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STRENGTH AND QUALITY EVALUATION OF CONCRETE ELEMENTS USING NON-DESTRUCTIVE TESTING

PROCENA ČVRSTOĆE I KVALITETA BETONSKIH ELEMENATA ISPITIVANJEM BEZ RAZARANJA

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- ultrasonic pulse velocity (UPV)
- rebound hammer (RH)
- concrete strength
- quality assessment
- velocity correlations

Abstract

Ultrasonic pulse velocity (UPV) and Rebound Hammer (RH) are NDT techniques used routinely to evaluate the health of concrete elements. Concrete elements can be evaluated using UPV in three different methods i.e., direct, in-direct, semi-direct methods based on the direction of waves passing through concrete. In this paper, work is divided into three phases: in phase 1, a correlation between direct and in-direct velocities (V_d and V_s) for ON and OFF of reinforcement is developed for quality assessment of concrete through UPV. Much work has not been done in previous literature on the correlation between direct, in-direct, and semi-direct methods for assessing uniformity, homogeneity, and quality of concrete. Beams, columns and slabs are measured using two different methods, i.e. direct and in-direct. The best fit correlation between V_d and V_s is obtained using regression computational technique. In phase 2, the compressive strength of concrete is predicted using methods RH, UPV, and SONREB, and inter comparison is established. In phase 3, a series of reinforced concrete beam specimens are cast with different reinforcement percentages (1, 1.5, and 2), and the difference in velocity at stress conditions is obtained. The velocity is 10 to 20 % less in the in-direct method compared to direct method, and the best fit correlation is obtained between V_d and V_s. The effect of stress results in a decrease in UPV direct measurements for stressed beams. The reliability of predicting strength using SONREB method is enhanced as compared with the UPV and RH methods.

Ključne reči
- ispitivanje bez razaranja (IBR)
- brzina ultrazvučnog impulsa (UPV)
- sklerometar (RH)
- čvrstoća betona
- procena kvaliteta
- poređenje brzine

Izvod

Brzina ultrazvučnog impulsa (UPV) i sklerometar (RH) su metode IBR za rutinsko određivanje stanja betonskih elemenata. Betonski element se ispituje određivanjem UPV kod tri različite metode, na pr. direktno, indirektno, ili poludirektnom metodom, prema pravcu prostiranja talasa kroz beton. U radu je postupak podeljen u tri faze: u fazi 1, za ocenu kvaliteta betona preko UPV uspostavlja se veza između direktne i indirektne brzine (V_d i V_s) za ON i OFF varijante ojačanja betona. U dosadašnjoj literaturi nisu u većoj meri obrađene veze između vrzina prostiranja talasa kod direktne, indirektne i poludirektne metode radi procene uniformnosti, homogenosti i kvaliteta betona. Grede, stubovi i ploče se ispituju primenom dve različite metode, na pr. direktno ili indirektno. Najbolja korelacija između brzina V_d i V_s postiže se regresionom analizom. U fazi 2, pritisna čvrstoća betona se procenjuje korišćenjem metoda RH, UPV i SONREB, a zatim se upoređuju rezultati. U fazi 3 se priprema serija uzoraka nosača od armiranog betona, sa različitim procentom ojačanja (1, 1,5 i 2), a zatim se određuje razlika u brzini prostiranja talasa u uslovima opterećenja. Brzina prostiranja talasa je od 10 do 20 % manja kod indirektne metode u poređenju sa direktnom metodom, uz određivanje najbolje korelacije između V_d i V_s. Uticaj napona se ogleda u padu UPV kod direktnog merenja prednapregnutog betona. U poređenju sa metodama UPV i RH, kod metode SONREB je poboljšana pouzdanost određivanja čvrstoće.

INTRODUCTION

The non-destructive test of concrete in today's scenario has received great importance concerning practical and engineering value /14/. Non-invasive testing techniques are utilised to determine the homogeneity, integrity of material, component, or structure, or to quantitatively measure some other characteristics of concrete /15/. Especially in predicting concrete compressive strength and mechanical properties, NDT techniques are prevalent testing methods of great scientific and practical importance /10, 11/. Nowadays, various countries have shown interest in applying NDT in engineering, /3/. The subject has received growing attention during recent years, especially the quality characterisation of damaged structures of concrete, using NDT testing. Supporting the speed of decay, the structure is tailored to repair, rehabilitation, and renovation. Advantages of NDT as a reduction in labour consumption for testing /17/ can help save significant amounts of material and time, and also use cheaper testing tools /4/. The foremost advantage of NDT methods is to avoid concrete damage or structural component performance of a building /22/. Non-destructive evaluation (NDE) of concrete is well-known and extensively used and it's vital to select appropriate NDE techniques. One technique may not be sufficient; therefore, a combination of techniques is adopted to urge truly representative data of the condition of the structure. Commonly used NDE methods are rebound hammer test, UPV test, chloride test, and carbonation test. The UPV is littered with numerous factors, including properties and proportion of constituent materials, aggregate and water content, age of concrete, presence of micro-cracks, stresses within the concrete specimen, path length, shape and size of the specimen surface condition, the temperature of the concrete, presence of reinforcement, and so on /2, 19, 26/. However, it is demonstrated that the standard ultrasonic method employing a direct method for concrete can estimate the strength only with ±20 % accuracy in laboratory conditions /21, 24, 28/. Unique relations exist between hardness and strength of concrete, but experimental data reveal relationships obtained from a given concrete /23/. However, this relationship depends on factors affecting the concrete surface just like the carbonation, temperature, degree of saturation, surface preparation, and site, and sort of surface finish /16/. Therefore, using the UPV or RH alone to predict f_{ck} is not reliable. An in-depth review of combining different NDT techniques to assess concrete strength and additionally, their usage is straightforward and quick /5, 9/. The SONREB method is one amongst the combinations of NDT techniques developed by RILEM Technical Committees 7 NDT and TC-43 CND /18, 20/. SONREB measurements include computational modelling, artificial intelligence, and parametric multivariable regression models. The ultrasonic pulse velocity tester is most typically used in practice and the test is described in /7, 12/. Longitudinal ultrasonic waves are a favourite tool for investigating concrete. Such waves have the highest velocity, so it is simple to separate them from other wave modes /29/. The speed of the wave varies as a function of material density and can be used for detecting discontinuities. The thought is to project the ultrasonic pulses inside the material and measure the time necessary for the wave to propagate through. Once the distance is known, it is possible to workout the average pulse velocity, which will depend on several factors such as the nature of the material, and the presence of water in pores, among others, and generally, based on the placement of two transducers on either side, as seen in Fig. 1.

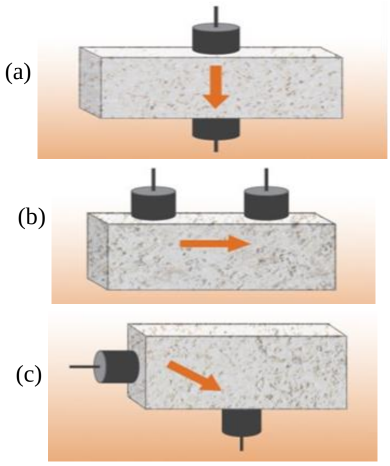

Figure 1. a) Direct; b) in-direct; and c) semi-direct method.

Some inevitable situations in in-situ testing conditions of reinforced concrete structural elements by UPV are even more serious when there is no access to two opposing sides of the element, because of walls and other members. Ironically, the UPV measurement using the surface method dropped significantly /28/. The cause has yet to be identified, hence requires further research. The in-direct method is the least sensitive of the arrangements and, for a given path length, the direct transmission produces a signal of 100 % amplitude, whereas indirect transmission has 2 to 3 % of direct transmission. The indirect velocity is invariably lower than direct velocity in the same concrete element. This difference may vary from 5 to 20 % depending largely on the quality of concrete under test /7/. The main objectives of this study are to identify correlations between direct and the in-direct velocities for both on and off reinforcements, the effect of stress on UPV values, and prediction of concrete strength using a parametric multivariable technique of the SONREB method.

EXPERIMENTAL SETUP

A Proceq (Pundit Lab +) portable ultrasonic tester is used to evaluate direct, indirect, and semidirect UPV measurements in concrete. This tester measures the propagation time of ultrasound pulses in a sample within the range 0.1-9999.9 μs with a precision of 0.1 μs. The transducers used are 50 mm in diameter and of maximal resonant frequency of 54 kHz.

The rebound hammer test method is based on the principle that the rebound of an elastic mass depends on the hardness of the concrete surface against which the mass strikes. Thus, the hardness of concrete and rebound hammer reading can be correlated with the compressive strength of concrete /6/. The weight of the Schmidt bounce back sledge is about 1.8 kg. The bounce-back separation of the hammer mass is estimated on a discretionary scale extending from 10 to 100. A compression test is conducted to get actual compressive strength for each type of concrete sample. The procedures are referred to as in /13/.

SPECIMENS USED

Concrete elements chosen for NDT test are the slab model made up of concrete and thermocol in the core, acting as a hollow slab of 1000×300×110 mm, a precast beam of 4000×300×300 mm, a slab of 2000×1560×110 mm. A column of 2000×600×300 mm is also chosen to find the rebar location and compressive strength using UPV. This column is a precast element, and it is not yet loaded.

Concrete cubes of size 150×150×150 mm are cast using OPC 53 grade for this study. Compressive strength and the specific gravity of cement are 40 MPa and 3.1 g/cm^3, in respect. The maximal coarse aggregate size of 20 mm is used. Bulk specific gravity of coarse and fine aggregate is 2.658 and 2.65, respectively. Concrete mix design parameters are summarised in Table 1. Nine concrete cubes are cast for each mix and three different mixes are used.

Three reinforced concrete beams of size 2000×300×150 mm with reinforcements of 1, 1.5, and 2 % are cast and indicated as RCB 1.0,1.5 and 2.0, in respect.

Details of specimen identification are shown in Table 2.

Table 1. Mix design parameters for C30 and for RCB 1.0, 1.5 and 2.

Concrete grade	Cement (kg/m^3)	Aggregate (kg/m^3)		Water (l/m^3)
		fine	coarse	
M30	355	660	1292	152

Table 2. Specimen identification.

Specimen ID	Description
C30	cube
HS	Slab made up of concrete and thermocol in the core
PS	precast slab
PRCB	precast RC beam
RCB1.0	beam with reinforcement with 1%
RCB1.5	beam with reinforcement with 1.5%
RCB2.0	beam with reinforcement with 2%
CL	column

METHODOLOGY

Profometer scanning and ultrasonic measuring technique

Structural elements are scanned using Profometer PM-600 for marking reinforcement grid lines and measuring cover, as shown in Fig. 2. UPV measurements are taken on different structural elements with direct and indirect methods for ON and OFF reinforcement to obtain a correlation between direct and in-direct velocities, /27/, and to find the effect of rebar on UPV, as shown in Fig. 2. The path length for the direct method is the thickness of the slab, or beam width, and column width, whereas the path length for in-direct method for ON reinforcement is the distance between ties and stirrups, but for OFF reinforcement it is 150 mm. For cubes, the path length is 150 mm, whereas for beams under stress condition it is 150 mm, i.e. the beam width in the direct testing method.

Figure 2. Scanning using Profometer PM-600**;** concrete quality testing using UPV.

The positions of transmitter and receiver for the cube are indicated in Fig. 3. Possible measurements are direct and semidirect for cubes. For the beam, the direct measurement is shown in Fig. 4, which will be the opposite face of the beam. But many times, this measurement may not be possible at the site, and then indirect measurement is obtained, as shown in Fig. 5. While measuring a slab using UPV, one may come across the rebars. Then the UPV values will be different for the transmitter placed ON reinforcement and OFF reinforcement /8/. Schematic representation is shown in Fig. 6. Work done in the present paper is presented in the form of a flow chart as shown in Fig. 7.

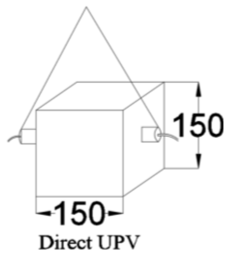

Figure 3. UPV measurements on concrete cubes.

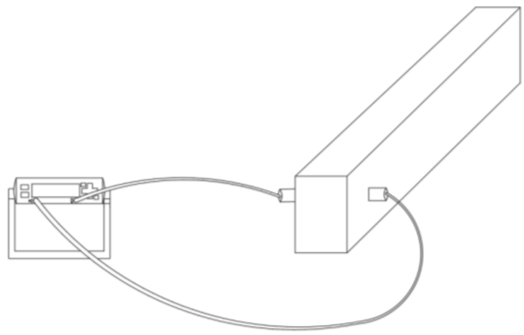

Figure 4. Position of transmitter and receiver in the direct method.

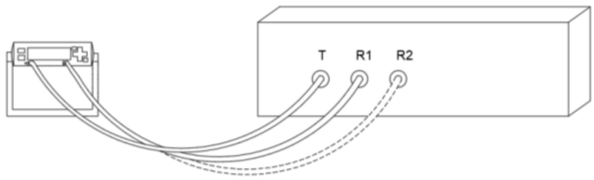

Figure 5. Position of transmitter and receiver in the indirect method.

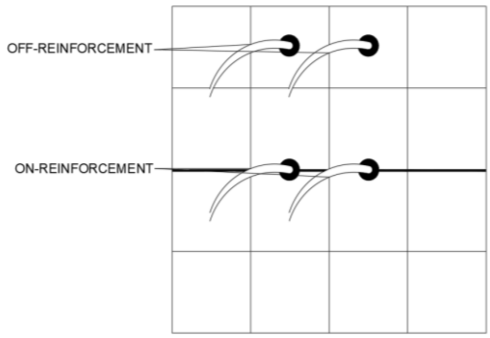

Figure 6. Indirect method of testing for ON and OFF the reinforcement using UPV.

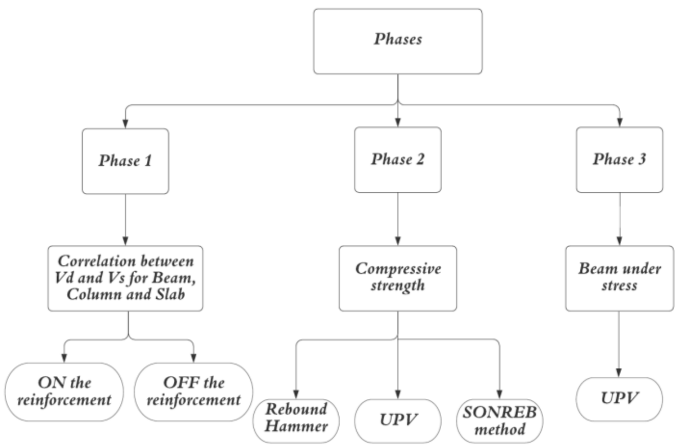

Figure 7. Phase-wise work done.

RESULTS AND DISCUSSION

Phase: 1

Correlation between direct and in-direct UPV measurements for ON and OFF reinforcement:

Collected data are analysed to study the correlative relationship between direct and in-direct UPV measurements for ON and OFF reinforcement, derived from various grades of concrete, and the effect of reinforcement on velocity variations.

Indirect (V_s) and direct velocity (V_d) are plotted on *X* and *Y*-axis, respectively. UPV observations are taken by direct and in-direct method on the HS, as shown in Fig. 9.

Figure 8. HS test specimen.

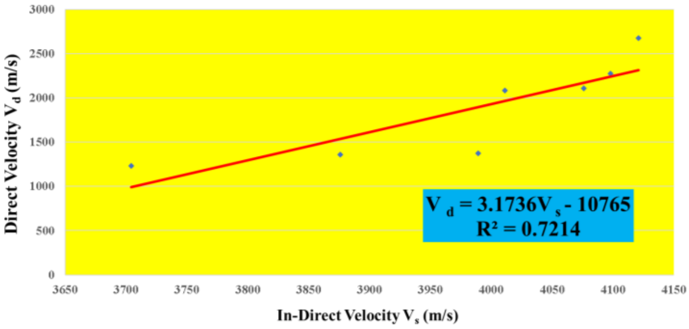

Figure 9. Correlation between direct and in-direct UPV for HS.

It is observed that direct velocities are reduced to half compared to indirect velocities. But in general, the direct velocity is greater than indirect velocity according to /3, 11/. Indirect velocities taken at in-situ conditions cannot be relied upon in all the situations because indirect velocities do not pass through concrete core but through the surface.

The aim is to find a correlation between direct and indirect velocity to calculate direct velocity under in-situ conditions using these correlations.

It is observed that V_d and V_s values for CL are in the range for OFF reinforcement, but for ON reinforcement, the values are not in the range (Figs.10 and 11).

The graph is plotted between the cover and indirect velocity on *X* and *Y*-axis, respectively, as shown in Fig. 12. Indirect velocity (V_s) increases as the cover provided to the column decreases.

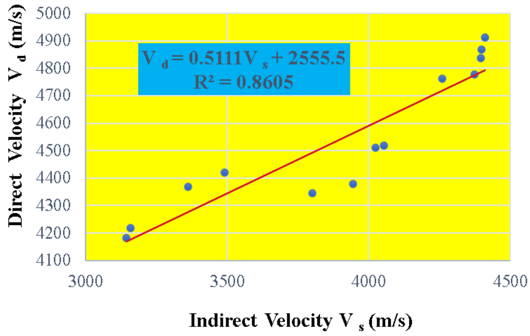

Figure 10. Correlation between direct and in-direct UPV for the CL OFF reinforcement.

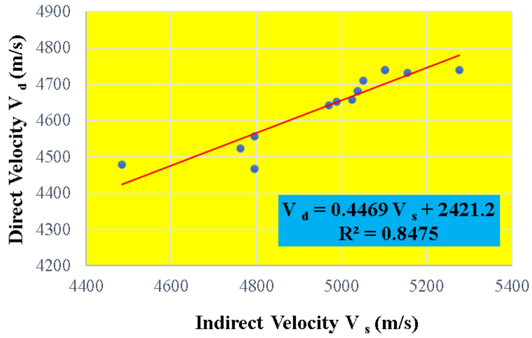

Figure 11. Correlation between direct and in-direct UPV for the CL ON reinforcement.

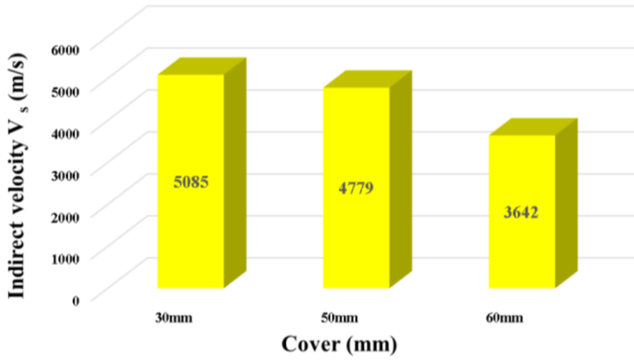

Figure 12. Effect of cover and reinforcement on in-direct velocity.

It is observed that V_d and V_s values are in the range for PRCB, for both OFF and ON reinforcement, in Figs. 13 and 14.

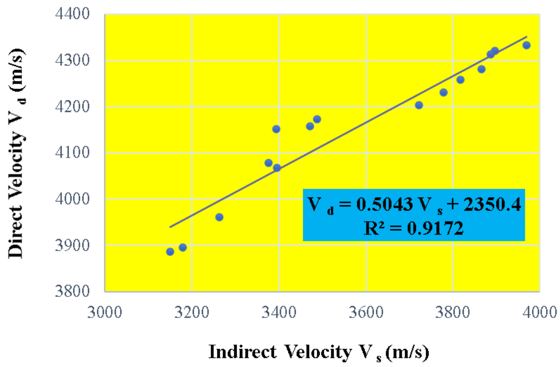

Figure 13. Correlation between direct and in-direct UPV for PRCB OFF reinforcement.

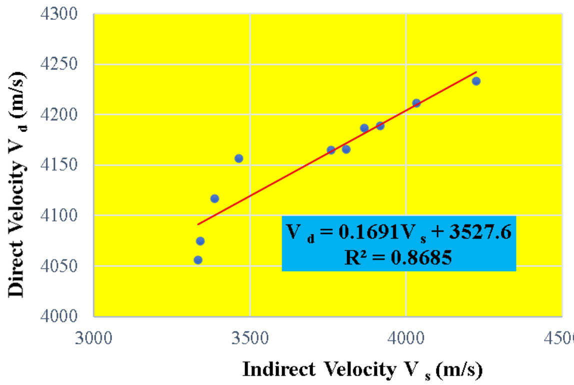

Figure 14. Correlation between direct and in-direct UPV for PRCB ON reinforcement.

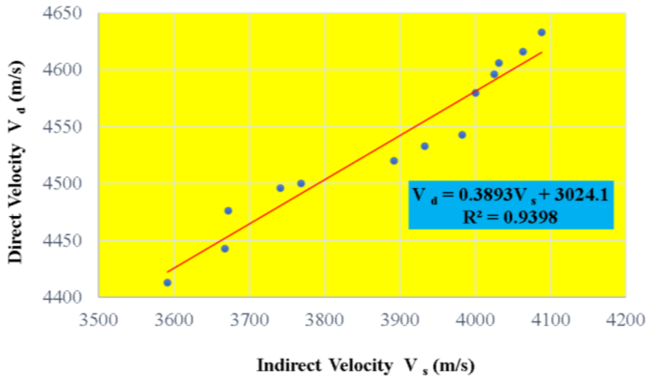

Figure 15. Correlative relationship between direct and in-direct UPV for the PS OFF reinforcement.

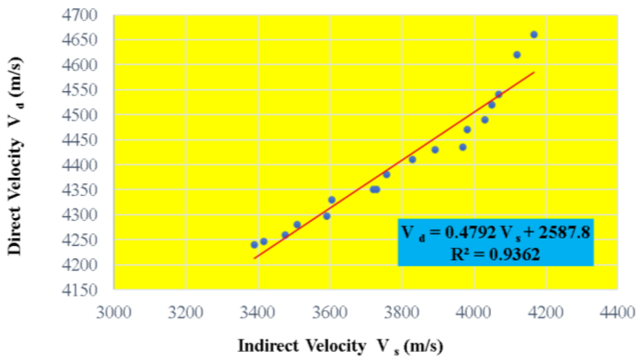

Figure 16. Correlative relationship between direct and in-direct UPV for the PS ON the reinforcement.

It is observed that V_d and V_s values are in the range for PS, for both OFF and ON reinforcement, in Figs. 15 and 16.

Best-fit lines representing the relationships are given in Table 3, where V_d and V_s indicate direct and in-direct velocity, coefficients of determination, R^2 clearly demonstrating that best fit lines in Figs. 10, 11, and in Figs. 13 to 16 show a good correlation.

Table 3. Correlation between V_d and V_s.

Structural element	'ON/OFF' the reinforcement	Regression equation	R^2
column	ON	$V_d = 0.4469\ V_s + 2421.2$	0.84
column	OFF	$V_d = 0.1691 V_s + 3527.6$	0.86
beam	ON	$V_d = 0.1691 V_s + 3527.6$	0.86
beam	OFF	$V_d = 0.5043\ V_s + 2350.4$	0.91
slab	ON	$V_d = 0.4792\ V_s + 2587.8$	0.93
slab	OFF	$V_d = 0.3893 V_s + 3024.1$	0.93

Comparisons of direct and in-direct (ON and OFF reinforcements) UPV measurements are given in Table 4. The average values of direct ultrasonic pulse velocity are 11, 15, 15, 17, and 14 % higher than average values of in-direct ultrasonic pulse velocity. In reinforced concrete members, ultrasonic pulse velocity value is affected by reinforcements. Thus, these UPV values are greater than those of concrete members without reinforcement, while their diameter is greater than 12 mm, /8/.

Table 4. Velocity ratios of direct and in-direct methods.

Structural element	ON/OFF reinforcement	V_d/V_s
column	ON	0.93
beam	ON	1.11
slab	ON	1.15
column	OFF	1.15
beam	OFF	1.17
slab	OFF	1.14

Phase: 2

Effect of stress on UPV

Collected data are analysed to study the effect of UPV under stress conditions. Beams are designed to study the shear failure crack pattern under loading conditions, and for those beams under stressed condition UPV measurements are done twice, i.e. once before applying load on the sample and the other after the beam has cracked. The arrangement of transducers will be placed directly facing the receiver on the opposite surface of the specimen. Beam width is the distance between the transducers. The ultrasonic wave will be directly transferred and this will ensure maximum interaction between transmitter and receiver. The path length is given as input to the equipment and the transducer is placed at each point, and at least three readings are taken to average the data. Five points are pre-chosen, i.e. 200 mm from support and others with increments of 200 mm from previous points, and vice-versa from the other supports and at the centre.

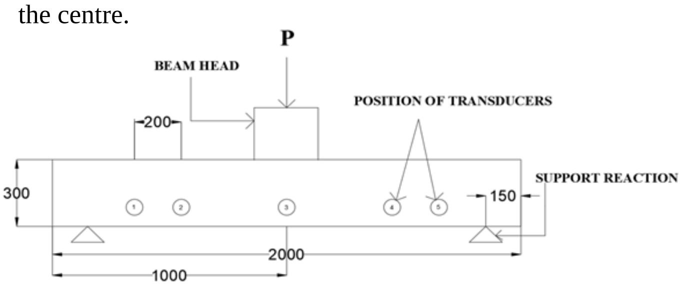

Figure 17. UPV test setup on stressed beam.

RCB1.0 is designed for load 90 kN and it has failed at a 120 kN and deflected up to 8.5 mm at the centre. A maximum variation of velocity at point 4 is observed, as shown in Fig. 19. RCB1.5 is designed for load 135 kN and has failed at 180 kN and deflected up to 12.8 mm. Maximum variation of velocity is observed at points 3 and 5, as shown in Fig. 20. RCB2.0 has a designed load 180 kN and has failed at 220 kN and deflected up to 14.5 mm, Fig. 21. Maximum variation of velocity is observed at point 5 as shown in Fig. 19. Figures 20 and 21 show that the weakest strength of the beams is located at L/4 from the end spans. The concrete quality before the loading test was excellent in terms of uniformity and homogeneity of the concrete, and after the loading test, concrete cracks are detected in the pre-cast reinforced concrete beam through the velocity difference and also through physical observation. After the load test, RCB1.0 and 1.5 are in good condition, and RCB2.0 is in medium condition.

Figure 18. Beam testing under stress condition using NDT.

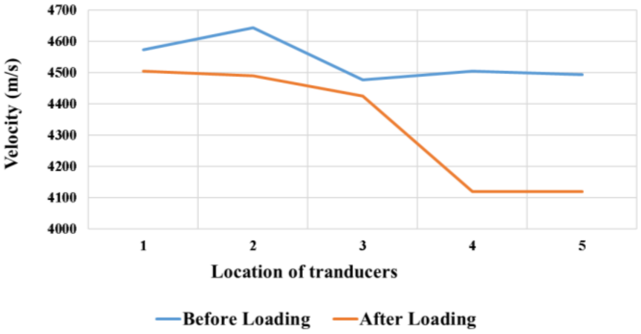

Figure 19. UPV for RCB1.0 before and after loading.

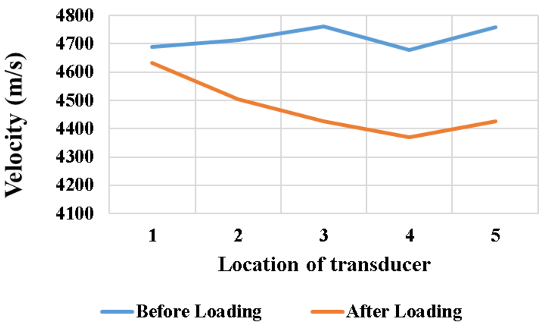

Figure 20. UPV for RCB1.5 before and after loading.

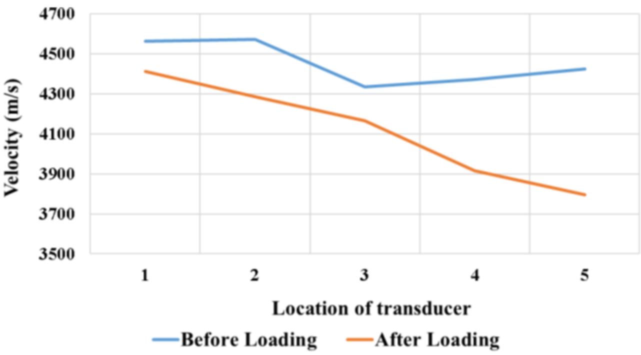

Figure 21. UPV for RCB2.0 before and after loading.

Phase: 3

Relationship between rebound number and compressive strength of concrete:

The rebound number value is plotted on *X*-axis and the compressive strength of concrete measured in the laboratory is plotted on *Y*-axis, as shown in Figs. 22 to 25.

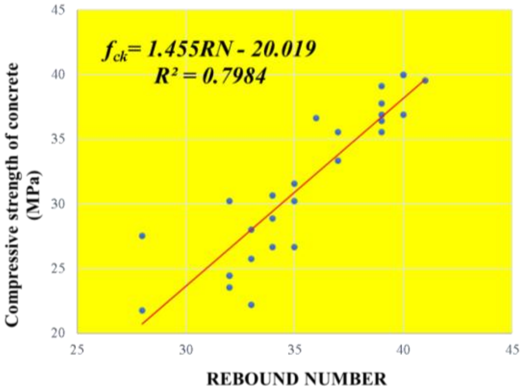

Figure 22. Linear correlation between RN and f_{ck}.

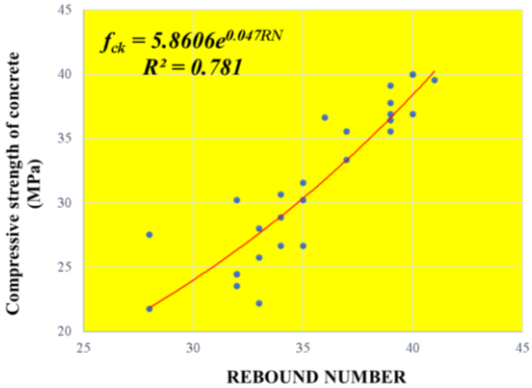

Figure 23. Exponential correlation between RN and f_{ck}.

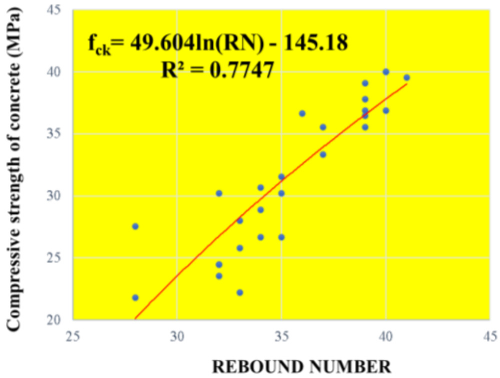

Figure 24. Logarithmic correlation between RN and f_{ck}.

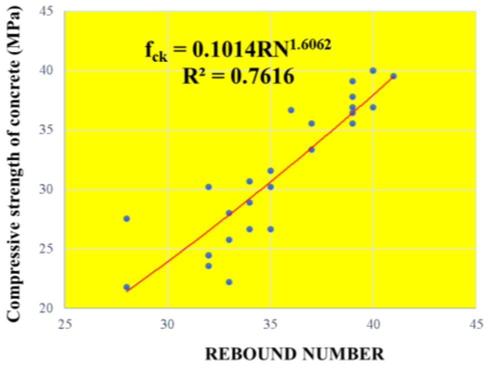

Figure 25. Power correlation between RN and f_{ck}.

It is observed that through the correlation between rebound number and compressive strength of concrete, a correlative coefficient of 0.798, which is maximum, is achieved in the linear correlation.

Relationship between UPV and compressive strength of concrete:

UPV measurements are plotted on *X*-axis and compressive strength of concrete measured in the laboratory is plotted on *Y*-axis in Figs. 26 to 29. It is observed that through the correlation between UPV and compressive strength of concrete, a correlative coefficient of 0.7 (maximum) is achieved in linear correlation. Owing that UPV and RN have different sensitivities to parameters that are important when predicting f_{ck} , can be eliminated using the SONREB method.

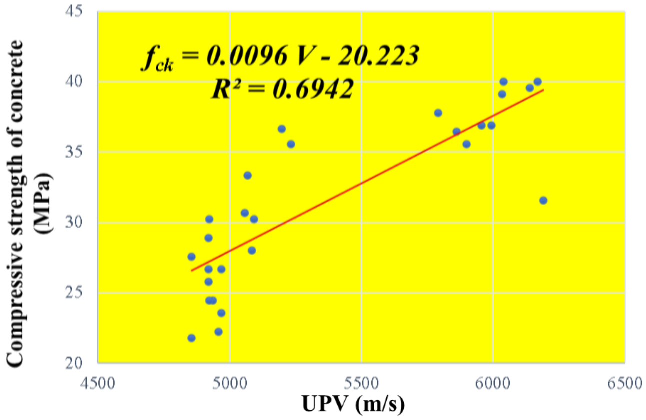

Figure 26. Linear correlation between UPV and f_{ck}.

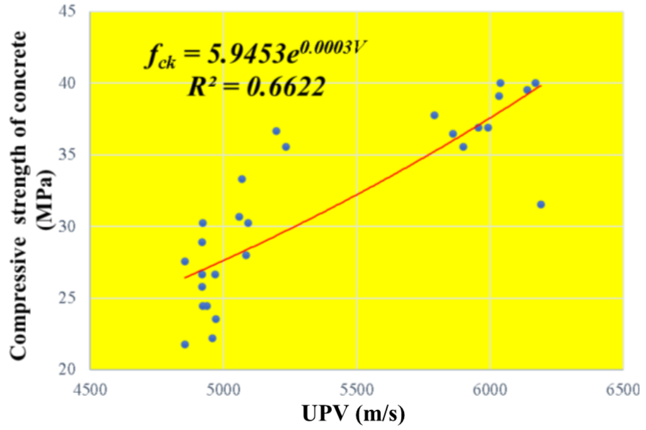

Figure 27. Exponential correlation between UPV and f_{ck}.

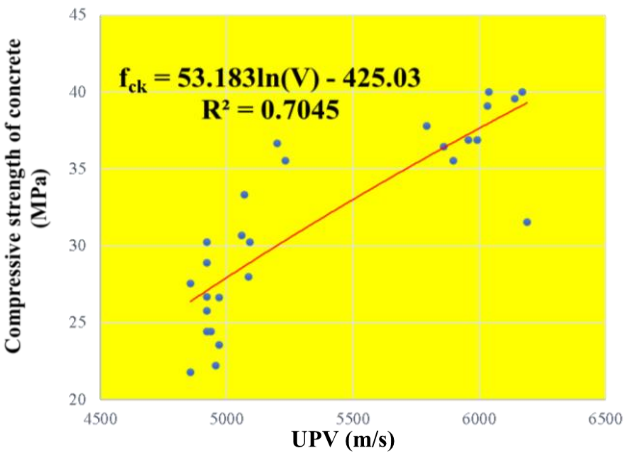

Figure 28. Logarithmic correlation between UPV and f_{ck}.

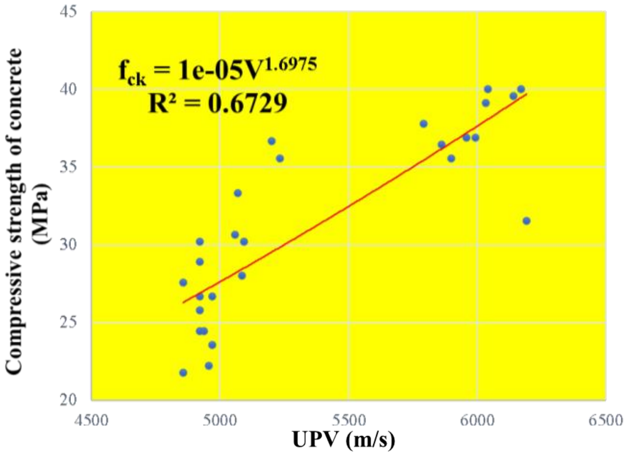

Figure 29. Power correlation between UPV and f_{ck}.

Combined method: SONREB METHOD

Parametric multivariable regression models are techniques that may be implemented with ease and utilised in practice for future applications such as reliability assessment of concrete structures in-situ conditions. A number of parametric regression models are developed using the SONREB method, using ultrasonic pulse velocity (UPV) and rebound number (RN) as parametric variables to predict the compressive strength of concrete. The combined method SONREB can evaluate concrete compression strength by combining experimentally obtained non-destructive parameters with correlations given in Eq.(1):

$$f_c = e^a \times V^b \times \mathrm{RN}^c \,, \tag{1}$$

where: f_c is concrete compressive strength (MPa); *V* is ultrasonic pulse velocity (m/s); *RN* is rebound number; *a*, *b*, *c* are dimensionless correlation parameters to be determined with multivariate analysis.

Equation 1 will change by logarithmic notation, within the multiple statistical regression analysis:

$$\ln\ln f_c = a + b \times \ln(V) + c \times \ln\ln \mathrm{RN} \;. \tag{2}$$

To identify the parameters of statistical regression, the method of minimum weighted squares usually applies:

$$w_i = f_{c,i}^2 \,. \tag{3}$$

The mean square error of statistical regression is obtained by the subsequent expression:

$$\in^2 = \frac{1}{n}\sum w_i[\ln\ln f_{c,i} - (a + b\ln\ln V_i) + c\ln\ln \mathrm{RN}_i] \,. \tag{4}$$

Unknown parameters *a*, *b*, *c* are decided to impose the condition that they minimize the mean square error. The minimal condition is detected by comparing to zero the derivatives of function $\in^2$ with unknown parameters, obtaining the system of equations:

$$\sum w_i \ln\ln f_{c,i} = a \times \sum w_i + b \times \sum w_i \ln\ln(V_i) + $$
$$+ c \times \sum w_i \times \ln\ln(\mathrm{RN}_i) \,, \tag{5}$$

$$\sum w_i \ln\ln(f_{c,i}) \times \ln\ln(V_i) = a \times \sum w_i \times \ln\ln(V_i) + b \times \sum w_i \ln^2(V_i) + $$
$$+ c \times \sum w_i \times \ln\ln(\mathrm{RN}_i) \times \ln\ln(V_i) \,, \tag{6}$$

$$\sum w_i \ln\ln(f_{c,i}) \times \ln\ln(\mathrm{RN}_i) = a \times \sum w_i \times \ln\ln(\mathrm{RN}_i) + $$
$$+ b \times w_i \sum(V_i) \times \ln\ln(\mathrm{RN}_i) + c \times \sum w_i (\mathrm{RN}_i) \,. \tag{7}$$

By solving this system of equations, the values of a, b and c can be determined. Constants values are determined by imposing the condition that minimizes the mean square error: $a = 2.210067546\times10^{-3}$, $b = 0.641619116$ and $c = 1.134074066$,

$$f_c = e^{2.21\times10^{-3}} \times V^{0.64} \times \mathrm{RN}^{1.134} . \qquad (8)$$

Relationship between SONREB and compressive strength of concrete:

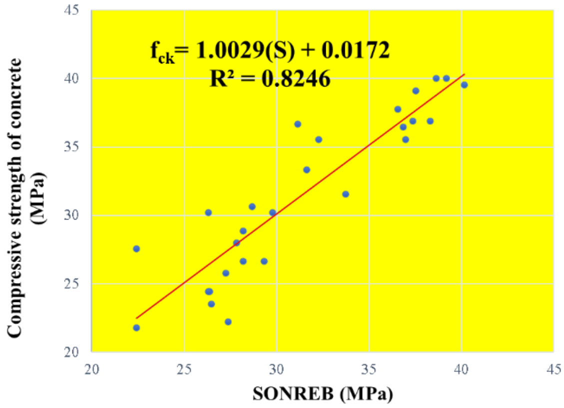

Figure 30. Linear correlation between SONREB and f_{ck}.

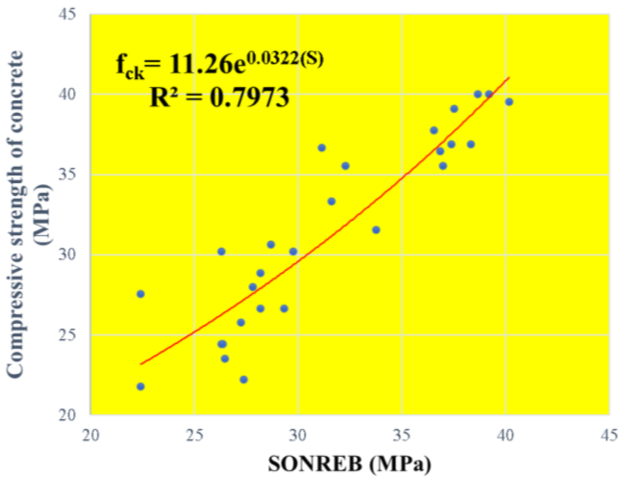

Figure 31. Exponential correlation between SONREB and f_{ck}.

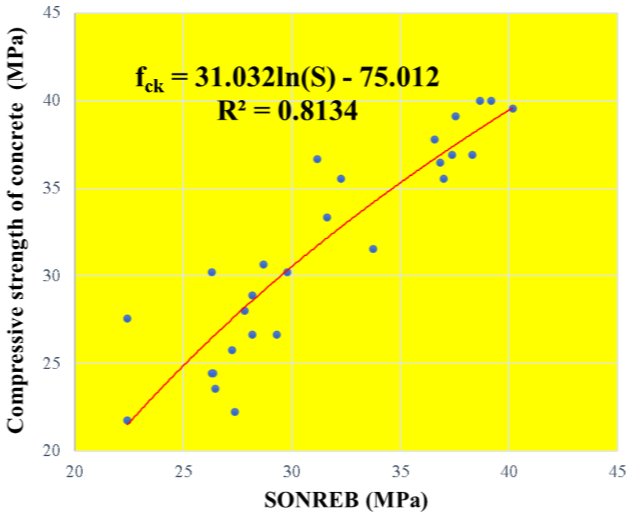

Figure 32. Logarithmic correlation between SONREB and f_{ck}.

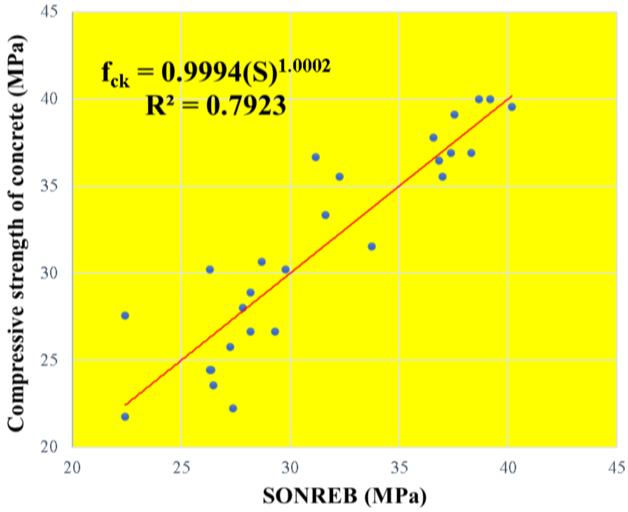

Figure 33. Power correlation between SONREB and f_{ck}.

SONREB measurements are plotted on X-axis and the compressive strength of concrete as measured in laboratory is plotted on Y-axis in Figs. 30 to 33. It is observed that through the correlation between SONREB and compressive strength of concrete, a correlative coefficient of 0.824 is maximum which is achieved in linear correlation (Table 5).

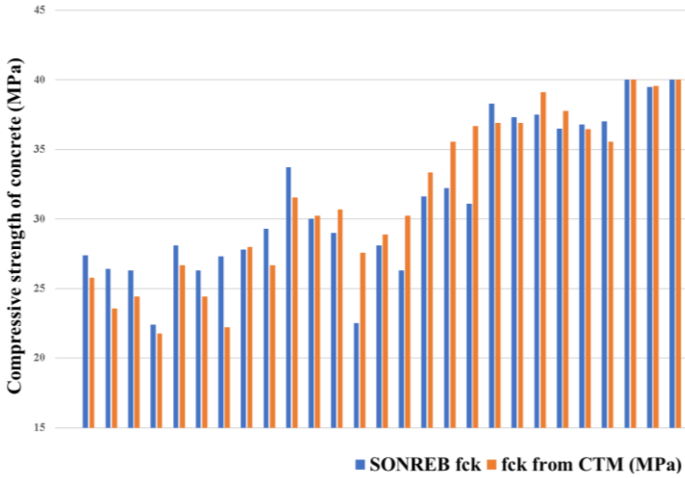

Figure 34. Comparison between DT. f_c - values and estimated NDT; f_c - values using SONREB method.

Figure 34 represents comparison between destructive test compressive strength and strength using SONREB method.

Table 5. Regression models for predicting strength.

Method	Regression model	Function expression	Correl. coeff.
Rebound hammer method	linear	f_{ck} = 1.455RN - 20.019	0.7984
	exponential	$f_{ck} = 5.8606e^{0.047RN}$	0.781
	logarithmic	f_{ck} = 49.604 ln (RN) - 145.18	0.7747
	power	$f_{ck} = 0.1014RN^{1.6062}$	0.767
Ultrasonic pulse velocity method	linear	f_{ck} = 0.0096 V - 20.223	0.6942
	exponential	$f_{ck} = 5.9453e^{0.0003V}$	0.6622
	logarithmic	f_{ck} = 53.183ln(V) - 425.03	0.7045
	power	$f_{ck} = 1e\text{-}05V^{1.6975}$	0.6729
Sonreb method	linear	f_{ck} = 1.0029(S) + 0.0172	0.8246
	exponential	$f_{ck} = 11.26e^{0.0322(S)}$	0.7973
	logarithmic	f_{ck} = 31.032ln(S) - 75.012	0.8134
	power	$f_{ck} = 0.9994(S)^{1.0002}$	0.7923

CONCLUSIONS

The correlation is performed between the direct and indirect velocity of UPV, i.e. for ON and OFF reinforcement, for reinforced concrete elements like beam, column, and slab. The effect of stress on the UPV velocities by applying incremental load on a pre-cast reinforced concrete beam of various reinforcement percentage (P_t) is observed. UPV measurements are done twice i.e. once before load applied on the sample, and after the beam has cracked. Prediction of compressive strength of concrete is done by using a parametric multivariable technique of the SONREB method.

Conclusions may be summarised as:

– The average direct UPV is 17, 15.8, and 14 % higher than the indirect UPV for beam, column, and slab, respectively for OFF reinforcement.
– The average direct UPV is 12 and 14 % higher than the indirect UPV for beam and slab, respectively, for ON reinforcement and the effect of reinforcement is not observed in our structural element column having a cover of 50 mm but for the slab, it is also not observed because reinforcement size is less, i.e. less than 12 mm.
– Based on the UPV measurement ON reinforcement, it is concluded that the indirect velocity is influenced by the depth of cover of the member.
– Effect of stress results in a decrease of UPV direct measurements for stressed beams. RCB1.0 resulted in 8.5 % decrease in UPV; RCB1.5 resulted in 7.5 % decrease in UPV; and RCB2.0 resulted in 14 % decrease in UPV.
– For the purpose of strength estimation, UPV, rebound-number independently have a correlation coefficient of 0.7 and 0.798, respectively, whereas combining the two methods by using the SONREB method results in a higher correlation coefficient of 0.824 through linear correlation.

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This note aims to correct an error in the list of authors' names of the published paper (given above). In the version of this article initially published, there was an error in the missing name of a third author: Yasser Rostamiyan. The correct list of authors is: 'Mohammad Afzali, Amirhossein Karimloo, and Yasser Rostamiyan.' The other elements of the paper, including author affiliations remain the same.