THE USE OF COMBINED NON DESTRUCTIVE TESTING IN THE CONCRETE STRENGHT ASSESSMENT FROM LABORATORY SPECIMENS AND EXISTING BUILDINGS

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Abstract: -Non Destructive Testing (NDT) as the name implies refers to a test that does not impair the intended performance of the element, member or structure under investigation.In this paper a series of non-destructive tests has been performed with the purpose to investigate on the mechanical properties of the concrete employed in the civil buildings.

A series of specimens were prepared in order to correlate the "in situ" concrete strengths obtained by combined non-destructive method with the cubical strength obtained by destructive methods. The combined method *(SonReb Method)* was used to quality control and strength estimation of the concrete.This combined method requires short time to obtain the results, it's a non-invasive method and it does not affect the resistance of structural elements.

Finally the investigation and comparison of experimental results of non-destructive tests and cubical strength with the help of statistical data obtained by testing of specimen as per recommended procedures by IS 13311:1992 and IS 516:1959 respectively.

From this exhaustive and extensive experimental work it was found that SonReb method, combining Schmidt rebound hammer and Ultrasonic Pulse Velocity methods, allows compensating the limits and the uncertainty typical of each method. The use of the combined methods (SonReb) increases the accuracy of the estimation of the in situ concrete compressive strength.

The research aims on the rehabilitation of reinforced concrete buildings that begin to show signs of decay and deterioration.

Keywords: - Concrete, Concrete compressive strength, Non-destructive investigations, Combined Methods, SonReb Methods.

I. INTRODUCTION

Concrete has been most widely used as construction material for over 100 years, because it is strong in compression. The evaluation of the concrete compressive strength is a fundamental step for assessment of existing reinforced concrete building according to the last seismic codes. This valuation can be conducted by the use of both destructive and non-destructive method. Through the concrete compressive strength, other concrete properties like elastic modulus, tensile strength and durability can be obtained.

Service life of concrete is found to be limiting in various environmental degrading factors as it is exposed to it. This therefore has brought about the need for test method to measure the in-place properties of concrete for quality assurance and for evaluation of existing conditions. Since such test are expected as non-impairing the function of the structure and allow for re-testing at the same location to evaluate the changes in property at some other point in time, these methods should be non-destructive.

The combination of several techniques of non-destructive testing is often used empirically, combining two techniques mostly used to enhance the reliability of the estimate compressive strength of concrete; the principle is based on correlations between observed measurements and the desired property.The standardized combine method and the most widely used internationally is SonReb method. First born and established in Romania then developed in Australia and in Europe.The best approach is generally to develop a relationship of correlation between the Ultra Sonic Pulse Velocity, the index of rebound hammer and the compressive strength of standardized laboratory specimen.

II. TEST SPECIMEN

A. Materials used

[1] *Cement:* Ordinary Portland cement (OPC) of 53 grade of Birla Super Cement is used in this experimental work. Weight of each cement bag is 50 kg.

[2] *Fine aggregates:* Crushed sand having specific gravity 2.77gm/cc and Fineness modulus as 3.15

[3] *Coarse aggregate:* Consist of 10 mm and 20 mm crushed aggregate. 10 mm aggregate having specific gravity 2.91gm/cc and FM as 2.012. 20mm aggregate having specific gravity 2.88gm/cc and FM as 2.1.

B. Mix proportion and casting procedure

Hand mixing over a mixing tray was done throughout. Coarse aggregates were placed first in the tray followed by crushed sand, and then cement. The materials were dry mixed thoroughly for 1 min.before adding water.Mixing continued for further few minutes after adding water.Concrete was then placed in IS specified moulds in three layers, each layer was being compacted by standard tamping road with more than 35 strokes.Exposed surface was finished with trowel to avoid uneven surface.

A total of 60 concrete specimens 150x150x150mm was designed and fabricated.Specimens were prepared to obtain characteristic cube strength of 15 MPa, 20 MPa, 25 MPa, 30 MPa, 35 MPa and 40 MPa. In particular, 10 specimens of each grade. Specimens were cured by immersing them in curing tank for 28 days.

TABLE 1

MIX PROPORTION AND CONCRETE BATCH

Grade	**Cement (kg/m^3)**	**Aggregate (kg/m^3)**		**Water (lit/m^3)**
		Fine	**Coarse**	
M15	270	711	1460	135
M20	320	794	1138	176
M25	340	775	1112	185
M30	380	760	1090	187
M35	410	735	1053	200
M40	430	718	1030	185

III. TEST PROGRAM

A. Rebound Hammer test on cubes

The Schmidt rebound hammer is principally a surface hardness tester, which works on the principle that the rebound of an elastic mass depends on the hardness of the surface against which the mass impinges. There is seemingly theoretical relationship between the strength of concrete and the rebound number of the hammer.

The weight of the Schmidt rebound hammer is about 1.8 kg and is suitable for both laboratory and field purpose. The rebound distance of the hammer mass is measured on an arbitrary scale ranging from 10 to 100. The rebound distance of the hammer is recorded as a “rebound number” corresponding to the position of the rider on the scale.

TABLE 2
HARDNESS CRITERIA FOR CONCRETE QUALITY GRADING (IS 13311 (PART 2):1992)

Average Rebound Number	Quality
Above 40	Very Good Hard Concrete
30 - 40	Good Concrete
20 - 30	Fair Concrete
Below 20	Poor Concrete

B. Ultrasonic Pulse Velocity test on cubes

The equipment consists basically of an electrical pulse generator, a pair of transducers, an amplifier and an electronic timing device for measuring the time interval between the initiation of a pulse generated at the transmitting transducer and its arrival at the receiving transducer.

Pulse velocity (in km/s or m/s) is given by:

$$v = \frac{L}{T}$$

where,

v is the longitudinal pulse velocity,
L is the path length,
T is the time taken by the pulse to travel path length.

TABLE 3
CONCRETE QUALITY GRADING USING VELOCITY CRITERION (IS 13311 (PART 1):1992)

Pulse Velocity		Quality
km/sec	ft/sec	
> 4.5	> 15	Excellent
3.5 – 4.5	12 – 15	Good
3.0 – 3.5	10 – 12	Doubtful
2.0 – 3.0	7 – 10	Poor
< 2.0	< 7	Very Poor

C. Compression testing of cubes

Compression testing machine of capacity 2000 kN is used for compression testing of cube as casted of size 150 x 150 x 150 mm and capable of giving load at the rate of 140 kg/sq.cm/min. Testing of the concrete cubes is tested under CTM at the age of 28 days. The wet cubes were placed in the machine between wiped and cleaned loading surfaces and load is given approximately at the rate of 140 kg/sq.cm/min. and ultimate crushing load is noted to calculate crushing strength of concrete according to IS: 516-1959.

The measuring strength of specimen is calculated by dividing the maximum load applied to the specimen during the test by the cross section area.

D. Calculation

The compressive strength of the specimen shall be expressed as f_{ck}.

In the case of the SonReb method the law of correlation among compressive strength, Rebound Hammer index and ultrasonic velocity can be expressed as (Pucinotti 2005):

$$f_{ck} = a \cdot V^b \cdot R^c \qquad \dots (i)$$

where,

a, *b*, *c* are constants
V - Ultrasonic Pulse Velocity
R - Rebound Number

IV. RESULT AND DISCUSSION

Among the obtained 60 results of Rebound Hammer, Ultrasonic Pulse Velocity and Compression testing, 20 random results are selected to obtain *a*, *b* and *c* constants.

TABLE 4
RESULTS

R	UPV	Compressive Strength by CTM
23	3620	16.8
24.8	3718	17.4
25.2	3906	18.1
26.8	3789	19.6
27.6	4003	20.1
27.4	4112	20.5
29.6	3964	21.4
31.8	4003	23.8
33	3998	25.6
32.2	4112	26.9
29.2	4049	28.9
29.8	4109	29.6
30.4	4112	30.3
32.4	4129	31.2
31.2	4219	32.4
31.8	4199	33.1
33.6	4112	35.8
34.2	4159	36.9
35.8	4259	38.4
39.8	4159	40.2

So the question is how to determine the constants *a*, *b* and *c* from the data.The LINEST function of EXCEL can be used to do this.

The *a*, *b* and *c* obtained are:

a = 1.64111E-09
b = 2.293662304
c = 1.30768373

So the law of correlation among compressive strength, Rebound Hammer index and ultrasonic velocity for this set of data would be:

$$f_{ck} = (1.64111E\text{-}09) \cdot V^{2.293662304} \cdot R^{1.30768373} \quad \ldots (ii)$$

TABLE 5
COMPRESSIVE STRENGTH BY SONREB USING FORMULA (*ii*)

f_{ck} (SONREB)
14.3987
16.8936
19.3173
19.526
23.0169
24.2481
24.6619
27.7009
28.9925
29.9471
25.4351
27.017
27.777
30.4776
30.4808
30.9108
31.661
33.2581
37.2848
40.5525

By using the above data, we can also see the effectiveness of the SonReb method.

i. Simply using the rebound values alone for strength estimation, a correlation coefficient of 0.798 is achieved.

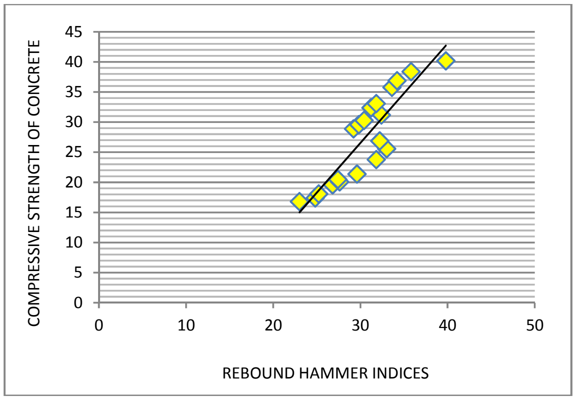

Fig. 1 Relationship of Rebound Hammer vs Compressive Strength

y = 1.6516x - 22.991

Accuracy obtained 0.798

ii. When using the ultrasonic pulse velocity for strength estimation, a correlation coefficient of 0.672 is achieved.

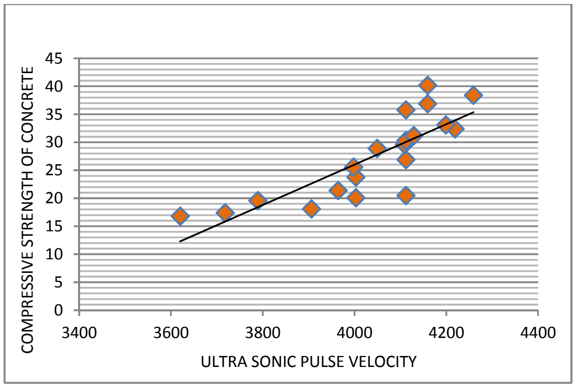

Fig.2 Relationship of Ultrasonic Pulse Velocity vs Compressive Strength

y =0.0362x - 118.57

Accuracy obtained 0.6724

iii. In comparison, combining the two methods by using the SONREB data gives a significantly highercorrelation coefficient of 0.867 as we have seen.

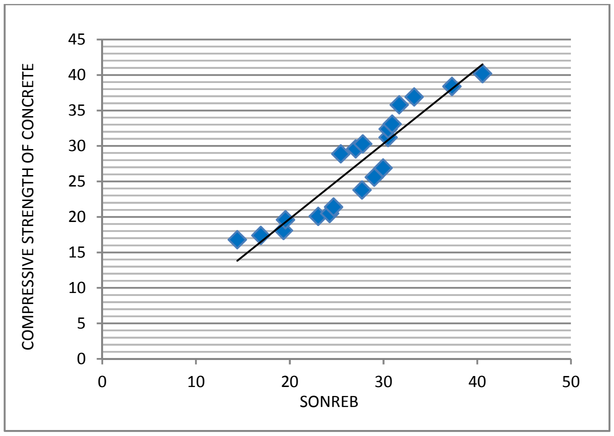

Fig.3 Relationship of SonReb vs Compressive Strength

$$y = 1.058x - 1.4048$$

Accuracy obtained 0.8669

From graph we can say that the regression equation of the Sonreb has a greater accuracy than the previous two equations.

V. CONCLUSION

[1] The comparison carried out shows how the use of known destructive methodologies (cores), associated with a non-destructive method (SonReb) allows to obtain a higher level of knowledge and a greater accuracy on the estimation of the concrete compressive strength if the relationship is calibrated on the individual building

[2] The SonReb method provides a reliable assessment of the onsite concrete compressive strength which allows obtaining the required levels of knowledge.

[3] This, in turn, allows limiting the number of destructive tests needed to properly characterize concrete strength in existing buildings.

[4] Simply using the rebound values alone for strength estimation, a correlation coefficient of 0.798 is achieved

[5] Using the ultrasonic pulse velocity for strength estimation, a correlation coefficient of 0.672 is achieved.

[6] Combining the two methods by using the SONREB higher correlation coefficient of 0.867 as we have seen.

[7] From the correlation generated, we can find more accurate compressive strength than the previous.

[8] Just by knowing the Rebound Hammer Number and UPV, strength can be calculated.

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