To Study the Behavior of Concrete Under NDT and DT Test by Partial Replacement of Sand with Stone Dust and form Relationship between NDT Parameters & Compressive Strength of Concrete

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Abstract : The infrastructure is developing day by day leads to increase in demand of concrete. Construction activity is readily dependent on concrete directly or indirectly., which significantly increase the demand of natural resources like sand (which is limited in nature) and using it significantly increase the impact on environment which result in erosion of river bed, lowering of water table etc. So, there is need to find the alternative for natural sand. Stone dust which is a waste produced in crusher while making aggregate, which can be used as an alternative of natural sand Stone dust has a similar specific gravity so it can be used. 24 Cubes of each grade has been casted and M20, M25, M30 grades are been casted and testes are being performed on them. NDT and DT tests are performed in them i.e. Compression testing using CTM (Compression testing machine) and in NDT Rebound hammer and ultrasonic pulse velocity tests are performed. Each cube is tested on 7days and 28 days and compression strength are found using all 3 tests and comparison is done and variation is found Between Compressive strength found using CTM and rebound hammer also variation is found between Compressive strength found using CTM and ultrasonic pulse velocity machine.IN CTM and Ultrasonic pulse velocity machine 3 readings are taken and then average is taken whereas in rebound hammer test 12 readings are taken from which the lowest and the highest is discarded and average is taken of 10 reading and rebound number is taken and using his rebound number compressive strength is found using the chart.

***Index Terms* - Non-Destructive test, Stone dust, Replacement, Rebound hammer, Ultrasonic Pulse Velocity.**

1.INTRODUCTION

Concrete is the most widely used man-made construction material in the world and is only second to water as the most utilized substance on the planet. A major portion of this concrete volume consists of coarse and fine aggregates. The selection of coarse and fine aggregates should be done carefully because they significantly influence the properties and durability of concrete. The demand for aggregates is enormous in the construction industry. The increased extraction of coarse and fine aggregates from the natural resources is required to meet this high demand. The increasing use of natural fine aggregate creates an ecological imbalance. Thus, the use of alternative a fine aggregate is vital in construction industry. The use of river sand as fine aggregate leads to exploitation of natural resources; lowering of water table, sinking of bridge piers and erosion of river bed. If fine aggregate is replaced by stone dust by specific percentage and in specific size range, it will decrease fine aggregate content and thereby reducing the ill effects of river dredging and thus making concrete manufacturing industry sustainable.

Aggregates are the important constituents in the concrete composite that help in reducing shrinkage and impart economy to concrete production. Most of the aggregates used are naturally occurring aggregates, such as crush rock, gravel and sand which are usually chemically interactive or inert when bonded together with cement. In region where natural sand deposits are scarce, stone dust is used as an alternative source of sand. The construction of rigid pavement, small to medium span bridges and culverts and buildings up to six stories high using stone dust concrete are quite common as stone dust is easily available in most of the region and are much cheaper as compared to natural sand. In spite of its extensive use and the apparent satisfactory performance of the structure built by concrete using stone dust, no systematic investigation on mix design of stone dust concrete has been conducted.

On the other hand, the modern technological society is generating substantially high amounts of solid wastes both in municipal and industrial sectors; posing an engineering challenging task for this effective and efficient disposal. Hence, partial or full replacement of fine aggregates by the other compatible materials like sintered rock dust, quarry dust, glass powder, recycled concrete dust, and others are being researched from past two decades, in view of conserving the ecological balance. Even though, use of several types of industrial solid wastes like metallurgical waste, glass pieces, quarry dust, tyre and rubber waste, crushed concrete waste, sludge's and others in making good field concrete is being effectively done at European countries, U.S.A., U.K., and Australia; Asian countries could not gear up to that level to match with those countries.

An enormous quantity of stone dust is generated all around the world; most of which is being dumped into landfill sites. The land filling of stone dust is undesirable because it is environmentally less friendly. India produces over two million tons of stone dust through specified sizes for use as aggregate in various applications such as, grit plastering, sand cover for sport turf and sand replacement in concrete. Concrete is most widely used man made construction material and its demand is increasing day by day.

When stone dust are reused in making concrete products, the production cost of concrete will go down This move will serve two purposes; first, it will be environment friendly; second, it will utilize in place of precious and relatively costlier natural resources.

2.OBJECTIVES OF STUDY

The main objective of the present study is to compare between strength and workability of different designed concrete mix by partial replacement of fine aggregate using stone dust. At the same time the Non Destructive study has also been conducted using (1) Rebound Hammer Apparatus and (2) Ultrasonic Pulse Velocity Apparatus. Following are the parameters of study.

- Replace natural fine sand by crushed stone. The following are the combinations
- (i) 100 % sand (ii) 80% sand, 20% crushed stone (iii) 60% sand, 40% crushed stone (iv) 40% sand,60% crushed stone.
- Grade of Concrete: The following grades of concrete have been designed
  (i) M-20 (ii) M-25 (iii) M30 grade. The strength at the end of 7 days, and 28 days has been studied. The workability of concrete has also been measured by slump test.

[1] Non Destructive Tests: - Non Destructive study has also been conducted
(i)Rebound Hammer Apparatus
(ii)Ultrasonic Pulse Velocity Apparatus

2. Materials used

The experimental study has been conducted in the laboratory using following materials are used.
Cement: OPC (Ordinary Portland Cement) conforming to IS 1489 -1991 part 1 brand name J.K. Cement is used in the entire work.

Sand: Fine aggregate resulting from natural disintegration of rock and which has been deposited by stream or glacier agencies. Aggregate which passes 4.75 mm IS sieve and contains 75 micron and conforms to IS 383-1970, zone -2 used in entire work.

Aggregate: Naturally occurring crushed stone passing 20 mm and retained 4.75mm IS sieve is used.

Crushed Stone: It is an ideal material for recycling or waste and was obtained from the aggregate mine. Its particle size was ranging from 4.75mm to 0.075 mm in order to achieve the grading of fine aggregate.

Water: Potable water was used for making the concrete of different grades.

The different ingredient namely cement fine & coarse aggregate stone dust have been purchased from the market. Cement used in this study is "OPC" which is available under the commercial name "J.K. Cement".

S. No.	Name of Test	Results Obtained	Standard as per IS:1489 (part1) 1991
1	Consistency	38.00%	
2	Initial Setting Time	96 Min	Not less than 30 Min
3	Final Setting Time	360Min	Not more than 600 Min
4	7 Days Compressive strength	22.39 MPa	Not less than16 MPa
5	28 Days Compressive strength	35.67 MPa	Not less than 22 MPa

TABLE I
Lab Test Results Conducted on Cement

specific gravity of cement is 3.15 and satisfy the requirement of IS: 1489(Part I)-1991. The Various tests were conducted in the laboratory and the results are tabulated in Table I while the grading of sand, crushed stone and aggregate is given in Table II.

Sieve size mm	Percentage of passing		
	Sand	Crushed Stone	Coarse Aggregate
40	-	-	100
20	-	-	12.68
10	100	100	0.27
4.75	95.6	90.24	0.0
2.36	93.6	75.24	-
1.18	87.8	52.19	-
600	85.72	31.44	-
300	79.54	21.23	-
150	76.34	5.27	-
Pan	75.34	0.00	0.0
Fineness Modulus	2.7	3.24	7.87
Specific	2.67	2.75	2.85

Gravity			

TABLE II
Grading of Aggregates

3. Methodology adopted

After procuring the ingredient required for making the concrete the design of concrete mixes of M-20, M-25 and M-30 Grades was done for natural fine and coarse aggregate. Concrete cubes of 150 mm size were casted after mixing the stipulated quantities of several ingredients. There are three grades of concrete i.e. M20, M25, M30 and four different combinations of natural sand and artificial crushed stone

That are 0% stone dust & 100% sand , 20% stone dust and 80% sand , 40% stone dust & 60% sand, 60% stone dust and 40% sand . These all proportions cubes were casted and then kept in curing tank for 7days and 28 days. After 7 days cubes strength was tested in CTM(Compression testing machine)

,Rebound hammer and Ultrasonic pulse velocity machine .in CTM 3 cubes of same grade and same proportion was tested and average reading is taken whereas in rebound hammer 12 readings is taken from which max and min is eliminated and then 10 readings average is taken. Using this readings the comparison is done between Rebound hammer and compressive strength(C.T.M) , also between Compressive strength (CTM) and Ultrasonic pulse velocity.

4.Non-Destructive Testing (NDT)

Non-destructive testing (NDT) is defined as the course of inspecting, testing, or evaluating materials, components or assemblies without destroying the service ability of the part or system. The purpose of NDT is to determine the quality and integrity of materials, components or assemblies without affecting the ability to perform their intended functions. Extensive attempts and advancements have been made to develop NDT methods capable of indicating mechanical, acoustical, chemical, electrical, magnetic, and physical properties of materials. One of the earliest documented attempts of NDT dates to the 19th century where cracks were detected in railroad wheels by means of acoustic tap testing. More sensitive, reliable and quantifiable NDT methods have expansively emerged in recent years. NDT methods have materialized as a response to the need for structural damage detection and prevention. The major factors that influence the success of a non-destructive survey are depth of penetration, vertical and lateral resolution, contrast in physical properties, signal-to-noise ratio and existing information about the structure. The understanding of material properties and the key issues associated with their application in structural engineering is imperative for the success of any NDT method.

5.Determination of Rebound Number

The Standard Rebound Hammer provides a simple, easy and inexpensive method to estimate concrete strength properties. However, the results of the test on concrete are affected by various factors such as smoothness of the surface, geometric properties of the test specimen, age of the test specimen, surface and internal moisture conditions of the concrete, type of coarse aggregate, type of cement, type of mold and carbonation of the concrete surface. Strength estimation from rebound readings of specimens similar to correlation curve specimens are achieved within an accuracy of 15%to 20% (Concrete Institute of Australia, 2008). It is therefore recommended that the standard rebound hammer test be used as a method of testing variability of strength
properties between concrete samples rather than as a substitute for standard compression testing.

The factors that contribute to within-test variability are attributable to operator error, equipment error, size of aggregates and the cubes (6 cubes for crushing strength at 7 days curing and 6 cubes for crushing strength at 28 days of curing) of each grade and each combination were prepared for testing the crushing strength rebound hammer and ultra sonic pulse velocity. Thus there are 144 numbers of concrete cubes were casted and kept immersed in curing tank. The workability of concrete mixes was measured by the slump tests. The most significant factor that affects within-test variability is aggregate size. For example, a 5% coefficient of variation is expected for testing samples of 20mm aggregate size; whereas, a 14% coefficient of variation is expected for samples of 55mm aggregate size. Nevertheless, variations in the estimated early strength of concrete are low to moderate, which provides a reasonable degree of accuracy and certainty for the removal of form work in concrete constructions. Using this chart the compressive strength is found using the rebound number, which depends on the angle in which rebound hammer is used , using the curve of the angle on which rebound hammer is used the compressive strength is determined.

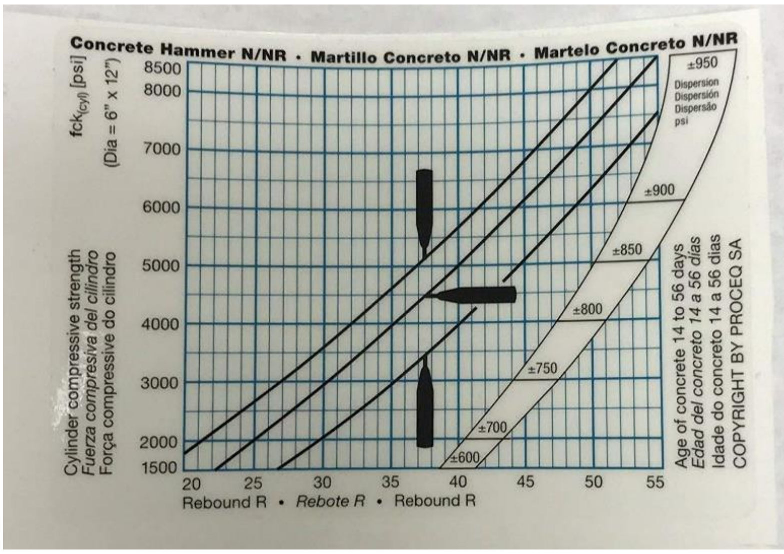

Fig 1:Chart of rebound hammer

7.Ultrasonic Pulse Velocity

Ultrasonic pulse velocity methods involve propagating ultrasonic waves in solids while measuring the time taken for the waves to propagate between a sending and receiving point. The features of ultrasonic wave propagation can be used to characterize a material's composition, structure, elastic properties, density and geometry using previously established correlations, known patterns and mathematical relationships. This non-invasive technique is also use to detect and describe flaws in material as well as their severity of damage by observing the scattering of ultrasonic waves. The basic technique of ultrasonic pulse velocity methods involve the transformation of a voltage pulse to an ultrasonic pulse and back by a transmitting and receiving transducer respectively. The transmitting transducer is placed onto the concrete surface and is allowed to transmit an ultrasonic pulse through the specimen medium. The ultrasonic pulse travels through the concrete specimen and is detected by a receiving transducer at the opposite end which transforms the ultrasonic pulse to a voltage pulse .Knowing the distance between the two points, the velocity of the wave pulse can be determined. The velocity of the ultrasonic pulse provides a detailed account of the specimen under investigation. The following publications present standard guidelines for ultrasonic pulse velocity testing:
ASTM C 597: Standard Test Method for Pulse Velocity through Concrete.
BS EN 12504-4:2004 Testing Concrete. Determination of Ultrasonic Pulse Velocity

8.Observation

Curing Time	Concrete Grade	Combination of sand and crushed stone	Slump Value (mm)	Crushing Load (kN)	Rebound Hammer Number	Ultrasonic Pulse Velocity (cm/Sec)	Crushing Strength (σ_C) (MPa)	Crushing Strength (σ_R)based on equation Using RHN	% Variation in σ_R & σ_C	Crushing Strength (σ_U)based on equation Using UPV	Crushing Strength (σ_U)based on equation Using UPV
1	2	3	4	5	6	7	8	9	10	11	12
7 Days	M20	100	45	351	17.5	4219	15.6	17.12	-9.76	17.26	-10.65
	M20	80 -20	40	399	24	4222	17.73	18.10	-2.04	17.28	2.55
	M20	60 - 40	35	416	25.5	4420	18.49	18.32	0.91	18.63	-0.75
	M20	40 - 60	35	436	23.5	4350	19.38	18.02	7.00	18.15	6.33
	M25	100	40	403	24	4418	17.91	18.10	-1.03	18.61	-3.93
	M25	80 -20	35	398	19.5	4439	17.69	17.42	1.51	18.76	-6.04
	M25	60 - 40	35	427	24.5	4451	18.98	18.17	4.25	18.84	0.73
	M25	40 - 60	30	422	25.5	4450	18.76	18.32	2.32	18.83	-0.41
	M30	100	45	419	33	4362	18.62	19.44	-4.41	18.23	2.09
	M30	80 -20	45	434	29	4503	19.29	18.84	2.30	19.19	0.50
	M30	60 - 40	40	422	31	4295	18.76	19.14	-2.07	17.78	5.21
	M30	40 - 60	40	426	31	4403	18.93	19.14	-1.11	18.51	2.22
28 Days	M20	100	45	578	24	4409	25.69	26.89	-4.69	26.69	-3.88
	M20	80 -20	40	601	25.5	4322	26.71	26.82	-0.43	26.22	1.86
	M20	60 - 40	35	624	26	4560	27.73	26.80	3.36	27.50	0.84
	M20	40 - 60	35	651	23.5	4378	28.93	26.92	6.97	26.52	8.35
	M25	100	40	568	27.5	4214	25.24	26.73	-5.90	25.63	-1.54
	M25	80 -20	35	586	27.5	4287	26.04	26.73	-2.65	26.03	0.07
	M25	60 - 40	35	604	31	4370	26.84	26.57	1.01	26.47	1.38
	M25	40 - 60	30	587	29	4324	26.09	26.67	-2.21	26.23	-0.53
	M30	100	45	654	34.5	4416	29.07	26.42	9.12	26.72	8.06
	M30	80 -20	45	662	33.5	4393	29.42	26.46	10.07	26.60	9.60
	M30	60 - 40	40	667	34	4365	29.64	26.44	10.82	26.45	10.78
	M30	40 - 60	40	672	33	4347	29.87	26.48	11.33	26.35	11.77

Table III Laboratory Test Results of Crushing, Strength, NDT Parameters & Workability

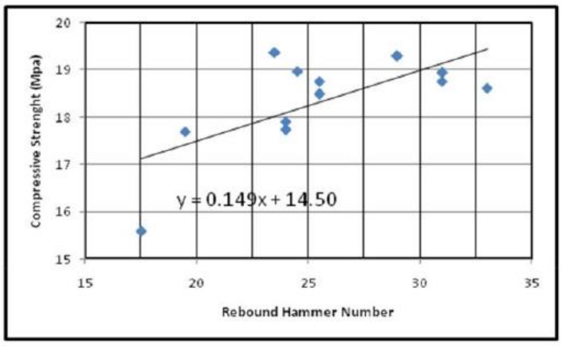

FIG. 1(a)
Graph between 7 days Crushing strength and Rebound Hammer Number

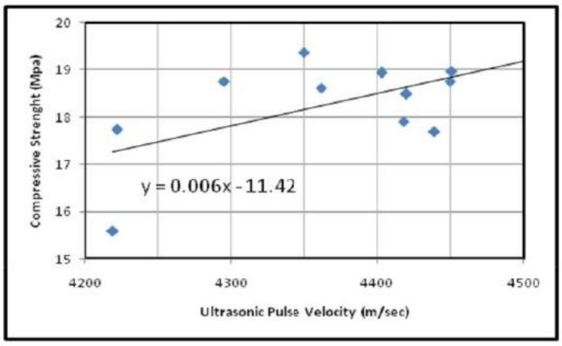

FIG.2(a)
Graph between 7 days Crushing Strength and Ultrasonic Pulse Velocity

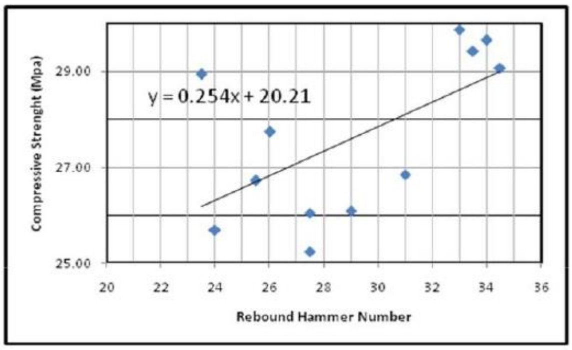

FIG. 1(b)
Graph between 28 days crushing strength and Rebound hammer number

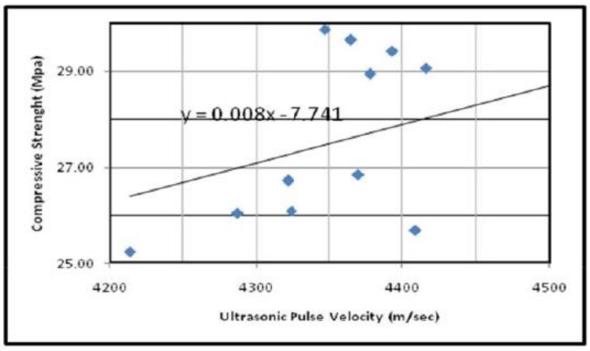

FIG. 2(b)
Graph between 28 days Crushing Strength and Ultrasonic Pulse Vek

9.RESULT AND DISCUSSION

In conducting the experimental studies to replace the fine aggregate with artificial crushed stone and attempting to established a relationship between the crushing strength of concrete with NDT parameters viz. Rebound Hammer Number (R) and Ultrasonic Pulse Velocity (V) a total of 144 cubes of size 150 mm were prepared using the stipulated amount of different ingredients. Six numbers of cubes of specified grade and selected proportion of natural fine sand and artificial crushed stone were taken out of the tank kept for curing of cubes after 7 days and were tested for Rebound Hammer Number, Ultrasonic Pulse Velocity and compressive strength. Similarly six cubes were tested for above parameters after 28 days of curing.

The Rebound Hammer Number (RHN) and Ultrasonic Pulse Velocity (UPV) were recorded for the different faces of cubes and averaging was done. The observations of Crushing Strength (S), RHN (R) and UPV (V) along with other details are tabulated in table 3. After finding the crushing strength (7days) and NDT parameters, a graph is drawn between seven days crushing strength of concrete (MPa) and rebound hammer number and is shown in Fig 1(a). Similarly, another graph is drawn between twenty eight days crushing strength of concrete (MPa) and rebound hammer number and is shown in Fig 1(b)

The equation of this line was found to be follows.

S_7= (0.1497)*R+14.503

S_{28}= - (0.0455)*R+27.985

Where, R= Rebound Hammer Number, S_7= 7 Days crushing strength, S_{28}= 28 Days crushing strength

Based upon the above equation the strength of concrete cubes was calculated and percentage deviation between the above calculated value and those found in the laboratory was also calculated. These values are also tabulated in Table 3 (column 8 and 9)

Similarly a graph between the seven days crushing strength of concrete (s in MPa) and Ultrasonic Pulse Velocity (m/sec) was drawn and shown in Fig. 2(a) and another graph between twenty eight days crushing strength of concrete and Ultrasonic Pulse Velocity was drawn and shown in Fig. 2(b)

The equation of this line was found to be as follows.

S_7= (0.0068)*V - 11.428

S_{28}= (0.0054)*V+2.8766

Where, V= ultra sonic pulse velocity (m/sec), S_7= 7 Days crushing strength, S_{28}= 28 Days crushing strength.

Based upon the above equation the strength of concrete cubes was calculated and percentage deviations between the above calculated value and those found in the laboratory was also calculated. These values are tabulated in table 3(column 10 and 11).From table 3 it is observed for M-20 & M-25 grades of concrete the characteristics strength was achieved at 28days curing while for M30 grade the achieved strength after 28 days is marginally below the characteristics strength.

10.CONCLUSIONS

In this experimental study the mix of M 20, M25 and M30 with different ratio of sand & crushed stone were prepared and tested for workability and compressive strength at 7 and 28 days curing. In addition the NDT (i.e. Rebound Hammer Number & Ultrasonic Pulse Velocities) were done. Based upon the experimental observations following conclusions can be drawn from this study:

1. The crushed stone can easily used in place of natural sand which is becoming a scare material up to 60% by weight for different grades of concrete without the much difference in crushing strength either at the end of 7 or 28 days.

2. The Non Destructive Tests i.e. Rebound Hammer and Ultrasonic Pulse Velocity can be used to evaluate the compressive strength of concrete.

3. A relationship between NDT parameters and Compressive Strength of Concrete at 7 and 28 days can be developed.

4. Workability of concrete decrease with increase in percentage of crushed stone.

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