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DAMAGE DETECTION AND ITS REPAIR AND REHABILITATION TECHNIQUES BY USING NDT ON RCC STRUCTURE FOR CORROSION MAPPING

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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. 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 main criteria is how to repair a reinforced concrete elements of structures and for this the skills, knowledge, and experience required to repair damaged or deteriorated structures are decidedly different from those required to build new structures. The purpose of this paper is 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 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.

I.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. Some reasons of deteriorations due to ageing and error in design and detailing can be analyzed. 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 1) Half-cell potential meter 2) Resistivity meter. 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.

II.REPAIR, REHABILITATION AND RETROFITTING CONCEPTS

A. 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

C. Retrofitting

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.

D. Origin of Deterioration

- Drying Shrinkage-
- Temperature stresses - This may be due to difference in temperatures between the inside of the building with its environment and variation in internal temperature of the building or structure.
- Absorption of moisture by concrete Corrosion of reinforcement - This could be caused by entry of moisture through cracks or pores and Electrolytic action
- Aggressive action of chemical Weathering action-
- Poor design details at re-entrant corners, changes in cross section, rigid joints in precast elements, deflections - this lead to leakage through joints, inadequate drainage, inefficient drainage slopes, unanticipated shear stresses in piers, columns and abutments etc, incompatibility of materials of sections, neglect in design
- Errors in design, Errors in earlier repairs, Overloading.

III. METHODOLOGY USED

1. FORMS OF CORROSION

- Uniform Corrosion
- Pitting Corrosion
- Crevice Corrosion
- Galvanic Corrosion
- Intergranular Corrosion
- Selective Leaching Erosion Corrosion
- Stress Corrosion

2. STATES OF CORROSION

- Passivity state
- State of pitting corrosion
- State of general corrosion
- State of active

- low corrosion potential

3. FACTORS INFLUENCINGCORROSION

- Inadequate cover thickness
- Quality of concrete in the cover regions
- Environmental conditions
- Chloride level in concrete
- Presence of cracks etc.

4. 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)

5. 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

6. 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 b. D 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. In the corrosion process anodic and cathodic areas are formed on the reinforcement, causing dissolution of the steel and the formation of expansive corrosion products at the anode.

1. HALF-CELL POTENTIOMETER :

Principle and Procedure: 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.

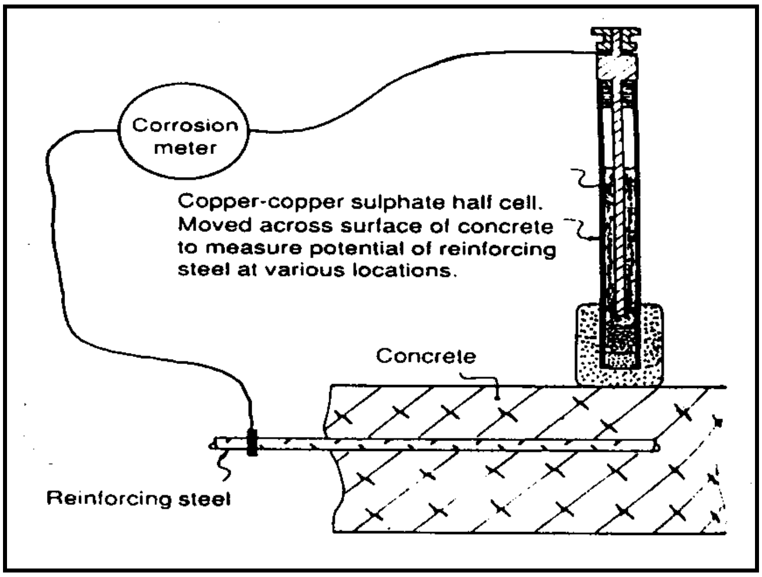


Fig.1: Half-cell Potential Test

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	10%
Between -200 to -350	50% (uncertain)

Above -350	90%

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.

Reliability and Limitation: The test does not corrosion rate or whether corrosion activity ahs already started, but it indicates the probability of the corrosion activity depending upon the actual surrounding conditions. if this method used in combination with resistivity measurement, the accuracy is higher. If the concrete surface has dried to the extent that it is dielectric, then pre wetting of concrete is essential.

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

2. RESISTIVITY METER (RESI)

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. There are various factors which affect the observations such as moisture content, carbonation and chloride contents, temperature, connection between probe and concrete.

For taking reliable measurements good contact between the foam pad of the resistivity probe and the concrete surface is essential. Though resistivity meter is used to monitor corrosion but if this technique is used with half-cell potential measurements, it will give more accurate results and corroded zone can be monitored more efficiently.

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

Limitation

I. It is difficult to measure resistivity in very close reinforcement

II. Carbonation may affect the resistivity

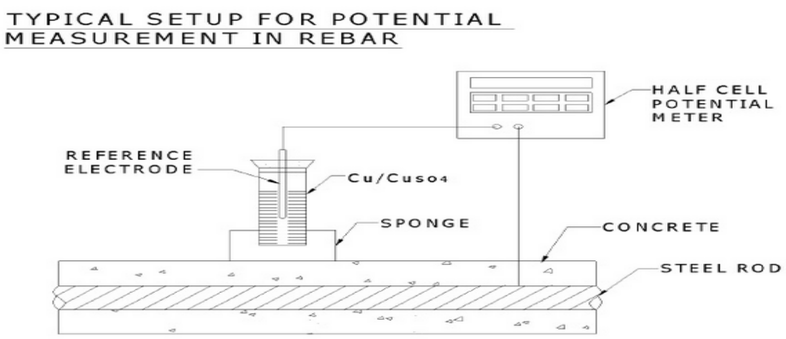
III. It cannot be used where ambient change in temperature is there.

IV. Experience operator is required to handle this equipment.

METHODOLOGY

- A beam specimen of size is 750x150x100mmare caste.
- The impressed current is applied to accelerate the corrosion process.
- Stainless steel plate is act as cathode.
- Main reinforcements in a beam are connected to anodic part of D.C power supply.
- The half-cell potentiometer readings of the specimens are compared to the M20&M30specimens.
- The half-cell potentiometer readings of the specimens are analyzed.

HALFCELL POTENTIAL MEASUREMENT



CORROSION PROCESS

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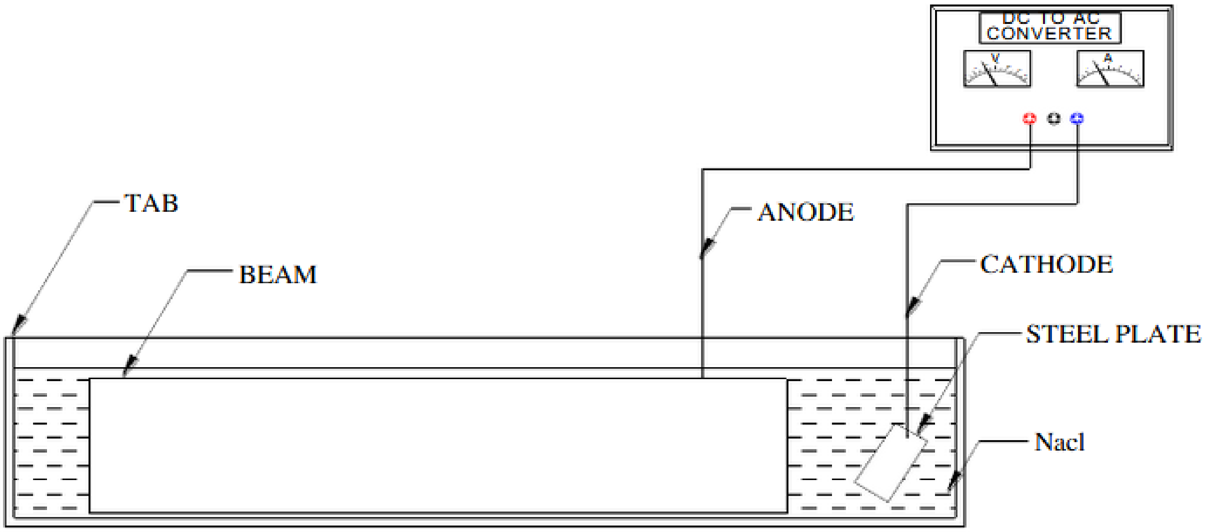
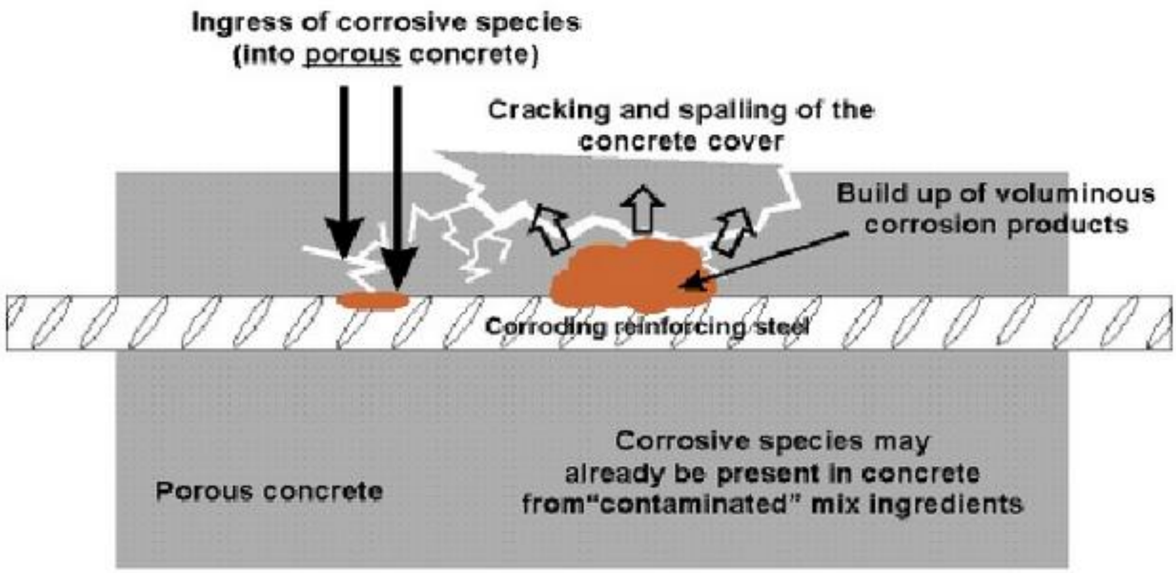


CORROSION MECHANISM



Half-cell potentiometer readings (For M30-Normal)

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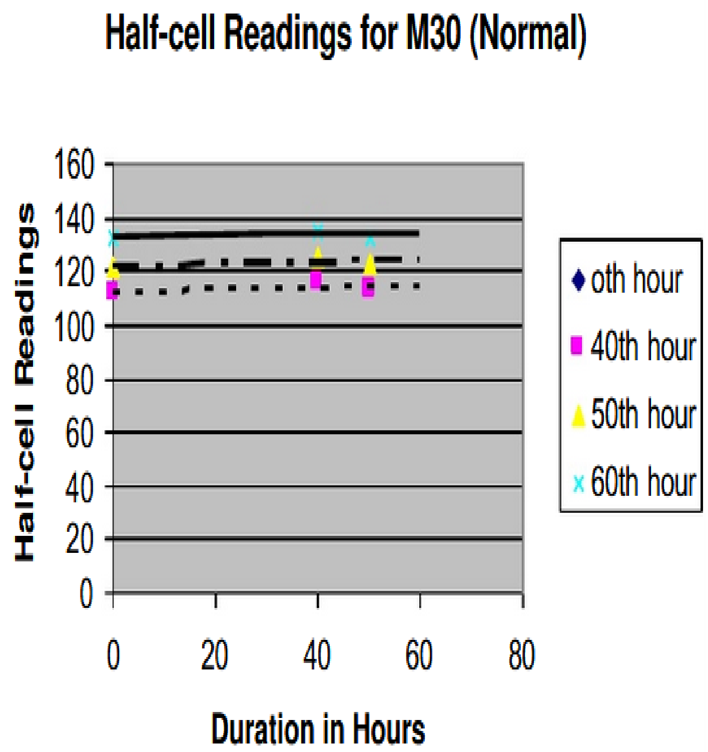
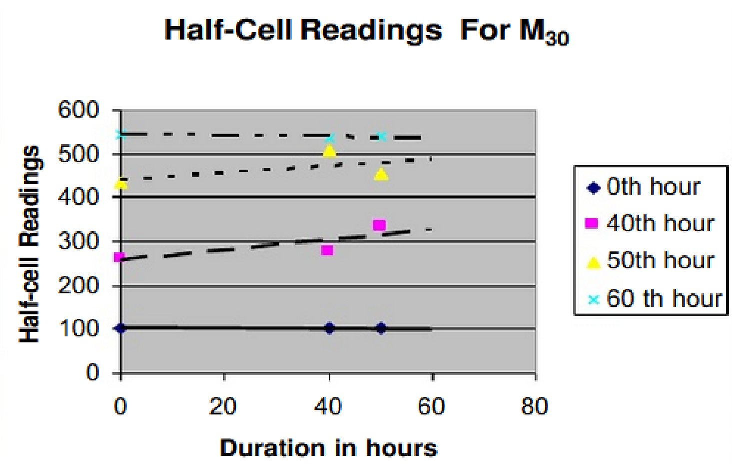
Time in hours	0th hour			40 hours			50 hours			60 hours		
Phase of Beam	Top	Sides	Bottom	Top	Sides	Bottom	Top	Sides	Bottom	Top	Sides	Bott om
Half-cell readings	101	100	98	112	110	115	126	123	120	134	139	136
	99	102	97	110	115	113	123	124	122	131	137	134
	102	104	96	115	117	109	124	122	121	132	135	132
	105	102	99	117	115	116	120	128	125	135	134	138
	98	98	98	109	118	119	118	125	123	129	131	129
	96	99	100	108	116	108	119	127	128	130	133	125
Average	100.1	100.8	98	111.8	115.1	113.3	121.6	124.8	123.1	131.8	134.8	132.3



From the above figure corrosion is not initiated up to 60 hours

Half-cell potentiometer readings (For M30)

Time in hours	0th hour			40 hours			50 hours			60 hours		
Phase of Beam	Top	Sides	Bott om	Top	Sides	Botto m	Top	Sides	Bottom	Top	Sides	Bottom
Half-cell readings	104	106	99	296	256	182	417	484	490	540	551	529
	99	101	98	252	263	272	430	508	483	555	519	534
	100	100	96	202	321	345	416	509	420	553	520	542
	102	98	100	277	306	439	438	479	406	524	563	538
	105	99	103	240	253	391	450	523	449	534	544	528
	104	100	101	298	256	359	440	526	474	546	522	554
Average	102.3	100.6	99.5	260.8	275.8	331.3	431.8	504.8	453.6	542	536.6	537.5



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	Bot tom
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

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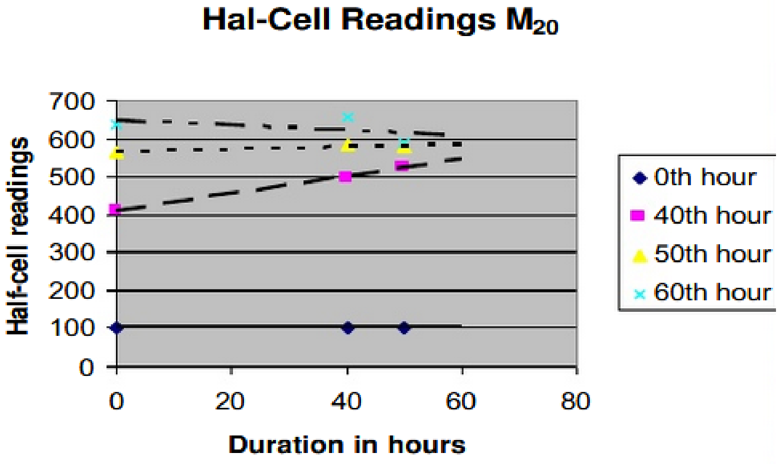

From the above figure corrosion is initiated in 40 hours

IV. METHODS FOR REPAIR AND REHABILITATION OF STRUCTURES

The various methods are available for carrying out the structural repair to distressed structures. The basic methods, which can be used singly or in combination of more than one, are as following:

A. Guniting/Shotcreting Methodology:

Shotcrete is defined as pneumatically applied concrete or mortar placed directly on surface the cement and sand are batched and mixed in the usual way and conveyed through a hose pipe with the help of compressed air. A separate pipe line brings water under pressure and the water and cement aggregate mix are passed through and intimately mixed in a special manifold and then projected at high velocity to the surface being repaired. In good quality work, a density around 2100kg/m3 is achieved. For effective guniting, the nozzle should be kept at 60cm to 150cm from the work normal to the surface. Before guniting is applied, the old concrete surface is prepared properly, all the cracks treated and the new reinforcement fixed in position. Cracks wider than about 0.5 mm should be cut out and filled with hand-applied mortar or with gunite.

B. Types of Shotcrete

1) Wet Mix Shotcrete

Wet mix Shotcrete is a method that involves premixing of all ingredients including binder, water, aggregates and admixtures. The wet mix process shall consist of thoroughly mixing all the ingredients with the exception of the accelerated admixture (if used). Then mixtures have to be feed into the delivery equipment and deliver it by positive displacement or compressed air to the nozzle. This mixture is jetted from the nozzle at high velocity on to the surface to receive the shotcrete If specified, fibres of steel, poly propylene or other material, as may be specified could also be used together with the admixtures to modify the structural properties of the concrete/mortar being placed in position.

2) Dry Mix Shotcrete

Dry mixing involves premixing of binders and aggregates which are fed into special mechanical feeder metering the premixed materials into a hose. The mix is jetted out along with compressed air from a nozzle connected to the hose having a water ring outfitted to it. This mix is injected to the repair spot. The resultant hardened properties include increased flexural, compressive strengths and more durability.

C. Routing and Sealing Methodology:

Routing and sealing is a common method of repairing dormant cracks. The procedure should not be used on active cracks. A minimum surface width for a crack to be routed and sealed is one-quarter inch. When you are dealing with pattern cracks or narrow cracks, the routing will enlarge the cracks to make them suitable for sealants. Sealants are used to prevent water infiltration. This involves enlarging the crack along its exposed face and sealing it with crack fillers. Care should be taken to ensure that the entire crack is routed and sealed. Routing and sealing of cracks can be used in conditions requiring remedial repair and where structural repair is not necessary. This method involves enlarging the crack along its exposed face and filling and sealing it with a suitable joint sealant (Fig.(e)). This is a common technique for crack treatment and is relatively simple in comparison to the procedures and the training required for epoxy injection. The procedure is most applicable to approximately flat horizontal surfaces such as floors and pavements. However, routing and sealing can be accomplished on vertical surfaces (with a non-sag sealant) as well as on curved surfaces (pipes, piles and pole).

Routing and sealing is used to treat both fine pattern cracks and larger, isolated cracks. A common and effective use is for waterproofing by sealing cracks on the concrete surface where water stands, or where hydrostatic pressure is applied. This treatment reduces the ability of moisture to reach the reinforcing steel or pass through the concrete, causing surface stains or other problems.

D. Epoxy Injection Methodology

The Injection of polymer under pressure will ensure that the sealant penetrates to the full depth of the crack. The technique in general consists of drilling hole at close intervals along the length of cracks and injecting the epoxy under pressure in each hole in turn until it starts to flow out of the next one. The hole in use is then sealed off and injection is started at the next hole and so on until full length of the crack has been treated. Before injecting the sealant, it is necessary to seal the crack at surface between the holes with rapid curing resin. For repairs of cracks in massive structures, a series of holes (Usually 20mm in diameter and 20mm deep spaced at 150 to 300mm interval) intercepting the crack at a number of location are drilled. Epoxy injection can be used to bond the cracks as narrow as 0.05mm. Epoxy injection is a highly specialized job requiring a high degree of skill for satisfactory execution. The general steps involved are as follows.

1) Preparation of the Surface

The contaminated cracks are cleaned by removing all oil, grease, dirt and fine particles of concrete which prevent the epoxy penetration and bonding and removed by flushing the surface with water or a solvent. And the surface have to be dried, the crack should be routed to a depth of about 12mm and width of about 20mm in V-shape, filled with an epoxy, and stuck off flush with the surface.

2) Installation of Entry Ports

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The entry port or nipple is an opening to allow the injection of adhesive directly into the crack without leaking. In case of V-grooving of the cracks, a hole of 20mm diameter and 12 to25mm below the apex of V-grooved section is drilled into the crack.

3) Mixing of Epoxy

The mixing can be done either by batch or continuous methods. In batch mixing, the adhesive components are premixed in specified proportions with a mechanical stirrer, in amounts that can be used prior to the commencement of curing of the material.

4) Injection of Epoxy:

In its simplest form, the injection equipment consists of a small reservoir or funnel attached to a length of flexible tubing, so as to provide a gravity head. For small quantities of repair material small hand-held guns are usually the most economical. They can maintain a steady pressure which reduces chances of damage to the surface seal. For big jobs power-driven pumps are often used for injection. The injection pressures are governed by the width and depth of cracks and the viscosity of resin and seldom exceed 0.10Mpa. The low pressure for fine cracks is a common practice to increase the injection pressure during the course of work to overcome the increase in resistance against flow as crack is filled with material.

5) Removal of Surface Seal:

After the injected epoxy has occurred; the surface seal may be removed by grinding or other means as appropriate. Fittings and holes at the entry ports should be painted with an epoxy patching compound

V.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. After analyzing the problem of building, we can apply the appropriate repair methods which are described above i.e. Guniting, Routing and Epoxy Injection. The purpose of this paper is 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.

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