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# Study of Repair, Maintenance and Protection of RCC Structure

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**ABSTRACT:** Since the 1970s, various research projects and field studies on different methods for protecting reinforced concrete structures from corrosion damage have been conducted. The goal of this project is to investigate the various methods used for the protection, maintenance, and repair of RCC structures. The goal is to learn about RCC, the main causes of corrosion, and how to avoid damage through maintenance, protection, and repair. Because the climatic conditions, soil bearing capacity, and capital for construction vary in different cases, we primarily focus on determining the most common and cheapest method for RCC protection. Alternative reinforcement and slab design, barrier methods, electrochemical methods, and corrosion inhibitors are among the methods available. Some methods are described, as well as the underlying principles. The performance of stainless steel-clad reinforcement should be similar to that of solid stainless-steel bars if the stainless-steel coating is continuous and the black steel core, exposed at the bar ends, is covered so that it does not come into contact with the concrete pore solution.

**KEYWORDS:** Protection, Maintenance, Repair, RCC Structure, Investigate.

## I. INTRODUCTION

Corrosion of reinforcing steel is a significant economic and safety problem, preventing many buildings from attaining their design life. It is now a must look into field as corrosion of reinforcing steel is seen almost in every 10 out of 100 constructions within a life of 10 years. Nowadays the increase content of pollutants in the city atmosphere has very much affected the lifespan of RCC structures. The increased content of pollutants includes a very high rates of Sulphides and Chlorides which when these mixes with rainwater and falls over these structures and damages the visible parts. Some metals, such as gold, silver, and platinum, occur naturally in their pure form. Many other metals, including iron, can be found in their natural state as ores, natural oxides, sulphides, and other reaction products. These metals must be extracted from their ores through smelting, in which the metal absorbs and retains the energy required to liberate it from the ore. However, this metallic state is unstable because the metal tends to recombine with elements in the environment and return to its natural state, losing the extra energy in the process. The process of a metal reverting to its natural state is known as oxidation or corrosion. Steel has a natural tendency to corrode and revert to its original state as iron ore, typically ferric oxide. Steel corrosion rates are affected by the availability of water, oxygen, and aggressive ions, as well as the pH and temperature of the surrounding environment, as well as internal steel properties such as composition, grain structure, and entrained fabrication stresses. Because of the high pH of the concrete pore water solution, a passive film (oxide layer) forms and remains on the surface of the reinforcing steel. The rate of corrosion is very low as long as the passive film on the reinforcing steel remains intact. If the oxide layer is broken, oxygen can react with the steel, resulting in corrosion. Steel does not corrode significantly in concrete that is either very dry or continuously saturated.

## II. ALTERNATE REINFORCEMENT AND SLAB DESIGN

High quality concrete is the first line of defence against reinforcing steel corrosion. However, high-quality concrete can crack, and chlorides can penetrate even the best low-permeability concrete over time. As a result, the reinforcement is the final line of defence against corrosion in reinforced concrete. Because conventional mild steel is not very corrosion resistant, it must either be coated with an effective and cost-effective barrier or replaced with a more corrosion-

resistant material to improve its performance in contaminated concrete. Barriers are less expensive than solid corrosion-resistant bars and can be divided into two types: organic and metallic. The most commonly used organic coating for reinforcing steel is epoxy, which is organic.

### **1. Epoxy –Coated Reinforcing Steel**

Currently, the primary corrosion protection system epoxy-coated reinforcing steel. Epoxy-coated reinforcing steel has been used since the 1970's and still now one of the most efficient methods. In the early 1970s, epoxy-coated reinforcement was developed in response to the need for improved corrosion protection in reinforced concrete. The method of coating reinforcing steel with epoxy was adapted from the method used by utility companies to coat pipes in the petroleum industry. To remove mill-scale, rust, and contaminants, the bar is cleaned by blasting it with grit to a near-white finish. The bar is then heated to the required temperature for the application of the epoxy powder, typically 230°C, and passed through an electrostatic spray that applies charged, dry epoxy powder to the steel. The epoxy melts, flows, and cures on the bars, which are then quenched, typically with a water spray bath. Epoxy-coated steel, in conjunction with higher quality concrete and deeper cover, can provide effective corrosion distress protection for more than a decade. Many researchers believe epoxy-coated steel is a viable option for long-term protection of reinforced concrete structures. According to them, reports of problems with epoxy-coated reinforcement are isolated, and each problem is caused by a flaw in the specific materials or construction.

### **2. Metallic Coating and solid Metallic Reinforcing Bars**

Metallic coatings have been successfully used for years to prevent corrosion of steel in environments other than concrete, raising hopes that they could also protect steel in concrete. There are two types of metallic coatings for reinforcing steel: sacrificial and noble. Metals with a higher corrosion potential than steel, such as zinc, are used in sacrificial coatings. If the sacrificial coating is compromised, a galvanic breakdown will occur. The cell is established, and the coating corrodes while protecting the steel. Noble coatings such as copper and nickel do not corrode in concrete; however, if the coating is broken, any exposed steel becomes anodic and corrodes.

Stainless Steel –Clad Reinforcing Bars

Nickel-Clad Reinforcing Bars

Titanium Reinforcing Bars

Copper-Clad Reinforcement Bars

## **III. METHODOLOGY**

### **1. Electrochemical Methods**

Cathodic protection can effectively stop corrosion in contaminated reinforced concrete structures while also lowering the concentration of chloride ions at the protected reinforcement's surface. The titanium mesh anode, used in conjunction with a concrete overlay, is currently the most common impressed-current anode in use for cathodic protection of reinforced concrete. This anode satisfies the requirement for a long-lasting impressed-current cathodic protection anode on bridge decks and pilings. As long as water is kept out of the system, zinc-hydrogel anodes can protect substructure members.

### **2. Cathodic Protection of Prestressed Concrete**

There are two main concerns with cathodic protection of pre-stressed concrete structures. The first is hydrogen embrittlement, caused when hydrogen generated by a cathodic reaction at the surface of the steel migrates into the steel rather than being released into the surrounding electrolyte. The initial cathodic reaction in cathodic protection systems is oxygen reduction.

### **3. Potential Side Effects of Cathodic Protection**

1.10 volts [-1.02 volt (SCE)] compared to a copper-copper sulphate reference electrode (CSE). However, because they are more negative than the prescribed maximum potentials to avoid hydrogen embrittlement, potentials high enough to induce a drop in bond strength should never be attained. At a voltage greater than -1.05 volts (CSE), hydrogen was shown to develop on steel [-With a pH of 12.5, 0.97 volts (SCE)] in concrete Hydrogen embrittlement of the steel can result from this hydrogen development. When the pH has been decreased by corrosion or other effects, hydrogen can be created at lower potentials.

### **4. Electrochemical Chloride Extraction**

The removal and replacement of all contaminated concrete from around the reinforcing is a standard repair approach for chloride contaminated concrete buildings. This approach has a number of drawbacks. Partially replacing the

concrete can result in changes in the structure. the structure's strength and create possible disparities in the reinforcement, which might speed up corrosion. The old concrete might also damage the reinforcement and expose workers to dust and noise during the removal process. Electrochemical chloride extraction (also known as desalination) was created as an alternative repair procedure for polluted concrete, in which chloride ions are extracted and the concrete remains in place.

#### IV. CORROSION INHIBITORS

Corrosion inhibitors are chemicals that slow or prevent reinforcing steel corrosion in concrete. Sodium nitrite, sodium and potassium salts of chromate, and benzoate were among the first inhibitors. Sodium and potassium salts reduced the concrete's strength and had mixed results in terms of corrosion inhibition. Other inhibitors, on the other hand, protected reinforced concrete from corrosion. Calcium nitrite, a common inhibitor, was created to be used in concrete as a non-corrosive set accelerator.

#### V. RESULT AND DISCUSSION

##### 1. Rebound Hammer Test

The Schmidt Rebound Hammer measures the hardness of material at the surface by the rebound of hammer mass after an elastic impact against the surface. The mass is released from a standard pre-compressed spring thus having a fixed amount of energy. Principle of this test is that the rebound of the elastic mass depends on the hardness of the surface upon which it impinges. Energy is lost on impact due to localized crushing and internal friction within the body of the concrete. This internal friction is the function of the elastic properties of concrete constituents. Rebound Number is the distance travelled by the mass after the elastic impact expressed as a percentage of original distance. This gives a measure or indication of hardness and an estimate of the strength of concrete. here are several factors other than concrete strength that influence rebound hammer test results, including surface smoothness and finish, moisture content, coarse aggregate type, and the presence of carbonation.

##### Preparation Of Specimen

Three Beams (50cmX 10cmX10cm) of M25 grade were cast and discontinuities were created using Thick Paper Sheet at a depth of 5cm

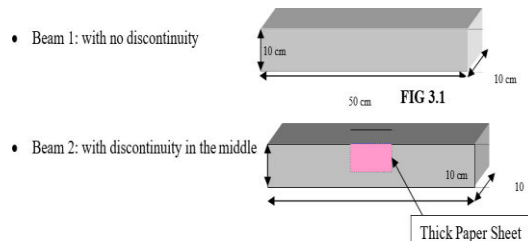


Fig. Specimen

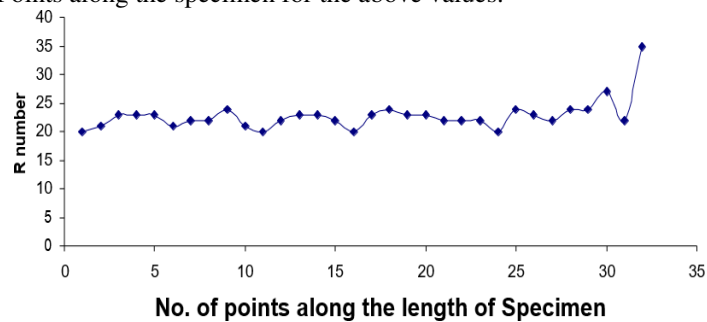


Fig. Rebound Hammer Test

**Result of rebound hammer test 1**

Point Number	Rebound Number (R)	Point Number	Rebound Number (R)
1	23	17	20
2	21	18	20
3	20	19	21
4	22	20	22
5	20	21	21
6	19	22	20
7	19	23	21
8	22	24	19
9	21	25	20
10	19	26	-
11	19	27	19
12	20	28	-
13	20	29	-
14	21	30	-
15	23	31	-
16	21	32	-

R numbers vs Number of Points along the specimen for the above values.



**Fig. Rebound Hammer test result on beam with no discontinuity**

As expected, there is not much variation in the value of R number along the length of specimen.  
Beam 2: (with discontinuity at the center)

**Table – Result of rebound hammer result 2**

Point Number	Rebound Number (R)	Point Number	Rebound Number(R)
1	23	17	20
2	21	18	20
3	20	19	21
4	22	20	22
5	20	21	21
6	19	22	20
7	19	23	21
8	22	24	19
9	21	25	20
10	19	26	-
11	19	27	19
12	20	28	-
13	20	29	-
14	21	30	-
15	23	31	-
16	21	32	-

R number vs Number of points along the specimen for the above values.

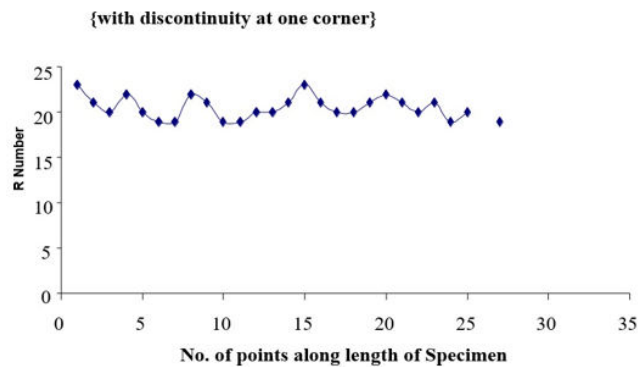


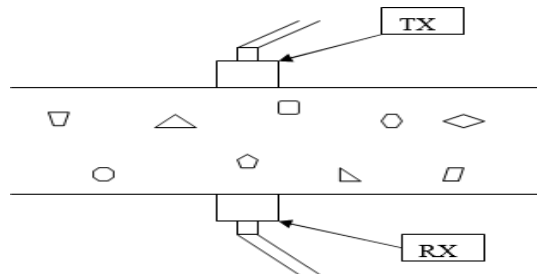
Fig. Rebound Hammer test result on Beam with discontinuity at one corner.

**2. Ultra-Sonic Pulse Velocity Test:**

The velocity of ultrasonic pulses traveling in a solid material depends on the density and elastic properties of that material. Ultrasonic testing is used to detect internal flaws which send echoes back in the direction of the incident beam and these are picked up by a receiving transducer.

The measurement of the time taken for the pulse to travel from a surface to a flaw and back again enables the position of the flaw to be located. The frequencies generally used lies in the range of 20 kHz to 250 kHz with 50 kHz being most suitable for concrete. The wavelength corresponding to this frequency range is about 200 mm to 16 mm. For assessing the quality of material from ultrasonic pulse velocity measurement, it is necessary for this measurement to be of higher order of accuracy i.e. (+/-) 1%.  $Pulse\ Velocity = Path\ Length / Transit\ Time$

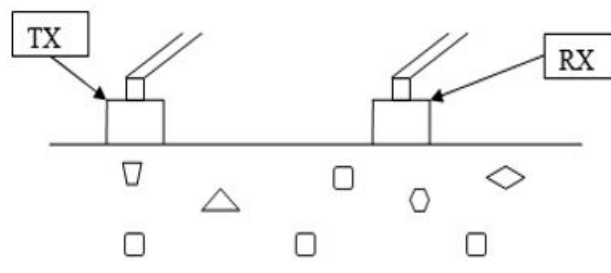
a) **Direct:** where Transmitting and Receiving Transducers are on the parallel surface.



**Direct method of testing (USPV)**

TX: Transmitting Transducer  
 RX: Receiving Transducer

b) **Indirect:** where Transmitting and Receiving Transducer are on the same surface



**Indirect method of testing (USPV)**

c) Semi Direct where Transmitting and Receiving Transducer are on the perpendicular surface.

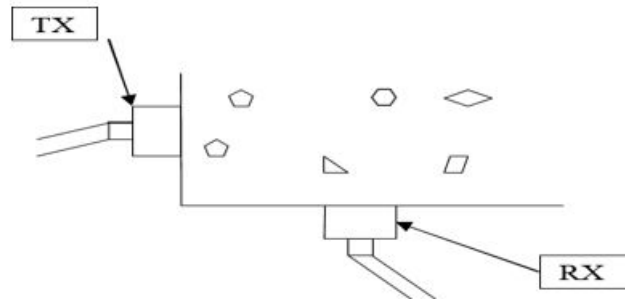


Fig.6.5.3: Semi Direct method of testing (USPV)

**Results**

USPV Test was conducted on the rectangular beams having thick paper sheet discontinuities at different locations and the results obtained are as under:

BEAM 1: (with no discontinuity)

Table – 6.3: Result of USPV test 1

Point Number	Time taken by pulse to travel from one end to other (microseconds)	Point Number	Time taken by pulse to travel from one end to other (microseconds)
1	19.8	6	20.3
2	20.5	7	21.8
3	20.2	8	21.5
4	20.2	9	20.8
5	21.2	10	21.0

Average value plot of point number vs time is:

USPV {with no discontinuity}

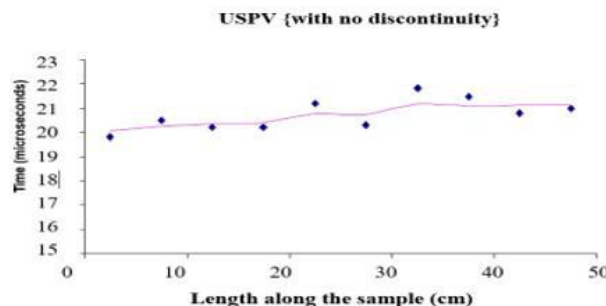


Fig: USPV test result on beam with no discontinuity.

**3. Thermal Imaging Technique**

Thermal imaging technique is an active method for quantitative investigations of the near surface region of various structures. It has recently been applied and optimized to applications in civil engineering. By using either an internal or external heat source, parts of the structure under investigation are heated up and the transient heat flux is observed by recording the temperature change at the surface as a function of time. This method is very well suited for the detection of voids in concrete, up to concrete covers of 10 cm as well as for the location of delamination’s in multi-layered systems (e.g., Plaster on concrete, CFRP-laminates on concrete, asphalt on concrete).



Fig. Experimental set up of showing the position of specimen and heat sources.

In the experimental procedure used during this project, 1KW halogen lamps (external heat source) (4 in number) and square pulse waves were used for heating the specimen. The heating was done for about 25 to 30min and the Thermal Images were captured at 20 Hz frequency, 10000 frames and for 500 seconds in the cooling cycle.

**Experimental Set:**

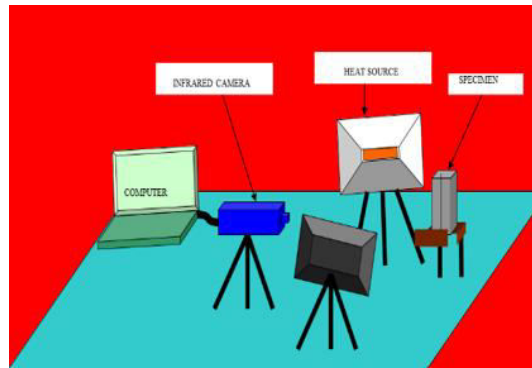


Fig. Schematic diagram showing the experimental set up of Thermal imaging technique.

Thermal Imaging technique was performed on the Beams having thick paper sheet discontinuities and on the square slabs having wooden defects and the thermal image was captured during the cooling cycle for 500 seconds and 10000 frames.

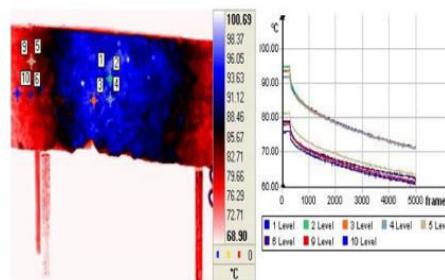


Fig. Thermal Image and the cooling curve of beam with discontinuity in the middle

BEAM 2: (with discontinuity in the middle)

**Summary**

Each method and its underlying principles are described. The methods discussed in this project include: alternative reinforcement and slab design, including epoxy-coated steel, galvanized steel, solid stainless steel, stainless steel-clad, nickel-clad, titanium, copper-clad, and fiber reinforced plastic reinforcement, and steel-free slabs; barrier methods, including the use of low permeability concrete, low water/cement ratio mix designs, the use of mineral admixtures, overlays, waterproof membranes, sealers, and deep polymer impregnation; electrochemical methods, including cathodic protection and electrochemical chloride extraction; and corrosion inhibitors. In this experiment whole





specimen can be scanned in a single shot unlike Rebound Hammer Test and USPV test where each and every point is to be scanned.

The results we got, by this experiment clearly show the picture (blurred image) of the defect. The result could be improved further, and a sharp image of the defect can be seen by the use of high peak energy heat sources. In IIT the heat source available are of 1KW power and to obtain the sharp image the heat sources required should have energy of 4KW.

## VI. CONCLUSION

Ensuring adequate concrete cover over conventional steel reinforcement and using quality concrete is sufficient, but on structures that are exposed to corrosive environments further protection is very much required. The most common corrosion protection method available today is the use of epoxy-coated reinforcing steel. Although controversial in many areas, epoxy-coated reinforcement has performed well in many areas. Based on the analysis performed, the use of epoxy-coated reinforcement alone is more cost-effective than building with black steel reinforcement and no other corrosion protection method, but there are other methods that now appear to be more cost-effective than either of these options. The more cost-effective corrosion protection options include epoxy-coated reinforcement in combination with another system such as a membrane, overlay, or corrosion inhibitor. The increase in the cost with epoxy-coated steel over black steel reinforcement is very small, so even if it is not expected to improve the service life of a structure, epoxy-coated steel is a low-cost backup to other corrosion protection methods. Stainless steel-clad reinforcement is much less expensive than solid stainless-steel reinforcement. In fact, its in-place cost is not much more than that of epoxy-coated steel. The performance of stainless steel-clad reinforcement should be similar to that of solid stainless-steel bars if the stainless-steel coating is continuous and the black steel core, exposed at the bar ends, is covered so that it does not come into contact with the concrete pore solution.

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