INFLUENCE OF STEEL REINFORCEMENT ON ULRTASONIC PULSES VELOCITY

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Abstract - In this paper the influence of the steel bars presents in the concrete on the propagation velocity of the ultrasonic waves is reported. In particular a series of 5 specimens of concrete were considered and a series of non-destructive tests were conducted with the objective to assess the influence of both longitudinal and transversal steel reinforcements on velocity measurements.

Keywords: Non Destructive testing, concrete, ultrasonic pulses velocity, steel reinforcements, specimens.

1 Introduction

The characterization of the materials utilized during the construction of "ancient" structures, results of fundamental importance when the structural resistance or the seismic damageability assessment are conduct in this type of structures where the ravages of time not consent a correct evaluation of the mechanicals characteristic of the materials. The use of Ultrasonic method to assess the actual strength of concrete is generally justifiable only if a reliable correlation for a particular type of concrete is developed prior to the evaluation of the subject quality concrete. In the preparation of correlation curves it is important to consider how the concrete reinforcements influence the ultrasonic pulse velocity. In fact, it is common knowledge, that the pulse velocity measured in reinforced concrete in the vicinity of reinforcing bars is usually higher than in plain concrete of the same composition. This is because the pulse velocity in steel may be up to twice the velocity in plain concrete and, under certain conditions, the first pulse to arrive at the receiving transducer travels partly in concrete and partly in steel. The apparent increase in pulse velocity depends upon the proximity of the measurements to the reinforcing bar, the diameter and number of bars and their orientation with respect to the propagation path.
A series of 5 experiment tests has been conducted on an simple concrete 300x300x500-mm specimen and on 4 300x300x500-mm reinforced concrete specimens unlike each other for the longitudinal and transversal spaces of reinforcements with the principal objective to establish how the steel concrete reinforcement influences the velocity of the ultrasonic waves.
The steel bars presents in the concrete generally influence the propagation velocity of the ultrasonic waves [1].
British Standard [2] affirms that *the position of paths along which pulses are propagated should be chosen, whenever possible, so as to avoid the vicinity of reinforcing bars parallel to these paths. If this cannot be achieved, the measured values of pulse velocity should be corrected to take into account the presence of steel.*
On the British Standard the effect of steel bars parallel to direction of propagation of ultrasonic waves is considered.
The factors that influencing the pulse velocity measurements are [2]:

1. moisture content;
2. temperature of the concrete;
3. path length;
4. shape and size of specimen;
5. effect of reinforcing bars.

The pulse velocity measured in reinforced concrete in the vicinity of reinforcing bars is usually higher than in plain concrete of the same composition [1,2]. In fact the pulse velocity in steel may be up to twice the velocity in plain concrete and , under certain conditions, the first pulse to arrive at the receiving transducer travels partly in concrete and partly in steel. The apparent increase in pulse velocity depends upon the proximity of the measurements to the reinforcing bar, the diameter and number of bars and their orientation with respect to the propagation path.
The correction will depend on the distance between the line of the path and the edge of the nearest bar, the bar diameter, and the pulse velocity in the surrounding concrete [2].
In [2] the pulse velocity in the concrete v_c (km/s) is given by the following equation:

$$v_c = \frac{2a \cdot v_s}{\sqrt{(4a^2 + (T \cdot v_s - L)^2)}} \tag{1}$$

Provided that $vs \geq vc$, where, (see figure 1):

- v_s is the pulse velocity in the steel bar (in Km/s);
- a is the offset, measured as the distance from the surface of the bar to the line joining the bnearest point of the two transducers (in mm);
- T is the transit time (in µs);
- L is the length of the direct path between transducers (in mm).

The influence of steel disappears when:

$$\frac{a}{L} > \frac{1}{2}\sqrt{\frac{(v_s - v_c)}{(v_s + v_c)}} \tag{2}$$

In this case the equation (1) is not applicable. The zone which the steel may influence measurements thus depends upon the relative values of pulse velocity within the steel and concrete but an upper limit of *a/L* of about 0.25 may be expected for large diameter bars in low quality concrete. For high quality concrete the limiting value of *a/L* is unlikely to be greater than 0.15 but may be considerably less for bar diameters of 12mm or below. Bars of 6 mm diameter or less will be virtually impossible to detect in practical situations and may be ignored.
Figure 1 shows the influence of steel reinforcement on pulse velocity in the case of bar parallel to pulse path [1].

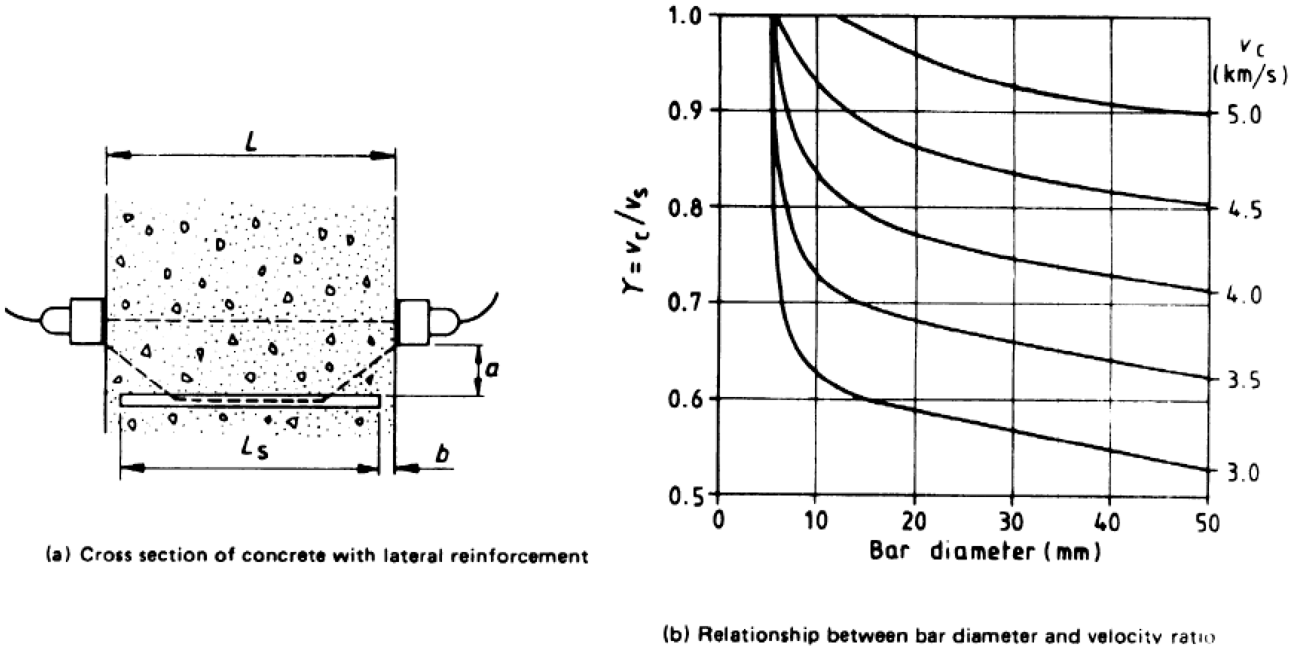

Figure 1: BS 1881-203-1986 - Influence of steel reinforcement on pulse velocity (bar parallel to pulse path) [2]

26. Ultrasonic Pulse Velocity

The Ultrasonic Pulse Velocity method [1, 5] is a very suitable method for the study of the quality of concrete by means of the measure of the elocity of propagation of ultrasound waves. They can be used for the appraisal of the uniformity, the location of defects or cavity inside both reinforced or masonry structures, for the determination of the depth of fractures and for the assessment of the elastic module and therefore of the compressive strength of the concrete. The parameters that influence the velocity of propagation of ultrasound waves are [1, 4]:

(i) the entity of the load;
(ii) the age of the concrete (the speed increases with the age of the concrete);
(iii) the form and the dimension of the structure;
(iv) the run length;
(v) the presence of metallic reinforcements (the speed increases in proximity of the steel bars);
(vi) the ratio water/cement;
(vii) the state of strength,
(viii) the temperature;
(ix) the humidity of the concrete.

In this paper we consider only the influence of metallic reinforcements.

3 Experimental Tests

A total of 5 specimens (300x300x500-mm), in the following appointed as PIL, were designed and fabricated at the Laboratory of the Faculty of Engineering of Mediterranean University of Reggio Calabria. The specimens differ of each other from the quantity and the arrangement of steel reinforcement (Figure 2):

- PIL1, 4 ϕ16 longitudinal steel bars and stirrup ϕ8@100 (mm);
- PIL2, 4 ϕ16 longitudinal steel bars and stirrup ϕ8@150 (mm);
- PIL3, 8 ϕ16 longitudinal steel bars and stirrup ϕ8@150 (mm);
- PIL4, 4 ϕ16 longitudinal steel bars and stirrup ϕ8@200 (mm);
- PIL5, plain concrete.

Specimens were investigated by ultrasonic method at different time (14, 28 and 36).

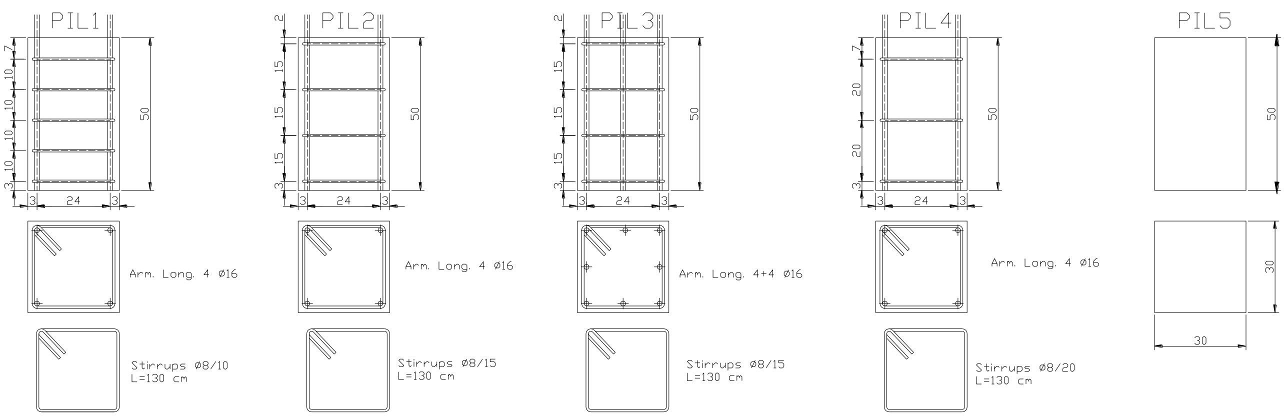

Figure 2: Reinforced concrete and concrete Specimens

In the casting of specimens, the following materials and proportions of components were employed:

- Cement: 33.5 N of Portland-limestone cement CEM II/A-LL 42.5 R including 6-20 % limestone, 80%-94% clinker and others secondary components according to EN 197-1 were used19;
- Water-Cement ratio: W/C=0.37; 12.3 liters of water for every cubic meter of concrete was employed;
- Superplastifier Sika ViscoCrete® 3073-I (VP). Dosage: 1% of the cement contents ;
- Aggregate: Commercial, locally available sand and coarse aggregate with a nominal maximum aggregate size of 25.00 mm was used.

4 Experimental Results

In this section the more important results of non destructive investigation (Ultrasonic Pulse Velocity measurement) conduced on concrete and reinforced concrete specimens are shortly reported.

The Points of specimens where Ultrasonic Pulse Velocity measurement were conducted are showed in Figure 3.

Figure 4 shows the ultrasonic velocity measurement results. The presence of stirrups seems not modify the ultrasonic velocity. Only for the specimen appointed as PIL1 the ultrasonic velocity in the vcinity of the stirrups increases of about 30% of the measured value in plain concrete. Moreover, in the specimen appointed as “PIL1”, the ultrasonic velocity were smaller of that measured in all other specimens, due an incorrect compacting of the concrete during the casting phase.

This is visible also in the Figure 5 where the mean ultrasonic pulse velocity of all specimens are compared. The same Figure shows how the presence of transversal steel reinforcements substantially not influences the ultrasonic velocity.

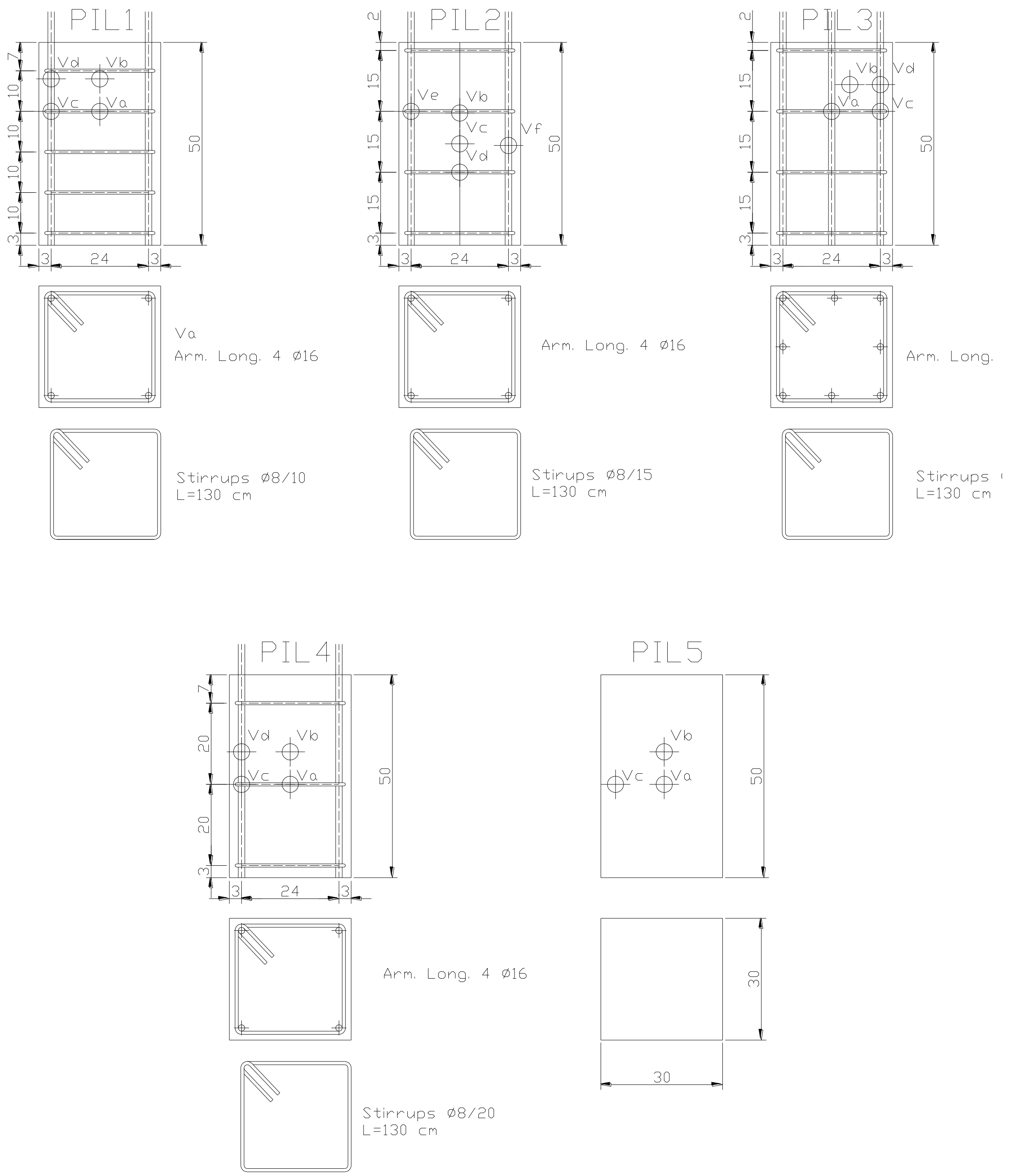

Figure 3: Points of Ultrasonic Pulse Velocity measurement

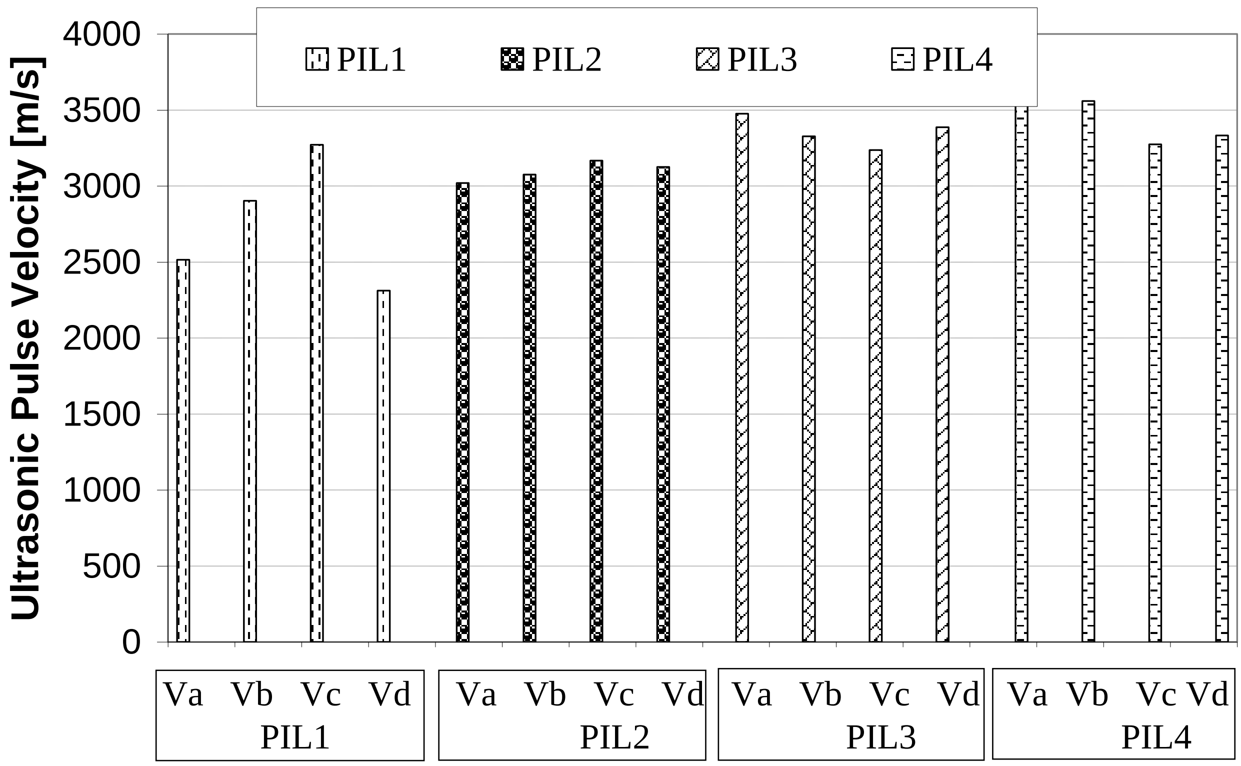

Figure 4: Ultrasonic Pulse Velocity

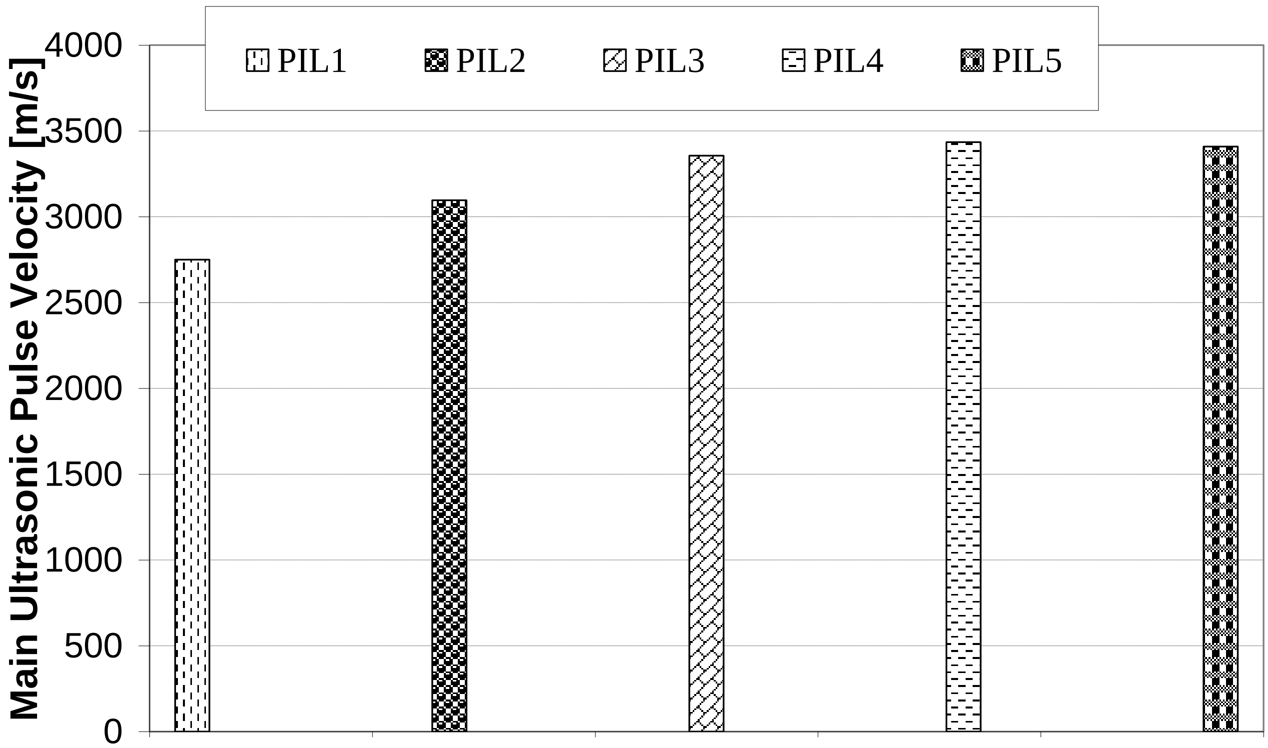

Figure 5: Ultrasonic Pulse Velocity

5 Conclusions

A series of experiment tests has been carried out on an simple concrete 300x300x500-mm specimen and on 4 300x300x500-mm reinforced concrete specimens unlike each other for the longitudinal and transversal spaces of reinforcements.
In the cases examined specimens, it is possible to see that, transversal steel reinforcements (stirrups of 8-mm diameter), also slightly modifying the course of the ultrasonic waves, not modify significantly its velocity.

References

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