LIMITS OF ULTRASONIC WAVES PROPAGATION IN CONCRETE: APPLICATION OF WATERMAN & TRUELL MODEL

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ABSTRACT

In non-destructive testing of concretes, acoustic methods are interesting because of their sensitivity to the evolution of mechanical parameters depending on the damage. Difficulties in linking observable quantities, such as velocity and attenuation, to the evolution of material justify the need to learn more about the phenomenon of propagation of the ultrasonic wave in a diffusing medium and attenuating such as concrete. A synthesis of propagation models of longitudinal and transversal ultrasonic waves revealed the interest of Waterman and Truell model which is both flexible and fast and allows many adaptations. This study aims to clarify the limits of this model by comparing the calculated results with experimental ones. Model samples were carried out to facilitate the crossing information. The same base matrix composition was maintained and only was changing the nature, size and the number of diffusers. The decomposition method of the medium is based on a diffusers density of 46 % by through two successive areas, which is higher than conventional values.

Keywords: Non destructive tests, ultrasonic wave, heterogeneous media, concrete, Waterman and Truell model.

INTRODUCTION

Ultrasonic methods are highly suitable for the measurement of thickness [2], and detection of voids and cracks in concrete [3]. It is possible to connect the ultrasonic mechanical parameters to those based on the propagation equations synthesized by Helmholtz. In addition, the ultrasonic testing is a technique often used because of the large apparent simplicity of implementation and its ability to explore a deep structure.

The ability to diffuse the incident wave of all these ingredients (cement, aggregates, sand) and these defects (cracks, cavities, pores) are grouped under the name of "diffusers". Many phenomena in the diffusion depend on the rate and the size of the diffusers, frequency and composition of each of the media. To model the propagation ultrasonic waves through a scattering medium we use the effective medium theory initiated by Foldy (Foldy 1945). The synthesis of propagation models longitudinal and transversal ultrasonic waves (Lavoisier 2006, Shubert et al 2001, . . . ) revealed the interest of the model Waterman and Truell. This model both flexible and fast, allows many adaptations: the size distribution and the ability to take into account several types of diffusers. This study highlights some limitations of this model by comparing the simulated results with experimental ones, especially in terms of ka and density.
We studied four types of matrices (Table 1).

Table 1 - Composition of the samples

<table>
<thead>
<tr>
<th>Sample</th>
<th>Cement (%)</th>
<th>Water (%)</th>
<th>Sand Ø&lt;0.5 mm (%)</th>
<th>Glass balls Ø10 mm (%)</th>
<th>Polystyrene Ø2,8 mm (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CF</td>
<td>28,5</td>
<td>40,6</td>
<td>30,9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CF-B10</td>
<td>20,0</td>
<td>28,5</td>
<td>21,8</td>
<td>29,8</td>
<td>-</td>
</tr>
<tr>
<td>CF-P3</td>
<td>19,9</td>
<td>28,5</td>
<td>21,7</td>
<td>-</td>
<td>30,0</td>
</tr>
<tr>
<td>CF-B10-P3</td>
<td>15,3</td>
<td>21,8</td>
<td>16,7</td>
<td>23,1</td>
<td>23,1</td>
</tr>
</tbody>
</table>

**RESULTS AND CONCLUSIONS**

In this study, the experimental results for each test CF-B10, CF-P3 and CF-B10-P3, were represented and compared with theoretical results simulated by Waterman and Truell model of propagation on the basis of CF results. We observe in Figure 1 that the velocities of CF, CF-B10 and CF-P3 specimens on the set points is almost constant (mean values of 4320, 4660 and 3890 m/s, respectively) which leads that the wave propagates in a quasi-homogeneous medium and low dispersion.

![Fig. 1 - Phase velocity of different matrices](image)

Velocities on deferent points of CF-B10-P3 specimens vary due to the use of both of glass and polystyrene balls which act as diffusers (case of concrete), and then the wave propagates in a quasi heterogeneous and dispersive medium. The limit can be set for k.a equal to 4.5. In the case of samples with 46% of diffusers, the iterative calculation implementation allows to move towards a consistent velocity curve by incrementing from basic composition the diffuser density is less than 30%. For CF-P3 specimen, the break in slope can be explained by the poor distribution of polystyrene beads in the tested sample as we found by making a cut on the thickness. We have verified that the change of the final velocity is between the velocity of the matrix and that of the diffusers. By using the theoretical results we obtain substantially the same pattern with a significant shift of the experimental rate.

**REFERENCES**

