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The study of ultrasonic pulse velocity on plain and reinforced damaged concrete

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Introduction

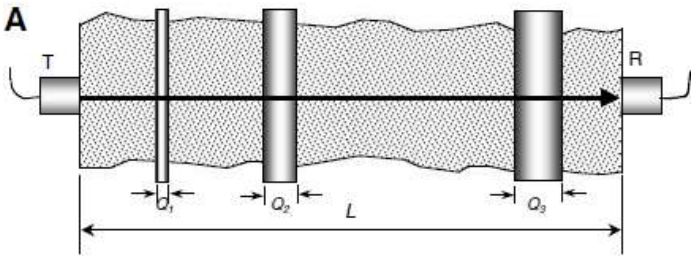
Background

- Ultrasonic pulse velocity method is a kind of non-destructive testing in materials.

- It has been applied to investigate the quality of concrete material:
    - Detecting any defects, internal cracking,
    - Evaluating durability effect.
    - Predicting in situ concrete mechanical properties

Introduction

- Research on ultrasonic pulse velocity in concrete has been developed.
- Most of the research, study on relationship between ultrasonic pulse velocity and mechanical properties of concrete.
- In presence of steel reinforcement, the ultrasonic pulse velocity in steel is higher than that of in concrete. Therefore, it is commonly supposed reinforced concrete has higher velocity (*).



* V.M. Malhotra and N.J. Carino, Hand Book on Non-Destructive Testing in Concrete, CRC Press (2004)
J.H. Bungey, S.G. Millard, M.G. Grantham, Testing of Concrete on Structures, Taylor and Francis (2006)
R. Pucinotti, L. Hinterholz, A. D'Elia, R.A.D. Lorenzo, Influence Of Steel Reinforcement On Ultrasonic Pulses Velocity, 4th International Conference on NDT (2007)

Introduction

- However, this condition is not always found during the testing.

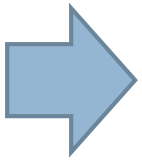
- Other research on ultrasonic velocity on concrete shows that the velocity is not obviously affected by the present of reinforcement. Furthermore, another study found that the reinforcement decreases the pulse velocity in concrete. Concrete having more reinforcement produces smaller velocity (**).

- Besides the effect of reinforcement, various concrete damages can as well be found during the measurement which influences the velocity. Cracks and materials delamination are often found on existing concrete which affect the velocity.

** N. Sabbağ, O.Uyanık, Prediction Of Reinforced Concrete Strength By Ultrasonic Velocities, Journal of Applied Geophysics (2017)
U. Lencis, A. Ūdris, A. Korjakins, Decrease of the Ultrasonic Pulse Velocity in Concrete Caused by Reinforcement, Journal of Materials Science and Engineering (2011)

Background

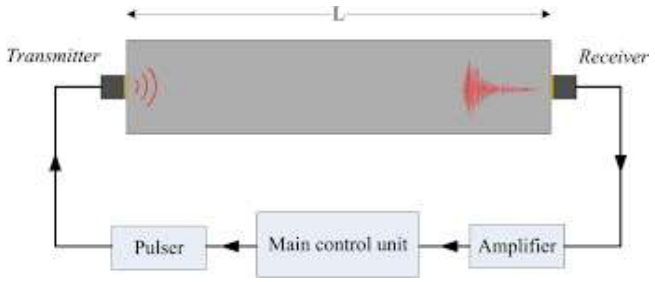
- It must be recognized that exact evaluation of reinforced concrete in structures by using ultrasonic methods is still challenging.



- This research **emphasizes the study of ultrasonic pulse velocity in plain and reinforced damaged concrete.**

Theory of

Ultrasonic Pulse Velocity on Concrete



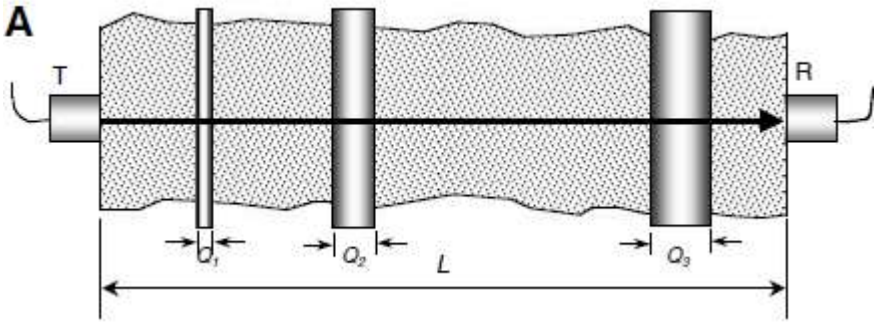
- The transmitter sensor of the pulse velocity device transmits a wave into the concrete and the receiver sensor, at a distance *L*, receives the wave through the concrete at another location.

- The compressional wave pulse velocity *V* is the length, L divided by pulse travelling time, Δt a time for the compressional wave propagating through the concrete :

$$V = \frac{L}{\Delta t} \qquad (1)$$

- The influence of reinforcing steel on concrete:

$$\frac{V_C}{V} = 1 - \frac{L_S}{L}\left(1 - \frac{V_C}{V_S}\right) \qquad (2)$$



V_c = velocity in concrete;

V = velocity in reinforced concrete;

V_s = velocity in steel;

L = transmission length;

L_s = total length of steel

Experiment

Material

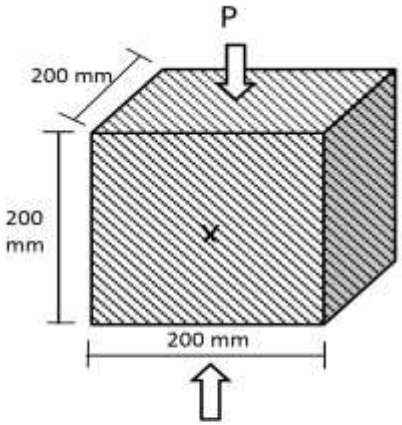
- A target concrete compressive strength of 25 MPa, 35 MPa, and 45 MPa were designed.
- Specific gravity of coarse aggregate and fine aggregate were 2.56 and 2.65 respectively.
- Local crushed stone was used for coarse aggregate with 20 mm of maximum diameter.

Target Strength (MPa)	Water-Cement Ratio	Cement (kg/m^3)	Water (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)
25	0.56	360	205	740	1110
35	0.48	427	205	713	1070
45	0.42	477	205	693	1040

Specimen

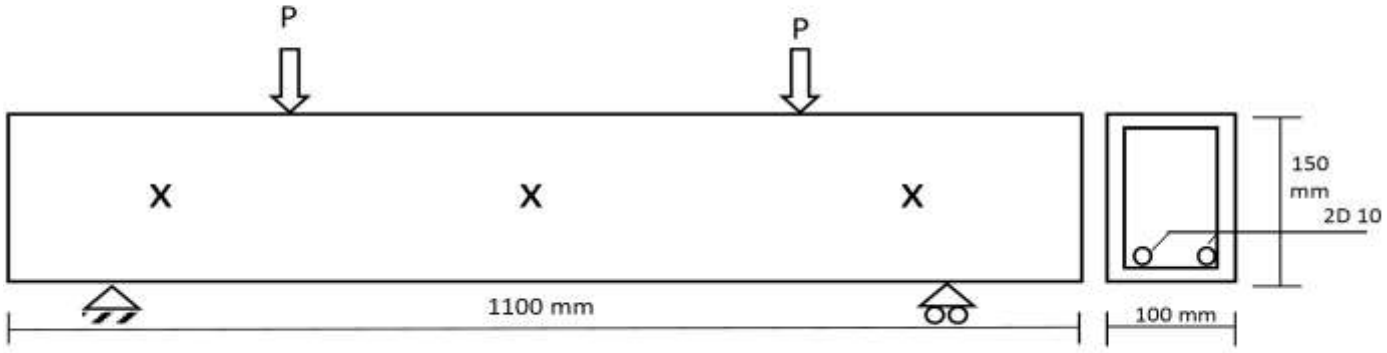
- Plain concrete:

Cube 200 mm x 200 mm x 200 mm



- Reinforced concrete:

Beam 100 mm x 150 mm x 1100 mm



X = sensor locations

Method and Testing

- The ultrasonic wave was measured in some damaged condition of concrete.
- Damage level was determined by a percentage of loads from maximum load, set by 25% and 50% of maximum load.
- Therefore, the wave was recorded during three conditions:

  Sound (0% damage),

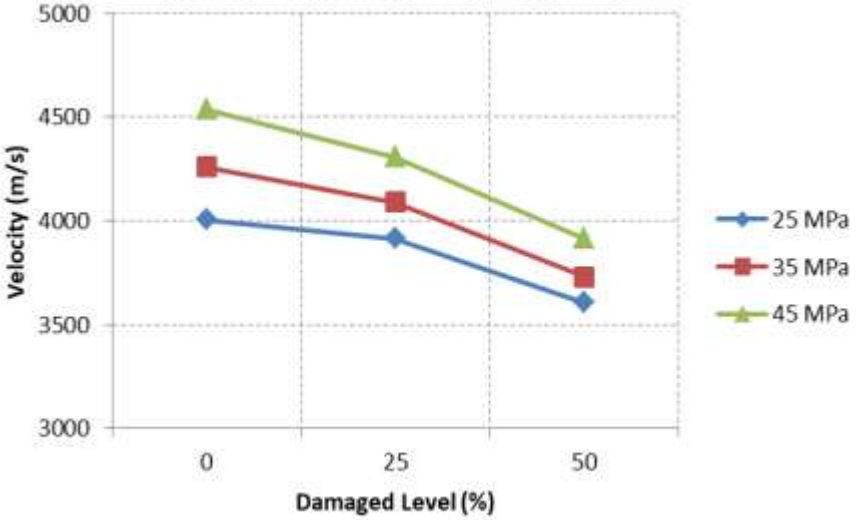
  Damage (25% and 50% damage)
- Concrete cube was subjected to axial compression load;
- Beam specimen was subjected flexural load based on third point loading mechanism.

Ultrasonic Pulse Velocity Equipment

- Testing was conducted after all of the specimens reached 28 days of curing time.
- Ultrasonic pulse velocity testing measurement was from 'Pundit Plus CNS Farnell' consisted of a transmitter, a receiver sensor, and ultrasonic device.
- The testing met the requirement of American Society for Testing and Materials (ASTM) C597-09 "Standard Test Method for Pulse Velocity through Concrete".
- Direct measurement was adopted.

Result and Discussion

Ultrasonic Pulse Velocity of Plain Damaged Concrete

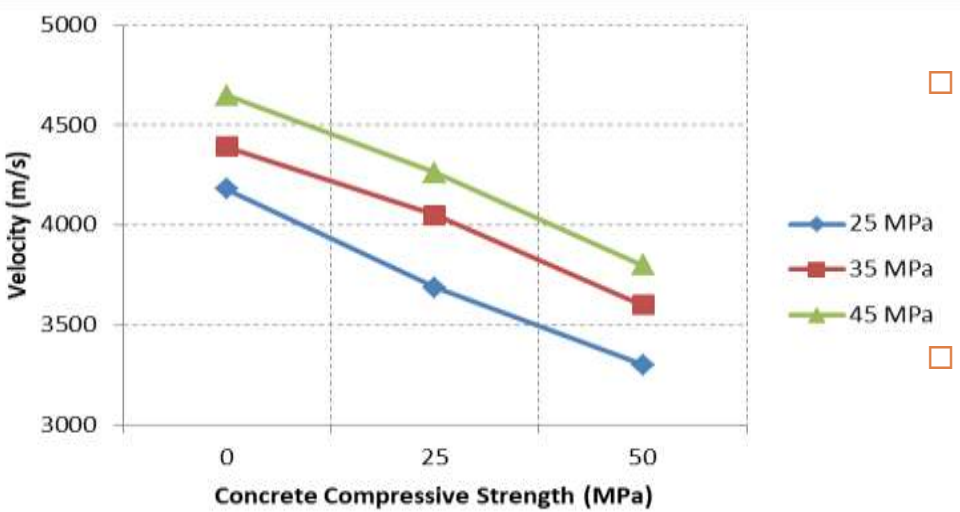


- In all concrete grades, the ultrasonic velocity decreases as the damage level increase.
- The higher compressive strength of concrete the higher ultrasonic pulse velocity.

Concrete Strength (MPa)	Average Velocity in Each Damage (m/s)			Velocity Decrease (%)	
	0	25	50	0-25	0-50
25	4004	3914	3604	2,25	9,99
35	4259	4089	3727	3,99	12,49
45	4535	4307	3914	5,03	13,69

- However for damaged condition, the velocity decrease in higher-grade concrete is more significant than in that in the lower grade ones

Ultrasonic Pulse Velocity of Reinforced Damaged Concrete

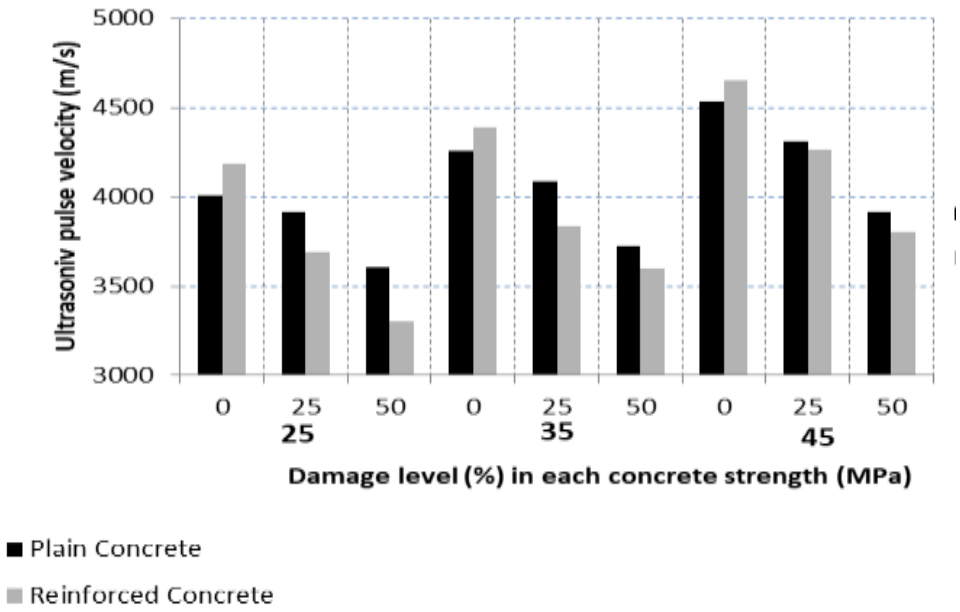


- Similar to plain concrete, the ultrasonic velocity of reinforced concrete decreases as the damage level increase
- The higher the compressive strength of concrete, the higher the ultrasonic pulse velocity

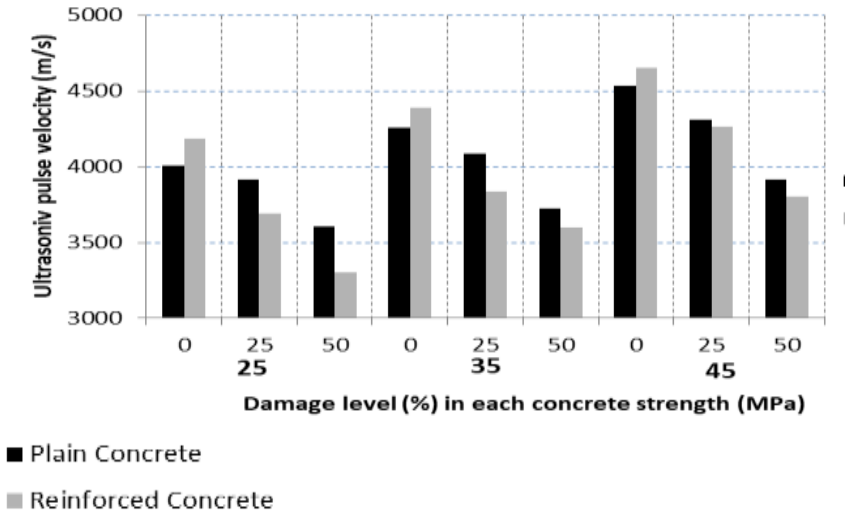
Concrete Strength (MPa)	Average Velocity in Each Damage (m/s)			Velocity Decrease (%)	
	0	25	50	0-25	0-50
25	4182	3688	3300	11,81	21,09
35	4391	4050	3601	7,77	17,99
45	4650	4262	3801	8,34	18,26

- However unlike plain concrete, the velocity decreases more in lower grade concrete.

Influence of Damage Level to the Ultrasonic Pulse Velocity of Plain and Reinforced Concrete



- Higher damage level produces lower ultrasonic pulse velocity in all concrete grades
- In sound condition, reinforced concrete has higher velocity than plain concrete in each concrete strength.
- This is in line with related theory (*) that ultrasonic pulse velocity in reinforced concrete is higher than that of plain concrete



- However, unlike the sound concrete the velocity of damaged reinforced concrete is lower than the plain damaged concrete.
- The higher damage level, the lower the velocity decrease is observed.
- Dismantling of reinforcing bar from concrete surfaces and some cracking in concrete might occur in damaged concrete causing more time propagation of wave and resulting lower in velocity reading.

Comparison of Experimental Result with Theoretical Method

- The experimental result of pulse velocity in plain and reinforced concrete are then compared to the Equation 2.

- The apparent experiment result in ultrasonic pulse velocity is almost similar to theoretical method

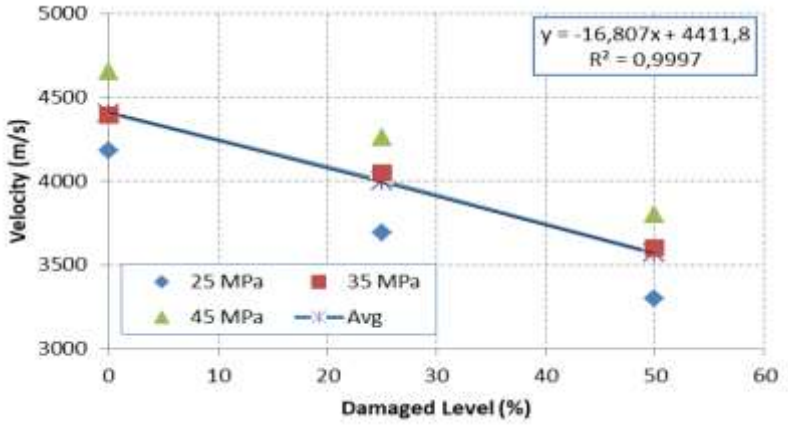
Concrete Compressive Strength (MPa)	Ultrasonic Pulse Velocity (m/s)			Difference (2)/(3)
	Plain Concrete	Reinforced Concrete		
		Experiment	Theoritical	
	(1)	(2)	(3)	
25	4004	4182	4110	1.02
35	4259	4391	4345	1.01
45	4535	4650	4596	1.01

- It is found that the theoretical method can only be applied for intact reinforced concrete due to higher velocity of reinforced concrete obtained than that of plain concrete during experiment.

- However, the theoretical method cannot be applied to damage one due to lower velocity of reinforced concrete obtained than that of plain concrete during the experiment.

- Therefore, the new regression is proposed in this research to predict the ultrasonic pulse velocity in reinforced damaged concrete based on experimental result

Ultrasonic Pulse Velocity Prediction for Damage Reinforced Concrete



A regression is proposed in this research to predict the ultrasonic pulse velocity in reinforced damaged concrete based on experimental result

$$y = -18.60x + 4411.8$$

y = ultrasonic pulse velocity in reinforced concrete (m/s);
x = concrete damage level (%)

Conclusion

- In all concrete grades of both plain and reinforced concrete, the ultrasonic velocity decreases as the damage level increase.
- During intact condition, the velocity of reinforced concrete is higher than that of plain concrete.
- Damaged reinforced concrete has lower velocity that the plain damaged one
- Dismantling of reinforcing bar from concrete surfaces and some cracking in concrete might occur in damaged concrete causing more time propagation of wave and resulting in a lower velocity reading

Thank you

Further contact:

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UPV value in km/sec (V)	Concrete quality
V greater than 4.0	Very good
V between 3.5 and 4.0	Good, but may be porous
V between 3.0 and 3.5	Poor
V between 2.5 and 3.0	Very poor
V between 2.0 and 2.5	Very poor and low integrity
V less than 2.0 and reading fluctuating	No integrity, large voids suspected