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# Structural Health Monitoring by using Non-Destructive Testing of Bridge

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**Abstract:** Civil Engineering Industry is one of the oldest industries which provide a basic infrastructure to all the human beings. Failure of any structure causes damage to life and economy. To avoid such drastic loss and to ensure structure is safe, sound knowledge of structural evaluation is important. Quality of structure depends on good construction practices. On the other hand, Continuous repairs and maintained preserve the quality of construction. Non-destructive evaluation and testing provides relevant means for periodic inspections in order to maintain the quality of constructed structure. This project focuses on various non-destructive testing and partial destructive testing to find out structural parameters like strength, serviceability and durability. A review of these tests has been provided to conduct effective structural health assessment of a structure. The results obtained are then compared with standards. Structure is modelled and analysed using Staddpro in which analysis is performed and remedial measures are applied as per requirements. The challenge is to minimize the losses due to structural failure. Therefore it is fitting to monitor it intermittently by taking an expert opinion.

## I. INTRODUCTION

### Structural Health Monitoring Using NDT

The quality of new concrete structures is subject to numerous components, for example, kind of cement, sort of aggregates, water cement ratio, curing, natural conditions. Besides this, the control exercised during construction so contributes a lot to achieve the desired quality. The present system of checking slump and testing cubes, to assess the strength above requirements, need of testing of hardened concrete in new structures as well as old structures, is the need to assess the actual condition of structures. The NDT being fast, easy to use at site and comparatively more cost-effective are often used for

- (i) Testing any number of points and locations
- (ii) Assessing the structure for various distressed conditions
- (iii) Assessing damage due to fire, chemical attack, impact age etc.
- (iv) Detecting cracks, voids, fractures, honeycombs and weak locations
- (v) Assessing the particular condition of reinforcement.

### Objectives:

1. To study the causes of structural damages. To find out quality of structure.
2. To find out critical areas of structure and suggest remedial measures for repair if required
3. Analysis and design of bridge by using STAAD pro
4. To understand the effects of different load condition.

## II. LITERATURE REVIEW

**Sandeep kumar dwivedi et al. [2017]** studied the field of non-destructive evaluation (nde) or non-destructive testing (ndt) involves the identification and Characterization of damages or defect on the surface and interior of materials without cutting apart or otherwise Altering the material, using a single test method is Acceptable.

**Jan Bien et al. [2019]** studied the main purpose of this work is to propose an approach to integrated classification of contemporary non-destructive field tests as a part of general strategy of diagnostic investigations of bridge materials and structures.

**Junwon Son et al.[2015]** A Review of Non-destructive Test Methods for Bridges studied the prevalence of cracks in a steel girder of a bridge is generally due to the stress fluctuation from the passage of trucks. In certain regions, cold temperature may also trigger fracture in steel girders with or without the aggravation of the stress fluctuation effect. In reinforced or prestressed concrete girders and in concrete deck slabs, crack development constitutes a much more complicated phenomenon. Although stress fluctuation is still regarded as a major factor, many other factors may contribute to the formation of cracks and prevalence of fracture.

**Jennifer C et al. [2006]** author tells about pier cap was initially tested with three types of nondestructive testing (UPV, hammer sounding, and surface hardness) to assess the relative concrete condition and identify locations for more intensive nondestructive, as well as destructive, testing.

**Erin Santini Bell et al.[2009]** author tells One method of nondestructive testing is a controlled static load test, where a pre weighed truck is placed at predetermined locations on the bridge and the response is measured via strain, rotation, and deflection measurements.

**Akash Jaina et al.[2013]** author tells Ultrasonic pulse velocity values were greatly influenced by the cements and aggregate, extent of moist curing and presence of flaws and voids in concrete, more than their influence on the measured strengths dating and parameter estimation.

**Zhengqi Li et al.[2009]**Cracks in concrete occur when tensile stress exceeds the strength of concrete in tension. Significant cracks prompt the project stakeholders to question the integrity of the structure and to retain investigation teams to see the extent of defects or distresses, identify potential causes, and assist in developing a remediation plan. Non-destructive evaluation (NDE) techniques are gaining interests for field assessment.

**Rama Seshu D et al.[2013]** researcher tell The tests available for testing concrete range from the completely non-destructive, where there's no damage to the concrete, through those where the concrete surface is slightly damaged, to partially destructive tests, like core tests and pullout and achieve tests, where the surface must be repaired after the test.

**Sangwook LEE et al.[2014]** evaluation of NDT methods to spot how they're implemented in state agencies within the U.S. The findings and analysis presented herein were supported the results obtained from a survey questionnaire, targeted at Departments of Transportation (DOTs) altogether U.S. states and territories.

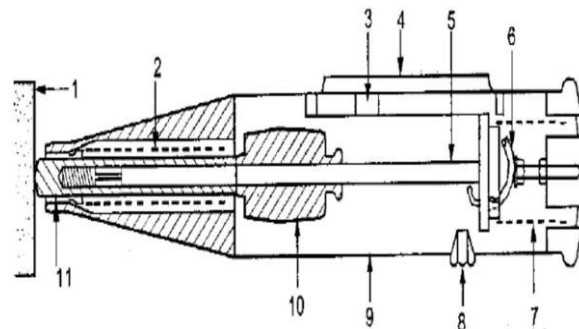
**Parag C. Das et al.[2015]** In recent years, variety of non-destructive testing methods are used, mainly unproved basis, for a spread of structures related applications including some involving bridges.

### III. METHODS & EQUIPMENTS

#### 3.1 Rebound Hammer test:

The Schmidt rebound hammer is largely a surface hardness test with little apparent theoretical relationship between the strength of concrete and therefore the rebound number of the hammer. Rebound hammers test the surface hardness of concrete, which can not be converted on to compressive strength. the strategy basically measures the modulus of elasticity of the near surface concrete. The principle is predicated on the absorption of a part of the stored potential energy of the spring through plastic deformation of the rock surface and also the mechanical waves propagating through the stone while the remaining elastic potential energy causes the particular rebound of the hammer. the gap travelled by the mass, expressed as a percentage of the initial extension of the spring, is termed the Rebound number. there's a considerable amount of scatter in rebound numbers thanks to the heterogeneous nature of near surface properties (principally thanks to near-surface aggregate particles).

There are several factors apart from concrete strength that influence rebound hammer test results, including surface smoothness and finish, moisture content, coarse aggregate type, and also the presence of carbonation. Although rebound hammers are often wont to estimate concrete strength, the rebound numbers must be correlated with the compressive strength of molded specimens or cores taken from the structure.



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

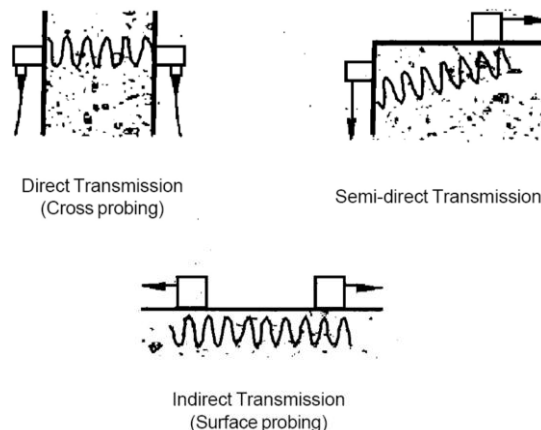
**Fig :3.1 Components of a Rebound Hammer**

Procedure for obtaining correlation between Compressive Strength of Concrete and Rebound Number

The most satisfactory way of creating a correlation between Compressive strength of concrete and its rebound number is to live both the properties simultaneously on concrete cubes. The concrete cubes specimens are held in a very compression testing machine under a hard and fast load, measurements of rebound number taken then the compressive strength determined as per IS 516: 1959.

### 3.2 Ultrasonic Pulse Velocity Test

Non-destructive sonic test was abundantly used in past for assessing and determining the civil structures and materials. This method is based on the stress waves. Mechanically, stress waves are transmitted into the structure and when intervene by any discontinuity; these waves reflect and collected by the receivers. Transmission modes for sonic wave tests include (a) direct, (b) semi-direct, (c) Indirect. In direct transmission method compressional waves of frequencies ranging from 500 Hz to 10 kHz penetrate through the structure. Waves are transmitted from one side of structure and received at opposite site. Upgraded form of direct transmission is semi-indirect transmission mode. Semi-indirect transmission method, also known as sonic tomography, is used on the paths which are not transverse to wall surfaces of structure. The efficiency of results is increased by adopting a dense grid system for data recording it used the recorded travel time data of sonic signal waves to draw 3-D velocity distribution across the entire structure.



**Fig:3.2 Different Transmission**



**3.1.2 Core sampling strength test:**

For the core strength test, this study considers the standard size of the core to be 100 mm in diameter and 200 mm in length, which is same size as the concrete cylinder. In general, conducting a core strength test using specimens above the standard size may cause harmful damage to the constructed concrete members, due to the partial destruction of concrete and steel reinforcement, which occurs when the spacing of the reinforcement is not sufficiently large to avoid hitting the core drill bit. As indicated by an assessment manual, smaller core strength tests (with diameters under 100 mm) are permitted in the estimation of the compressive strength of concrete. However, this is only permitted when the maximum aggregate size is less than 10 mm. As concrete core size decreases, the possibility of damage to the concrete members is minimized. In order to investigate the compressive strength effect due to variation in the core size, square concrete blocks without steel rebar were fabricated with target strength of either 40, 60 or 100 MPa. The concrete core diameters used in this study were 100, 50, and 30 mm and their slenderness (Length/Diameter) was fixed at 2.0.

**3.1.4 Half cell potential test:**

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 movement of the steel reinforcement and the concrete leads them to be considered as one half of feeble battery cell with the steel going about as one electrode and the concrete as the electrolyte. The name half-cell reviewing gets from the way that the one half of the battery cell is viewed as the steel strengthening bar and the encompassing concrete. The electrical capability of a point on the outside of steel strengthening bar can be estimated contrasting its latent capacity and that of copper-copper sulfate reference electrode on a superficial level. 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 generally readings taken are at grid of 1 x 1 m for slabs, walls and at 0.5 m c/c for Column, beams, pier. The risk of corrosion is assessed by methods for the potential gradient got, the higher the gradient, the higher danger of corrosion. The test outcomes can be deciphered dependent on the accompanying table

**Table no. 3.1 : % chance of corrosion activity**

Half – cell potential ( mv) relative to	% chance of corrosion activity
Less than – 200	10 %
Between – 200 to – 350	50 % ( uncertain)
Above – 350	90%

**3.1.5 Carbonation test :-**

The extent / depth of carbonation is determined by treating freshly broken / core cut concrete surface or a drilled powder obtained from various depths, with a phenolphthalein indicator. A purple red colouration are obtained where the highly alkaline concrete has been unaffected, but carbonated portion will remain uncoloured. The change of colour corresponds to a pH of about 8.3.

**3.1.6 Rebar Locator:-**

The reinforcement bar is detected by magnetising it and inducing a circulating “eddy current” in it. After the end of the pulse, the eddy current dies away, creating a weaker magnetic field as an echo of the initial pulse. The strength of the induced field is measured by a search head as it dies away and this signal is processed to give the depth measurement. The eddy current echo is determined by the depth of the bar, the size of bar and the orientation of the bar. This detection of location of reinforcement is required as a pre-process for core cutting.

**3.1.7 Site selection:** Basic Information of Site

Type of Structure -Bridge Address -Old SangaviDapodi ,Pune



**IV. RESULT AND DISCUSSION**

**4.1 Non-Destructive tests**

**4.1 .1Rebound Hammer Tests Result**

Location	Rebound Hammer Reading												Rebound Index	Rebound No.	Remark
	35	37	39	35	37	34	34	32	34	33	34	32			
Point 1	35	37	39	35	37	34	34	32	34	33	34	32	416	34.66667	Direct
Point 2	35	37	32	34	30	32	33	35	30	34	39	38	409	34.08333	Direct
Point 3	12	13	12	11	12	15	13	11	13	12	11	13	148	12.33333	Indirect
Point 4	22	19	15	23	19	17	19	19	17	20	21	19	230	19.16667	Indirect
Point 5	39	31	41	41	37	38	37	36	41	40	38	40	459	38.25	Indirect
Point 6	11	12	19	17	18	13	19	20	17	21	16	18	201	16.75	Indirect
Point 7	15	17	17	20	16	18	19	15	20	15	18	14	204	17	Indirect
Point 8	17	19	16	17	15	17	14	17	18	19	16	16	201	16.75	Indirect
Point 9	25	27	23	25	31	28	27	29	32	33	30	31	341	28.41667	Indirect
Point 10	21	37	26	32	39	40	37	33	38	40	38	36	417	34.75	Indirect
Point 11	30	28	37	30	31	29	27	32	31	33	29	30	367	30.58333	Indirect
Point 12	20	21	19	18	17	20	21	16	17	19	22	23	233	19.41667	Indirect
Point 13	36	34	33	31	30	33	34	37	36	32	31	35	402	33.5	Indirect
Point 14	12	13	17	19	12	13	12	16	17	16	19	17	183	15.25	Indirect
Point 15	23	22	19	21	20	26	24	22	23	21	23	24	268	22.33333	Indirect
Point 16	33	22	30	31	36	30	35	31	32	30	34	31	375	31.25	Indirect
Point 17	37	35	37	33	32	31	38	35	36	39	36	38	427	35.58333	Indirect
Point 18	12	13	15	19	15	21	17	16	16	17	14	18	193	16.08333	Indirect
Point 19	15	13	20	18	17	17	16	16	19	18	17	15	201	16.75	Indirect
Point 20	15	18	13	18	12	13	15	13	14	17	12	14	174	14.5	Indirect
Point 21	20	19	17	15	19	18	13	14	12	17	15	13	192	16	Indirect
Point 22	12	11	13	18	16	17	15	17	16	19	17	16	187	15.58333	Indirect
Point 23	28	20	22	23	25	20	27	26	22	28	27	26	294	24.5	Indirect
Point 24	15	17	20	20	17	17	15	19	18	15	17	19	209	17.41667	Indirect
Point 25	30	32	28	26	24	26	30	28	25	29	26	32	336	28	Indirect

**4.1.2Ultrasonic Pulse Velocity Test :**

Location	Width (mm)	Time (micro sec)	Velocity (km/sec)	Remark
Point 1	270	290.4	0.929752066	Direct
Point 2	270	305.7	0.883218842	Direct
Point 3	300	100.7	2.979145978	Indirect
Point 4	300	193.7	1.548786784	Indirect
Point 5	300	144.2	2.080443828	Indirect
Point 6	300	140.4	2.136752137	Indirect



Point 7	300	157.8	1.901140684	Indirect
Point 8	300	180.4	1.662971175	Indirect
Point 9	300	154.5	1.941747573	Indirect
Point 10	300	238.6	1.257334451	Indirect
Point 11	300	209.2	1.434034417	Indirect
Point 12	300	220.8	1.358695652	Indirect
Point 13	300	163.2	1.838235294	Indirect
Point 14	300	167.8	1.78784267	Indirect
Point 15	300	180.6	1.661129568	Indirect
Point 16	300	136.5	2.197802198	Indirect
Point 17	300	166.6	1.800720288	Indirect
Point 18	300	186.6	1.607717042	Indirect
Point 19	300	159.3	1.883239171	Indirect
Point 20	300	202.7	1.480019734	Indirect
Point 21	300	116.4	2.577319588	Indirect
Point 22	300	207.6	1.445086705	Indirect
Point 23	300	195.6	1.533742331	Indirect
Point 24	300	186.7	1.606855919	Indirect
Point 25	300	156.6	1.915708812	Indirect
Point 26 (p 2-3)	300	192.6	1.557632399	Indirect
Point 27 (p 3-4)	300	128.4	2.336448598	Indirect
Point 28 (p 4-5)	300	146.7	2.044989775	Indirect
Point 29 (p 6-7)	300	156.9	1.912045889	Indirect

**4.1.3 Core cutting test results**

SR NO.	ID No.	Diameter (mm)	Length (mm)	Weight (kg)	Crushing Load (KN)	Compressive Strength (N/mm <sup>2</sup> )
1	p3-4(left)	65	90	0.688	49.1	14.8
2	p1-2(left)	65	125	0.666	27.1	12.7
3	p1-2(Right)	65	96	0.915	54.52	12.93

**4.14 Half cell Potential Test Result**

Sr No	Member ID	Cover	Exposed Corr.Lvl	Spacing (mm)	Readings
1	2-3 East	25	Minor	400	-190
					-150
					-200
2	2-3 West	25	Moderate	400	-220
					-250
					-230



3	3-4 West	25	Moderate	400	-260
					-270
					-370
4	4 West	25	Moderate	400	-120
					-380
					-210
5	4-5 East	25	Major	400	-480
					-440
					-500
6	4-5 West	25	Major	400	-400
					-380
					-390
7	5-6West	25	Moderate	400	-320
					-350
					-380
8	6-7East	25	Moderate	400	-360
					-290
					-350
9	6-7East	25	Moderate	400	-350
					-300
					-340
10	8-9 West	25	Moderate	400	-360
					-350
					-360
11	9West	25	Major	400	-410
					-350
					-400
12	5-6West	25	Major	400	-350
					-360
					-350
13	1-2West	25	Major	400	-390
					-360
					-400
14	1 Centre	25	Minor	400	-140
					-120
					-160
15	1-2East	25	Moderate	400	-480
					-210
					-330



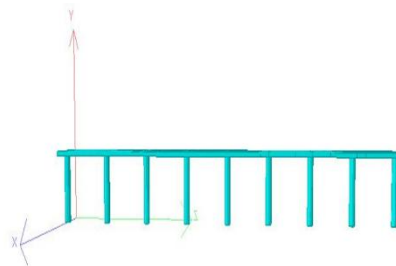
**4.1.5 Carbonation depth test Result**

Sr No	ID	Carbonation depth range
1	P 3-4 (Left)	No Carbonation
2	P 1-2 (left)	No Carbonation
3	P 1-2 (right)	No Carbonation

**4.2 Discussion :**

**4.2.1 Design:**

The project gives an idea about the analysis and design of Bridge using IRC Loading 70R by STAAD.Pro V8i. Here the model is being designed as per IRC 70R loading which is applicable on all roads on which the permanent bridges and culverts can be constructed. Analysis and Design process by STAAD Pro determines the performance of Structures. The designing by the software saves the design time and by this way we can check the safety of the structure very easily



Bridge Pier

**4.2.2 Analysis of Results:**

The output data for the bridge loadings are considered which include Peak Top Pier Lateral Displacements ,Base Shear, Inter-Storey Drift STAAD. Pro V8i and suggested remedial measures

**4.2.3 Remedial Measures :**

- 1) We need to strengthening of pier number 4 because we found pier number 4 is weak as compare to others and also found major structural crack to avoid collapsing of pier we need to improve strength of pier number four.
- 2) Reconstruction of Parapet wall.

**V. CONCLUSION**

Non destructive Methods applicable to structures are reviewed. This project focuses on various non-destructive testing and partial destructive testing to find out structural parameters like strength, serviceability and durability. A review of these tests has been provided to conduct effective structural health assessment of a structure. The results obtained are then compared with standards. Structure is modeled and analyzed using Stadpro in which analysis is performed and remedial measures are applied as per requirements. The challenge is to minimize the losses due to structural failure. Finally the relation between some of well known NDT methods and most common problems encountered.Hence.the importance of structural health monitoring is highlighted

1. This project concludes the, analysis and design of flyover by using STAAD pro
2. The location of the flyover is Old Sangavi Dapodi, Pune
3. STAAD.pro in combination with STAAD.beava can be used to analyse bridges as per the IRC code. By using STAAD.pro construction of bridge geometry is done and by using STAAD.beava AASHTO 2002 load positions can create the maximum load response. 4. These loads that create the maximum load responses can then be transferred into STAAD.pro as load cases to load combinations for further analysis and design. Similarly we can use this design method for design of concrete members, slab elements and foundations
5. Rectangular cross sections are provided for four longitudinal girders.

6. The structure is designed as per IRC class 70R loading.  
7. Analysis and design of the Slab Bridge as per IRC codes (here IRC 70R loading) can be easily done by STAAD.Pro. In connection with STAAD.pro mechanism is well understood. 8. It is must for today's engineers, designers, research scholars to make an effective contribution to what is the purpose of each high quality design and for the improvement of quality of environment in which we all are residing. Thus evolution of software must be properly used so that it meets the beneficiary needs.

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