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SonReb Method for Evaluation of Compressive Strength of Concrete

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Abstract. Ultrasonic Pulse Velocity (UPV) and Rebound Hammer (RH) are continually adopted methods by the researchers to assess the characteristics and to estimate the compressive strength of the concrete. As matrix of concrete is very complex, it's obvious that the strength of concrete can be influenced due to even minor change in any of the factor. The factors that influenced the strength of concrete largely are the type and size of aggregates, cement content, physical and mechanical factors. To evaluate the compressive strength considering these factors with higher precision, UPV and RH methods are combined henceforth called SonReb. The results of testing of on-site casted cube samples and cores samples taken from the existing buildings in Pune, India are presented here. The application of the regression model to observe destructive and non-destructive testing were used through SonReb method to evaluate the reliability of concrete. Equations are obtained using multiple regression statistical analysis (MRSA) to access concrete compressive strength and the accuracy of the strength prediction technique is discussed in this paper. The regression curve of proposed model strongly consistent with the models suggested by Meynink, Ramyar et al. and Khedar et.al. It is also concluded that the results obtained from core are underestimate, which reflects the age factor when compared with the samples tested in laboratory. It is also seen that the regression coefficient of both the formulation are closely matching, which indicates no effect of age of samples tested. SonReb results seems to be more accurate and reliable than any individual test performed on the same samples.

1. Introduction

These It is of great interest to evaluate concrete properties, whether to detect enhanced regions or to control the quality of concrete and to estimate its compressive strength. Typically the most searched over attribute is the concrete compressive strength. This allows the combination of UPV and RH results [1]. Major benefit of non-destructive test approach is to prevent concrete disruption to the reliability of structural elements of building. Concrete testing in structures involves the use of less expensive equipment in which the cores cannot be drilled. [2]. All obtainable techniques for in situ concrete assessment has constrained, their efficiency is often called into question mark, as well as the blend of two or more techniques arises as a reaction to all these problems. [3].

The application of certain non-destructive testing techniques is very often applied scientifically, incorporating two most commonly used methods to improve the accuracy of the estimation of concrete compressive strength; the theory is focused on comparisons between the measurements obtained and the expected value. [4]. The most frequently adopted standard combination method is the SONREB



technique provided by RILEM [5], which was first developed in Romania and implemented in Europe and Australia.

The formulation suggested by different authors varies with the location and majorly influenced by locally available materials. That is why the consistency of results is depends upon the formulation and applicable only to its own use. This paper intended to bring the formulation using SonReb method as per the locally available material used in casting of samples tested in laboratory and in-situ testing condition.

1.1. Objective of Research

The main objective of this paper is to assess in-situ compressive strength of the concrete. The development of correlation between the independent variable (rebound number, ultrasonic pulse velocity) and dependent variable (compressive concrete strength) is used to evaluate the strength of standard laboratory samples and core samples taken from existing buildings. To present comparative analysis between proposed and suggested models by different researchers using multiple regression statistical analysis (MRSA).

2. Literature Review

In mixing with those acquired by ultrasonic pulses, even Schmidt's use of rebound hammer dates back to the mid-sixties, although Facaoaru should be assigned the first significant scientific article. [6].

Researcher's recommends techniques for assessing concrete strength predicated on certain correction factors depending on the type and dosage of the cement, and also the aggregate type and size. Afterward, throughout 1970s, Samarin [7] started using the combined SonReb method, in which the only recognized factors prior to the test were the type of aggregate and age of concrete. Many research papers have been published since the end of the seventies and based on formulations that were calibrated informal to determine the mechanical strength of the concrete using the SonReb process. [8, 9]. In 1993, RILEM NDT4 [10] also suggested using this SonReb technique and supplied ISO based strength relation in terms of curves where both the rebound index and the ultrasonic velocity are known to evaluate the compressive strength of concrete. Application of both techniques simultaneously, certain improvement in the effect of several factors that affect the RH and UPV test could be accomplished in part. A contemporary example of this implementation is the SonReb process, produced by RILEM technical committees 7 NDT and TC-43 CND in particular [5]. Improving the accuracy of the Facaoaru strength prediction [6] had accomplished by using correction factors that take into account the effect of cement type, cement content, fine aggregate fraction and total aggregate volume.

The reliability of the compressive strength will not reflect the overall performance of the concrete building material when it is located, but it is altered to take into consideration the special circumstances which may impact the strength of the sample [17], such as the slenderness and diameter of the sample, the presence of steel bars and the disruption caused by the mode of extraction.

Table 1. Formulation suggested by different authors

Year	Author	Equation used
1979	Bellander [8]	(Polynomial) $f_c = -25.568 + 0.000635 \times R^3 + 8.397V$
1979	Meynink et al [9]	(Polynomial) $f_c = -24.668 + 1.427 \times R + 0.0294V^4$
1991	Arioglu et al. [11]	(Power) $f_c = 18.6E^{0.019 \times R} + 0.515V$
1993	RILEM [10]	(Power) $f_c = 9.27 \times 10^{-11.11} \times R^{1.4} \times V^{2.6}$
1994	Di Leo, Pascale [12]	(Power) $f_c = 1.2X \cdot 10^{-9} \times V^{2.446} \times R^{1.058}$
1996	Ramyar et al. [13]	(Linear) $f_c = -39.570 + 1.532 \times R + 5.0.614 \times V$
1996	Arioglu et al. [11]	(Power) $f_c = 0.00153 \times (R^3 \times V^4)^{0.611}$
1998	Khedar et al. [14]	(Power) $f_c = 0.0158 \times R^{1.1171} \times V^{0.4254}$

2004	Menditto et al. [15]	(Power) $fc = 0.00004 \times R^{1.88148} \times V^{0.80840}$
2009	Faella et al. [16]	(Power) $fc = 2.6199 \times 10^{-8} \times R^{0.5341} \times V^{2.2878}$

Table 1 shows the correlation between rebound number, UPV and compressive strength suggested by different authors in terms of equation given in power and polynomial function. The formulation given in table is the results obtained from laboratory tested cube samples. Where R is rebound number, V is ultrasonic pulse velocity, fc is compressive strength of cube sample.

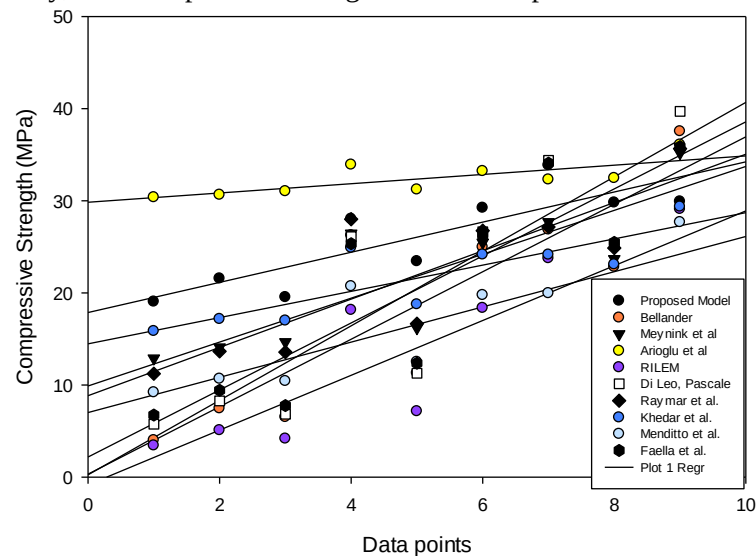


Figure 1. Regression analysis of proposed and suggested models of various authors (RH & UPV)

These equations are formulated and calibrated based on the experimental results obtained in laboratory. It is observed that several equations greatly underestimates the type of sample used by researchers, while others tend to substantially overestimate the cubic compressive strength. Compared to the model proposed, the Arioğlu model in Fig.1 showing a much higher estimate of strength than the experimental values. Also the laboratory-prepared samples of Meynink and Ramyar et.al. and Khedar et.al. Models provides accurate forecast, with numerical values closely matching to those of the experimental values. The Bellander, Menditto et. al., DI Leo, Pascale, RILEM, and Fallea models underestimating the strength than experimental values and is unsatisfactory. The proposed models showing very similar strength predictions when compared with experimental values.

3. Experimental Program

For conducting this research work, huge data were expected and the same were obtained from testing laboratory of Pune. The data obtained from laboratory is consist of non-destructive test (UPV and RH) and destructive test conducted on core samples taken from the buildings having age of 20 year and 30 year. Samples prepared in laboratory considering same parameters and tested at various ages. Results are interpreted by combining correlations between non-destructive techniques and mechanical test techniques i.e. SonReb. The materials properties are estimated in laboratory and used for making of concrete are shown in Table 2. Casting of 27 cubes of grade M20, size 150x150x150 mm is done in laboratory strictly as per IS: 10262-1982 and IS: 456-2002. The curing is done for a period of 7, 14 and 28 days under standard temperature conditions. Relationships between 7, 14 and 28 day compressive strength specimens prepared in laboratory and measurements of non-destructive test for RH and UPV is done. Before extracting cores from buildings, NDT tests has been carried out using UPV with direct transmission. The mean diameter of core is in the range of 70mm -75 mm. The core cylinder strength is converted into equivalent cube strength applying uniform loading at the rate of 5MPa/s.

Table 2. Material Properties

Ingredients	Cement	Coarse Aggregate	Fine Aggregate
Grade	OPC- 53 Grade	Max. nominal size: 20 mm	Max. nominal size: 4.75 mm
Specific gravity	2.76	2.65 (Zone II of IS: 383)	2.74
Water absorption	-	4.71%	1.52%
w/c ratio	0.5		

4. Statistical Analysis

Research has shown that the various factors have a significant impact on RH and UPV values. It is important to calibrate the measurements from the two tests in order to resolve inconsistent outcomes and enhance the accuracy of results. Regression analysis tends to be the response to investigate experimental data utilizing mechanical test results on specimens and cores and is essential to calibrate these tests. It is observed that, the better correlation has been identified between the experimental outcome from core test data and non-destructive test (UPV and RH). The results are plotted in graphical form and for each regression line, SIGMAPlot is used to obtain the coefficients of the curves (Regression line) and (R²) determination. The concrete specimen from a structural framework can be considered as part of a population of infinite dimensions whose mechanical properties are the subject matter. Since an unlimited number of experimental observations cannot be conducted.

5. Result and discussion

The proposed model was built by conducting a non-linear regression analysis, which varies from each other for its mathematical structure. The application of regression enables a mathematical relationship to be established between a dependent variable and one or more independent variables. The independent variables are assumed to be the velocity of the ultrasonic pulse and the average number of the rebound, while the compressive strength was considered a dependent variable are shown in Table 3. The power expression was calibrated for the entire sample of experimental data by reducing the error between numerical prediction and experimental data.

Table 3. Summary of results obtained from laboratory testing and in-situ testing.

Rebound value	UPV	Compressive strength (MPa)	Age	Rebound value	UPV	Compressive strength (MPa)	Age
25.82	2220	19.8	7	40.02	3598	23.36	20
26.28	2560	20.9	7	39.01	3074	41.25	20
26.95	2340	19.4	7	38.08	2834	25.10	20
31.62	3780	25.4	14	39.93	2060	12.47	20
27.25	2860	25.5	14	39.77	3401	29.55	20
30.52	3870	23.1	14	15.96	2777	14.63	30
29.07	4388	37.2	28	12.44	2516	9.37	30
29.33	3856	30.6	28	13.55	2655	11.30	30
34.90	4300	34.5	28	12.37	2277	12.48	30

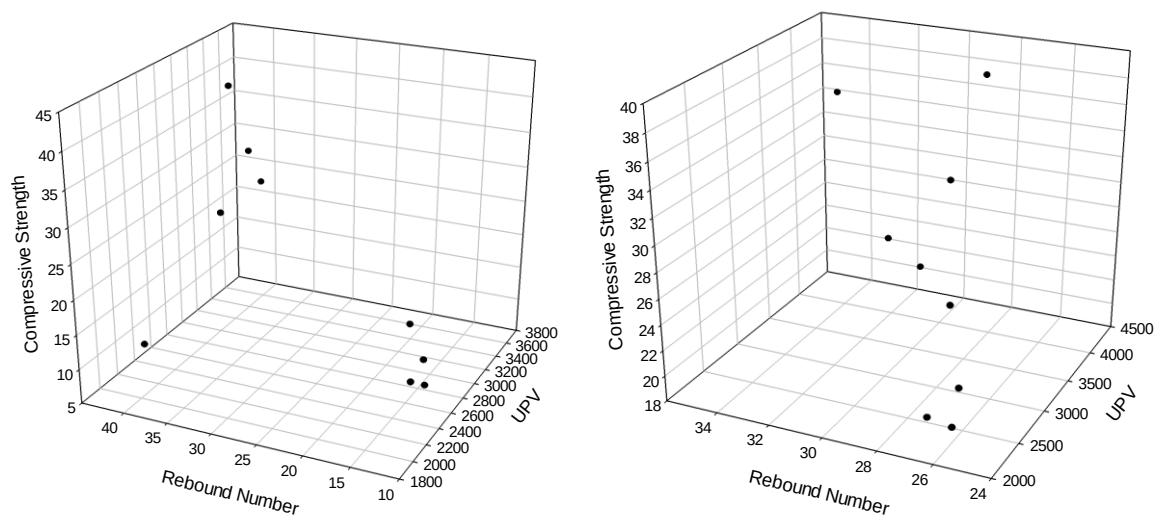


Figure 2. Compressive strength vs. Rebound number and UPV (a. Laboratory test, b. Core Test)

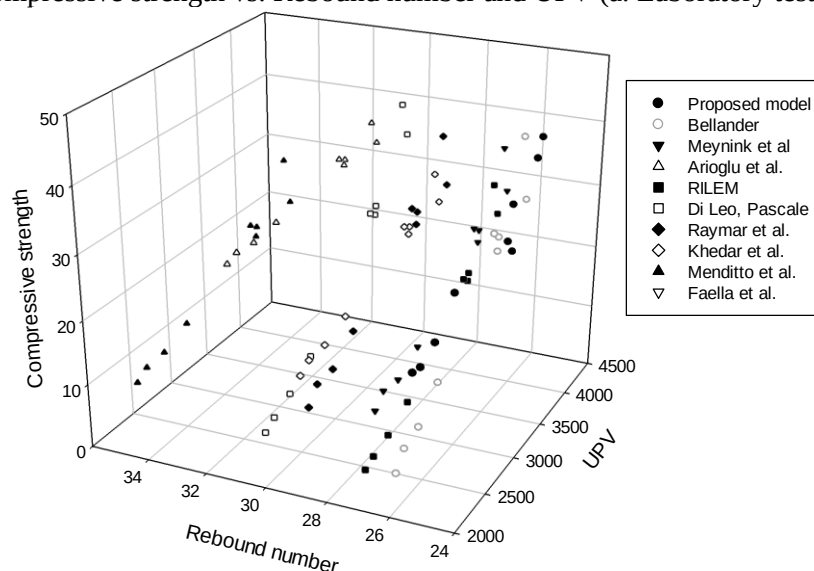


Figure 3. Comparison of proposed model with predicated model results

Table 4. Proposed model equation

Plot equation	R^2	Condition
$f_c = 0.0841 \times R^{-0.572} \times V^{0.945}$	0.769	Laboratory testing
$f_c = 0.517 \times R^{-0.546} \times V^{0.997}$	0.757	Core sample testing

The relationships are categorized as linear, polynomial, power, exponential and logarithmic as a further significant parameter for classifying the forecast relationships between concrete strength and independent variables. The rebound values and UPV values obtained from the lab are always rational prediction for the proposed model of the researcher. Due to greater variation in results as shown in Fig. 2 and Fig. 3, results obtained from cores are not significantly matched with the suggested model. The SonReb method is adopted and the results of testing done on laboratory and core samples are checked with proposed equations. The proposed equations and results are shown in Table 4 for two different

testing conditions. It is observed that, the proportion of the variance for a dependent variable are closely matched for both the conditions with different age samples. In case of laboratory testing done by RH, rebound values showing no difference in spite of age criteria. Whereas, in case of UPV the result reflects the change in compressive strength with age. This indicates that only consideration of the results obtained by RH are inadequate for strength estimation.

6. Conclusion

Based on the review of models suggested by different researchers and proposed model on experimental observations, following conclusions can be drawn:

1. The regression curve of proposed model strongly consistent with the models suggested by Meynink, Ramyar et al. and Khedar et.al.
2. It is also seen that the regression coefficient of both the formulation are closely matching, which indicates no effect of age of samples tested.
3. Only consideration of the results obtained by RH are inadequate for strength estimation as compared to UPV in case of laboratory testing in spite of same age criteria, this supports use of SonReb methodology.
4. SonReb results seems to be more accurate and reliable than any individual test performed on the same samples. It can help to assess concrete performance more accurately and it will be easier to track concrete behaviour after long period of service.

7. References

- [1] D. Breyse, "Quality of NDT Measurements and Accuracy of Physical Properties," Concrete NDTCE'09, Nantes, 30 June-3 July, 2009.
- [2] Hobbs and K. Tchoketch, "Nondestructive Testing Techniques for the Forensic Engineering Investigation of Reinforced Concrete Buildings," Forensic Science International, Vol. 167, No. 2-3, 2007, pp. 167-172.
- [3] J. H. Bungey and S. G. Millard, "Testing of Concrete in Structures," 3rd Edition, Blackie Academic & Professional, London, 1996.
- [4] Breyse, "Combining Information, Reliability and Maintenance," Diagnosis of NEC Works, 2008
- [5] Rilem Report TC43-CND, "Draft Recommendation for in Situ Concrete Strength Determination by Combined Non- Destructive Methods," 1983.
- [6] Facaoru, "Non-Destructive Testing of Concrete in Romania, Symposium on NDT of Concrete and Timber," Institute of Civil Engineers, London, 1970, pp. 39-49.
- [7] Samarin, G. Smorchevsky, The non-destructive testing of concrete, Central Research Laboratory, International Tech. Rep. 54 (1973).
- [8] U. Bellander, NDT testing methods for estimating compressive strength in finished structures – evaluation of accuracy and testing system, in: RILEM Symp. Proc. On Quality Control of Concrete Structures, Session 2.1 vol. 1, Swedish Concrete Research Institute, Stockholm, Sweden, 1979, pp. 37–45.
- [9] P. Meynink, A. Samarin, Assessment of compressive strength of concrete by cylinders, cores, and non-destructive tests, in: RILEM Symp. Proc. On Quality Control of Concrete Structures, Session 2.1, Swedish Concrete Research Institute Stockholm, Sweden, 1979, pp. 127–134.
- [10] RILEM NDT 4, Recommendation for in Situ Concrete Strength Determination by Combined Non-destructive Methods, Compendium of RILEM Technical Recommendations, E&FN Spon, U.K., London, 1993.
- [11] Arioglu, O. K oyl oglu, Discussion of prediction of concrete strength by destructive and non-destructive methods by Ramyar and Kol, Cem. Concr. World 3, (1996) 33–34.
- [12] Di Leo, G. Pascale, "Prove non distruttive sulle costruzioni in cemento armato", Convegno Sistema Qualita e Prove non Distruttive per l'affidabilit  e la sicurezza delle strutture civili, 1994. Bologna SAIE (in Italian).
- [13] K. Ramyar, P. Kol, Destructive and non-destructive test methods for estimating the strength of

- concrete, *Cement Concr. World* 2 (1996) 46–54 (in Turkish).
- [14] G.F. Kheder, A two stage procedure for assessment of in-situ concrete strength using combined non-destructive testing, *Mater. Struct.* 32 (1999) 410–417.
- [15] 1G. Menditto, S. Bufarini, V. D’Aria, M. Massaccesi, Nuove curve di correlazione per lo sclerometro, ultrasuoni e metodo combinato, in: *Concreto*, vol. 57, Maggioli Editore, Italia, 2004, pp. 84–89 (in Italian).
- [16] G. Faella, M. Guadagnuolo, A. Donadio, L. Ferri, Calibrazione sperimentale del metodo SonReb per costruzioni della Provincia di Caserta degli anni in: atti del XIV Convegno Nazionale L’Ingegneria Sismica in Italia, 18-22 settembre 2011, 2011. Bari, Italia (in Italian).
- [17] M.T. Cristofaro, A. D’Ambrisi, M. De Stefano, M. Tanganelli, “Concrete compressive strength extracted from existing buildings”, in: L. Dezi, G. Moriconi, R. Realfonzo (Eds.), *The New Boundaries of Structural Concrete Session D: Concrete Quality Control on Site*, ACI Italian chapter, 2011.