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Evaluate the Expressions of Compression Strength and UPV Relationship

Abdelmajeed Altlomate[1*], Shahiron Shahidan[2], Faesal Alatshan[1], Mohammed Elkher[1], Nurul Izzati Raihan Ramzi Hannan[2], Sharifah Salwa Mohd Zuki[2], Faisal Sheikh Khalid[2], Mohd Haziman Wan Ibrahim[2]

[1]Instructor, Department of Civil Engineering, Faculty of Civil Engineering, Site University, Sirte, Libya.
[2]Jamilus Research Center-Sustainable Construction, Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor Bahru, Malaysia

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Abstract: Ultrasonic pulse velocity method UPV has been commonly implemented to examine the mechanical properties and reliability of concrete structures. The principle of UPV is the speed of propagation of waves that depends on the density and the modulus of elasticity of the concrete. UPV is a simple and easier method of non-destructive testing (NDT) for evaluating the structures and material. The results can be rapidly achieved and data can be periodically collected from the same test points. This paper aims to find a general formula will apply for all types of concrete, wide range of ages and compressive strength. The current formulae assimilate limited numbers of experimental tests. This is because of the formula produced of these data is limited to the specimens were tested only. In this study, 575 different experimental tests between 3 and 180 days for compressive strengths ranging from about 20 to 100 MPa were collected and summarized. Moreover, the current equations have been developed to give an accurate correlation between Compressive strength and UPV. In addition, a contemporary design formula was presented.

Keywords: Concrete, Nondestructive, Ultrasonic Pulse Velocity, Compression Strength, Density

1. Introduction

Plans and implementation of various projects depend on the availability of construction materials, despite of the evolution of building materials used over time.[2] The concrete material still occupies on top ranking applications and its developed and improved production of concrete, dramatically with various types of concrete demand such as, foam concrete, sustainable concrete and other related material.[3]

There were many uses of concrete in the construction field, and there were various types of test methods. The traditional test (Compression test) for cubes of concrete does not fit with the modern types of concrete, also it does not provide enough indicators of the quality of the concrete in terms of loading and permanence outward appearance, therefore researchers' efforts went to investigate new types of tests could diagnose the validity of concrete very quickly. Non-destructive tests NDT are used to determine the properties of concrete in the lab or in-situ without damaging the constructed members. The UPV is commonly used to locate the cracks, voids, steel reinforcement and cover concrete. UPV and Schmidt hammer are used to evaluate the structures initially before going with another accurate method.[4] This study contributes to a better understanding of a direct UPV method in concrete, and to widespread the technique with more confidence. A more relationship between UPV and fcu was found. Due to the lack or research area of understanding the direct method of UPV in concrete strength, therefore this research paper will be mainly emphasized on expressions of compression strength and UPV relationship.

2. The Applications of UPV in Concrete

The technique of UPV utilized first in 1946 by the Hydro-Electric Power Commission of Ontario to check the cracks in dams in Canada.[4] The UPV is calculated from the distance between the two transducers and transit time of the pulse measured by the device as:

$$UPV = l/t \text{ (m/s)} \quad (1)$$

Where l = stress wave path length and t = travel time. Compressive strength of concrete can be calculated from obtained values of UPV as it is shown in Table 1. [6-18] The UPV methods have been used widely to monitor the concrete compressive and tensile strength development or deterioration in laboratory, estimation of strength, elastic modulus, Poisson's ratio and deterioration of in-situ concrete, assessment of in-situ concrete uniformity, detection of cracking and gaps in in-situ concrete, also an

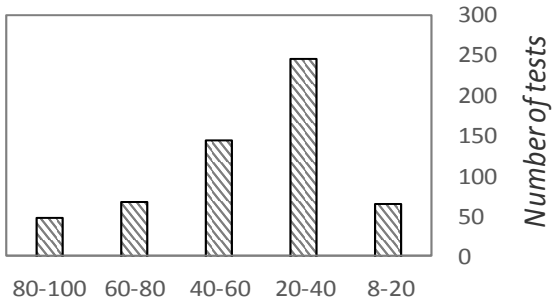
*Corresponding author: shahironshahidan@gmail.com

assessment of crack depth and the measurement of layer and paving thickness in in-situ concrete.[13, 19].

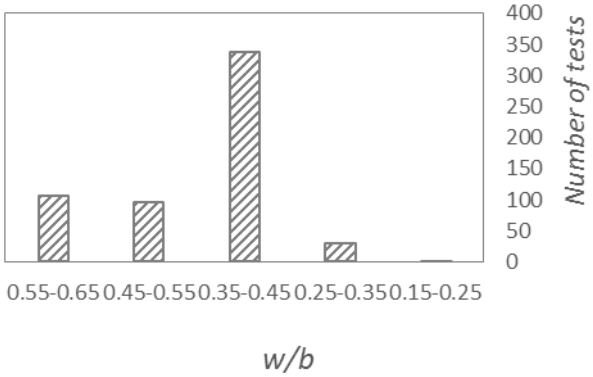
3. Methodology / Experimental Work

Data were collected for one type of ultrasonic wave velocity tests, which is a direct test method (the transmitter and receiver placed on the two faces of the opposite aspects of the model), because it is preferred to use, most widely used and most accurate. The tests were conducted depends on the British Specifications (BS 4408 and BS 1881 Part 201[20] and ASTM Specifications (ASTM C597)[17].

A database of 575 experimental UPV subjected to UPV test was compiled from the previous investigations. These are, Al Rawi and Al Khafagy[22], Frieh et al.[23], Habeeb and Hadi[24], Hamid and Salih[25], Haitham[8], Khlef[26], Muhammed et al.[27], Al-jaberi and Ali[28], Khalid Alhawi[29], Altlomate et al.[30], Alatshan et al.[31], Nik and Omran[32], R. Madandoust et al.[33], Bashar et al.[34], Akash Jain et al.[35] and M. Desa et al. [36] as showed in Table 1. The data of the previous experimental studies were collected in this paper covered a wide range of concrete strengths (fcu) ranging from 20 MPa to 100 MPa and most specimens have a value of UPV between 3.1 and 5.6 km/sec. Additionally, the dyes of tests ranged from 3 days to 90 days and the value w/b ranged between 0.25% and 0.55% as shown in Fig. 1 (a, b, c and d).



(a)



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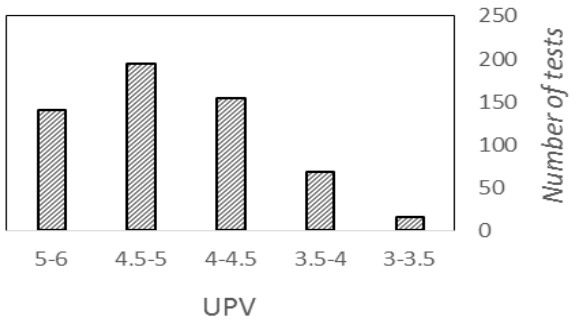

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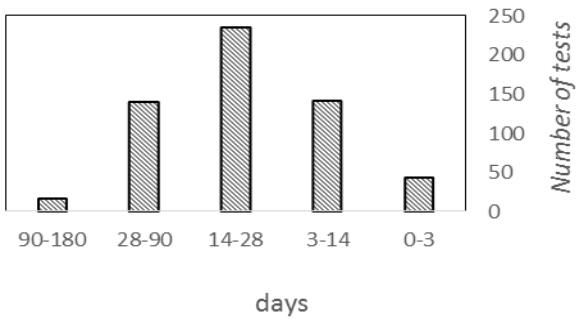

(d)

Fig. 1 The relationship between the data collected and Fcu, w/c, UPV and days.

Through the previous studies [6-18] it was seen that most of researchers handled with the estimation of fcu from UPV test results as shown in Table 1. This paper aims to find a general formula will apply for all types of concrete, wide range of ages and compressive strength. Where v is speed of propagation of waves.

Table 1 represent a few numbers of experimental tests for direct UPV

No.	Auther	Year	Current expressions
1	Jones[1]	1962	f_{cu}=2.8 $e^{0.53v}$
2	Elvery & Ibrahim[2]	1976	f_{cu} =0.0012 $e^{2.27v}$
3	Raouf & Ali[3]	1983	f_{cu} =2.016 $e^{0.61v}$
4	Abdul-salam[15]	1992	f_{cu} =-199+ 123v
5	Lopes & Neponmuceno[12]	2001	f_{cu} =0.00015 e^2.885v
6	Tumendemberel & Baigalimaa[17]	2001	f_{cu} =1.356* 10^{-5}*v^2-0.076v+111.502
7	Malhotra & Carino[13]	2004	f_{cu} =109.6+0.033v
8	Nash't et al.[14]	2005	f_{cu} =1.19 $e^{0.715v}$
9	Amir Al-dlemi[6]	2007	v=0.449 ln f_c-1.249
10	Lawson et al.[11]	2011	f_{cu} =0.053 $e^{0.001v}$
11	Shariati et al.[16]	2011	f_{cu} =15.533v-34.358
12	Jassim[9]	2012	f_{cu} =0.395 $e^{0.964v}$
13	Haitham Z. hussein[8]	2012	f_{cu} =4.141 $e^{0.488v}$

4. Results and Discussion

The Fig. 2 shows the mean value of ultrasonic pulse velocity UPV and compressive strength fcu were obtained from a total of 575 results are considered, involving different UPV ranging between 3.1 to 5.6 km/s and day tests from 3 to 90 days.

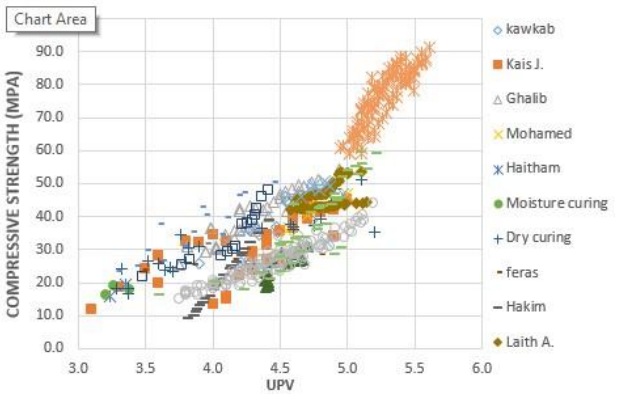

Fig. 2 Relation between UPV (Km/sec) and The Data collected

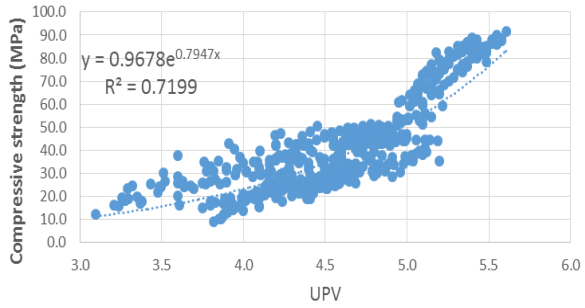

Fig. 3 Relation between UPV (Km/sec) and Compressive strength (MPa)

Fig. 3 shows the relationship between fcu and UPV for all the data collected in this study, and the best fit line representing this relationship was found to be:

$$fcu=0.9678e0.7947v \qquad R^2=0.7199 \qquad (2)$$

where V and fcu are the ultrasonic pulse velocity (km/s) and compressive strength (MPa) respectively. The R2 (coefficient of determination) value was found to be 0.7199.

The Fig. 4 shows the mean value of ultrasonic pulse velocity UPV and day tests obtained for each sample, a total of 575 results are considered.

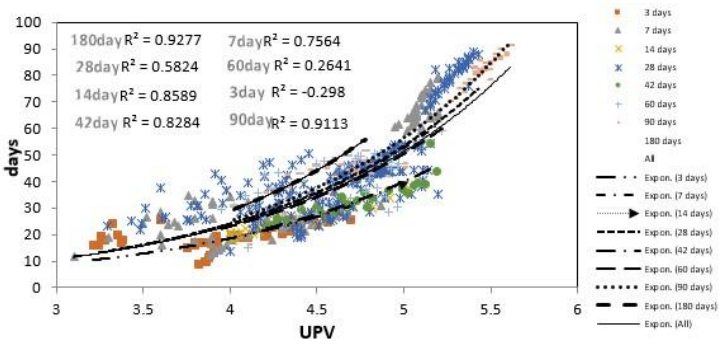

Fig. 4 Relation between UPV (Km/sec) and Age (days).

Table 2 presents the results of the average and standard deviation (STDEV) of the current expressions [6-18] and new expression (Equation 2) for direct UPV to quantify the amount of variation of a set of data were collected. Best result was found from the new expression compared with the current formulae that is because of the current formulae produced of these data is limited to the specimens were tested only.

Table 2 Comparisons between the current expressions and new expression for direct UPV

Auther	Current expressions	Average	STDEV
Jones[1]	f_{cu}=2.8 $e^{0.53v}$	0.897	0.285
Elvery & Ibrahim[2]	f_{cu} =0.0012 $e^{2.27v}$	1.426	0.937
Raouf & Ali[3]	f_{cu} =2.016 $e^{0.61v}$	0.928	0.276
Abdul-salam[15]	f_{cu} =-199+ 123v	10.289	3.858
Lopes & Neponmuceno[12]	f_{cu} =0.00015 $e^{2.885v}$	3.770	3.454
Tumendemberel & Baigalimaa[17]	f_{cu} =(1.356* 10^{-5})v^2-0.076v+111.502	3.359	1.725
Malhotra & Carino[13]	f_{cu} =109.6+0.033v	3.316	1.702
Nash't et al.[14]	f_{cu} =1.19 $e^{0.715v}$	0.883	0.245
Amir Al-dlemi[6]	v=0.449 ln f_c-1.249	15558	9949
Lawson et al.[11]	f_{cu} =0.053 $e^{0.001v}$	0.002	0.001
Shariati et al.[16]	f_{cu} =15.533v-34.358	1.021	0.356
Jassim[9]	f_{cu} =0.395 $e^{0.964v}$	0.9211	0.240
Haitham Z. hussein[8]	f_{cu} =4.141 $e^{0.488v}$	1.097	0.361
New Expression (eq.2)	f_{cu}= 0. 9678$e^{0.7947v}$	1.035	0.276

5. Summary

The direct ultrasonic pulse velocity method was used to evaluate the compressive strength of samples. The 575 data were collected to assess the exist UPV-fcu formulae, and the new formula (Equation No. 2) was found. Based

on the results presented, the following conclusion can be drawn:

- UPV tests can be considered as one of the best methods for assessing the concrete structures.
- The existing formulae as shown in Table 1 covered limited numbers of samples.
- A new general expression as shown in equation no. 2 that allows a more accurate estimate of fcu from UPV was found and can apply for a wide range of compressive strength and many types of concrete.

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