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Assessment of quality of self-compacting concrete using ultrasonic pulse velocity method

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Abstract:
Due to rapid industrialization and urbanization, the demand for usage of electricity is increasing at an alarming rate. At the same time, fly ash and pond ash is produced in thermal power plant in large quantity. Fly ash is used as an alternative material in construction industries while pond ash is disposed-off on huge land areas. This study focuses on assessing the quality of self-compacting concrete(SCC) incorporating pond ash by using ultrasonic pulse velocity method which is non-destructive testing method of concrete.Fine aggregate is replaced by pond ash in percentages of 10, 15, 20, 25 and 30 in SCC.This research aims to study the influence of pond ash as a fine aggregate on quality of SCC. The compressive strength of SCC tested at 7, 28 and 90 days of curing. At 90 days of curing UPV testing was done to check the quality of SCC. The results revealed that as pond ash percentage increases UPV values decreases. The strength of mixes increases with decreasing UPV value concludedto check the durability properties.
***Key Word**: Self compacting concrete; Pond ash; UPV; Compressive strength; Fine aggregate.*

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I. Introduction

Non-destructive determination of the compressive strength of concrete is ahuge goal for researchers. Currently, the rebound number and ultrasonicpulse velocity (UPV) are recognized as two true non-destructive methods forestimating concrete strength in a structure. Unlike the rebound numbertechnique, which measures concrete properties near the surface, the UPVtechnique yields information about the concrete throughout the thickness ofa structural member that is accessible from two opposite sides [1].

Theapplication of the UPV technique to the evaluation of concrete strength hasbeen widely investigated for more than 50 years. However, theheterogeneous nature of concrete makes it almost impossible to obtain atheoretically admissible relation between UPV and strength, and, as a result,the progress of this application has been hindered. Previous studies havedemonstrated that it is necessary to establish an empirical relationshipbetween UPV and compressive strength for strength estimation [2][3][4][5][6][7].

For early-age concrete, the pulse velocity increases rapidly relative tostrength [8][9]. UPV is influenced by many variables, such as mixtureproportions, aggregate type and quantity, age of concrete, moisture content,and so on. Unfortunately, the factors that significantly affect pulse velocitymeasurements may have little influence on concrete strength and vice versa.For instance, the pulse velocity of concrete with a water/cement ratio (w/c) ofmore than 0·5 is drastically increased by increasing the aggregate content,while little change is observed in strength. The establishment of a calibrationcurve between UPV and compressive strength is thus needed to obtain areliable estimation of concrete strength with the pulse velocity method [6].

Several previous studies [2][3][6][7][10] have concluded that, for concrete witha particular mixture proportion, there is a good correlation between UPV andstrength measured at different ages. However, for concretes with a widevariety of mixture proportions, the paired data of UPV and strength are widelydistributed in a scatter plot. Consequently, no clear rules have beenestablished to describe how the relationship between UPV and concretecompressive strength changes with mixture proportion.

A step towards abetter interpretation of the relationship was reported for hardened saturatedconcrete [11]. The coarse aggregate content was a ruling factor in establishinga UPV–strength relationship for concrete with various mixture proportions.The established relationship curves were verified to be suitable for theestimation of the strength of hardened saturated concrete with a measuredUPV value. Here in this research work, a new material pond ash is introducedas a partial replacement of {ne aggregate in SCC. The influence of pond ashon compressive strength is studied with the help of a linear relationshipbetween UPV value and compressive strength.

II. Material And Methods

The Self-compacting concrete occupies all the space in the formwork withoutany external efforts. The most common form of concrete consists of Portlandcement, coarse aggregate, sand, and water. The following materials wereused for preparing SCC trial mixes with superplasticizer in this research.

Ordinary Portland cement 53 grade was used for making the concretespecimens. Ordinary Portland cement of 53 Grade confirming to IS 269-2015was used in the study.

The manufactured aggregate is available in abundantquantity, so it was used in order to minimize the cost of SCC. For this researchwork, coarse aggregate having a size of 12 mm was used. Crushed sand wasused as a fine aggregate.

Pond ash is a combination of fly ash and bottomash; thus, pond ash can be used as a filler material with very little pozzolanicproperty [8][2][9][10]. Pulverized pond ash from Rattan India Power Ltd.Amravati, Maharashtra was used for trial mixes.

A minimum dose of PCEbased superplasticizer gives better performance in the fresh state andhardened state of SCC[11]. Auramix 350 was used as a superplasticizer that isPCE-based.

In this study, pond ash was replaced with sand in self-compactingconcrete. The purpose was to assess the performance of pond ash as a fineaggregate in SCC in terms of the quality of SCC. The physical properties of allmaterials and mechanical properties of all trial mixes were determined bysome tests during the experimental work. Experimental analysis was donewith reference to fresh and mechanical properties of SCC such as flowability,passing ability using IS 1199:2019 and compressive strength using IS 456:2000(Reaffirmed in 2021) by addition of pond ash in the SCC was conducted. In thisstudy, the slum |ow test was conducted for flowability and segregation ofSCC, L-box test for passing ability of SCC, and the compressive strength ofM30 SCC measured using a compression test machine at 7, 28, and 90 days ofcuring period. Compressive strength tests were done at 7, 28 and 90 dayswith percentages of 0, 10, 15, 20, 25 and 30 pond ash for {ne aggregatereplacement [10].

Using the basic test results, concrete mix design was doneconsidering severe exposure conditions as per IS 456:2000 and proportioningmethod as per IS 10262:2019 for Grade M30, with different percentages of fineaggregate replacement[12][13]. Mix proportions obtained are given in Tableno.1. The compressive strength of all trial mixes prepared with increasingpercentage replacement of sand by pond ash are tabulated in Table no. 2. Thesame cubes were used for UPV and crushing compressive strength.

UPV testis a non-destructive test method of concrete for assessing concrete quality. Onsite in the existing structure of concrete its quality is assessed withoutdisturbing the structure. In the laboratory concrete cubes are tested for their

quality and related to compressive strength actually calculated by breaking ina compression testing machine. The cubes cured for 90 days are dried outbefore the test. Any suitable couplant like grease or petroleum jelly is applied

on the concrete cube's center surface and faces of the transducer for propercontact between them. The direct transmission method was used for thisresearch work. The distance is measured between the center points ofopposite faces of a cube and noted. Transducers are pressed against bothfaces and the ultrasonic pulse velocity meter is switched on. The traverse timeis recorded. From the time taken to travel the distance and the distancerecorded, velocity is calculated. Table no.3 shows IS standards for UPV values.UPV test was conducted as per the standard procedure given in IS 516-part 5section 1. All the mixes were tested for UPV and recorded.

Table no.1 Mix IDs with percentage replacement

Sr. No.	Mix ID	Water (Kg. /m^3)	Cement (Kg. /m^3)	W/C	Pond ash % replacement	Pond ash (Kg. /m^3)	Fine aggregate (Kg. /m^3)	Coarse aggregate (Kg. /m^3)	Superplasticizer
1	T1	180	429	0.42	0	0	1029	782	1.2
2	T2	180	429	0.42	10	102.9	926.1	782	1.2
3	T3	180	429	0.42	15	154.35	874.65	782	1.2
4	T4	180	429	0.42	20	205.8	823.2	782	1.2
5	T5	180	429	0.42	25	257.25	771.75	782	1.2
6	T6	180	429	0.42	30	308.7	720.3	782	1.2

Table no. 2 Compressive strength of Mix IDs

Sr. No.	**Mix ID**	**Compressive strength (N/mm²)**		
		7 Days	**28 Days**	**90 days**
1	T1	22.3	42.1	43.42
2	T2	23	40.42	44.56
3	T3	24.8	41.63	44.85
4	T4	25.1	43.3	43.62
5	T5	23.5	40.68	43.5
6	T6	19.42	37.92	42.79

Table no. 3IS standards for UPV values

Sr. No.	UPV in Km/s	Concrete quality
1	>4.4	Excellent
2	3.75 to 4.40	Good
3	3.00 to 3.75	Doubtful
4	Below 3.00	Poor

III. Result and discussion

The prediction of compressive strength is shown in Table no. 4 and the correspondingcorrelation plots are shown in Figure no. 1. For the predicted compressive strength ofdifferent mixes, it was observed that the strength of mix T2, T3 and T5 confirmed theexpected strength of that particular mix. The mixes T1, T4 and T6 fall below the estimated strength. For all SCC mixes the percentage variation did not exceed plus orminus 2.5%. In all mixes, all parameters were kept constant with percentagereplacement of fine aggregate by pond ash only. Figure no. 1 shows that as thepercentage of pond ash increases UPV value was decreasing up to 20% replacementsthat may be because of poor workmanship, or improper curing. For 25% and 30%replacement UPV value was increasing that is only because of less water cement ratio,as powder content contributing to cementitious material in the mix is increasing. Poorworkmanship or improper curing results in less durable concrete with pore and capillaryformation in concrete though it was having good compressive strength.

Table no.4 Predicted and Actual compressive strength of all mix IDs

Mix ID	**Actual compressive strength (N/mm²)**	**UPV (Km/sec)**	**Predicted compressive strength (N/mm²)**	**Percentage variation**
T1	43.42	5.3	43.61	0.43
T2	44.56	5.1	43.93	-1.43
T3	44.85	5.2	43.77	-2.47
T4	43.62	4.8	44.43	1.81
T5	43.5	5.4	43.44	-0.13
T6	42.79	5.4	43.44	1.51

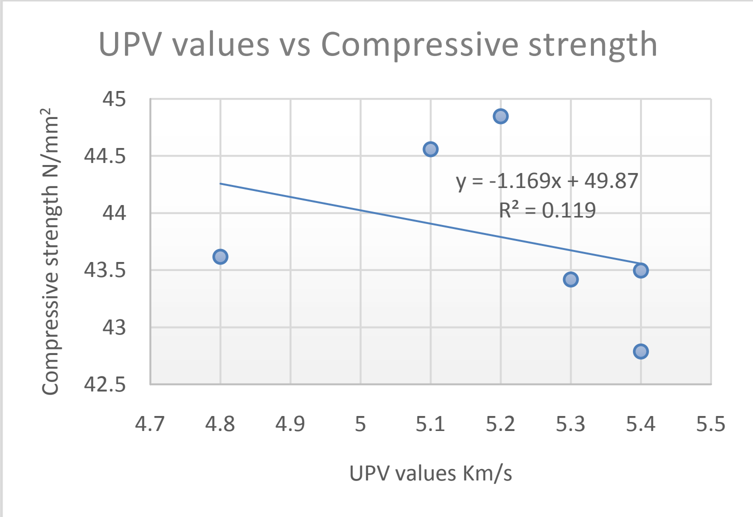

Figure no. 1 UPV values vs compressive strength

IV. Conclusion

The following conclusions have been drawn based on the results and linear regression modelpresented here.

1. The compressive strength of SCC increases with an increase in thepercentage of pond ash up to 15% replacement. Later on, strength decreases.
2. Fromthe results of the UPV test, negative regression is obtained. UPV is influenced byworkmanship and curingconditions of mixes as all parameters were kept constantexcept the pond ash percentage increase.
3. As the compressive strength mixesincrease UPV value is decreasing to 15%. So, durability properties need to bechecked.

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