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Assessment of Characteristic Compressive Strength in Concrete Bridge Girders Using Rebound Hammer Test

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ABSTRACT:
The aim of the present paper is to check the compressive strength for assessing concrete bridges girder. This paper reviews various NDT methods available and presents a case study related to the evaluation of existing bridge pier. The assessment involves the Rebound hammer tests. Even though there are many methods for Non Destructive Test (NDT) but every method have it own boundaries and which mean the method cannot afford an accurate and consistence result for difference cases and to detect different defect. This paper is an attempt to capture the most current ideas for a very specific application of NDT: determining the condition of reinforced concrete bridges overall and bridge girders, in particular. To this end, attention is given to why NDT is needed and what aspects of concrete condition can be addressed with NDT. Some NDT methodologies that are, or may soon be, promising for concrete applications are discussed. Case studies are presented to demonstrate how NDT can be applied to concrete bridge girders and proposals are made for future areas of study and development. The use of non-destructive testing methods can help reduce the backlog of deficient bridges in two ways. First, these techniques will allow inspectors to get a more accurate view of the condition of a bridge. The second way by which NDT can help is by allowing inspectors to locate damage earlier. The data obtained from each test has been evaluated and the accurate and precise device was determined.

KEYWORDS: *Non Destructive Testing; Bridge Pier; Case Study.*

I. INTRODUCTION

It is often necessary to test concrete structures after the concrete has hardened to determine whether the structure is suitable for its designed use. Ideally such testing should be done without damaging the concrete. The tests available for testing concrete range from the completely non-destructive, where there is no damage to the concrete, through those where the concrete surface is slightly damaged, to partially destructive tests, such as core tests and pullout and pull off tests, where the surface has to be repaired after the test. The range of properties that can be assessed using non-destructive tests and partially destructive tests is quite large and includes such fundamental parameters as density, elastic modulus and strength as well as surface hardness and surface absorption, and reinforcement location, size and distance from the surface. In some cases it is also possible to check the quality of workmanship and structural integrity by the ability to detect voids, cracking and delamination. Non-destructive testing can be applied to both old and new structures. For new structures, the principal applications are likely to be for quality control or the resolution of doubts about the quality of materials or construction. The testing of existing structures is usually related to an assessment of structural integrity or adequacy. In either case, if destructive testing alone is used, for instance, by removing cores for compression testing, the cost of coring and testing may only allow a relatively small number of tests to be carried out on a large structure which may be misleading. Non-destructive testing can be used in those situations as a preliminary to subsequent coring.

Typical situations where non-destructive testing may be useful are, as follows:

1. Quality control of pre-cast units or construction *in situ*.
2. Removing uncertainties about the acceptability of the material supplied owing to apparent non-compliance with specification.
3. Confirming or negating doubt concerning the workmanship involved in batching., mixing, placing, compacting or curing of concrete.
4. Monitoring of strength development in relation to formwork removal, cessation of curing, prestressing, load application or similar purpose.
5. Location and determination of the extent of cracks, voids, honeycombing and similar defects within a concrete structure.
6. Determining the concrete uniformity, possibly preliminary to core cutting, load testing or other more expensive or disruptive tests.
7. Determining the position, quantity or condition of reinforcement.
8. Increasing the confidence level of a smaller number of destructive tests.
9. Determining the extent of concrete variability in order to help in the selection of sample locations representative of the quality to be assessed.
10. Confirming or locating suspected deterioration of concrete resulting from such factors as overloading, fatigue, external or internal chemical attack or change, fire, explosion, environmental effects.

II. BASIC METHODS FOR NDT OF CONCRETE STRUCTURES

The following methods, with some typical applications, have been used for the NDT of concrete:

1. Visual inspection, which is an essential precursor to any intended non-destructive test. An experienced civil or structural engineer may be able to establish the possible causes of damage to a concrete structure and hence identify which of the various NDT methods available could be most useful for any further investigation of the problem.
2. Half-cell electrical potential method, used to detect the corrosion potential of reinforcing bars in concrete.
3. Schmidt/rebound hammer test, used to evaluate the surface hardness of concrete.
4. Carbonation depth measurement test, used to determine whether moisture has reached the depth of the reinforcing bars and hence corrosion may be occurring.
5. Permeability test, used to measure the flow of water through the concrete.
6. Penetration resistance or Windsor probe test, used to measure the surface hardness and hence the strength of the surface and near surface layers of the concrete.
7. Cover meter testing, used to measure the distance of steel reinforcing bars beneath the surface of the concrete and also possibly to measure the diameter of the reinforcing bars.
8. Radiographic testing, used to detect voids in the concrete and the position of stressing ducts.
9. Ultrasonic pulse velocity testing, mainly used to measure the sound velocity of the concrete and hence the compressive strength of the concrete.
10. Sonic methods using an instrumented hammer providing both sonic echo and transmission methods.
11. Tomography modeling which uses the data from ultrasonic transmission tests in two or more directions to detect voids in concrete.
12. Impact echo testing, used to detect voids, delamination and other anomalies in concrete.
13. Ground penetrating radar or impulse radar testing, used to detect the position of reinforcing bars or stressing ducts.
14. Infrared thermography, used to detect voids, delamination and other anomalies in concrete and also detect water entry points in buildings.

2.1 Rebound Hammer Method:-

This method is explained in IS: 13311 (part2):1992.

Principle of test: When the plunger of the rebound test hammer is pressed against the surface of the concrete the spring controlled mass rebounds and the extent of such rebounds depends upon surface hardness of the concrete. The rebound is then be related to the compressive strength of concrete.

Rebound hammer is an equipment to determine the strength of material such as concrete and rock. Its measures the rebound of a spring loaded mass impacting the surface of the material. The equipment will hit the surface of material and it's dependent on the hardness of the material. When conducting the test, the equipment should be place perpendicular to the surface. The surface must clean, clear, smooth, flat and not moist.

Factors affecting the Rebound Number:-
i. Type of cement.
ii. Type of aggregate.
iii. Concrete moisture condition.
iv. Curing and age of concrete.
v. Presence of surface carbonation.

III. CASE STUDY

3.1. General Information:-

The following case studies have been selected to demonstrate the effectiveness for NDT for detecting anomalies in reinforced concrete structures. While the cases do not all deal directly with concrete bridge girders, the methods demonstrated all can be applied readily to girders.

The NDT is applied on New Aatish Market Metro (Phase-I-East West Corridor) at Jaipur Rajasthan. The Jaipur Metro Rail Corporation has entered into an agreement (05.08.2010) with the Delhi Metro Rail Corporation (DMRC) for development of Phase-I-A from Mansarovar to Chandpole on 'deposit work' basis covering a length of 9.718 kms and Phase-I-B (Chandpole to Badi Chaupar) covering a length of 2.349 kms. The plan of New Aatish Market Metro Jaipur shown in Figure 1, below, is a reinforced concrete box girder bridge, originally constructed in 2011. It is oriented East West Corridor. This Report is prepared as study about the New Aatish Market Metro Jaipur under Phase-I-East West Corridor. The superstructure of a large part of the viaduct comprises of simply supported spans. However at major crossing over or along existing bridge, special steel or continuous unit will be provided. The standard spans c/c of piers of simply supported spans constructed by precast segmental construction technique has been proposed as 28.0m. The other spans (c/c of pier) comprises of 31.0 m, 25.0 m, 22.0 m, 19.0 m & 16.0 m, which shall be made by removing/adding usual segments of 3.0 m each from the centre of the span. The pier segment will be finalized based on simply supported span of 31.0m and the same will be also kept for all simply supported standard span. The viaduct superstructure will be supported on single cast-in-place RC pier. The shape of the pier follows the flow of forces. For the standard spans, the pier gradually widens at the top to support the bearing under the box webs. The size of pier is found to be 1.6 m diameter of circular shape and height of pier is found to be 5.5 m (from base to cap bottom).

3.2. Scope of work:-

The quality of the concrete was to be evaluated by performing Non-destructive Testing. In order to assess the quality of concrete, the following methods of testing were employed:

(i) Rebound Hammer test as per IS: 13311-1992 (Part 2).

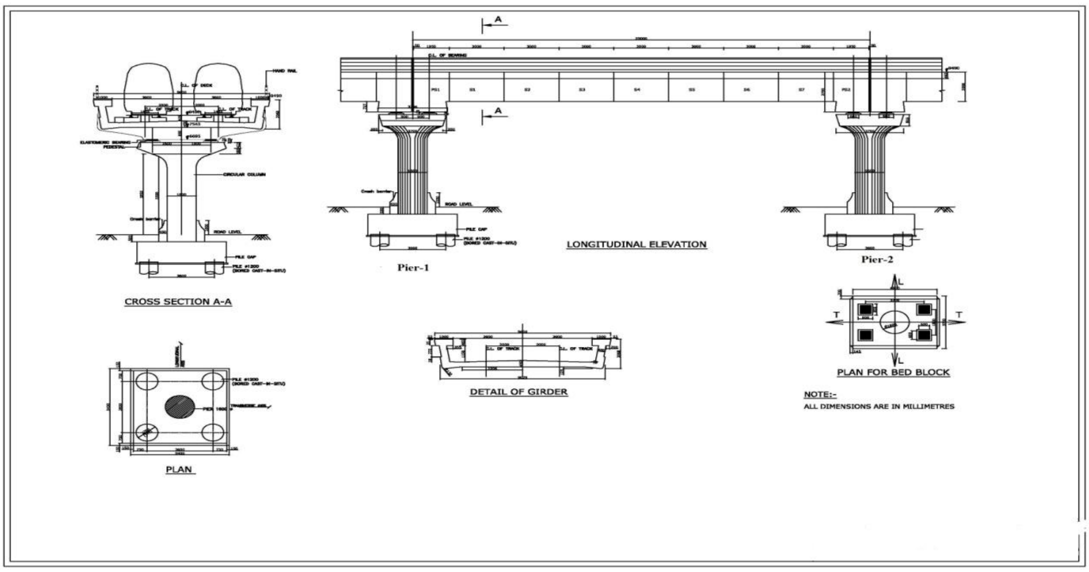

Figure 1: Plan of bridge

3.3. Analysis of Test Results:-

3.3.1. Rebound Hammer Test:-

Table 2: Rebound Hammer Test Results

S.No.	Location		Rebound value (R)	Compressive Strength (f_{ck}=N/mm^2)	Direction
1	Pier-1.1		43	46	←(Held Horizontal)
2	1.2		46	51	←(Held Horizontal)
3	1.3		51	61	←(Held Horizontal)
4	1.4		53	65	←(Held Horizontal)
5	1.5		47	53	←(Held Horizontal)
6		**Average Pier-1**	**48**	**55**	
7	Pier-2.1		54	67	←(Held Horizontal)
8	2.2		53	64	←(Held Horizontal)
9	2.3		52	62	←(Held Horizontal)
10	2.4		55	69	←(Held Horizontal)
11	2.5		51	61	←(Held Horizontal)
12		**Average Pier-2**	**53**	**65**	
		Total Average	**50.5**	**59.5**	

Combined Average Rebound Value = (48+53)/2=50.5
Combined Average Compressive Strength = (55+65)/2=59.5 MPa

3.3.2 Results:-

Compressive Strength of Concrete (as interpreted from the Rebound value) = 59.5 MPa**.** As per the guidelines laid in IS-13311-Part 2-1992, Since the compressive strength (i.e 59.5 MPa) is above 59 MPa, it can be inferred that the concrete used M40 grade concrete.

3.3.3 Correlation Between Compressive Strength of concrete & NDT Parameters viz. Rebound Index:-

In an attempt to develop correlation between compressive strength & Rebound number were casted of same grades and cured and left to meet with the site conditions. A total of 2 piers each of M40 Grades concrete were obtained for testing in the sites. As per IS:13311-1992 (part 2), the piers were tested by Rebound hammer by holding them in compression testing machine. Rebound Number or indices for horizontal position were obtained. About 5 readings on each of piers were noted. Values of Rebound indices and compressive strengths of the piers are presented in table 2. Based on the procedure outlined in IS-13311-1992 (part 2) relationships between compressive strength and Rebound numbers have been developed using regression shown in figures 2 to 3. From the relevant correlation curves, most likely compressive strength of concrete has been obtained after allowing for necessary corrections.

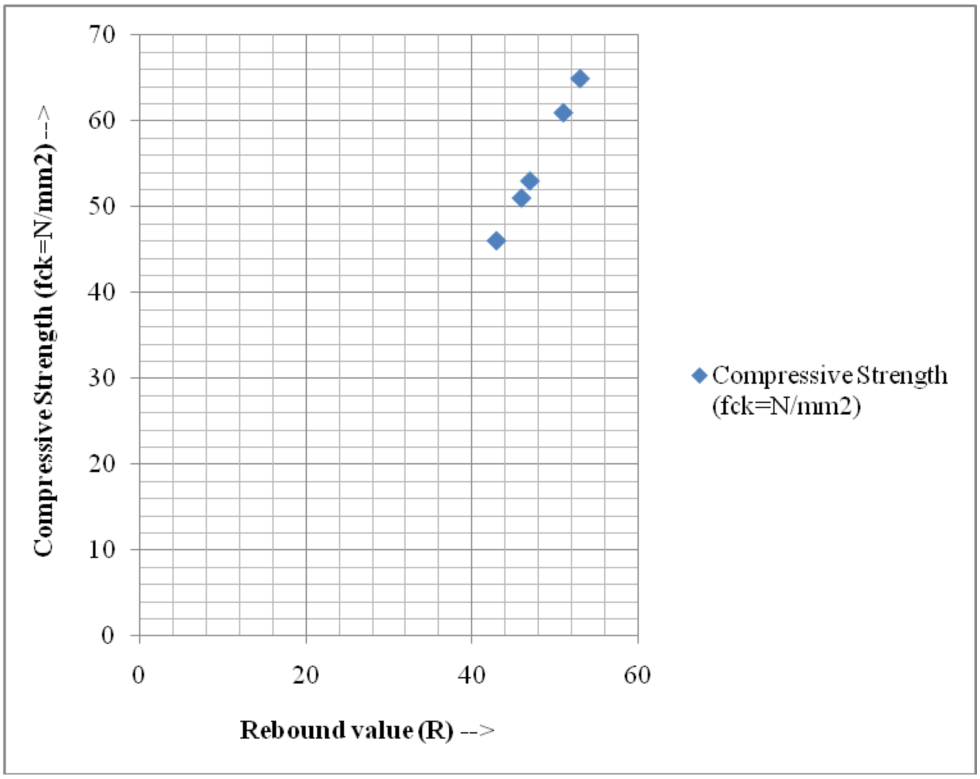

Figure 2: correlation between compressive strength & Rebound number –pier-1

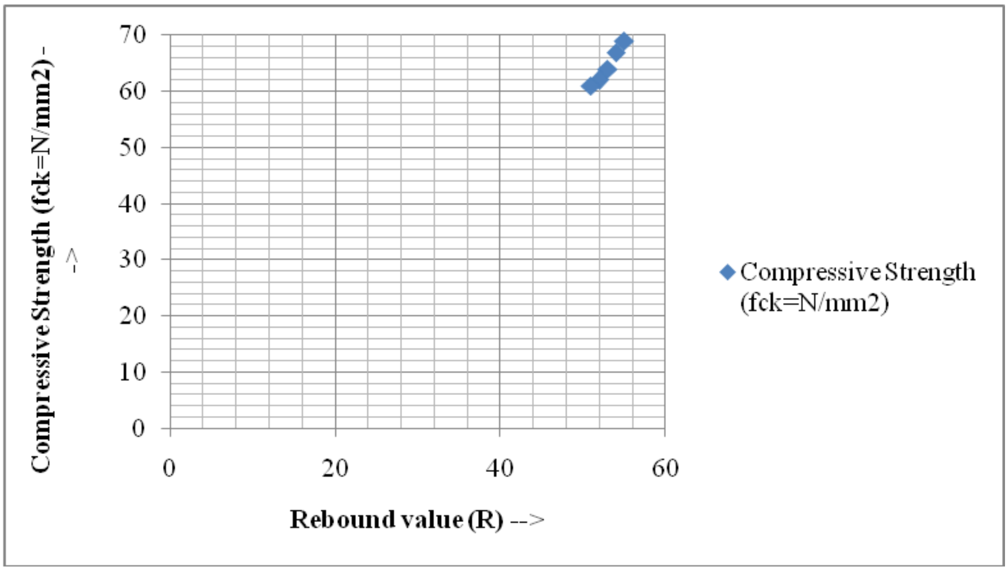

Figure 3: correlation between compressive strength & Rebound number –pier-2

Using these relationships, the compressive strengths of concrete have been evaluated from the observations taken on the actual structure.

3.3.4 Compressive Strength from Rebound indices

Bridge pier-1 and pier-2, Grade adopted M40 Average value of Rebound number with hammer held horizontal pier-1 = 48(←), pier-2=53(←).

From the correlation developed between rebound numbers and compressive strength, compressive strength was obtained as pier-1= 55 MPa. , pier-2=65 MPa.

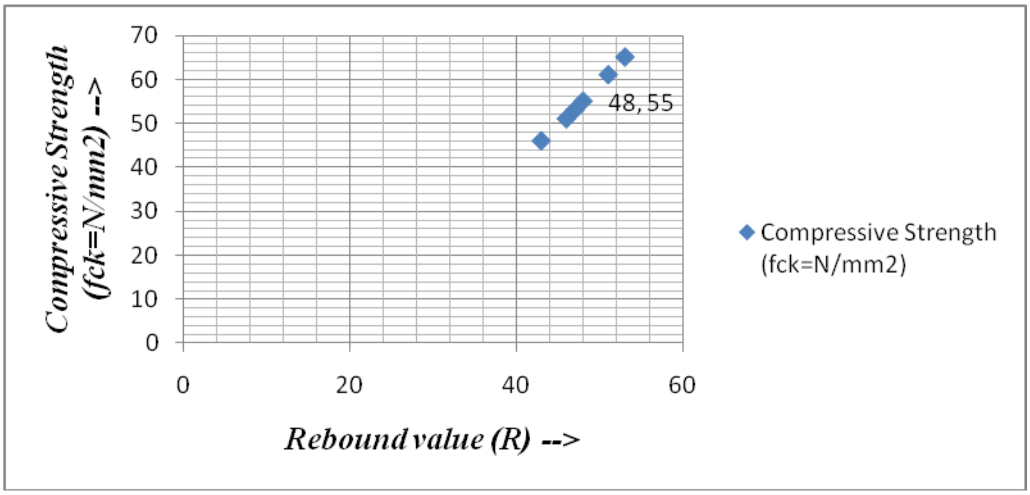

Figure 4: correlation between compressive strength & Average Rebound number –pier-1

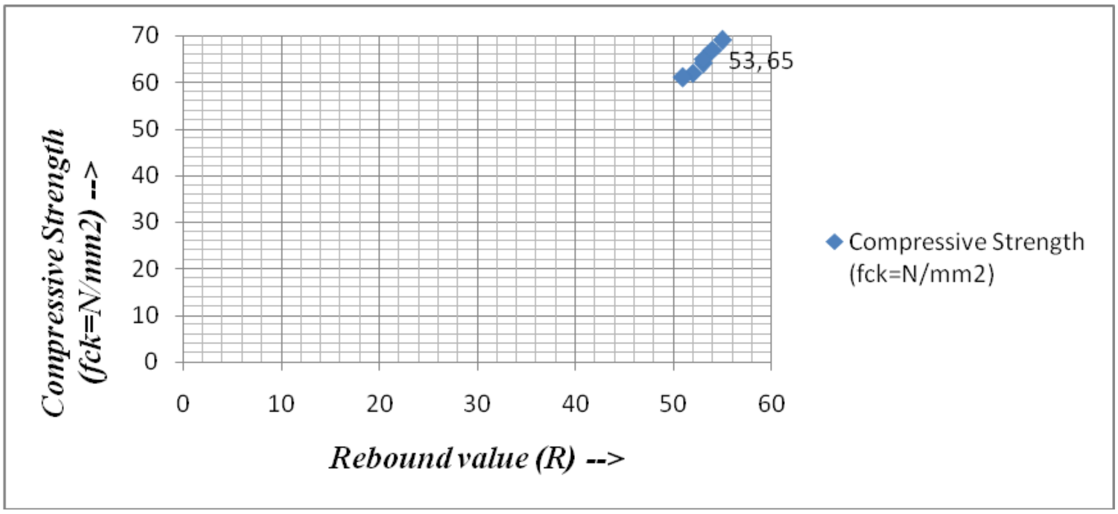

Figure 5: correlation between compressive strength & Average Rebound number –pier-2

IV. CONCLUSION

NDT methods such as Rebound hammer becomes very useful for compressive strength of the structures and structures provided the periodical monitoring of the same member of the structures is being carried out. Since the concrete is heterogeneous and tests are affected by various factors such as age of the concrete, carbonation depth, reinforcement, cracks and voids inside the concrete, a combined test helps for assessment the strength and durability. The experimental investigation showed that a good co-relation exists between compressive strength and rebound hammer. Nevertheless rebound hammer should be used alone to determine the compressive strength of the structures.

V. RESULTS

From the experimental data, the following conclusions can be drawn:-
1. The average of compressive strength on both pier is 59.5 MPa.

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