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Correlation Between Ultrasonic Pulse Velocity And Concrete Compressive Strength

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Abstract—Ultrasonic pulse velocity is used to evaluate the compressive strength of concrete which was used in Plain jointed cement concrete pavements laid in Kalyan –Dombivli area during 2014. It is used to determine the concrete quality by using regression analysis model between compressive strength and ultrasonic pulse velocity values. For this study 40 concrete cores were extracted from Plain jointed cement concrete pavements. First of all the ultrasonic pulse velocity of the concrete cores was determined and then the cores were crushed under compression. A good correlation is found to exist between the concrete compressive strength and ultrasonic pulse velocity.

Keywords-ultrasonic pulse velocity; regression analysis; correlation; compressive strength; determination coefficient.

I. INTRODUCTION

The infrastructure, particularly the road network, has been given a high priority by the government of India. To modernize and upgrade our road system in order to bring it in line with the best in the world, it would be imperative to provide it with long lasting, maintenance free pavements, which are unaffected by the weather. Concrete roads have a long life of 30 years or more and do not develop ruts or potholes. They are not adversely affected by floods and other vagaries of weather. They reduce fuel consumption of load carriers using them. Concrete pavements meet all the required parameters and hence are ideally suited for Indian roads. India has a road network of over 46, 89,842 kilometers in 2013 and it is the second largest road network in the world. India's road network carries over 65 percent of its freight and about 85 percent of passenger traffic. The country, at present has taken up massive road programs including construction of expressways, four laning of major corridors, construction of rural roads etc.

The salient features of the Portland cement concrete (PCC) pavement construction of the study area are presented below.

Table 1. Salient features of the pavement

Type of PCC pavement	Jointed plain concrete
Concrete grade	M 40
Cement used	OPC 53 grade
Concrete batching	Weigh batching
Concrete source	Ready Mix Concrete
Curing period	14 days wet curing
Joint cutting	Machine cutting after setting concrete
Contraction joints	After every 4.5 m
Expansion joints	After every 45 m
Size of pavement block	3.5mx4.5m

A general cross section of the concrete pavement above the existing crust is presented below:

300 mm thick PQC layer
150 mm thick DLC layer
250 mm thick GSB layer

Figure 1. Cross section of pavement

So far as the concrete road construction is considered, it is difficult to predict the quality of construction by visual inspection or by knowing the quality of raw materials used. So it needs to take samples (cores) for laboratory testing from constructed pavement to check the quality of construction. Destructive tests thus give clear idea about the quality of construction in terms of strength while non-destructive test is fast, easy to use at site and relatively less expensive which can give impressive results when used correctly without damaging the structure.

II. EXPERIMENTAL

The pavement slabs were evaluated by extracting concrete cores from chosen locations and testing them under compression, in order to ascertain the strength of concrete and physically inspect the quality of construction. Prior to crushing, concrete cores were also tested for their ultrasonic pulse velocity. Total 40 concrete cores were taken from study area in Kalyan-Dombivli for testing. Concrete cores were received in laboratory after proper dressing, capping etc. Pundit plus ultrasonic pulse velocity testing machine is used for testing cores using direct transmission i.e. cross probing in the laboratory. This test essentially consist of measuring travel time, T of ultrasonic pulse of 50 to 54 KHz, produced by an electro-acoustical transducer, held in contact with one plane surface of concrete core under test and receiving the same by a similar transducer, held in contact with other plane surface at the other end. With the path length L, (i.e. the distance between the two probes) and time of travel T, the pulse velocity (V=L/T) is calculated.

Test specimens:

Test specimens consisted of 40 concrete cores having height of 280 mm and diameter of 143 mm for 36 concrete cores and remaining 4 concrete cores were having height of 300 mm and diameter of 153 mm. The all 40 specimens were tested for the correct level of both plane surfaces after capping using sprit level. The cores were also tested for their axis being perpendicular to the plane surfaces over which capping is done. Contact surfaces of most of the concrete cores were found to be sufficiently smooth and it ensured good acoustical contact by the use of the coupling medium (grease) and by pressing the transducer against the concrete surface.

Experimental setup of UPV test:

The PUNDIT PLUS ultrasonic pulse velocity testing machine used for the study is shown below along with electrical pulse generator, a pair of transducer, amplifier and electronic timing device. Some of concrete cores are shown below.

Figures 2&3. Setup of UPV machine and concrete cores

The appearance of concrete, any evidence of apparent honeycombing and exposure of reinforcement were studied by visual inspection. After the concrete cores were tested for ultrasonic pulse velocity, the cores were also been tested on the same day for determination of their compressive strength values under compression testing machine. Prior to crushing of the concrete cores, their height, weight and diameter were noted. Also as per IS 516, the rate of loading on the compression testing machine was so set that the load was applied without shock and increased continuously at a rate of approximately 140 kg/sq.cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. The maximum load applied to the specimen was then recorded and the appearance of the concrete and any unusual features in the type of failure were noted.

III. RESULTS AND DISCUSSIONS

The results of the laboratory testing and correlation are shown below:

A. LABORATORY TEST RESULTS

Table 2. Core testing data

Core No.	Length of core(mm)	Cube Compressive strength (MPa)	UPV(m/sec)	Concrete quality as per IS 13311 Part1: 1992
1	300	18.82	2898.55	Doubtful
2	300	23.51	3018.10	Medium
3	300	28.26	3289.47	Medium
4	300	48.18	4087.19	Good
5	280	58.42	4294.47	Good
6	280	51.03	4216.86	Good
7	280	61.16	4154.30	Good
8	280	46.91	4191.61	Good
9	280	56.58	4255.31	Good
10	280	48.63	4281.34	Good
11	280	55.31	4229.60	Good
12	280	53.33	4381.84	Good
13	280	59.55	4105.57	Good
14	280	54.65	4255.31	Good
15	280	57.93	4255.31	Good
16	280	58.62	4287.90	Good
17	280	52.07	4341.08	Good
18	280	55.62	4301.07	Good
19	280	58.66	4294.47	Good
20	280	56.51	4281.34	Good
21	280	60.16	4223.22	Good
22	280	63.82	4320.98	Good
23	280	46.76	4236.00	Good
24	280	58.77	4301.07	Good
25	280	59.08	4287.90	Good
26	280	57.86	4274.80	Good
27	280	60.81	4301.07	Good
28	280	50.83	4334.36	Good
29	280	59.12	4216.86	Good

30	280	59.66	4341.08	Good
31	280	55.81	4287.90	Good
32	280	55.55	4301.07	Good
33	280	58.05	4334.36	Good
34	280	59.32	4327.66	Good
35	280	44.55	4416.40	Good
36	280	54.57	4191.61	Good
37	280	56.38	4185.35	Good
38	280	42.56	4320.98	Good
39	280	60.51	4261.79	Good
40	280	55.03	4287.90	Good

B. CORRELATION BETWEEN COMPRESSIVE STRENGTH AND UPV

Based on the experimental results, Tharmaratram and Tan gave the relationship between UPV in a concrete and concrete compressive strength as

$$F'c = ae^{bVc}$$

Where, F'c = concrete compressive strength in MPa;
a and b = constants;
Vc = UPV in m/sec.

Taking the population that includes 40 concrete cores a regression analysis between pulse velocity and compressive strength was performed, obtaining a correlation coefficient equal to 0.90 by using exponential model which is the best fitted for the relationship under study. Eq. (1) shows the obtained model.

$$F'c = 2.845e^{0.0007Vc} \qquad (1)$$

The dispersion diagram from the laboratory data is shown in figure 4

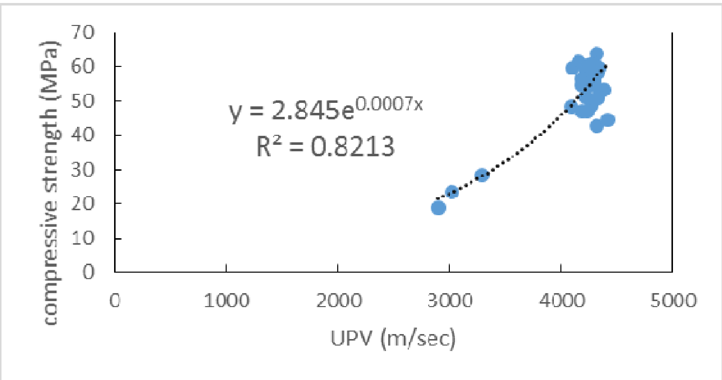

Figure 4. Correlation between UPV and compressive strength

IV. CONCLUSIONS

- Use The UPV test showed a consistent range of velocity for 37 concrete cores. As per IS: 13311 (Part 1): 1992, as the velocities obtained for 37 cores were in the range from 3500m/s to 4500m/s, the concrete is considered to be of good quality. One core is having velocity 2898.55m/s and it is considered as doubtful. Two cores were having UPV between 3000m/s to 3500m/s and are considered of medium quality. The results of the test were in agreement with the visual inspection of the cores.

- The correction factor for H/D ratio of 1.96 was found to be 0.99 from IS 516: Methods of tests for strength of concrete. The minimum equivalent cube strength of 18.82 MPa and maximum equivalent cube strength of 63.82 MPa was found for cores 1 and 22 respectively. First three concrete cores were found to have low strength. Out of 40 tested cores, 26 cores were found to have the equivalent cube compressive strength in between 50 MPa to 60 MPa. The cores did not show any evidence of apparent honeycombing and the appearance of concrete surface was good for all cores.
- A determination coefficient (R^2) of 0.82 indicates a good exponential relationship between UPV and compressive strength.

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