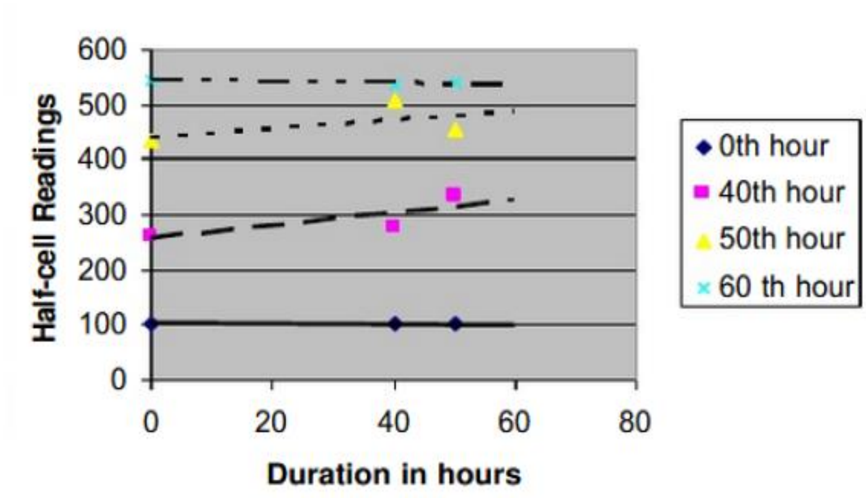
One end of Half-Cell connected to the reinforcement

Half-Cell Potential Test of Column

Marking of Slab and Pre-wetting for Half-Cell Potential Test

Half-Cell Potential Test of Slab

Fig.3 USPV Tester



From the above figure corrosion initiated after 40 hours **Half-cell potentiometer readings (For M20)**

Time in hours	0th hour			40 hours			50 hours			60 hours		
Phase of Beam	Top	Sides	Bottom	Top	Sides	Bottom	Top	Sides	Bottom	Top	Sides	Bottom
Half-cell readings	94	104	100	392	460	509	530	564	589	610	599	609
	99	102	102	384	472	542	563	594	590	642	664	647
	104	104	101	398	525	501	532	568	560	659	671	599
	100	99	99	410	493	560	557	593	576	623	655	589
	106	102	96	483	522	508	590	589	583	665	664	567
	108	103	101	396	500	530	598	584	569	634	671	529
Average	**101.8**	**102.3**	**99.8**	**410.5**	**495.3**	**525**	**561.6**	**582**	**577.8**	**638.8**	**654**	**590**

HALF CELL POTENTIOMETER READINGS

5. CONCLUSION

Repair and Rehabilitation is necessary to save hazardous failure of structures due to deterioration. It is recommended for old buildings which have some signs like cracks, corrosion of embedded materials, etc. Therefore timely maintenance of structures is required. The selection of technique is used as per cost, location of site and other factors. Thus for proper maintenance, the techniques likewise Rebound Hammer Testing, Ultrasonic Pulse Velocity Evaluation, etc. are utilized. In Rebound Hammer 10 readings (rebound numbers) were obtained for each cube, at different locations on the surface of the specimen. The cube was divided into grid blocks of equal spacing and 10 points were marked at equal intervals for taking the Rebound Hammer test. The cubes were then given a load of 7 N/mm^2 (as specified by the IS CODE 13311) in the Compression Testing Machine and the Rebound Values were obtained. The cubes were then loaded up to their ultimate stress and the Breaking Load was obtained. Rebound numbers (rebound index), Mean Rebound Value, Standard Deviation, the Dead Load on the specimen at the time of testing, the Breaking Load, the Predicted Compressive Strength as predicted by the Rebound Hammer and the actual Compressive Strength as obtained by the Compression Testing Machine. 3 readings of Ultrasonic Pulse Velocity (USPV) were obtained for each cube. The cubes were then given a load of 7 N/mm^2 (as specified by the IS CODE 13311) in the Compression Testing Machine and the USPV were obtained. The cubes were then loaded up to their ultimate stress and the Breaking Load was obtained. The following table lists the USPV in each specimen with their mean velocity, the Dead Load, the Breaking Load and the actual Compressive Strength as obtained by the Compression Testing Machine. It seems that corrosion initiated after 40 hours on the basis of Half-cell potentiometer readings (For M20). By comparing all these NDT results without harming existing structure we recommend and suggest all necessary replacement, changes and repairs and get required strength to the structure.

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