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ADVANCED NDT METHODS FOR EVALUATION OF BRIDGES

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ABSTRACT

Bridges are the most crucial members along lifelines of nation. The bridges constructed along road and rail network must be in sound intact condition and must be inspected periodically to keep it in working condition. Bridge inspection is generally conducted through visual inspection or structural analysis. Most common is visual inspection method. But is can show only surface defects. Incase of internal defects it shows limitations and may depend on experience of Investigator. Non destructive testing (NDT) method has proved to be a noble solution on this issue. It is widely used now a days for periodical inspection of bridges. NDT results can help to estimate the quality and strength of existing bridges that deteriorate with time and finally result into failure. Advanced testing methods can decide repairs & maintenance plan or complete replacement of bridges.

Keywords: Corrosion, Delamination, Echo, Radiography, Ultrasonics, Voids.

I. INTRODUCTION

Transportation lines are laid throughout the nation in the form of road and railway lines. They are crossed by other transportation lines i.e. roadways, railway line or water bodies. Therefore there is a need to maintain a continuous flow over these lines without obstructing each other. The only suitable, convenient and cost effective means is by construction of bridge over these lines. Hence bridges get strategic as well as structural importance in terms of their construction and long service life. Sudden failure of bridge can lead to accidents that may prove to be fatal. Hence bridges must be maintained in sound condition throughout its service life. By implementing proper nondestructive assessment of bridge deck it can help in reducing the risk of bridge failure.

Basic objective for conducting Non destructive testing includes,

- To assess present condition of bridge and propose its future life
- To decide action plan for repair and maintenance
- To perform structural audit i.e. structural health monitoring (SHM) of bridge.

II. ADVANCED NDT METHODS FOR BRIDGE INSPECTION

Different Non destructive testing methods are adopted to determine the subsurface defects and it's extent in bridge structure. Also by investigating surface defects and developing certain relation between surface and subsurface defects will help in future scope of work for bridge investigation. It can also help to decide the action to be taken regarding repairing, maintenance or complete replacement of structure.

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2.1. Delamination, Honeycombing, Voids

The following test methods are suitable for detecting and evaluating the extent of delamination, honeycombing, and voids in concrete decks. Some of these methods may also be used to determine the thickness of the concrete deck.

2.1.1. Chain Drag Method-The area of defect will give hollow sound which can be investigated further.

2.1.2. Hammer Sounding-Simple rubber hammer tappings used to get the location of defect.

2.1.3. Infrared Thermography (IT)-Thermal infrared camera obtains image showing subsurface defects as higher rate of radiant temperature change than the surrounding concrete thus producing “hot spots” within the thermal infrared image. Due to heat requirements measurements are generally taken during morning or evening time since at that time the temperature changes in bridge deck shows greater variations.

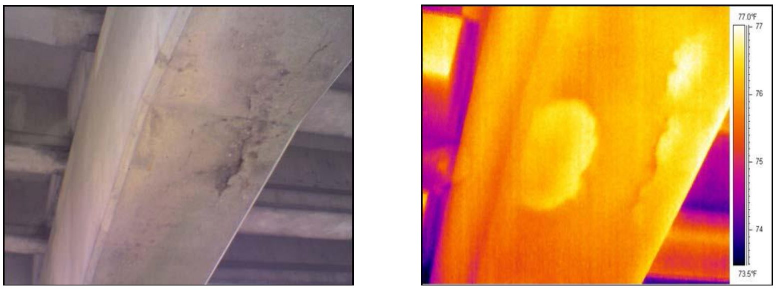

Fig.1. Optical and thermal image showing subsurface defects in the bridge member

2.1.4. Ground Penetrating Radar (GPR)-Ultra high frequency radio waves (frequency generally 100 MHz) are transmitted using portable control unit and recorder. A part of the penetrating wave is reflected by interfaces or objects with dielectric properties different from that of the general medium. Thus GPR locates the reinforcement bars, cables, zones of moisture, thickness of deck slab, cracks and voids in concrete.

2.1.5. IMPACT ECHO (IE)-Short duration impact (sound) waves are generated by exciter i.e. steel ball. These waves are reflected back from internal flaws towards transducer. These signals are analyzed to find defects.

2.1.6. Spectral Analysis of Surface Waves (SASW)-Surface waves (R-wave) used to determine mechanical characteristics of bridge structural members, also detection of voids, and assessment of damage.

2.1.7. Radiography-Radiographic image can show interior flaws such as cracks, voids cables, reinforcing bars in the form of dark coloured spots on image as they are unable to block the radiation. Cracks perpendicular to radiation beam are difficult to interpret.

2.1.8. Visual Inspection-It directly gives possible locations of defects by observing location, age, state and orientation of cracks, presence of alkali-silica reaction or efflorescence, surface dampness etc. It gives overall idea of further investigation to be needed or not. It depends on experience and knowledge of investigator

2.1.9. Intrusive Visual Examination-The access hole is drilled into the concrete to allow the fiber optics, video cameras, and periscopes to explore inside the member or inspect inaccessible areas like abutments or supports.

2.1.10. Core Sampling-Cores are extracted to determine compressive strength, voids and delaminations. It is an intrusive method that requires subsequent repair.

2.1.11. Ultrasonic Pulse Velocity (USPV)-Through transmission method which uses ultrasonic waves for testing concrete. Waves traveling through concrete member will require longer time if they go through inferior concrete

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or around a large crack or void. This is detected by USPV unit in terms of velocity. The quality of concrete is thus found based upon pulse velocity as per IS Code 13311 part-I 1992.

Table 1. Ultrasonic Pulse Velocity values

Sr. No.	Pulse Velocity in Km/sec	Concrete Quality Grading
1	Above 4.5	Excellent
2	3.5 to 4.5	Good – Very Good
3	3.0 to 3.5	Medium
4	Below 3.0	Doubtful

2.1.12. Volume Of Permeable Voids (VPV)-Water permeability of hardened concrete determined by extraction of core from bridge members. It evaluates the quality and performance of concrete members in bridge.

2.1.13. Ultrasonic Pulse Echo method-It can make assessment form one side by measuring travel time of echo and processed using oscilloscope as a time-domain waveform. Finds defect depth and voids in thin members.

2.1.14. Ultrasonic Thickness Gauge-To obtain section size and strength of the member.

2.1.15. Uranyl Acetate Fluorescence-Uranyl acetate solution is sprayed on member. Under ultraviolet light it shows yellowish colour which indicates alkali-silica activity in concrete

2.1.16.Ultrasonic tomography method: Suitable when only one side is accessible. The probes can generate ultrasonic pulses with a frequency of 50 kHz to test the element.

2.1.17. Electrical impedance tomography (EIT)-It gives 3D image of dampness distribution in concrete members through measurements of its electrical properties

2.2. Cracks in Bridge members

The following methods are used for detecting and finding the extent of cracks in bridge members.

2.2.1. Visual Inspection

2.2.2. USPV

2.2.3. Impact Echo

2.2.4. Light Detection and Ranging (LiDAR)-(Laser-Assisted Data and Readout - LADAR)-It is an optical remote sensing technology. LiDAR unit consists of transmitter, receiver, data acquisition and control unit. It uses visible, ultraviolet or infrared light as light energy source. LiDAR's receiver identifies and collects reflected photon signals from the illuminated object while minimizing background noise. The data acquisition and control system contains a very precise clock for data tagging, a discriminator, computer and respective software.

2.3. Corrosion of Reinforcement

Different NDT methods are suitable for investigation of corrosion in reinforcement provided in bridge members.

2.3.1. Half-Cell Potentiometer- Half-cell potential method detects the flow of negative charge which provides an indication of corrosion activity. This method is not applicable to epoxy-coated bars. It requires a direct connection to the reinforcement and an internal connection among the reinforcing inside the concrete element.

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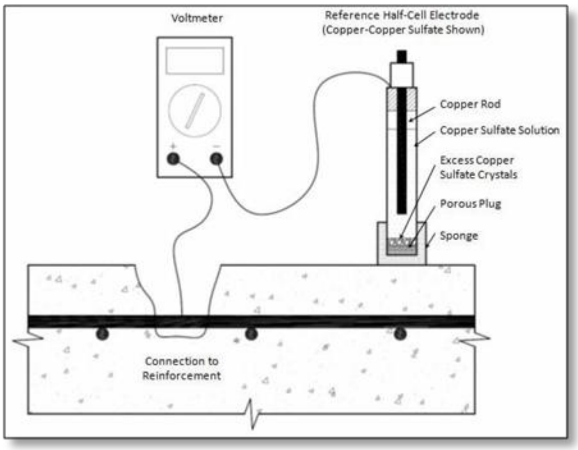

Fig.2. Half-cell Potential Test

2.3.2. Linear Polarization-The electrolytic test cell uses polarization resistance technique to determine corrosion rate. The technique measures the change in the open-circuit potential of a short-circuited electrolytic cell when an external current is applied to the cell.

2.3.3. Magnetic Flux Leakage (MFL)-The system introduces a magnetic field into reinforcement embedded within the concrete deck and measures changes in the magnetic field that are representative of damaged reinforcement.

2.3.4. Cover meter/ Pachometer-It can determine location of reinforcement and extent of cover. The cover meter provides low frequency alternating magnetic field into concrete surface and voltage change is then detected and displayed in meter. This technique is affordable and suitable upto depth of 100 to 125mm.

2.3.5. AC Resistance-It gives the extent of corrosion. The test setup consists of four equally spaced electrodes placed in drilled holes. The outer electrodes are connected to an alternating current. The inner electrodes are connected to a voltmeter. The apparent resistivity (ρ),

$$\rho = (2 \pi s V / I)$$

Where: s = spacing of probes, V = voltage between inner electrodes, and I = current between outer electrodes.

2.3.6. Resistivity Meter (RESI) It is used to determine the state of corrosion in the reinforcement bars. RESI consists of probe and display unit. Moisture content, chloride contents, temperature etc may affect the results.

2.4. Excessive Permeability and Chloride Content

The partially destructive tests are adopted by extracted concrete core and testing in laboratory. Different methods are used to study used to access ingress of chemicals and corrosion of reinforcement steel.

2.4.1. Drilling and Sampling-Chloride content at different depths is checked by drilling and extracting concrete powder. It is lab method.

2.4.2. Schonlin Test-The test determines the permeability index of concrete by using a 50mm diameter chamber of known volume and vacuum pump place on concrete surface to create a pressure less than –99 kPa.

2.4.3. SHRP Surface Airflow Method-The test is used to determine the relative permeability of concrete surface. It measures airflow into a vacuum plate placed on a concrete surface. The plate is fitted with a rubber gasket that is held in contact with the concrete surface. Moisture and surface roughness can affect the result.

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2.4.4. Specific Ion Probe-The drilled sample is tested using a chloride specific ion probe to find overall total chloride content.

2.5. Low Material Quality

NDT methods can be used to determine material quality used in bridge construction and its present condition

2.5.1. Ultrasonic Pulse Velocity test (USPV)

2.5.2. Spectral Analysis of Surface Waves (SASW)

2.5.3. Impact Echo (IE)

2.5.4. Core Sampling

2.5.5. Windsor Probe-powder charge is used to drive a steel probe into hardened concrete. The depth of penetration is an indication of concrete strength and concrete quality.

2.5.6. Moisture Meter-Determines in-situ moisture content of concrete members.

2.5.7. Rebound Test-Schmidt/ Rebound Hammer used to measure the surface hardness of concrete. The rebound of hammer after collision with surface gives the rebound number. Empirical correlation gives strength using rebound number. Factors like surface finish, moisture content, etc affects the results.

2.5.8. Direct Transmission Radiometry (DTR)-Nuclear method capable of determining the in-place density of concrete. It requires access to both faces of the member.

2.5.9. Backscatter Radiometry (BSR)-Nuclear surface moisture density gauge consists of concentrated gamma ray source and detector. It measures the intensity of reflected radiation that has passed through the concrete component. The method is used when only one face of a component is accessible. It is used to determine the in-place density.

2.5.10. Phenolphthalein

It gives indication of the alkaline or acidic nature of the concrete. Phenolphthalein is sprayed on exposed fresh concrete surface. If colour changes to pink then pH level is greater than 10. If no colour change then pH value must be less than 10. Litmus paper may be used instead of phenolphthalein.

2.6. Piles and Footings

It involves evaluating the soundness of footings and piles. Surface reflective method considers impact waves reflections from top of piles and footings were as in other case recorder is inserted in drive holes upto entire depth of pile to get complete profile.

2.6.1. Pile Integrity Test (PIT)-Digital data acquisition unit measures time taken by Sonic or stress waves to travel from impact point i.e. is made at pile head to travel down the pile and to reflected back to an accelerometer coupled to the foundation head. Wave velocity is calculated to know about the concrete quality.

2.6.2. Impedance Logging-Mechanical impact generates stress wave that travels through the pile. Used to determine the characteristics of the pile, including diameter and depth.

2.6.3. Impulse Response Method-Controlled force vibration is introduced in pile and its vertical response is recorded by geophone velocity transducers and compared to the continuously monitored introduced vibration. It is used for detecting voids, honey combing and checking the length and continuity of piles.

2.6.4. Cross-Hole Sonic Logging- Suitable for deep, long concrete members. A transmitter is fed down in drilled tube and a receiver is fed down the other. Speed of pulse gets slower at locations of voids or damage.

2.6.5. Parallel seismic method- The pile cap is struck with a calibrated hammer and after each strike the time taken by acoustic wave to pass from the investigated element to the hydrophone is recorded. Software is used to process the registered signals in order to determine the acoustic wave passage time thus denoting concrete quality.

2.6.6. Gamma-Gamma Logging- Radioactive source feeds the waves from transducer placed in drilled hole and is received by receiver in other hole. It is suitable for determining the integrity of piles and large foundations. Detection of defects is more accurate than techniques that use surface impact.

2.7. Bridge Bearings

The important components of bridge that is subjected to wear and tear due to temperature effects. Different methods are suitable to determine cracks, corrosion and material flaws in bridge bearings

2.7.1. Visual Inspection

2.7.2. Magnetic Particle Testing-generally bridge components have paint coatings hence magnetic particle testing is used to quickly and effectively identify cracks and its extent.

2.7.3. Ultrasonic Testing- to determine Corrosion extent.

2.7.4. Dye Penetrant Testing-to determine the cracks in concrete.

III. CONCLUSION

- Different NDT studied above have their specific applications. Some show structural flaws, some show corrosion extent and some are specifically for bridge foundations or bearings. But each test has its advantages and its limitations. Combined NDT methods will thus help to get more reliable diagnosis.
- Some methods like radiography must follow strict operating standards, rules and regulations for safety.
- It is also necessary to find out the factors affecting the NDT results and find out suitable corrective measures.
- NDT lab tests require samples and cores that must be obtained carefully without damaging the structure.
- Thus NDT results help in assessing the structural health of bridges and form action plan for its repairs and maintenance.
- These results can help to predict the expected life span of bridges and make provision for strengthening the existing bridges to maintain or increase its service life.

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