Correlation between Compressive Strength of Concrete Using Schmidt Rebound Hammer and Universal Testing Machine of Concrete (Replacement of Cement with C.E.T.P Sludge)

Neelabh Singh, Anantha Singh T. S., Niragi Dave, Satvik Pratap Singh, Pranjal Chaudhary, and Bhargav Tukadiya
Pandit Deendayal Petroleum University, Gandhinagar, Gujarat, India
Email: neelabh.rocking@gmail.com

***Abstract*—This paper aims to study the correlation between Non-destructive testing of concrete also known as Schmidt Rebound Hammer Testing and Destructive testing methods which is testing in Universal Testing Machine (UTM). The rebound hammer was invented by Ernst Schmidt. The hammer measures the rebound of a spring-loaded mass impacting against the surface of the sample. The test hammer will hit the concrete at a defined energy. Its rebound is dependent on the hardness of the concrete and is measured by the test equipment. By reference to the conversion chart, the rebound value can be used to determine the compressive strength. The universal testing machine of 1000kN capacity was used to test the compressive strength of concrete. In this research work, industrial sludge from a common effluent treatment plant was utilized as a replacement of cement. This sludge was recovered from The Green Environment Services Co-op Society Ltd., Vatva, Gujarat. Cement is replaced by C.E.T.P (Common Effluent Treatment Plant) sludge by 2%, 5% and 10%, where cubes of different ages such as 28 days, 90 days and 180 days were casted.**

***Index Terms*—schmidt rebound hammer, universal testing machine, common effluent treatment plant, C.E.T.P (common effluent treatment plant) sludge by 2%, 5% and 10%.**

I. Introduction

A. Schmidt Hammer or Rebound Hammer

A [1] Schmidt hammer, also known as a Swiss hammer or a rebound hammer, is a device to measure the elastic properties or strength of concrete or rock, mainly surface hardness and penetration resistance.

[1] It was invented by Ernst Schmidt, a Swiss engineer. The hammer measures the rebound of a spring-loaded mass impacting against the surface of the sample. The test hammer will hit the concrete at a defined energy. Its rebound is dependent on the hardness of the concrete and is measured by the test equipment. By reference to the conversion chart, the rebound value can be used to determine the compressive strength. When conducting the test the hammer should be held at right angles to the surface which in turn should be flat and smooth. The rebound reading will be affected by the orientation of the hammer, when used in a vertical position (on the underside of a suspended slab for example) gravity will increase the rebound distance of the mass and vice versa for a test conducted on a floor slab. The Schmidt hammer is an arbitrary scale ranging from 10 to 100. The concrete cubes are cured for 28 days, 90 days and 180 days. Then the concrete cubes are tested in laboratory and were also tested with a Schmidt rebound hammer using two different impact directions on each testing points such as horizontal impact and vertical impact. A series of 5 rebounds were carried out for each cube.

B. Universal Testing Machine

[2] A universal testing machine (UTM), also known as a universal tester, materials testing machine or materials test frame, is used to test the tensile strength and compressive strength of materials. An earlier name for a tensile testing machine is a tensometer. The "universal" part of the name reflects that it can perform many standard tensile and compression tests on materials, components, and structures (in other words, that it is versatile).

C. Determination of Strength

Concrete is the major need for construction purpose. [3] Engineers usually specify the required compressive strength of concrete, which is normally given as the 28-day compressive strength. Strength gain depends on the type of mixture, its constituents, the use of standard curing and by proper testing. [3] Determination of compressive strength is the most important part for every researcher to check the strength of any type of concrete.

D. Materials & Methods

In this experimental study we aim to study the correlation between the rebound hammer test and testing under universal testing machine. The materials used were:

1) Portland Pozzolana Cement with 30% fly ash

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2) C.E.T.P Sludge
3) Sand (Fine Aggregate)
4) Course Aggregate
5) Water

TABLE I. PROPERTIES OF PPC [4]

Description	BIS specification PPC Grade (As per IS 1489:1991)
Chemical Requirement:	5.0 Max
Insoluble Residue (%)	X*+4.0(100-X)/100
Sulphuric Anhydride (%)	3.0 max
Magnesia (%)	6.0 max
Chloride Content (%)	1.0 max
Physical Requirements:	
Fineness (m2/kg)	300 min
Soundness:	
Le-Chatelier (mm)	10 max
Autoclave (%)	0.8 max
Setting Time (minutes):	
Initial	30 min
Final	600 max
Compression Strength (MPa):	
3 Days	16 min
7 Days	22 min
28 Days	33 min
Dry Shrinkage (%)	0.15 max

[4] Where 'X' is the declared percentage of fly ash in given Portland pozzolana cement.

According to the specifications given on the cement bag, the cement contains 30% of fly ash in it. M30 grade concrete cubes were casted in which cement was replaced by industrial C.E.T.P sludge by 2%, 5% and 10%. The cubes of different ages like 28 days, 90 days and 180 days were casted for testing. The quantities of materials used in the mix design are shown below in Table II. Table II Different composition of materials in M30 mix as per **IS 10262:2009**

TABLE II. PROPORTION OF CSA

Mix	% of Cement	% of Sludge	Fine Aggregate (kg/m3)	Course Aggregate (kg/m3)	Cement (kg/m3)	Sludge (kg/m3)	Water (kg/m3)
S 0%	100%	0%	732	1139	394.0	0.00	197.00
S 2%	98%	2%	732	1139	386.12	7.88	193.06
S 5%	95%	5%	732	1139	374.43	19.70	187.15
S 10%	90%	10%	732	1139	354.60	39.40	177.30

The dimensions of cube molds were 150mm*150mm*150mm. Reference cubes of M30 grade with 0% sludge content were also casted of same ages as 28 days, 90 days and 180 days. These cubes were casted for comparing the results with the cubes containing 2%, 5% and 10% sludge.

E. Procedure for Obtaining Correlation between Compressive Strength of Concrete and Rebound Number

[5] The most satisfactory way of establishing a correlation between compressive strength of concrete and its rebound number is to measure both the properties simultaneously on concrete cubes. The concrete cubes specimens are held in a compression testing machine under a fixed load, measurements of rebound number taken and then the compressive strength determined as per IS.516: 1956. The fixed load required is of the order of 7 N/mm2 when the impact energy of the hammer is about 2.2 N-m. The load should be increased for calibrating rebound hammers of greater impact energy and decreased for calibrating rebound hammers of lesser impact energy. The test specimens should be as large a mass as possible in order to minimize the size effect on the test result of a full scale structure. 150 mm cube specimens are preferred for calibrating rebound hammers of lower impact energy (2.2 N-m), whereas for rebound hammers of higher impact energy, for example 30 N-m, the test cubes should not be smaller than 300 mm. If the specimens are wet cured, they should be removed from wet storage and kept in the laboratory atmosphere for about 24 hours before testing. To obtain a correlation between rebound numbers and strength of wet cured and wet tested cubes, it is necessary to establish a correlation between the strength of wet tested cubes and the strength of dry tested cubes on which rebound readings are taken. A direct correlation between rebound numbers on wet cubes and the strength of wet cubes is not recommended. Only the vertical faces of the cubes as cast should be tested. At least nine readings should be taken on each of the two vertical faces accessible in the compression testing machine when using the rebound hammers. The points of impact on the specimen must not be nearer an edge than 20mm and should be not less than 20mm from each other. The same points must not be impacted more than once. In this experimental study 5 reading were taken on one plane side of the cubes with impacting it with the rebound hammer at an angle of 180 degree.

F. Procedure for Compression Test under Universal Testing Machine

Dimension of test cube is measured at three different places along its height/length to determine the average cross-section area.

1) Ends of the cube should be plane for that the ends are tested on a bearing plate.
2) The specimen is placed centrally between the two compression plates, such that the center of moving head is vertically above the center of specimen.
3) Load is applied on the specimen by moving the movable head.
4) The load and corresponding contraction are measured at different intervals.
5) Load is applied until the cube fails.
6) Data is recorded after the cube fails.
7) The computer shows the stress-strain graph
8) The maximum load taken by the cube and the compressive strength of concrete.

II. RESULTS AND DISCUSSION

A. Rebound Hammer Testing

The rebound hammer tests were conducted on cubes of dimensions 150*150*150mm. Cubes with sludge percentage of 2%, 5% and 10% were placed under the compressive testing machine under a constant force on a

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cleaned cube surface(cleaned with the help of a porous stone) after a period of 28 days, 90 days and 180 days.

The compressive strength of the concrete cubes were determine by referring the [7] graph given below:

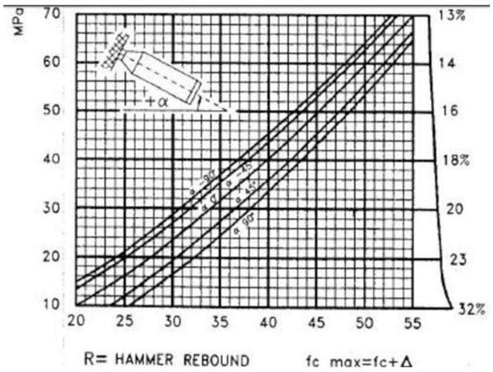

Figure 1. Rebound number Caliberation chart

The results recorded were as follows:

TABLE III. REBOUND HAMMER TEST FOR (28 DAYS)

SAMPLE	REBOUND HAMMER VALUE	KG/M³ 0°	MEAN COMPRESSIVE STRENGTH VALUE
REF	28 32 30 28 34 30 28 30 31 27	180 238 210 180 260 210 180 210 220 165	30.43
S 2%	28 26 25 26 28 32 31 30 28 27	180 158 140 168 180 238 220 210 180 165	28.11
S 5%	29 28 27 25 32 24 27 26 25 28	190 180 165 140 238 130 165 158 140 180	27.01
S 10%	28 22 25 24 27 25 27 25 26 24	180 110 140 130 165 140 165 140 158 130	24.88

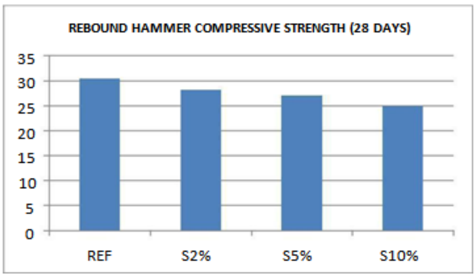

Figure 2. Rebound hammer compressive strenght (28 days)

TABLE IV. REBOUND HAMMER TEST FOR (90 DAYS)

SAMPLE	REBOUND HAMMER VALUE R	∝-0° KG/CM³	MEAN COMPRESSIVE STRENGTH VALUE (MPa)
S 0% C 100%	32 36 32 28 34 30 32 32 31 34	238 290 238 180 260 210 238 238 220 260	32.77
S 2% C 98%	28 26 26 29 28 33 31 33 33 29	180 158 158 190 180 250 220 250 250 190	29.625
S 5% C 95%	29 28 27 29 32 28 29 28 22 30	190 180 165 190 238 180 190 180 110 210	28.085
S 10% C 90%	30 27 26 24 27 25 26 25 29 26	210 165 158 130 165 140 158 140 190 150	26.54

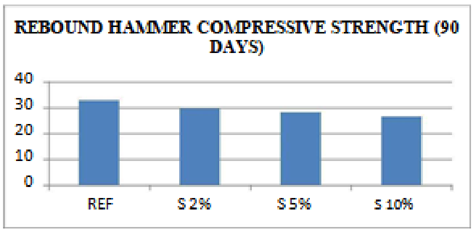

Figure 3. Rebound hammer compressive strength (90 days)

TABLE V. REBOUND HAMMER TEST FOR (180 DAYS)

SAMPLE	REBOUND HAMMER VALUE R	∝-0° KG/CM³	MEAN COMPRESSIVE STRENGTH VALUE
S 0% C 100%	32 34 30 30 32 32 34 36 32 30	238 260 210 210 238 238 260 290 238 210	32.88
S 2% C 98%	32 38 30 28 32 32 29 26 24 29	238 320 210 180 238 238 190 158 130 190	29.7
S 5% C 95%	30 27 26 27 27 29 26 25 29 26	210 165 158 165 165 190 158 140 190 158	27.77
S 10% c 90%	31 26 22 24 26 26 28 24 24 28	220 158 110 130 158 158 180 130 130 180	25.22

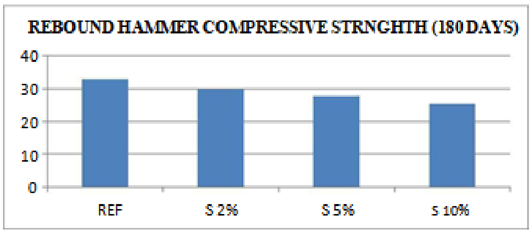

Figure 4. Rebound hammer compressive strength (180 days)

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B. Test Under Universal Testing Machine

For the determination of compressive strength of concrete with sludge percentage of 2%, 5% and 10%, there were 150*150*150*mm cubes were casted of different ages (28 days, 90 days and 180 days) and were tested under the UTM for the compression test. The maximum capacity of the UTM was 1000KN. The cubes were placed in such a manner that the load applied on the perfectly plane and smooth side of the cube so that there is no partial distribution of load. The loading rate on the cube was 125KN/min.

The results recorded were as follows:

TABLE VI. COMPRESSIVE STRENGTH (28 DAYS)

SAMPLE	COMPRESSIVE STRENGTH (KN/mm^2)	MEAN COMPRESSIVE STRENGTH (KN/mm^2)
REF	27.656 26.954	**27.305**
S 2%	25.450 25.139	**25.294**
S 5%	22.451 21.414	**21.904**
S 10%	18.165 19.444	**18.804**

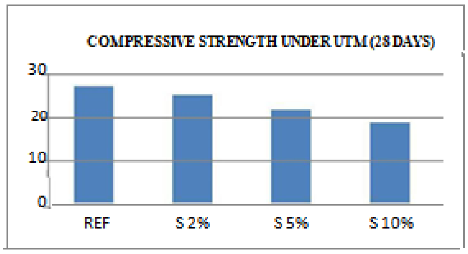

Figure 5. Compressive Strength Under UTM (28 Days)

TABLE VII. COMPRESSIVE STRENGTH (90 DAYS)

SAMPLE	COMPRESSIVE STRENGTH (KN/mm^2)	MEAN COMPRESSIVE STRENGTH (KN/mm^2)
REF	37.589 24.460 27.360	**29.80**
S 2%	24.000 30.489 28.311	**27.60**
S 5%	24.091 25.484 25.067	**24.88**
S 10%	22.900 23.333 23.312	**23.18**

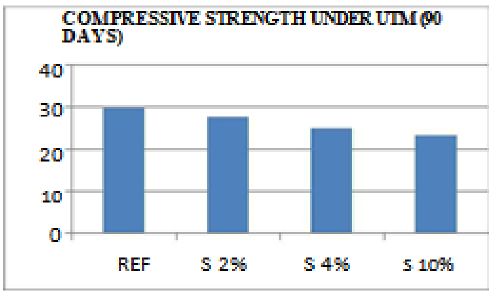

Figure 6. Compressive strength under utm (90 days)

TABLE VIII. COMPRESSIVE STRENGTH (180 DAYS)

SAMPLE	COMPRESSIVE STRENGTH (KN/mm^2)	MEAN COMPRESSIVE STRENGTH (KN/mm^2)
REF	28.973 28.330	**28.656**
S 2%	28.820 29.573	**29.196**
S 5%	23.820 24.091	**23.955**
S 10%	24.030 24.300	**24.165**

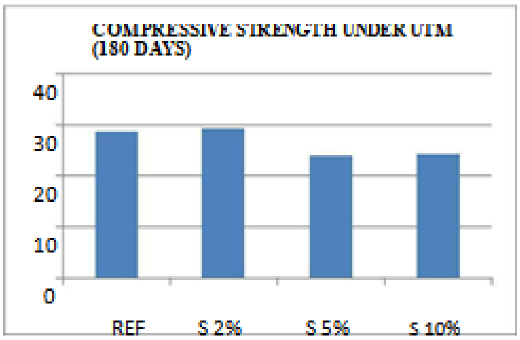

Figure 7. Compressive strength under UTM (128 days)

As seen through the graphical representation of the compressive strengths of the concrete with different sludge composition of 2%, 5% and 10% we can observed that:

The Non-destructive method of testing or also called as the Schmidt Rebound Hammer testing method was efficient in calculating the compressive strength of the concrete.

As seen in destructive testing method the cube was destroyed after testing hence the sample cannot be used for other testing or experiments.

As seen in the graphical representation below we can see that the compression strength measured by both Rebound Hammer and UTM have some correlation between them and can be compared.

The strength measured is almost same and nominal in both Rebound Hammer and UTM.

As we can see via graphical representation, the sludge content affects the concrete strength as it reduces the compressive strength.

After addition of 2% of sludge we can see the strength of concrete is reduced but it is nominal for construction purpose.

The strength of concrete after adding 5% of sludge we observed that the strength decreases but it is not nominal for construction or it may be used for specific loading conditions

The strength in concrete when 10% sludge is added, it decreases drastically can can't be used for any construction purpose. As the cube was of M30 grade, the compressive strength was not at all nominal for construction.

C. Correlation between the Rebound Hammer and the UTM

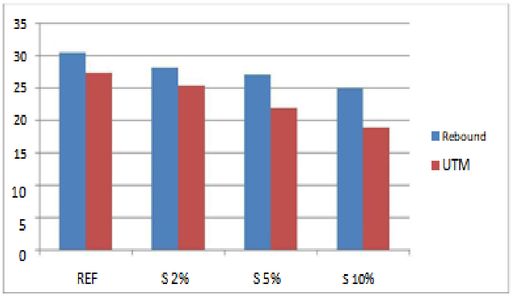

Figure 8. Comparison for cubes after 28 days of curing by UTM and rebound hammer.

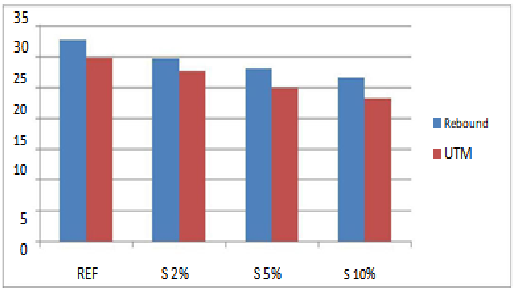

Figure 9. Comparison for cubes after 90 days of curing by UTM and rebound hammer.

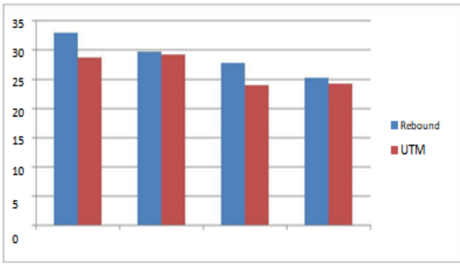

Figure 10. Comparison for cubes after 180 days of curing by UTM and rebound hammer.

III. CONCLUSION

The compressive strength obtained for 2% sludge content is nominal for construction as M30 grade concrete cubes were casted and as compared to the reference cube of M30 grade the compressive strength was found to be similar.

The cubes which have 5% of sludge content the compressive strength was lower as compared to the reference cubes were casted.

The cubes of 5% sludge content it was observed that the compressive strength was quite low and hence it is not suitable for construction purpose but can be used for some specific loading.

For the 10% sludge content the compressive strength was drastically low and hence it cannot be used for construction.

As for the correlation between the non-destructive and the destructive testing, the results on both rebound hammer and the UTM was similar.

The rebound hammer is considerably suitable because the cubes are not destroyed as in the UTM and can be reused for further experiments.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Author Neelabh Singh, Satvik Pratap Singh, Pranjal Chaudhary and Bhargav Tukadiya contributed in the execution of the project. Author Neelabh Singh wrote the content of the paper and concluded the project. Author Dr. Anantha singh and Dr. Niragi dave came up with the idea of using c.e.t.p sludge in concrete and they helped in the processing of the project.

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Neelabh Singh born on 23rd December 1996 is currently pursuing B. Tech (final year) in Civil Engineering at Pandit Deendayal Petroleum University Gandhinagar, Gujarat, India and have presented his paper in conference ICCUE 2019.

Anantha Singh is a Assistant Professor and has done his B.E. (Civil Engineering, Sun College of Engg and Tech., Nagercoil/Anna University Chennai), 2009. M.Tech. (Environmental Engineering, National Institute of Technology Trichy), 2011. Ph.D (Environmental Engineering, National Institute of Technology Trichy), 2014. His professional Affiliation- Certified Lead Auditor for Environmental Management System ISO 14001. **Accolades-** Anna University Chennai, 37th rank holder in BE- Civil Engineering (2005-2009 batch) Awarded first prize in the views talk, in SELECT-X3, organized by CSIR- CECRI, 15th-16th February- 2013 Own 25000 cash prize in the poject presentation competition organized by Hi-Tech solution and IIM Ahmedabad.