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Uncertainties of strength concrete estimation by ultrasonic NDT (Admixture effects)

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Abstract:
The velocity measurement of ultrasonic wave propagation through the concrete is currently used to diagnose the possible severe zones of concrete degradation or to detect singularities in the concrete. In addition, on the theoretical level ultrasonic velocity is used to determine the dynamic modulus of elasticity and the density of the concrete. For the relationship with compressive strength, several parameters can intervene so that we have not only one and simple relation between ultrasonic velocity and the strength of concrete. Differences can exist, if various compositions and ages of the concretes are used in the relationship ultrasonic velocity/compressive strength. This experimental work is interested in the study of uncertainties between ultrasonic velocity (vpu) and the strength (f_c,) introduced by the difference of admixture of concrete. Seven compositions of concrete are tested whit various water/cement ratios (W/C) and fine aggregates fins/aggregates ratios (S/S+G). The tests related to measurements ultrasonic velocity through cylindrical samples (16/32). These same samples were crushed in order to determine their compressive strengths at various ages (7, 14 and 28 days).

Keys words: Concrete, Admixture, Ultrasound (B), Compressive strength, Correlation (B).

1. Introduction

The non destructive methods for simple concrete or reinforced concrete structures are particularly interesting because of the high proportion of these constructions and the importance which has the quality control directly on construction. The advantages of these tests compared to the others can be summarized in the non-destructive character. We can obtain information in fields inaccessible to the traditional methods, economise materials, time and tools for test, by the possibility of even carrying out the tests on material in the structures or on only one sample a practically infinite number of tests. The principal disadvantage of the non-destructive testing methods lies in the fact that in the present time, they cannot provide sufficiently precise data to replace the destructive methods completely in the principal applicability. Some non-destructive methods are based on the fact that some physical properties of the concrete can be connected at strength. These physical properties include porosity, hardness, and penetration resistance of the projectiles, capacity of bounce and to transmit the ultrasonic impulses and x-rays and gamma. The velocity measurement of ultrasonic wave propagation through the concrete can inform us about compressive strength. Differences can exist, if various compositions and ages of the concretes are considered, in the relation ultrasonic velocity/compressive strength. This study is interested in uncertainties, between ultrasonic pulse velocity (vpu) and the compressive strength (fc), introduced by the difference of the admixtures concrete to estimate a correlation between these two properties.

2. Experimental details

2.1. *Materials*

The choice of materials used was made on their availability in the area of Guelma city (east of Algeria), the materials used are a sand (absolute specific mass = 2.67 g/cm ^{3}), two gravels (5/15 and l5/25) (absolute specific masses = 2.63 g/cm ^{3} (5/15), 2.70 g/cm ^{3} (15/25)) and a cement CPJ classifies 32.5 (absolute specific mass= 3.1 g / m ^{3}).

2.2. *Compositions of the concretes*

The performances of the concrete are related to the choice and the proportions of its components. The methods of composition are numerous, we distinguish those which use curves of references and those based on other principles [1]. The various compositions used in this study were determined by the method of Dreux-Gorisse [2,3]. The following table summarizes all seven compositions tested.

Table 1 Compositions of the various concretes

Compositions / Materials [Kg/m^3]	B1	B2	B3	B4	B5	B6	B7
Sand	500	750	1000	552	539	614	750
Gravel 5/ 15	928	613	520	1023	525	629	700
Gravel 15/25	232	307	130	264	509	610	350
Cement	440	440	440	350	350	350	350
Water	220	220	220	197	222	197	206
S/S+G	0.30	0.45	0.60	0.30	0.34	0.33	0.41
W/C	0.50	0.50	0.50	0.56	0.63	0.56	0.59

We notice on this table the variation of the parameters, which we are fixed to vary in the objective of this study. These parameters are the water/cement ratios (W/C) and fine aggregates fins/aggregates (S/S+G).

3. Experimental results and discussions

The results of the experimental tests carried out concern:
- Measure of ultrasonic pulse velocity,
- Measure of compressive strength by the destructive test.

The tests were carried out on cylindrical samples (16/32) according to standards [4, 5, and 6]. The measurement of ultrasonic velocity was carried out by an ultrasonic tester (standard: 58-E0048, mark controls) including a transmission head and a reception head (54 KHz). These properties were determined for the various compositions of the concrete at 7, 14 and 28 days. Six samples were tested for each admixture and age of the concrete. The ultrasonic velocity was measured in direct transmission along the sample (L=16 cm). From the results of the experimental tests, we try to establish an existing relation between the ultrasonic pulse velocity and compressive strength of the concrete according to the effect of ratios W/C and S/S+G.

Table 1 and figure 1 show the whole of the results grouped by curing age. It is noticed that the results at the various ages are not definitely separate. Ultrasonic velocity at 7 days present 76 % (B1) to 93 % (B2) of those at 28 days, while compressive strength vary from 63 % (B7) to 85 %(B3) for the various water/cement ratios. The use of all results (ages, ratios W/C and S/S+G) to determine a correlation between the ultrasonic velocity and the compressive strength of the concrete can induce significant errors in the estimate of strength.

Table 2 Relations: ultrasonic velocity- compressive strength

Ratios (W/C) \ Age (days)		07	14	28
0.50 (B1)	V (m/s)	3965.66 ± 217.18	4164.25 ± 90.58	4463.0 ± 466.69
	f_c (MPa)	17.55 ± 1.04	19.44 ± 0.39	22.66 ± 1.26
0.50 (B2)	V (m/s)	3874.16 ± 228.34	4169.00 ± 59.77	4299.50 ± 6.36
	f_c (MPa)	15.69 ± 0.66	17.05 ± 0.01	18.76 ± 0.04
0.50 (B3)	V (m/s)	3905.50 ± 217.24	4129.25 ± 86.5	4205.50 ± 45.96
	f_c (MPa)	16.83 ± 0.95	17.41 ± 1.34	19.73 ± 0.99
0.56 (B4)	V (m/s)	3461.92 ± 195.55	3543.26 ± 90.62	3915.82 ± 100.21
	f_c (MPa)	14.71 ± 0.88	15.00 ± 0.87	19.11 ± 1.71
0.63 (B5)	V (m/s)	2846.24 ± 110.25	3252.15 ± 98.45	3733.33 ± 110.60
	f_c (MPa)	16.72 ± 1.01	20.50 ± 0.98	21.72 ± 2.31
0.56 (B6)	V (m/s)	3561.73± 88.35	3639.28 ± 105.66	3993.33 ± 99.52
	f_c (MPa)	18.51 ± 1.08	20.43 ± 1.12	24.04 ± 1.65
0.58 (B7)	V (m/s)	3496.66 ± 185.54	3697.60 ± 228.94	3931.10 ± 212.43
	f_c (MPa)	12.47 ± 0.56	14.78 ± 0.07	19.58 ± 0.23

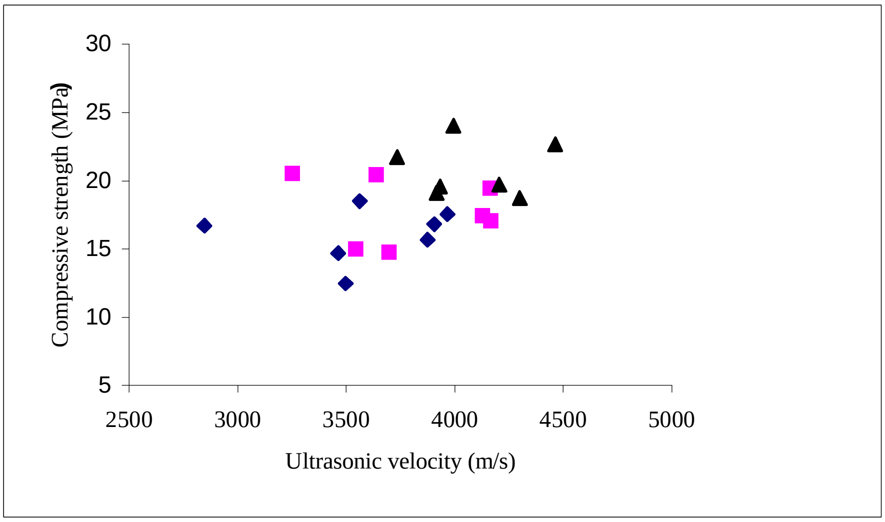

Fig. 1 Relations between ultrasonic velocity and compressive strength at the various ages

It is noticed that a same velocity (3700 m/s) corresponds to two strengths presenting 50 % of difference (f_{c14} and f_{c28}). We should thus consider age of the concrete to decrease uncertainties in the establishment of a correlation between ultrasonic velocity and strength. This separation of the ages is illustrated by fig. 2 which regroups concretes at ages of 7 and 28 days. It is noticed that dispersion is less marked for the same age and that the relations between ultrasonic velocity and strength are better coherent.

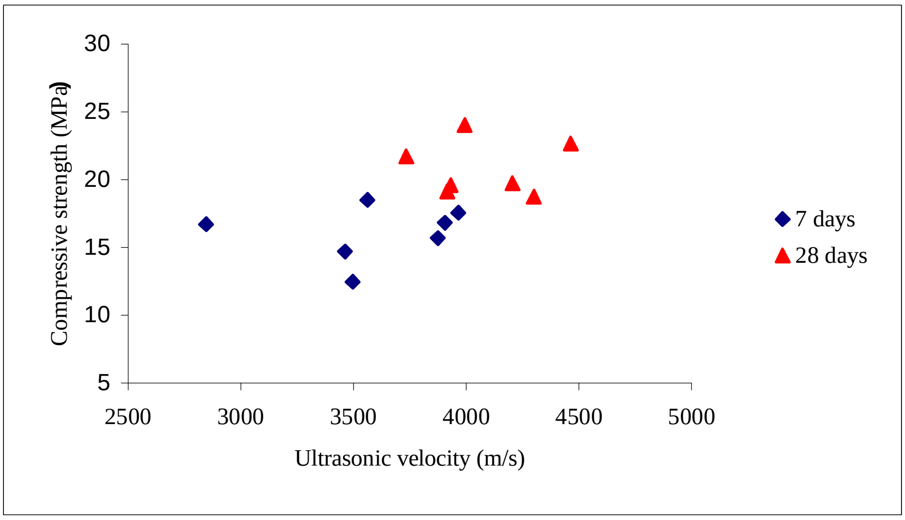

Fig. 2 Relations between ultrasonic velocity and compressive strength at 7 and 28 days

3.1. Effect of "W/C" ratio

We studied in this part the influence of the modification of ratio W/C for ultrasonic pulse velocity and strength. Figure III shows the relations vpu-compressive strength for various water/cement ratios. It is noticed that the ultrasonic velocity decrease according to ratio W/C for a given strength. This can be due that the concrete strength, with high ratio W/C, at late ages approaches the concrete strength with low ratio W/C at early age. However, the hardened concretes present velocity faster than the concretes at the early age because of a larger density. We notice finally that the prediction of strength from the ultrasonic velocity presents variations between 10 and 20 MPa, as indicated in this same figure.

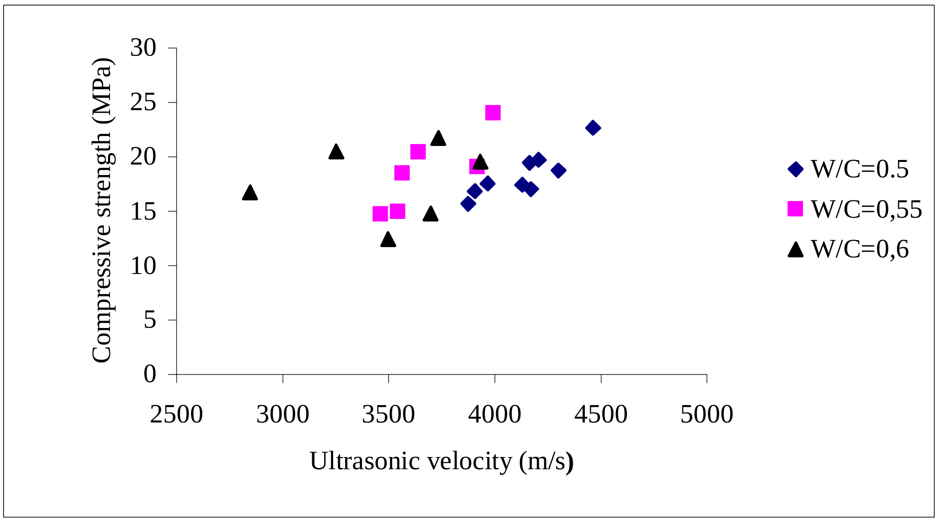

Fig. 3 Relations between ultrasonic velocity and compressive strength for various ratios E/C

3.2. Influence of "S/S+G" ratio

Figure 4 shows the relation between the velocity and strength of all the tests grouped according to the ratio sands on aggregates (S/S+G). Results indicate that the velocity increase when the (S/S+G) ratios decrease for a given strength. We also notice that for a given velocity, strength presents a difference from 10 to 20 MPa due to the variation of S/S+G ratio. If concrete strength is influenced by admixture S/S+G ratios, ultrasonic velocity also depends on these ratios but with a less effect. The highest velocity measured for W/C=0.5 ratio, at 28 days, is 4463 m/s for S/S+G=0.3. This velocity decreases up to 4205.50 m/s by the incorporation of more gravels (S/S+G=0.6) for a concrete with the same E/C ratio. Consequently, the ratio of the aggregates is one of the significant factors which influence the relation between ultrasonic velocity and strength of concrete.

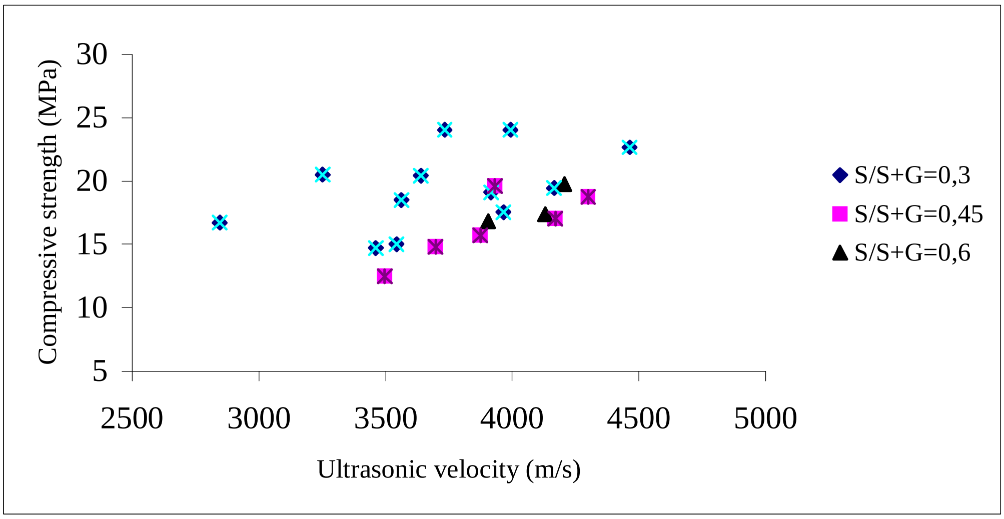

Fig. 4 Relations between ultrasonic velocity and compressive strength for various ratios S/S+G

By eliminating the effects of the age and W/C ratio, we present in figures 5 and 6 relations between ultrasonic velocity and strength for various S/S+G ratios. It is noticed that the correlation is better and the curves of regression present a good coefficients of determination for a linear smoothing. Resistance can be then determined from the ultrasonic pulse velocity measurement with less uncertaintie

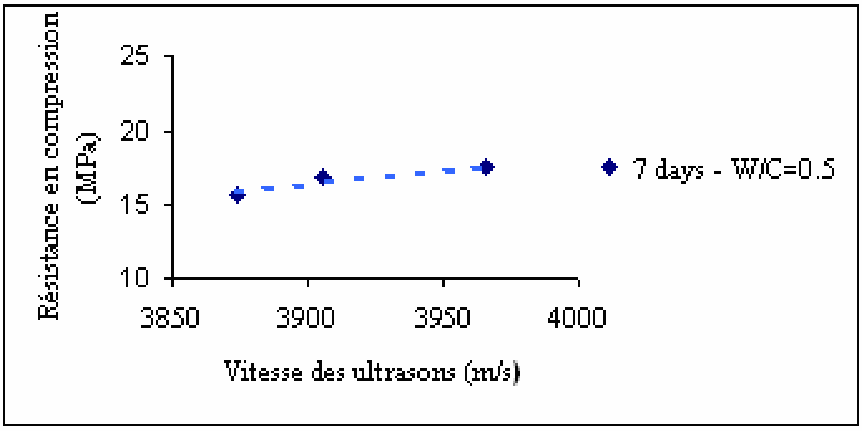

Fig. 5 Relations between ultrasonic velocity and strength at 7 days (W/C=0.5)

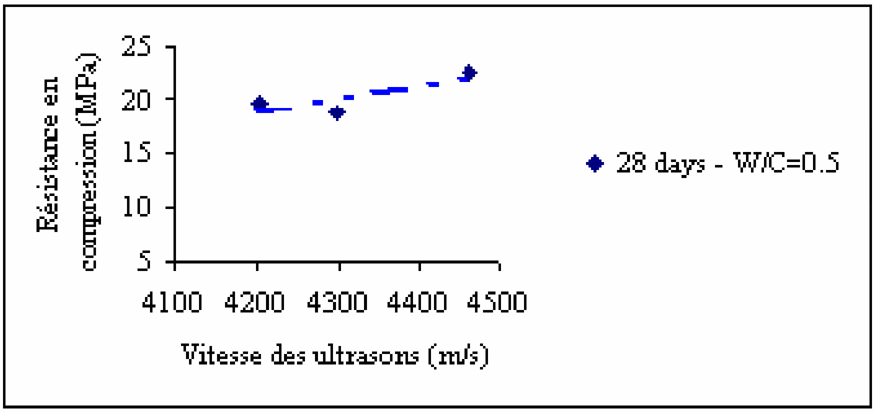

Fig. 6 Relations between ultrasonic velocity and strength at 28 days (W/C=0.5)

4. Conclusions

This work consisted to study influence of the variation of W/C and S/S+G ratios to predict compressive strength of the concrete from the measurement of ultrasonic pulse velocity (vpu). This prediction comprises broad uncertainties if admixture variation and ages of the concretes are not considered. Ultrasonic velocity increase with the water/cement ratio, for a given strength. The effect of the variation S/S+G ratio for compressive strength depends then from strength level and W/C ratio of the concrete. For the concrete with normal strength, strength increases when S/S+G ratio increases. We can explain it, that compressive strength is controlled by the strength of the paste and the resistance of the interface (paste-aggregates). The density of the concrete increases with S/S+G ratio, this leads to less of cracks between the paste and the aggregates (gravels). The same phenomenon does not occur for the high strength concretes because their strengths are dominated by the strength of aggregates [7]. Another report is that for a given strength, ultrasonic velocity through the concrete decreases with the increase of S/S+G ratio. The velocity variation decreases when the compressive strength increases by the effects of the age or the ratio W/C reduction.

5. References

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