Prediction of High Compressive Strength of Concrete using Waste Foundry Slag and Alccofine by NDT

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***Abstract* - In this study, non-destructive testing (NDT) such as ultrasonic pulse velocity (UPV) and Schmidt rebound Number(RN) are correlated with compressive strength(CS) of high strength concrete prepared with Foundry slag (FD) which is used as a partial substitute of fine aggregate in varying proportions (0, 10, 20, 30, 40, 45 and 50%) and alccofine1203(AF) was used in optimum amount of 15% of cement as a partial substitute for Portland Pozzolana Cement(PPC) and relationships were developed after 28 days of curing .150 mm x 150mm x 150 mm cube samples were casted, cured for 7, 14, 28, 56 and 90 days, dried and tested in the laboratory for estimating UPV, RN and CS. Results showed increase in UPV and RN with increase in FD content and age. UPV and RN also showed increase with CS. Then CS was compared with UPV and RN to develop the correlation between them. The best fit curve for CS with UPV and RN relationships were obtained after 28 days of curing through processing correlation among the data sets and equations were developed. These equations can be applied to existing concrete structures as well as newly constructed concrete structures for the determination of relative strength properties.**

Keywords: Concrete; NDT; UPV; RN; CS; FS; TS

1.0 INTRODUCTION

L.Zeghichi [1] has studied the effect of slag as a replacement material on strength properties of concrete. Juan Manso et al. [2] have been reported to use electric arc furnace slag as a partial replacement of fine aggregate in Concrete. Mohammed Nadeem and A. D. Pofale [3] had used granular slag as an alternative replacement material for natural sand in civil engineering applications either partially or fully.

Alccofine(AF), a supplementary cementitious material(SCM) containing high glass content with high reactivity and ultra fineness is a product manufactured by Ambuja Cements Ltd. Sunil Suthar et.al [4] have been reported to study the effect of alccofine and fly ash on mechanical properties of HSC. A comprehensive literature survey was carried out by Malhotra [5] for the non destructive methods used for concrete testing and evaluation. Leshchinsky [6] summarized the advantages of nondestructive tests. Turgut,P. [7] determines correlation between concrete strength and UPV Values. Yüksel,I. [8] used combined non destructive tests to determine concrete strength on a reinforced concrete structure. The correlation between concrete strengths and UPV determined by earlier researchers [9,10] were generally limited to the specimens prepared in laboratory conditions. Different correlation formulas were developed for different concrete mixture ratios. Amasaki S. [11] used rebound hammer method for the determination of strength of concrete structures. Popovics,S. [12] determines the effect of curing method and final moisture condition on the compressive strength of concrete Compressive strength of wet concretes is less than dry concrete but their UPV values are high.

The objective of the present research study is to determine ultrasonic pulse velocity(UPV) and rebound number(RN) using foundry slag(FD) as partial replacement for conventional fine aggregates and Alccofine (AF) as partial replacement of cement for different curing ages(7,14,28,56 and 90 days). Compressive strength (CS) of HSC at water binder ratio of 0.239 has been investigated experimentally and relationships between CS & UPV and CS & RN have been analyzed. Straight line equations have been derived by using regression analysis for the development of correlation between, CS & UPV and CS & RN.

II. EXPERIMENTAL PROGRAM

A Materials

A.1 Cement

Portland Pozzolana Cement available from Ultra-Tech Ltd. conforming to IS: 8112-1989 was used in this research study. Specific gravity of cement was 3.02 and the cement was tested according to IS 1489-1991(Part I).

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A.2 Coarse Aggregate

Saturated surface dry crushed coarse aggregate of size 10mm & 20 mm was used and arranged from Batching plant of Ultra-Tech Ltd, Mohali. Testing of coarse aggregate conforms to Indian Standard Specifications IS: 383-1970

A.3 Fine Aggregate

Natural River sand from Khizrabad conforming to zone -II from batching plant of Ultra-Tech Ltd, Mohali was used as fine aggregate. This material is washed to remove dust and dried at room temperature for 24 hours to control the water content in concrete. The maximum size of sand was taken 4.75 mm and minimum size was 150 micron. Testing of fine aggregate conforms to Indian Standard Specifications IS: 383-1970. [13]

A.4 Foundry Slag

Foundry slag from Mandi Gobindgarh steel plant of specific gravity 2.77 and fineness modulus of 3.00 was used in this study. The maximum size of slag was taken as 4.75 mm and minimum size was 150 micron. Foundry slag used in this research confirms to zone II as per IS 383-1970 code.

A.5 Water

In this investigation, normal tap water available in the laboratory was used. Water used in concreting and curing work conforms to IS: 456-2000.

A.6 Super Plasticizer

Commercially available super plasticizer Master Glenium Sky 8777 from BASF confirms to IS: 9103-1999 was used to produce high workability in fresh concrete and to reduce water cement ratio. Specific gravity of super plasticizer was 1.18 at 20^0 C.

A.7 Alccofine

Alccofine 1203 is a slag based SCM contains high glass content with high reactivity and ultra fineness from Ambuja Cement ltd. Specific gravity of alccofine1203 is 2.93 .Alccofine 1203 used in this research conforms to ASTM

B. Mix Proportion

Optimum dosage of AF was determined by varying the contents of alccofine(AF) from 5% to 20% for preparing concrete mix design of M100 grade, and was found to be 15%. Concrete mix was designed as per IS 10262;with a water binder ratio (w/b) of 0.239 and a targeted slump of 190 ± 35, by substituting fine aggregate with 10%, 20%, 30%, 40%,45% and 50% of FD and Portland pozzolanic cement (PPC) with 15% Alccofine(AF) contents. Concrete mixes prepared by substituting FA with 0%,10%, 20%, 30%, 40%, 45% and 50% FD have been given name as control (CTR), F10, F20, F30, F40, F45 and F50 respectively (**Table 1**). 150mm x150mm x150 mm cubes for compressive strength test were casted, cured, dried and tested after the curing age of 7, 14, 28, 56 and 90 days for determining CS, UPV and RN as per IS specifications. The values of CS are correlated with UPV and rebound number (RN) after curing period of 28 days and linear equation was developed between them.

Table1. Details of HSC Mixes in kg/m^2 [14, 15]

Materials	CTR	F10	F20	F30	F40	F45	F50
Cement kg	460	460	460	460	460	460	460
Alccofine kg	69	69	69	69	69	69	69
Water content liter	126.18	126.18	126.18	126.18	126.18	126.18	126.18
CA 10mm kg	459	459	459	459	459	459	459
CA 20mm kg	688	688	688	688	688	688	688
FA kg	735	662	588	514	441	404	367.5
FD kg	0	72	147	221	294	331	367.5
Super plasticizer (ml)	6.9	6.9	6.9	6.9	6.9	6.9	6.9

III. RESULTS AND DISCUSSION

A. *Compressive Strength*

In order to determine the optimum contents of Alccofine(AF), quantity of AF substituted from cement was varied from 0% to 20% by weight of cement and test specimens were casted and tested for determining CS after curing age of 28 days as per IS Specifications. Test results are given in the **Table**2. Maximum values of CS were observed at 15% substitution of PPC with AF. Hence Optimum dosage of AF was found to be 15% by weight of cement.

Table2. Results of CS(MPa) test[15]

	Specimen	Curing Age (days)				
		7	14	28	56	90
CS (MPa)	CTR	71.22	84.44	102.32	105.13	107.11
	F10	72.56	87.22	102.88	106.21	107.34
	F20	73.33	90.11	103.67	106.75	107.87
	F30	75.55	94.22	103.82	107.33	108.24
	F40	77.66	96.56	105.12	107.62	109.72
	F45	78.2	97.3	105.72	108.31	110.86
	F50	73.33	93.33	102.2	104.8	106.66

B. *Ultrasonic Pulse Velocity Test and Rebound Hammer Test*

The ultra sonic pulse velocity (UPV) and Rebound Number (RN) of the high strength concrete (HSC) samples were measured as per IS: 13311 (part1&2) 1992[16, 17]. Two transducers were placed at the centre of the opposite faces of the concrete samples and the average UPV was measured for each cube. Concrete samples used should be at a saturated condition during the test.

UPV and RN can be performed on concrete samples in the laboratory as well as on-site. The factors which affect the UPV results are smoothness of surface, maturity of concrete, homogeneity of concrete, water/cement ratio, type of cement used, the travel distance of the wave, the presence of reinforcement, mix design, size and type of aggregate, curing period of concrete, moisture content, etc.

[18, 19]. Figure1 & 2 represented the results of UPV and RN which showed increase in UPV and RN values with age and with FD contents up to 45%. Maximum value of UPV and RN was obtained with FD content at 45%. These results are consistent with Neville [20] and Sturrup [21]. Higher values of UPV and RN may be due to the improvement in the pore structure of concrete because of optimized particle distribution and ultra fineness of Alccofine which gives dense Packing. Higher toughness and roughness of FD ensures strong bonding and interlocking of aggregates with cement paste which is also responsible for the increase in UPV and RN values with increased FD contents[15]. UPV and RN was found to be reduced at FD contents of 50%. This may be due the effect of weaken bond between aggregates and cement paste because of formation of pores in **concrete[15].**

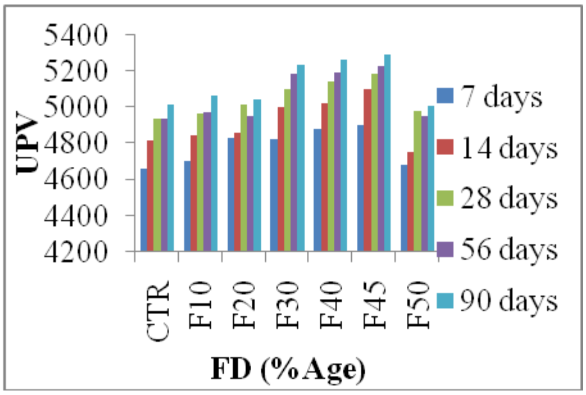

Figure 1. UPV (m/s) vs. Age

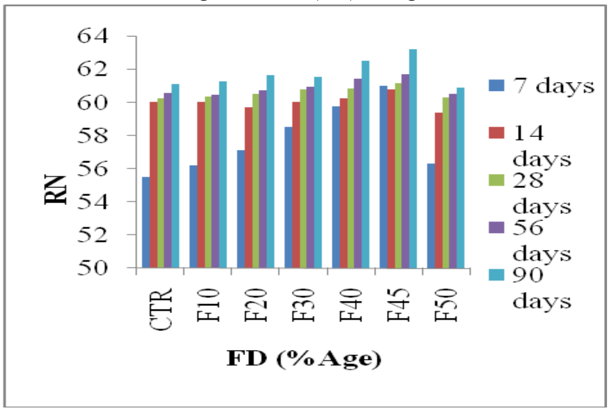

Figure 2. Rebound Number (RN) vs Age

Figure 3 & 4 show the relationship of Compressive strength with UPV and RN of high strength concrete specimens at 28 days. Results showed increase in UPV and RN with increase in CS and age. The relationship of CS with UPV and RN was found to be excellent and the correlation coefficients were 0.901 and 0.926 after curing periods of 28 days respectively. The following formulas were obtained as the best fit equation shown in table3 below.

Table3. Relationship of Compressive Strength with UPV and RN

Sr. No.	Days	Equation showing relationship b/w UPV and CS	R^2
1	28	y = .013x -35.59	.901
Sr. No.	Days	Equation showing relationship b/w RN and CS	R^2
1	28	y=3.813x -127.3	.926

Where;y represents compressive strength (MPa), x represents UPV and RN

Quasrawi et al. [22] had given the following linear equation for relationship between UPV and CS,

$$f_c = 36.72 \times V - 129.077 \quad (1)$$

where f_c = CS and V = UPV.

Neville [20] and Sturrup [21] had also given the similar equations.

Quasrawi et al. [22] had given the following linear equation for relationship between RN and CS.

$$f_c = 1.353R - 17.393 \quad (2)$$

where f_c = CS and R = RN which is consistent with the present study.

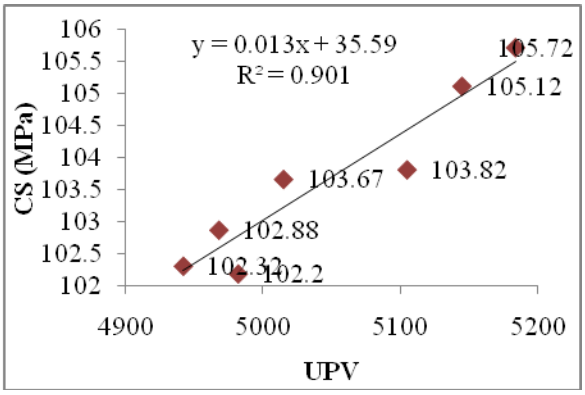

Figure3.Correlationb/wUPVandCSat28day

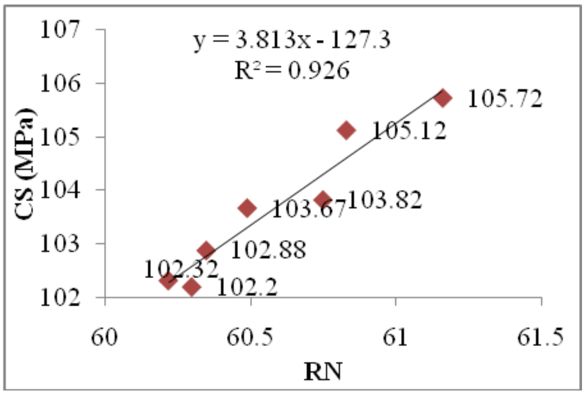

Figure4. Correlation b/w RN and CS at 28 day

C. Comparison between actual experimental value of CS and predicted value of CS from UPV and RN equations

Table4. Actual and Predicted Value of CS from UPV and RN

FD content 1	Actual CS from compression Test 2	Predicted CS from present equation(UPV) y=.013x+35.59 3	Predicted CS from present equation(RN) y=3.813x-127.3 4
CTR	102.32	99.84	101.72
F10	102.88	100.17	102.81
F20	103.67	100.79	103.35
F30	103.82	101.96	104.34
F40	105.12	102.48	104.64
F45	105.72	102.98	105.90
F50	102.20	100.36	102.62

From table4, it is evident that existing relations given by Quasrawi are not valid for the results obtained in the present study because existing equation was developed for normal strength concrete where as present study was done for high strength concrete and in the present study ,the predicted value of CS determined from UPV and RN are very nearer to the experimental values of CS .Figures5 and 6 show the linear relationship between actual compressive strength and predicted compressive strength and regression coefficient R^2>.9 which means that the equations derived from UPV and RN are valid and can be used for the prediction of CS from UPV and RN. It is also found that CS predicted from RN was more reliable than CS predicted from UPV.

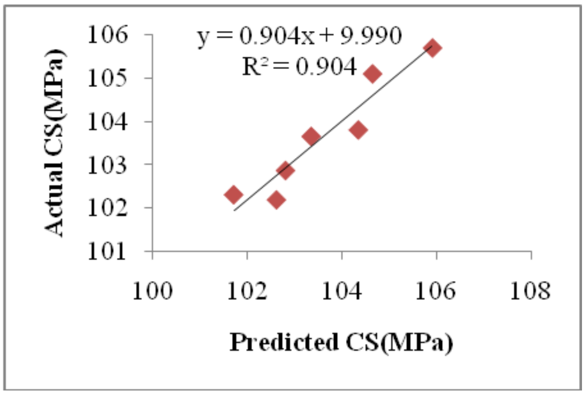

Figure6.Relation b/w Actual and Predicted CS(RN)

1V. CONCLUSIONS

1. Significant increase in UPV and RN over CTR has been increased with optimum substitution of FA with FD.
2. All concrete mix showed a normal progression in UPV and RN with increase in curing age. All concrete mix (F10 - F45) exhibited higher UPV and RN than that of CTR.
3. F50 concrete mix showed reduction in UPV and RN at all curing ages.
4. Correlation between UPV &CS and RN& CS was found to be good.

V. REFRENCES

[1] Zeghichi, L., 'The Effect of Replacement of Naturals Aggregates by Slag Products on the Strength of Concrete'. *Asian Journal of Civil Engineering (Building and Housing).* Vol. 7, 2006:27-35.

[2] Manso, J. M., Gonzalez, J. J., Polanco, J. A., 'Electric Arc Furnace Slag in Concrete', *ASCE Journal of Materials in Civil Engineering.* Vol. 16, No. 6, 2004:639- 645. doi:10.1061/(ASCE)0899-1561(2004)16:6(639)

[3] Mohammed, N., Pofale, A. D., 'Replacement of Natural Fine Aggregate with Granular Slag - A Waste Industrial By-Product in Cement Mortar Applications as an Alternative Construction Materials', *International Journal of Engineering Research and Applications (IJERA).* ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 5, September- October 2012:1258-1263.

[4] Suthar, S., Shah, B. K., Patel, P. J., 'Study on Effect of Alccofine & Fly Ash Addition on the Mechanical Properties of High Performance Concrete', *International Journal of Scientific Research &Development (IJSRD).* ISSN (online): 2321-0613, Vol.1, Issue 3 , 2013: 464-467.

[5] Malhotra, V. M., 'Testing Hardened Concrete: Non-destructive Methods', *ACI, monograph No. 9, Detroit,* US, 1976.

[6] Leshchinsky, A., 'Non-Destructive Methods Instead of Specimens and Cores, Quality Control of Concrete Structures', *Proceedings of the International Symposium Held by RILEM.* Belgium, E FN SPON, U.K., 1991, pp.377-386.

[7] Turgut, P., 'Research into the Correlation between Concrete Strength and UPV Values', *The e-J. Nondestr. Test.* 2004, p. 12.

[8] Yüksel, I., 'Determination of Concrete Strength Using Combined Non Destructive Tests and Application on a Reinforced Concrete Structure', MSc. Thesis, *Yildiz Technic University, Science of Technology Institute,* Istanbul, 1995.

[9] Prassianakis, I. N., Giokas, P., 'Mechanical Properties of Old Concrete Using Destructive and Ultrasonic Non-Destructive Testing Methods', *Magazine of Concrete Research.* 55 (2003) 171-176.

[10] Arioglu, E., Arioglu, N., 'Testing of Concrete Core samples and Evaluations', *Evrim Publisher. Istanbul,* 1998.

[11] Amasaki, S., 'Estimation of strength of concrete structures by the rebound hammer, *CAJ Proc Cem Conc* .45(1991): 345-351.

[12] Popovics, S., 'Effect of Curing Method and Final Moisture Condition on Compressive Strength of Concrete', *ACI Journal.* 83 (4) (1986) 650-657.

[13] IS: 383-1970: Specification for Coarse and Fine Aggregates from Natural Sources for Concrete, *Bureau of Indian Standard*, New Delhi-1970

[14] IS: 10262-1982, 2009, 'Guidelines *for Concrete Mix Design', Bureau* of Indian Standards. New Delhi, India.

[15] Sharma Devinder, Sharma Sanjay, Goyal Ajay, "Utilization of Waste Foundry Slag and Alccofine in Developing High Strength Concrete," *International Journal of Electrochemical Science,*11 (2016)

[16] IS: 13311(Part-1)1992, 'Non-Destructive Testing of Concrete method of test-Ultrasonic Pulse Velocity', *BIS.* New Delhi

[17] IS: 13311(Part-11)1992, 'Non-Destructive Testing of Concrete method of test- Rebound Hammer Test', *BIS.* New Delhi.

[18] Lin, Y., Lai, C., Yen, T., 'Prediction of Ultrasonic Pulse Velocity (UPV) in Concrete', *ACI Materials Journal.*Vol. 100, No. 1, 2003, pp. 21-28.

[19] Castro, P. F., 'An Expandable Sleeve Test for Assessing Concrete Strength', *University College London, England.* PhD Thesis, 1985.

[20] Nivelle, A.M., 'Properties of Concrete', 4th Edition *Longman Group Limited,* 1995.

[21] Sturrup, V. R., Vecchio, F. J., Caratin, H., 'Pulse Velocity as a Measure of Concrete Compressive Strength, In Situ/Non-Destructive Testing of Concrete', Ed.V.M. Malhotra, *ACI SP-82, 1984. Detroit, Michigan,* pp.201-227.

[22] Qasrawi, H. Y., 'Concrete strength by combined nondestructive methods simply and reliably predicted. *Cement and Concrete Research',.2000. No. 3, pp. 739 – 746.*