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NON-DESTRUCTIVE EVALUATION OF DETERIORATED REINFORCED CONCRETE SLAB USING EXPERIMENTAL AND NUMERICAL METHODOLOGIES

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ABSTRACT

This study concerns the NDT characterization by micro-seismic technique of a reinforced concrete slab exposed in high temperature, creating a decreasing damage thought the thickness. The dimensions of the slab were equal to 1.20 x 1.10 x 0.12 m (L x W x T). A welded wire mesh (200x200x10) and an OPC concrete reaching at 28 days a compressive strength of 32.7 MPa and a static modulus of elasticity of 35 GPa were used for the slab. At the age of two months, the slab was fixed instead of the door of a high volume furnace; it was heated until the exposed face had reached 300°C then cooled to room temperature. During heating, the temperature gradient through the concrete thickness reached more than 16°C/cm.

Keywords: non-destructive testing, Lamb waves, reinforced concrete, slab, damage.

INTRODUCTION

Accurate evaluation of damage in concrete structures is very important. The decisions that have to be taken concerning maintenance, repair, rehabilitation and risk prevention of the structure, depend indeed on this evaluation. During the last decades, most techniques concerning the assessment of concrete damage based on non-destructive testing (NDT) achieved important progresses. Among them, the micro-seismic technique, a fully non-destructive acoustic technique, was applied successfully on characterization of concrete quality of slabs [2, 3, 4]. This technique, based on the analysis of Lamb waves propagation induced by a low-energy mechanical impact, is able to determine the modulus of elasticity of concrete, even if the thickness of the slab is unknown, as well the presence of general degradation of concrete. However, further developments are necessary for evaluation of a gradient of damage in a reinforced concrete as in the case of degradation of structure exposed to a fire.

The heating deteriorates the concrete by thermal stresses and dehydration of cement's hydrated products. The deterioration is all the more important the temperature is higher [1] consequently, the residual modulus of elasticity of concrete varies with temperature gradient.

RESULTS AND CONCLUSIONS

The slab was characterized on both faces (exposed and non-exposed to high temperature) before and after heating with the micro-seismic technique and the mean value of dynamic modulus of concrete through the thickness was determined in any case. For the characterization, a small hammer was used to create an impact on the slab and generate its vibration. Thus, a series of seismograms was obtained with sampling frequency of 200 kHz using a series of accelerometers arranged in line and spaced 2 cm. A double FFT was applied on seismograms series leading to the determination of the phase velocity of the Lamb waves as a function of their frequency. Then, the phase velocity-frequency diagram was used to determine the modulus of elasticity of concrete by reverse calculation taking in account the theoretical symmetric and anti-symmetric vibration modes of the slab.

The inspection of the slab after heating concluded that there was no significant visual defect (cracking, pop-out or grumbling). However, the micro-seismic technique results show that the heating induces an important decrease of the mean value of dynamic modulus of elasticity of concrete from 38 GPa to 22 GPa. Moreover, the deterioration by the heating reinforces the diffusive character of concrete and attenuates strongly the frequencies higher than 15 kHz. The attenuation is even stronger when the micro-seismic technique is applied on the heated face. The phase velocity-frequency experimental diagram obtained in these conditions, is not enough rich for accurate discrimination between a varying with thickness damage and a homogenous damage through the entire thickness of the slab.

With the aim of improving the analysis of experimental results, a dynamic axisymmetric numerical simulation of the Lamb waves propagation in the slab after an impact was performed using a FEM software (Cast3M), allowing the calculation of the displacements at the measuring points and draw the corresponding seismograms. Three cases were simulated using the experimental values of dynamic modulus of elasticity: the case of sound concrete before heating, the case of deteriorate concrete after heating presenting a generalized homogenous damage and the case of deteriorate concrete presenting a decreasing with depth damage.

The comparison of simulation results with NDT results shows that in the case of sound concrete the numerical phase velocity-frequency diagram is very close to the experimental one. This confirms the efficiency of the micro-seismic technique to evaluate the concrete quality in this case. On the other hand, in the case of deteriorate concrete, the simulation results shows that the main differences between a homogeneous and a varying with depth damaging affects much more the field of higher than 15 kHz frequencies. However, the symmetric fundamental mode of vibration presents significant distortion at low frequencies allowing the identification of the presence of damage gradient. But in this case, signal processing is necessary for accurate identification of damage.

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