INTERPRETATION OF COMPRESSIVE STRENGTH IN CONCRETE CUBE AND CYLINDER

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Abstract:- *Concrete is the oldest and most important construction material in the world. Testing of the concrete specimens plays an important role to know about the parameters of the concrete. So this study is conducted primarily to determine the compressive strength of concrete cubes and cylinders by using Destructive and Non-Destructive Test(NDT). In order to calibrate the DT method(Compressive Testing Machine)and NDT methods (Schmidt hammer or Rebound number and ultrasonic pulse velocity) with various grades of concrete are M20,M25,M30 and M40 and the cure samples were tested using Destructive test and NDT methods according to the Indian Standards. The cube and cylinder specimens were tested in 28 days and the outcomes were compared. The outcomes of DT results are to verify that there are limitations in each NDT methods and are able to eliminate the limitations in the NDT.*

Key Words: Destructive test(DT), Non-destructive test(NDT), Compressive Strength.

I. INTRODUCTION

Concrete is the most commonly used construction materials in construction practices. So the determination of concrete strength has become the most important factor in the construction practices. The compressive strength is one of the most important property to known about the quality of concrete. There are various destructive and non-destructive Tests (NDT) methods are developed for determining the compressive strength in the concrete specimens. The aim of these, control concrete production and determine under service loads deteriorated concrete in buildings on time. But the destructive methods are uneconomical and time consuming. Also cube and cylinder, prepared in laboratory, concrete specimens are not representing in-situ concrete. Thus researches have developed the direct non-destructive test methods to find the compressive strength in the existing structures. The NDT methods are faster and economical when compared with the destructive test methods. But the NDT results are no value if the results are not reliable, representative and as close as possible to the actual strength the tested part of the structure. The NDT test methods have some limitations. To reduce these limitations of the NDT test result has to be correlated with results of Destructive test method. The purpose of this study is to investigate the correlation between the strength values obtained by destructive and NDT test methods on both concrete cubes and cylinders.

II. TEST SPECIMENS

A.Materials used

- Cement:Ordinary Portland cement (OPC) of 53 grade is used in this experimental work. Weight of each cement bagis 50 kg and the specific gravity is 3.6.
- Fine aggregates: Natural sand having specific gravity 2.378 and Fineness modulus as 2.60.
- Coarse aggregate: It consist of 12 mm and 20mm crushed aggregate and the specific gravity is 2.75

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 natural sand and then cement. The materials were dry mixed thoroughly for 1 minute 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 25 strokes. Exposed surface was finished with trowel to avoid uneven surface. A total of 48 concrete specimens 150x150x150mm& 300x150mmwas designed and fabricated. Specimens were prepared to obtain characteristic cube strength of 20 MPa, 25 MPa, 30 MPa and 40 MPa. In particular, 6 specimens of each grade concrete cube and cylinder then the Specimens were cured by immersing them in curing tank for 28 days.

REBOUND HAMMER TEST:

The Schmidt hammer test has been used world-wide as an index test for a quick concrete testing

Table 1 Mix Design Calculations For M20, M25, M30 & M40 Grade Concrete Mix proportion Of Concrete Per cubic mete

Concrete Grade	Cement (Kg/M3)	Fine Aggregate (Kg/M3)	Coarse Aggregate (Kg/M3)	Water Cement Ratio
M20	394	624	1192	0.5
M25	410	614	1186	0.48
M30	438	598	1182	0.45
M40	493	568	1172	0.4

III. TEST PROGRAM

COMPRESSIVE TESTING MACHINE:

Compression testing machine of capacity 2000 kN is used for compression testing of cube and cylinder as casted of size 150x150x150 mm and 150x300 mm and capable of giving load at the rate of 140 kg/sq.cm/min. Testing of the concrete cubes and cylinders are tested under CTM at the age of 28 days. The wet specimens 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. Equipment to estimate strength of concrete due to its rapidity and easiness in execution, simplicity, portability, low cost and non-destructiveness. It 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. The determination of compressive strength in the concrete specimens by using graphs which is related with the rebound number and compressive strength. The weight of the rebound hammer is about 1.8 kg and is suitable for both laboratory test and field test. The rebound hammer arbitrary scale is ranging from 10 to 100.

ULTRASONIC PULSE VELOCITY TEST:

The UPV test equipment consists of an transducers, electrical pulse generator, amplifier and electronic timing device. The test can be performed on samples in the laboratory after 28 days. The electronic timing device is used for measuring the time interval between the initiation of a pulse generated at the transmitting transducer and its arrival at the receiving transducer. Many factors are influencing the test results, mix proportion, curing period, moisture content, travel distance of the wave etc., The test is described in ASTM C597, EN12504-4:2004.
Pulse velocity (in km/s or m/s) is given by:

$$V = L/T$$

where,
V is the longitudinal pulse velocity,
L is the path length,
T is the time taken by the pulse to travel path length.
The method consists of measuring the ultrasonic pulse

Fig -1 Testing of Specimens by CTM, RH & UPV

IV. RESULT AND DISCUSSION

The following results were tabulated after testing specimen of cubes and cylinders by Compressive Testing Machine (Destructive Test), Rebound Hammer, Pulse Velocity Test (Non-Destructive Test).

A. FOR M20 GRADE OF CONCRETE:

S.NO S.No	Compressive Strength of Cube (N/mm2)		
	CTM Strength	RH Strength	UPV Strength
1	24.6	22	23.7
2	25.7	24	24.8
3	27.5	25	26.4
4	28	27	25.9
5	25.9	24	24.8
6	29.4	28	28.2
Average	26.85	25	25.63

Table No 2 Compressive Strength of Cube for M20 grade

S.NO S.No	Compressive Strength of Cube (N/mm2)		
	CTM Strength	RH Strength	UPV Strength
1	21.1	18	20.1
2	21.5	20	19.8
3	22.1	22	22.3
4	20.9	18	19.8
5	23.8	24	24.2
6	21.6	20	21.3
Average	21.83	20.33	21.21

Table No 3 Compressive Strength of Cylinder for M20 grade

B. FOR M25 GRADE OF CONCRETE:

S.NO S.No	Compressive Strength of Cube (N/mm2)		
	CTM Strength	RH Strength	UPV Strength
1	33.7	31	32.32
2	27.1	28	28.6
3	27.9	29	29.5
4	32.1	31	31.8
5	33.3	32	33.6
6	32.8	30	31.9
Average	31.15	30.16	31.28

Table No 4 Compressive Strength of Cube for M25 grade

S.No	Compressive Strength of Cylinder (N/mm2)		
	CTM Strength	RH Strength	UPVStrength
1	24.6	24	25.6
2	29.2	28	29.2
3	23.3	21	22.9
4	26.5	24	27.4
5	25.3	24	24.8
6	26.1	26	27.3
Average	25.83	24.5	26.2

Table No 5 Compressive Strength of Cylinder for M25 grade

B. FOR M30 GRADE OF CONCRETE:

S.NO S.No	Compressive Strength of Cube (N/mm2)		
	CTM Strength	RH Strength	UPV Strength
1	36.8	37	35.6
2	35.2	32	34.1
3	38.7	36	37.2
4	37.8	35	35.4
5	34.5	30	31.8
6	37.7	34	36.9
Average	36.78	34	35.16

Table No 6 Compressive Strength of Cube for M30 grade

S.NO S.No	Compressive Strength of Cylinder (N/mm2)		
	CTM Strength	RH Strength	UPV Strength
1	32.8	30	31.9
2	31.6	30	32.5
3	33.4	32	34.5
4	29.4	29	28.2
5	29.2	28	29.1
6	32.1	31	31.1
Average	31.41	30	31.21

Table No 7 Compressive Strength of Cylinder for M30 grade

B. FOR M40 GRADE OF CONCRETE:

S.NO S.No	Compressive Strength of Cube (N/mm2)		
	CTM Strength	RH Strength	UPV Strength
1	50.3	48	48.9
2	46.8	38	41.7
3	47	43	48.1
4	44.1	39	42.8
5	51.5	49	50.5
6	48.5	46	47.4
Average	48.03	43.83	46.56

Table No 8 Compressive Strength of Cube for M40 grade

S.NO S.No	Compressive Strength of Cylinder (N/mm2)		
	CTM Strength	RH Strength	UPV Strength
1	39.8	37	37.5
2	43.1	42	41.2
3	42.3	38	38.6
4	44.8	42	43.8
5	40.9	38	39.1
6	43.6	45	42.4
Average	42.41	40.33	40.43

Table No 9 Compressive Strength of Cube for M40 grade

5. COMPARISON OF RESULTS

From observation table comparison of average rebound strength, average UPV and average compressive strength of cylinders and cubes for M20, M25, M30 and M40 grades of concrete is done. It observed that,

1. Average rebound strength of cubes is greater than average rebound strength of cylinders.
2. Average UPV of cubes is greater than average UPV of cylinders.
3. Average compressive strength of cubes is greater than average compressive strength of cylinders.

The relation between average compressive strength of cubes (fcube) and average compressive strength cylinders (fcyl) are developed from above results is given below:

Grade	Relation between f_{cube} and f_{cyl}	Relation between f_{cube} and f_{cyl} as per IS 516-1959
For M20	f_{cube} =1.22 f $_{cyl}$	f_{cube} =1.25 f $_{cyl}$
For M25	f_{cube} =1.20 f $_{cyl}$	f_{cube} =1.25 f $_{cyl}$
For M30	f_{cube} =1.17 f $_{cyl}$	f_{cube} =1.25 f $_{cyl}$
For M40	f_{cube} =1.13 f $_{cyl}$	f_{cube} =1.25 f $_{cyl}$

Table No 10 Relation Between Cube and Cylindrical Compressive Strength

6. REGRESSION ANALYSIS

In the proposed work statistical methods are used for explanation of the tests results and the prediction of concrete strength. Statistical concepts indispensable in the analysis of any test result related to the mechanical strength of the concrete which obtained in lab from the compressive strength test carried out to a sample of core even in a standard cylinder form. This work included to predict the analytical relationships between

1. Cube Compressive Strength Vs Cube Rebound Strength.
2. Cube Compressive Strength Vs Cube UPV Strength.
3. Cube Rebound Strength Vs Cube UPV Strength.
4. Cylindrical Compressive Strength Vs Cylindrical Rebound Strength.
5. Cylindrical Compressive Cylindrical Strength Vs UPV Strength.
6. Cylindrical Rebound Strength Vs Cylindrical UPV Strength.

For analysis process of the results regression analysis method was used. The goal of regression method is to fit a line through points (results) so that the squared deviations of the observed points from that line are minimized. In regression analysis we obtain a set of coefficients for an equation.

7. EQUATIONS OF RELATIONSHIP AFTER REGRESSION ANALYSIS:

Different regress model of curve between rebound number, Pulse velocity and the compressive strength of concrete core according to the experimental data is given below:

Type of Eqations	CTM Vs RH Strength	CTM Vs UPV Strength	RH Vs UPV Strength
Linear	$f_{cube} = 0.877 R_{cube} + 1.930$ $R^2 = 0.94$	$f_{cube} = 0.985 U_{cube} - 0.338$ $R^2 = 0.983$	$R_{cube} = 1.059 U_{cube} - 0.568$ $R^2 = 0.971$
Exponential	$f_{cube} = 13.03 e^{0.025\,R_{cube}}$ $R^2 = 0.939$	$f_{cube} = 12.71 e^{0.027 U_{cube}}$ $R^2 = 0.972$	$R_{cube} = 12.64 e^{0.029\,U_{cube}}$ $R^2 = 0.959$
Logarithmic	$f_{cube} = 31.76\ln(R_{cube}) - 79.48$ $R^2 = 0.932$	$f_{cube} = 35.51\ln(U_{cube}) - 91.23$ $R^2 = 0.967$	$R_{cube} = 36.02\ln(U_{cube}) - 90.71$ $R^2 = 0.961$
Polynomial	$f_{cube} = 0.004\,R_{cube}^2 + 0.53 R_{cube} + 8.163$ $R^2 = 0.948$	$f_{cube} = 0.003\,U_{cube}^2 + 0.728 U_{cube} + 4.269$ $R^2 = 0.983$	$R_{cube} = -0.003\,U_{cube}^2 + 1.280x - 4.307$ $R^2 = 0.972$
Power	$f_{cube} = 1.169 x^{0.936}$	$f_{cube} = 0.964\,U_{cube}^{1.003}$	$R_{cube} = 0.976\,U_{cube}^{1.018}$

	$R^2 = 0.946$	$R^2 = 0.978$	$R^2 = 0.973$

Table No 11

Regress model between rebound strength, pulse velocity and the compressive strength of concrete cube for combination of M20, M25, M30 and M40 grade of concrete

Type of Eqations	CTM Vs RH Strength	CTM Vs UPV Strength	RH Vs UPV Strength
Linear	$f_{cyl} = 0.975R_{cyl} - 0.848$ $R^2 = 0.974$	$f_{cyl} = 0.924U_{cyl} + 1.701$ $R^2 = 0.980$	$R_{cyl} = 0.932 U_{cyl} + 2.924$ $R^2 = 0.975$
Exponential	$f_{cyl} = 10.18e^{0.033x}$ $R^2 = 0.952$	$f_{cyl} = 11.44e^{0.030U_{cyl}}$ $R^2 = 0.953$	$R_{cyl} = 11.88e^{0.030 U_{cyl}}$ $R^2 = 0.954$
Logarithmic	$f_{cyl} = 30.41\ln(R_{cyl}) - 74.04$ $R^2 = 0.969$	$f_{cyl} = 28.93\ln(U_{cyl}) - 68.03$ $R^2 = 0.984$	$R_{cyl} = 27.15\ln(U_{cyl}) - 60.49$ $R^2 = 0.969$
Polynomial	$f_{cyl} = -0.003 R_{cyl}^2 + 1.182 R_{cyl} - 3.998$ $R^2 = 0.974$	$f_{cyl} = -0.009U_{cyl}^2 + 1.526x - 7.472$ $R^2 = 0.984$	$R_{cyl} = -0.006U_{cyl}^2 + 1.318U_{cyl} - 2.607$ $R^2 = 0.978$
Power	$f_{cyl} = 0.817 R_{cyl}^{1.042}$ $R^2 = 0.972$	$f_{cyl} = 1.106U_{cyl}^{0.964}$ $R^2 = 0.978$	$R_{cyl} = 1.397U_{cyl}^{0.911}$ $R^2 = 0.976$

Table No 12

Regress model between rebound strength, pulse velocity and the compressive strength of concrete cylinder for combination of M20, M25,M30 and M40 grade of concrete

Type of Eqations	CTM Vs RH Strength	CTM Vs UPV Strength	RH Vs UPV Strength
Linear	$f_{cube} = 0.896f_{cyl} - 1.627$ $R^2 = 0.870$	$R_{cube} = 0.917R_{cyl} - 1.724$ $R^2 = 0.758$	$U_{cube} = 0.840 U_{cyl} + 0.627$ $R^2 = 0.825$
Exponential	$f_{cube}= 10.59e^{0.028f_{cyl}}$ $R^2 = 0.86$	$R_{cube}=9.797e^{0.031f_{cyl}}$ $R^2 = 0.754$	$U_{cube} = 10.95e^{0.028U_{cyl}}$ $R^2 = 0.816$
Logarithmic	$f_{cube}=32.44\ln(f_{cyl}) -84.77$ $R^2 = 0.856$	$R_{cube} = 31.49\ln(x) - 80.82$ $R^2 = 0.74$	$U_{cube} = 30.15\ln(U_{cyl}) - 76.39$ $R^2 = 0.837$
Polynomial	$f_{cube} = 0.000x^2 + 0.859 f_{cyl} - 0.957$ $R^2 = 0.870$	$R_{cube} = -0.015 f_{cyl}^2 + 1.989 f_{cyl} - 19.90$ $R^2 = 0.771$	$U_{cube} = -0.016 U_{cyl}^2 + 2.058 f_{cyl} -20.76$ $R^2 = 0.843$
Power	$f_{cube} = 0.726 f_{cyl}^{1.042}$ $R^2 = 0.863$	$R_{cube} = 0.636 f_{cyl}^{1.085}$ $R^2 = 0.773$	$U_{cube} = 0.820U_{cyl}^{1.011}$ $R^2 = 0.842$

Table No 13

Regress model between rebound strength, pulse velocity and the compressive strength of concrete cube and cylinder for combination of M20, M25, M30 and M40 grade of concrete

8. CORRELATION AND REGRESSION ANALYSIS

The strength of relationship and governing equation between the NDT and DT compressive strength test results were determined statistical tool.

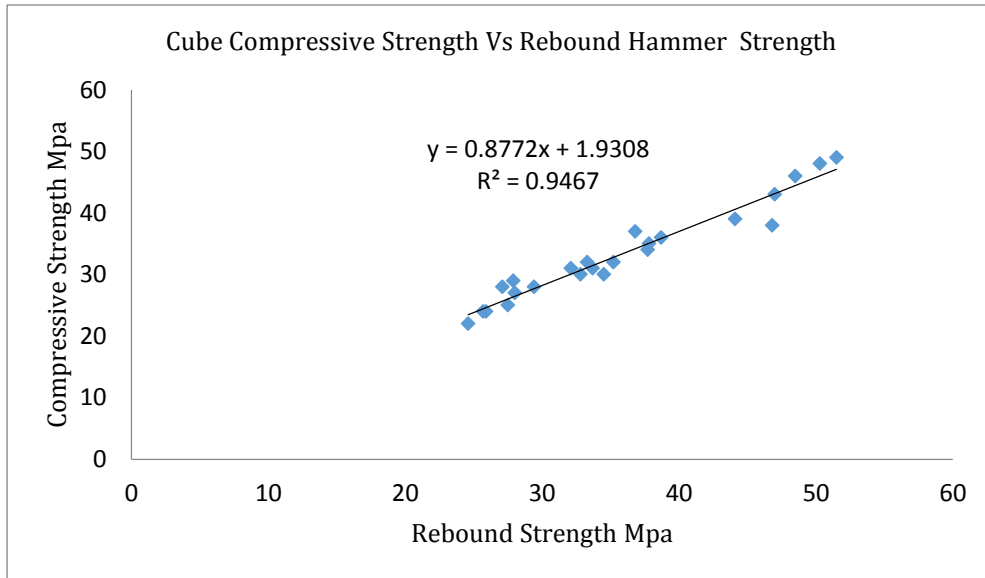**Calibration curves for CTM, RH & UPV are drawn using regression analysis of cubes** :

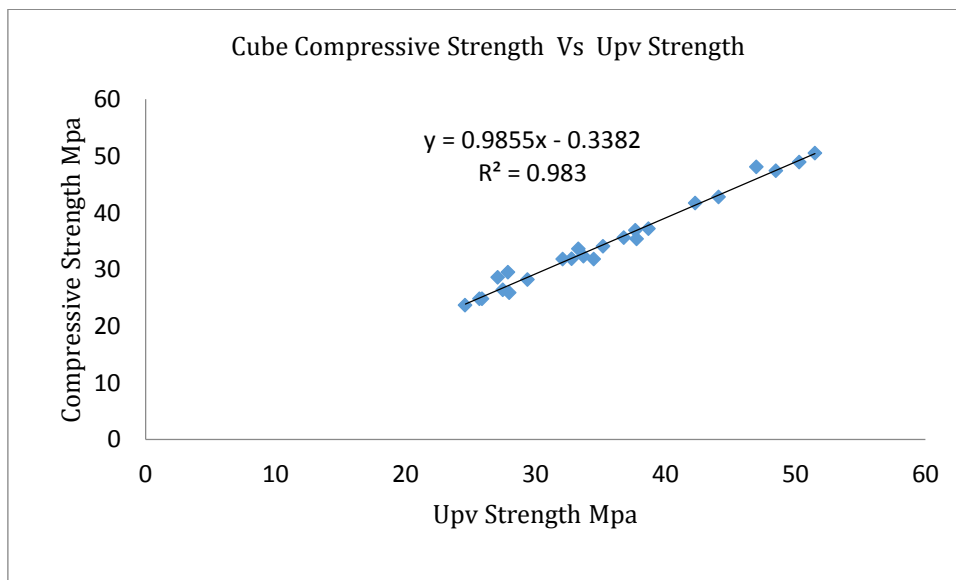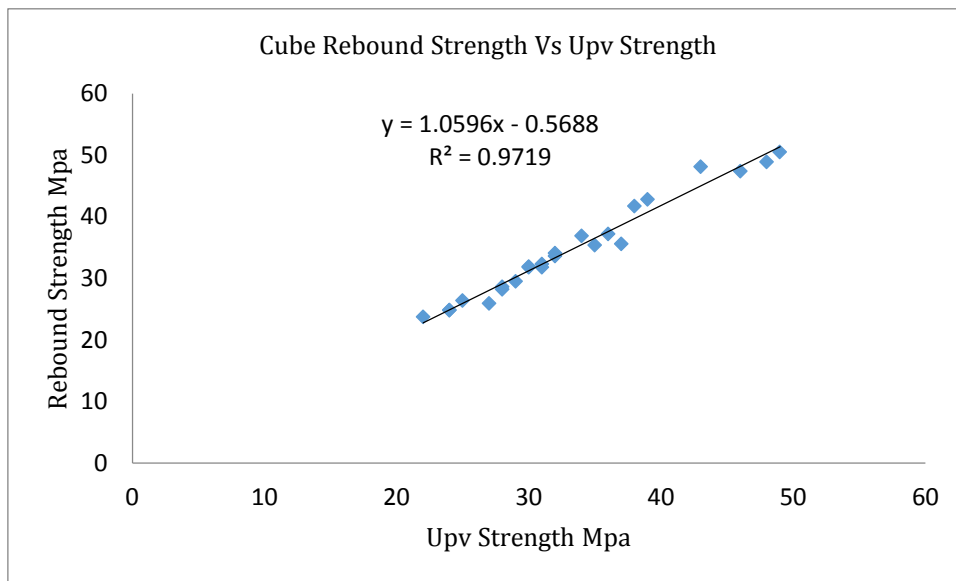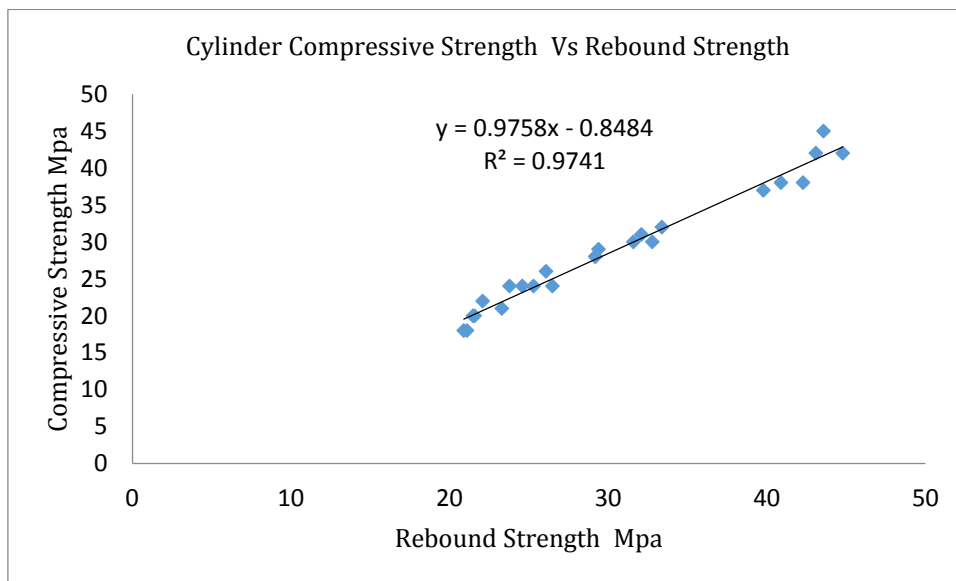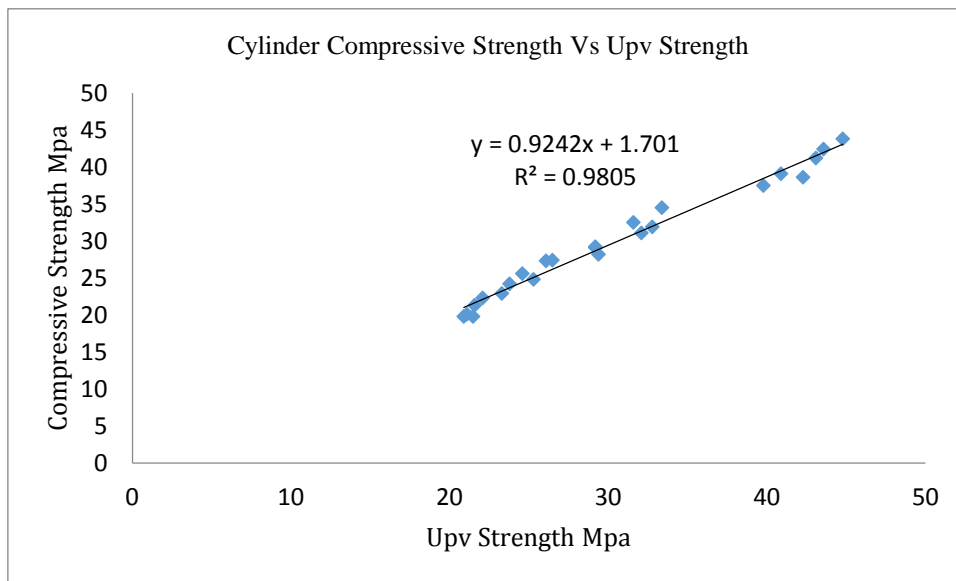**Chart-1** Cube Compressive Strength Vs Rebound Hammer Strength

Chart-2 Cube Compressive Strength Vs Upv Strength

Chart-3 Cube Rebound Strength Vs Upv Strength

Calibration curves for CTM, RH & UPV are drawn using regression analysis of cylinders:

Chart-4 Cylinder Compressive Strength Vs Rebound Strength

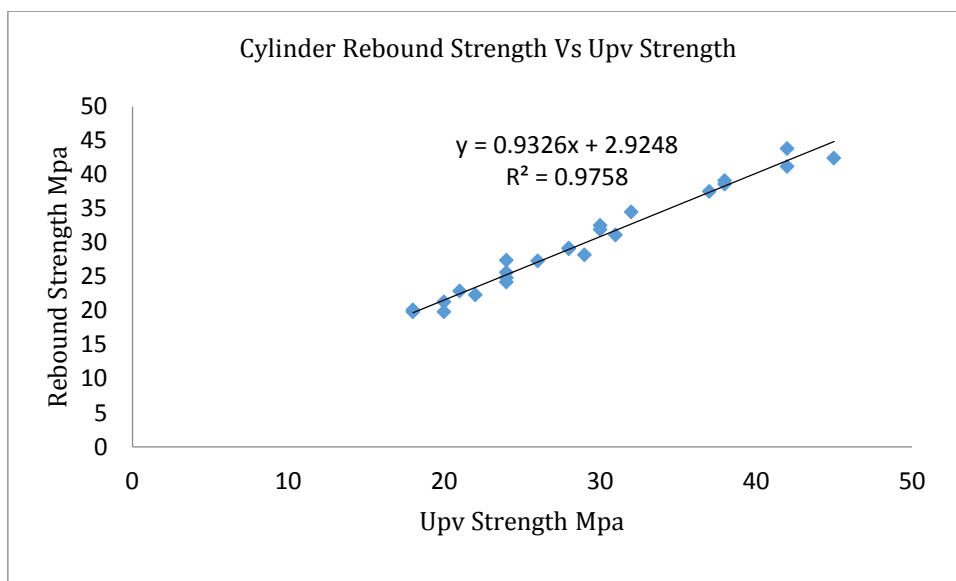**Chart-5** Cylinder Compressive Strength Vs Upv Strength

Chart-6 Cylinder Compressive Strength Vs Upv Strength

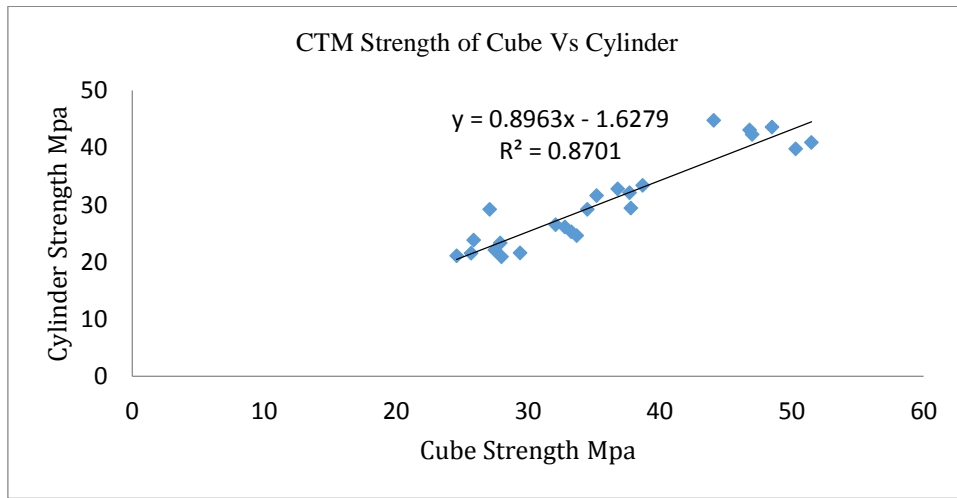**Calibration curves for CTM, RH & UPV are drawn using regression analysis of cube and cylinders:**

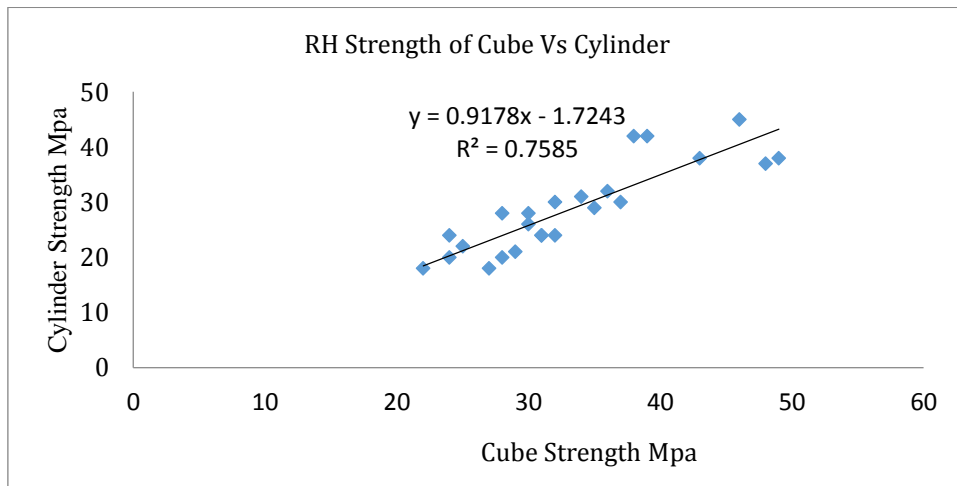**Chart-7** CTM Strength of Cube Vs Cylinder

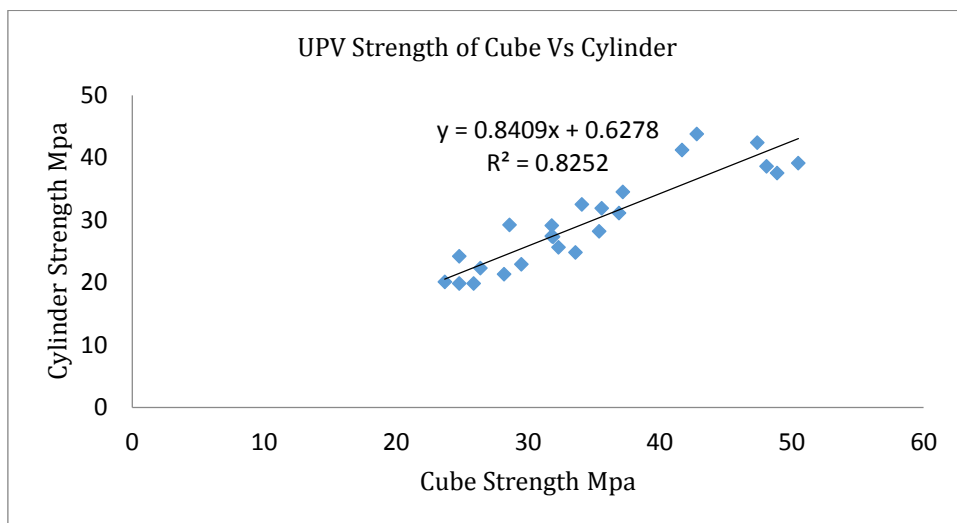**Chart-8** RH Strength of Cube Vs Cylinder

Chart-9 UPV Strength of Cube Vs Cylinder

9. CONCLUSIONS

From experimental and graphical study following conclusions were made

1. The ratio of the compressive strength of cube and cylinder is varying between 1.25 to 0.8 and the ratio is vary when the grade of concrete is changes.
2. The high rebound number and high velocity gives the high compressive strength while Vs.
3. The use of more than one NDT method would provide a better correlation, leading to predictable means of evaluation of strength in concrete.
4. The following relations are drawn by considering different tests such as compressive test, Rebound hammer test and ultrasonic pulse velocity test on casted cubes which are from lab.

The relation between the compressive strength of cube and compressive strength of cylinders
$f_{cube} = 0.877R_{cube} + 1.930$ $R^2 = 0.94$

The relation between compressive strength of cube and upv strength of cube are
$f_{cube} = 0.985U_{cube} - 0.338$ $R^2 = 0.983$

The relation between rebound strength and ultrasonic pulse velocity strength of cube is
$R_{cube} = 1.059U_{cube} - 0.568$ $R^2 = 0.971$

5. The following relations are drawn by considering different tests such as Compressive test, Rebound hammer test and Ultrasonic pulse velocity test on casted cylinders which are from lab:

i)   The relation between compressive strength and Rebound strength of cylinders
            $f_{cyl} = 0.975R_{cyl} - 0.848$ $R^2 = 0.974$
ii)   The relation between compressive strength and ultrasonic pulse velocity test strength of cylinders is
            $f_{cyl} = 0.924U_{cyl} + 1.701$ $R^2 = 0.980$
iii)   The relation between rebound strength and ultrasonic pulse velocity test strength of cylinder is
            $R_{cyl} = 0.932U_{cyl} + 2.924$ $R^2 = 0.975$

6. The following relations are drawn by considering different tests such as compressive test, Rebound hammer test and ultrasonic pulse velocity test on casted cubes and cylinders which are from lab:

i)   The relation between compressive strength of cubes and cylinders by compressive testing machine is
            $f_{cube} = 0.896f_{cyl} - 1.627$ $R^2 = 0.870$
ii)   The relation between compressive strength of cube and cylinders by conducting rebound hammer test is
            $R_{cube} = 0.917R_{cyl} - 1.724$ $R^2 = 0.758$
iii)   The relation between rebound strength and ultrasonic pulse velocity of cylinders

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