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Effect of Fly Ash and Quarry Dust on Properties of Concrete

K. Lakshmidevi ¹, A.V. Narasimha Rao ²

P.G. Student, Dept. of Civil Engineering, SVCET, R.V.S. Nagar, Chittoor, A.P, India¹

Professor, Dept. of Civil Engineering, SVCET, R.V.S. Nagar, Chittoor, A.P, India²

ABSTRACT: In the present work an attempt is made to study the effect of concrete when cement is replaced by fly ash at 0%, 10%, 20% and 30% by weight of cement, and sand by quarry dust at 20%, 30% and 40% by weight of sand for M₂₀ mix. The experimental studies are made to obtain the properties of concrete like the compression strength at the curing age of 7, 14, 28, 56 and 90 days and compressive strength of cylinders, split tensile strength, modulus of elasticity and ultrasonic pulse velocity of concrete at 28 days of curing period. Concrete mixtures were produced, tested and compared with the conventional concrete.

KEYWORDS: Concrete, Fly ash, Quarry dust, Compressive strength, Split tensile strength, Modulus of elasticity, Ultrasonic pulse velocity.

I. INTRODUCTION

The immense development in the developing countries creates a greater opportunity for infrastructure growth. The advancement of concrete technology can reduce the consumption of natural resources and energy sources and lessen the burden of pollutants on environment. In the past decade the addition of admixtures in concrete has become common in practice.

Fly ash, the most widely used supplementary cementitious material in concrete, is a by-product of the combustion of pulverized coal in electric power generating plants. Presently large amounts of fly ash are generated in thermal power plants with an adverse impact on environment and humans. In recent days there were many attempts to use fly ash as partial replacement for cement to have higher workability, long term strength and to make the concrete more economically available. The reduction in the sources of natural sand and the requirement for reduction in the cost of concrete production has resulted in the increased need to identify substitute materials to sand as fine aggregate in the production of concrete. Quarry dust, a by-product from the crushing process during quarrying activities is one of such materials. Granite fines or rock dust is a by-product obtained during crushing of granite rocks and is also called quarry dust. Quarry dust is known to increase the strength of concrete over concrete made with equal quantities of river sand, but it causes a reduction in the workability of concrete. The specific gravity depends on the nature of the rock from which it is processed and the variation is less. Shrinkage and water absorption is more in quarry dust when compared to that of the natural river sand.

To reduce the impact of the quarry dust and fly ash on environment and human beings, these waste by-products can be used to produce new products or can be used as admixtures in concrete so that the natural resources are used efficiently and hence environmental pollution can be reduced. This work describes the feasibility of using quarry dust as partial replacement of sand in addition to fly ash as partial replacement of cement in the production of concrete and to study the effect of these admixtures on the mechanical properties of concrete at different replacement levels and also to assess the quality grading of concrete.

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II. LITERATURE REVIEW

Abdullah Anwar et al. [1] studied the Compressive Strength of Concrete by Partial Replacement of Cement with High Volume Fly Ash and presented a brief review with mixtures containing 10%, 20%, 30% and 40% Fly Ash by the bulk of the cementitious material (OPC) for M_{30} and M_{40} grade of concrete. The test result indicates that the compressive strength of mix with 10%, 20% and 30% replaced with fly ash were more as compared with conventional concrete thus enhancing the durability of structures. When the percentage of replacement is increased the water/ binder ratio gets reduced, thereby, increasing the compressive strength. Also, it is observed that the compressive strength of concrete having more than 40% replacement of cement by fly ash suffers adverse effects though water/ binder ratio is gradually lost weight. The compressive strength of the concrete mix with 40% replacement with fly ash was lesser than the conventional concrete at 28 days. The result obtained for 28-day compressive strength confirms that the optimal percentage for replacement of cement with fly ash is about 30%. Yet, in reality approximately 50% of the Fly Ash produced throughout the world is stockpiled/land filled as a wasteland.

Balamurugan and Perumal [2] studied the behaviour of concrete by replacing sand by quarry dust. They reported that the variation in the strength of concrete when replacing sand by quarry dust from 0% to 100% in steps of 10%. M_{20} and M_{25} grades of concrete are taken for their study keeping a constant slump of 60mm. From their test results it is found that the maximum compressive strength, split tensile strength and flexural strength are obtained only at 50% replacement. So, they concluded that quarry dust can be utilized in concrete mixtures as a good substitute for natural river sand at 50% replacement with additional strength than control concrete.

Chandana Sukesh et al. [3] carried out a work on partial replacement of sand with quarry dust in concrete. The work mainly focus on the properties of concrete and to investigate some properties of quarry dust, the suitability of those properties to enable them to be used as partial replacement materials for sand in concrete. They concluded that the replacement of sand with quarry dust shows an improved in the compressive strength of the concrete and the ideal percentage of the replacement of sand with quarry dust is 55% to 75% in case of compressive strength. The further increasing the percentage of replacement can be made useful by adding the fly ash along with the quarry dust so that 100% replacement of sand can be achieved.

Felixkala and Partheeban [4] examined the possibility of using granite powder as replacement of sand along with partial replacement of cement with fly ash, silica fume and blast furnace slag. They reported that granite powder of marginal quantity as partial replacement to sand had beneficial effect on the mechanical properties such as compressive strength, split tensile strength and modulus of elasticity. They also reported that the values of plastic and drying shrinkage of concrete with granite powder were less than those of ordinary concrete specimens.

Jayeshkumar Pitroda et al. [10] had done the experimental investigations on partial replacement of cement with fly ash in design mix concrete and describe the feasibility of using the thermal industry waste in concrete production as partial replacement of cement. The use of fly ash in concrete formulations as a supplementary cementitious material was tested as an alternative to traditional concrete. The cement has been replaced by fly ash accordingly in the range of 0%, 10%, 20%, 30% and 40% by weight of cement for M_{25} and M_{40} mix. Concrete mixtures were produced, tested and compared in terms of compressive and split tensile strengths with the conventional concrete. These tests were carried out to evaluate the mechanical properties for the test results for compressive strength up to 28 days and split tensile strength for 56 days. This research concludes that fly ash can be innovative supplementary cementitious construction material but judicious decisions are to be taken by engineers.

Rama Raju et al. [13] had made an attempt to use quarry dust and fly ash as partial replacement for sand and cement respectively in SCC and to investigate some properties of quarry dust and fly ash and the suitability of those properties to enable them to be used as partial replacement materials for sand and cement in concrete. There was decrease in compressive strength initially the strength gained when quarry dust was increased to 100% replacing river sand fully. Even the strength was higher compared to the SCC with river sand and the maximum compressive strength observed was 60 MPa at 28 days. The optimum usage of fly ash content in place of cement can be 30%. The increase of fly ash content up to 30% showed an increase in compressive strength up to 54.81 MPa at 56 days in SCC containing 100%

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quarry dust and there was a decrease in compressive strength beyond the usage of 30%. When examining the qualities of fly ash and quarry dust it becomes apparent that if both are used together, the loss in early strength due to one may be alleviated by the gain in strength due to the other, but the results show that it was not possible.

Wankhede and Fulari [14] studied the effect of fly ash on the properties of concrete and stated that slump loss of concrete increases with increase in w/c ratio of concrete. Concrete with 10% and 20% replacement of cement with fly ash shows good compressive strength for 28 days than normal concrete for 0.35 w/c ratio for M₂₅ grade of concrete but in the case of 30% replacement of cement with fly ash ultimate compressive strength of concrete decreases.

III. MATERIALS

a) Ordinary Portland Cement

Cement used in the experimental work is Ordinary Portland Cement (OPC) of 53 grade (ZUARI brand) conforming to IS: 12269-1987. The various physical properties of cement are tabulated in Table 1.

Table 1 Physical properties of Ordinary Portland Cement

Sl. No.	Properties	Test values
1.	Specific gravity	3.13
2.	Standard consistency	33%
3.	Initial setting time	40min
4.	Final setting time	350min
5.	Fineness	6%
6.	Soundness	1mm

b) Fly Ash

In the present studies fly ash (Class F type) having specific gravity of 2.25 obtained from Rayalaseema Thermal Power Station which is located at Kadapa in Andhra Pradesh is used for the replacement of cement.

c) Fine aggregate

Locally available river sand passing through 4.75mm and retained on 150 micron IS sieves is taken as fine aggregate conforming to Zone-II as per IS 383-1970. The physical properties of sand are shown in Table 2.

Table 2 Physical properties of sand and quarry dust

Sl. No.	Properties	Test Values of Sand	Test Values of Quarry dust
1.	Specific gravity	2.58	2.64
2.	Bulking of sand	25%	27.56%
3.	Fineness modulus	3.12	3.18
4.	Bulk density i) Rodded bulk density ii) Loose bulk density	1718 kg/m ³ 1518 kg/m ³	1802 kg/m ³ 1746 kg/m ³
5.	Water absorption	1.22%	2.45%
6.	Particle size range	0.15 to 4.75mm	0.15 to 4.75mm

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d) Quarry dust

The quarry dust used throughout the experimental work is obtained from the quarry near Chittoor, Andhra Pradesh. The quarry dust passing through 4.75mm and retained on 150 micron IS sieves is taken. The physical properties of quarry dust are also shown in Table 2.

e) Coarse aggregate

The coarse aggregate is obtained from a local quarry. The coarse aggregate with size less than 20mm and greater than 12.5 mm having a specific gravity 2.76 and fineness modulus of 7.36 is used in the present study. The rodded and loose bulk density values obtained are 1605 kg/m³ and 1477 kg/m³ respectively and the water absorption is 0.41%.

f) Water

Water is an important ingredient of concrete as it initiates the chemical reaction with cement. Ordinary potable water is used throughout the investigation as well as for curing concrete specimens.

IV. MIX DESIGN

In this study the concrete mix design for M₂₀ grade of concrete is carried out according to Indian standard recommendation method as per IS 10262-2009 and IS 456-2000 to achieve the target mean compressive strength of 26.60 N/mm² at 28 days of curing period for M₂₀ grade of concrete. The concrete mix proportion (cement: fine aggregate: coarse aggregate) is 1: 1.27: 3.80 with water cement ratio of 0.55. The details of mix designations used in this experimental program are given in Table 3.

Table 3 Details of Mix designations

Sl. No.	Concrete mix Designation	Cement	Fly ash	Fine aggregate	Quarry dust	Coarse aggregate
1.	M0	100%	0%	100%	0%	100%
2.	M1	100%	0%	80%	20%	100%
3.	M2	90%	10%	80%	20%	100%
4.	M3	80%	20%	80%	20%	100%
5.	M4	70%	30%	80%	20%	100%
6.	M5	100%	0%	70%	30%	100%
7.	M6	90%	10%	70%	30%	100%
8.	M7	80%	20%	70%	30%	100%
9.	M8	70%	30%	70%	30%	100%
10.	M9	100%	0%	60%	40%	100%
11.	M10	90%	10%	60%	40%	100%
12.	M11	80%	20%	60%	40%	100%
13.	M12	70%	30%	60%	40%	100%

V. PREPARATION AND DETAILS OF SPECIMENS

The study is conducted to analyse the properties of concrete when the base materials i.e., when cement is replaced with fly ash and fine aggregate is replaced by quarry dust, respectively. The cement is replaced at 0%, 10%, 20% and 30% by fly ash and fine aggregate is replaced at 20%, 30% and 40% by quarry dust.

As the aggregate of size less than 20mm and greater than 12.5mm is used, cube moulds of size 150mmx150mmx150mm are used for compressive strength test and ultrasonic pulse velocity test. Cylindrical moulds of size 150mm diameter and 300mm height are used for casting specimens for compressive strength test of cylinders, split tensile test and modulus of elasticity test. Moulds are removed after 24 hours of casting and cured in water up to

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the date of testing. The cubes and cylinders are analysed after their curing periods. The each test result is the average test results of three specimens. The results of the replacements proportions of concrete are compared with that of the controlled concrete.

VI. RESULTS AND DISCUSSIONS

a) Compressive strength

Compressive strength test is the most common test conducted on hardened concrete as it is easy to perform and also most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. The tests are performed in a compression testing machine using cube and cylindrical samples. The compressive strength of concrete cubes are tested at 7, 14, 28, 56 and 90 days of curing period and compressive strength of concrete cylinders are tested at 28 days of curing period. The mean compressive strength is calculated and tabulated in Table 4.

Table 4 Compressive strength of concrete cubes and cylinders

Concrete mix Designation	Compressive Strength (N/mm ²)					
	Cubes					Cylinders
	7 days	14 days	28 days	56 days	90 days	28 days
M0	18.97	24.74	26.67	34.37	40.59	24.71
M1	17.93	20.74	24.30	32.59	38.52	20.56
M2	22.67	24.89	27.71	35.41	41.63	25.47
M3	25.48	31.56	34.22	41.04	42.96	28.48
M4	21.48	29.18	32.74	35.41	41.33	26.22
M5	19.85	24.89	27.71	36.44	42.37	25.84
M6	24.59	28.59	33.93	38.82	43.41	28.86
M7	26.07	32.15	36.30	41.18	44.44	30.37
M8	21.04	26.67	30.37	35.26	40.89	25.28
M9	16.59	22.67	25.93	32.59	37.48	21.69
M10	23.85	27.11	32.15	38.08	41.78	26.97
M11	22.81	26.67	30.52	36.74	40.80	26.03
M12	20.74	24.89	29.63	35.11	40.74	25.09

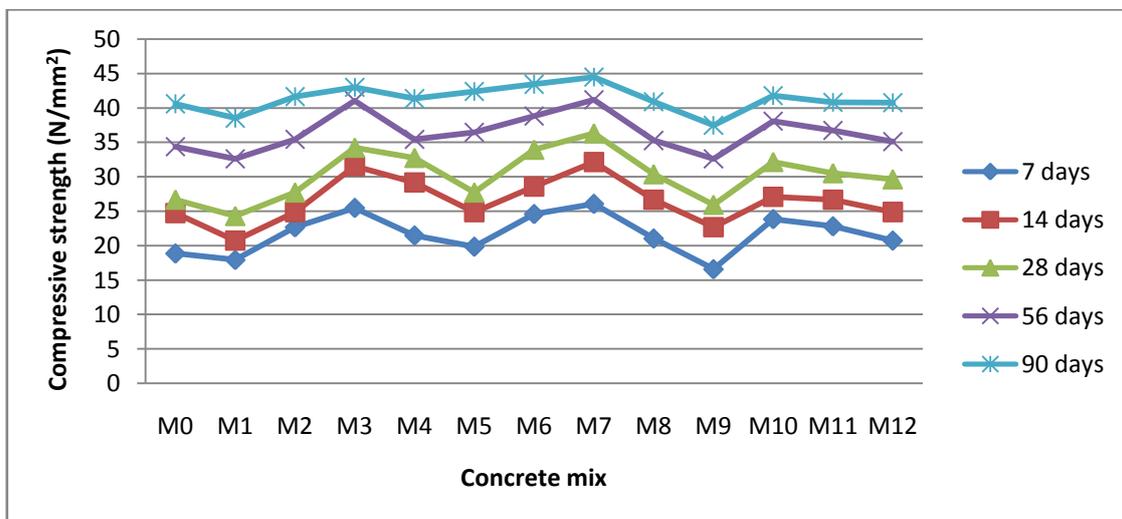


Figure 1 Variation of compressive strength of cube specimens for different concrete mixes

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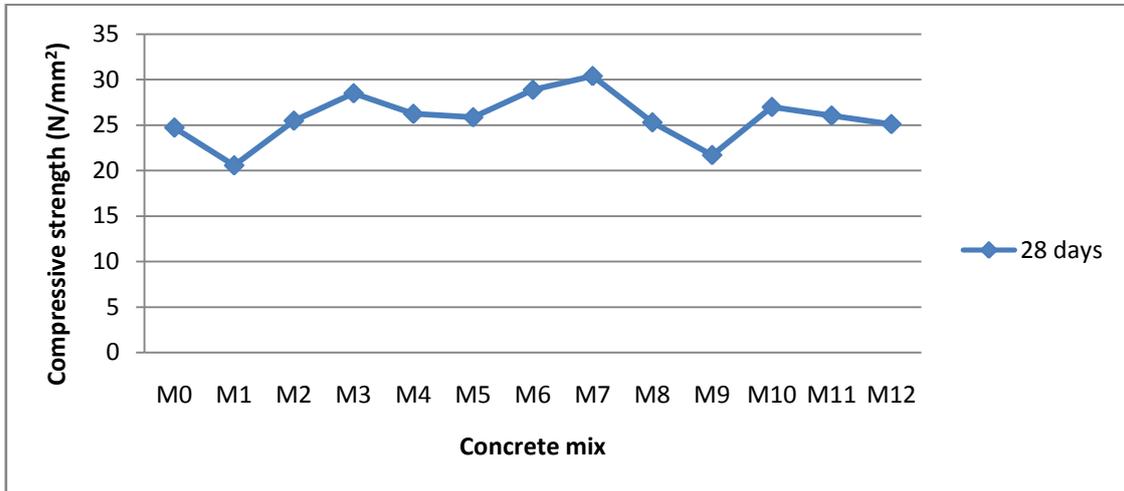


Figure 2 Variation of compressive strength of cylindrical specimens for different concrete mixes

From the Figures 1 and 2 , it is observed that the maximum strength occurs at 20% fly ash in case of 20% quarry dust (M3) and 30% quarry dust (M7) whereas it attains maximum at 10% fly ash in case of 40% quarry dust (M10) irrespective of curing period. The mix comprising 20% fly ash and 30% quarry dust (M7) attains higher strength irrespective of curing period among all the mixes considered. When compared to controlled concrete, for M7 mix the amount of improvement in strength of cubes is about 37%, 30%, 36%, 20% and 10% at 7, 14, 28, 56 and 90 days of curing period and the improvement is about 23% at 28 days of curing period in case of cylinders.

b) Split tensile strength

Split tensile test is done by placing the cylindrical specimen horizontally between the loading surfaces of a compression testing machine and the load is applied till the cylinder failed along the vertical diameter. Split tensile strength of concrete mixes is determined at the age of 28 days. The mean tensile strength is calculated and tabulated in Table 5.

$$\text{Split tensile strength} = \text{LOAD} / \text{AREA} = 2P / LD\pi$$

Table 5 Split tensile strength and Modulus of elasticity of concrete

Mix Proportions	Split tensile Strength (N/mm ²)	Modulus of elasticity (GPa)
	28 days	
M0	2.69	23.67
M1	2.59	20.90
M2	2.83	24.60
M3	3.02	28.66
M4	2.83	27.87
M5	2.78	25.48
M6	2.92	29.22
M7	3.11	30.57
M8	2.78	25.15
M9	2.55	22.04
M10	2.78	25.60
M11	2.74	23.91
M12	2.69	22.48

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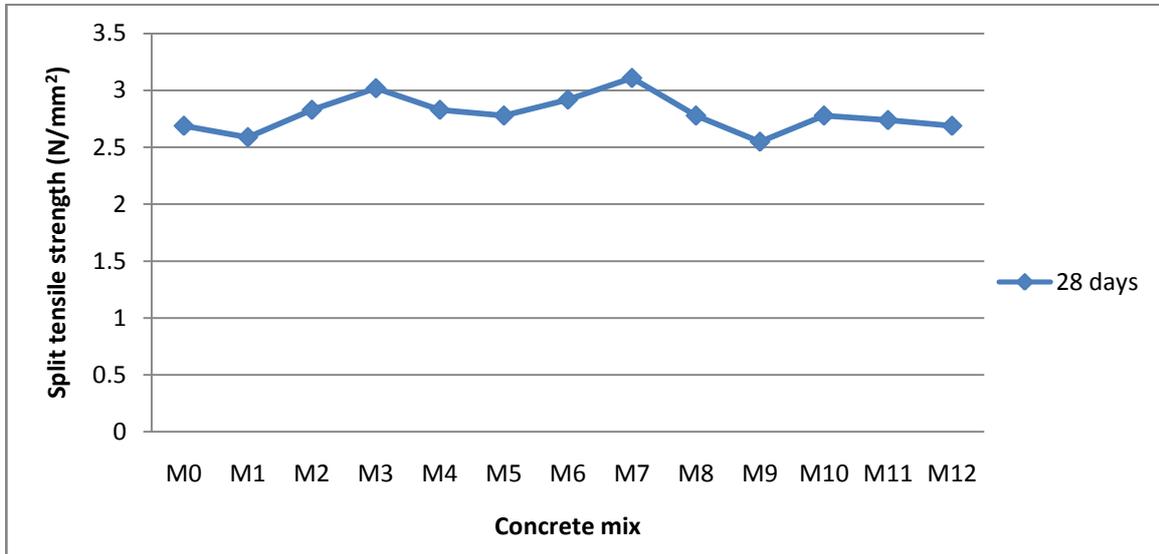


Figure 3 Variation of split tensile strength for different concrete mixes at 28 days

From the figure 3, it is observed that in case of 20% quarry dust and 30% quarry dust, the split tensile strength attains a maximum value at 20% fly ash, whereas at 40% quarry dust it attains a maximum value at 10% fly ash. The improvement in split tensile strength with respect to the controlled concrete is about 12%, 16% and 3.5% at mixes 20% fly ash and 20% quarry dust, 20% fly ash and 30% quarry dust, 10% fly ash and 40% quarry dust, respectively. The mix comprising 20% fly ash and 30% quarry dust (M7) attains higher strength among all the mixes considered.

c) Modulus of elasticity

In this investigation, the modulus of elasticity, which is also called secant modulus, is taken as the slope of the line from the origin to some arbitrary point on the stress-strain curve. The secant modulus is computed at a stress level corresponding to one-third of cube strength. Modulus of elasticity of concrete mixtures is determined at the age of 28 days. The mean tensile strength is calculated and is also tabulated in Table 6.

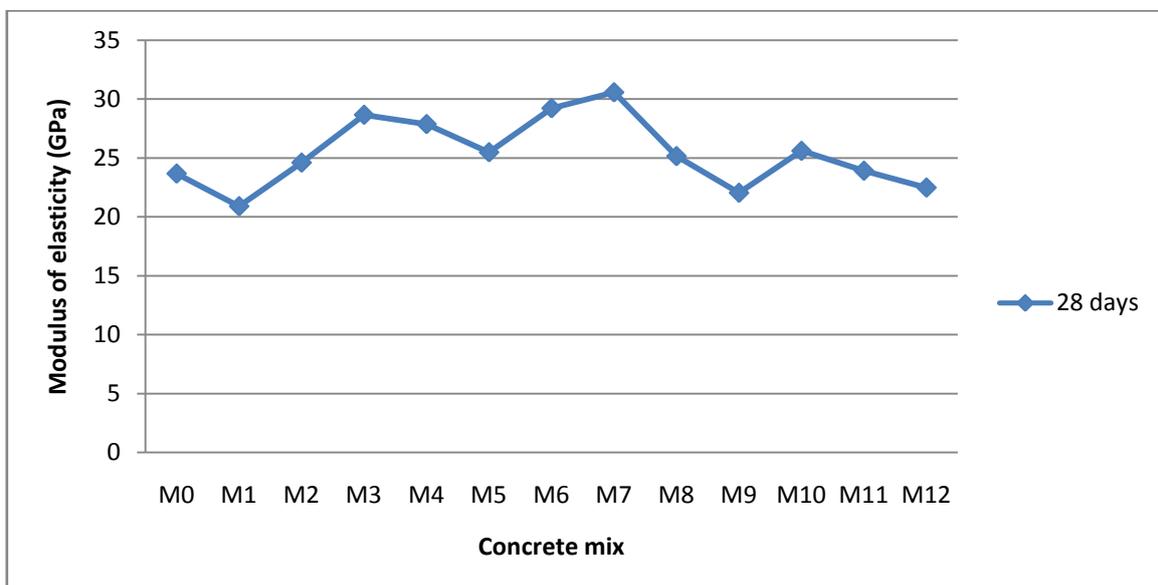


Figure 4 Variation of modulus of elasticity for different concrete mixes at 28 days

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From the Figure 4, it is observed that in case of 20% quarry dust and 30% quarry dust, the modulus of elasticity attains a maximum value at 20% fly ash, whereas at 40% quarry dust it attains a maximum value at 10% fly ash. The improvement in Young's Modulus with respect to the controlled concrete is about 21%, 29% and 8% at mixes 20% fly ash and 20% quarry dust, 20% fly ash and 30% quarry dust, 10% fly ash and 40% quarry dust, respectively. The mix comprising 20% fly ash and 30% quarry dust (M7) attains higher strength among all the mixes considered.

d) Ultrasonic pulse velocity test

The pulse velocity test is a convenient technique for investigating quality of structural concrete. The test involves measuring the velocity of sound through concrete for assessing quality of concrete. The pulse velocities computed for various mix proportions are compared with the pulse velocity ratings as suggested in the Indian Standard code [IS : 13311 (part 1)-1992] and the assessment is made for the quality of concrete.

In general, the ultrasonic pulse velocity values obtained for all the samples tested are in the range between 3.778 km/sec and 4.481 km/sec indicating that the quality of concrete is good. But for mix proportion (20% fly ash and 30% quarry dust), the pulse velocity is 4.654 km/sec which is above 4.5 km/sec, indicating that the quality of concrete is excellent.

VII. CONCLUSIONS

- Fly ash consumes more water for consistency and workability.
- Addition of fly ash to cement enhances the initial setting time whereas reduces the final setting time.
- In general, all the mixes attain more than the target strength when compared to the controlled concrete irrespective of curing period.
- All the mixes gain strength irrespective of curing period.
- The compressive strength of different mixes of cylindrical specimens is slightly less than that of the cube specimens.
- The concrete comprising 20% fly ash and 30% quarry dust is considered to be the optimum mix from compressive strength, tensile strength and modulus of elasticity of concrete point of view as well as from quality point of view.
- The partial replacement of cement by fly ash and sand by quarry dust in concrete not only enhances the strength of concrete, but also reduces the cost of production of concrete and at the same time, it also eliminates the environmental pollution and hazards caused due to the disposal of these waste by-products on land.

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