Civil Engineering for Sustainability and Resilience International Conference, CESARE '14
Amman, Jordan, 24-27 April 2014

Influence of the supplementary cementitious materials on the dynamic properties of concrete

E. Elbahi [1], S.M.A Boukli Hacene [1]
[1] EOLE laboratory, Department of Civil Engineering, Faculty of Technology, Aboubekr Belkaid University, Tlemcen 13000, Algeria.
bah.bach@yahoo.com, ***boukli_ma@yahoo.fr***

Keywords: Concrete, Non-destructive test, Dynamic elasticity modulus, Crushed limestone, Résistance, Natural pozzolan.

ABSTRACT:

The resonance frequency method is one of many non-destructive tests which allow us to evaluate construction materials. It was used to determine the dynamic properties of concrete, required in structures design and control, also considered as the key elements for materials dynamic.

In this study, we chose a non-destructive approach to quantify -in laboratory-, the influence of adding "crushed limestone" and "natural pozzolan" on local concrete's dynamic characteristics. However, several concrete mixtures have been prepared with limestone aggregates. The experimental used plan, allowed us to determine the dynamic modulus of elasticity, the dynamic modulus of rigidity of different formulated concretes.

1. INTRODUCTION:

To evaluate the state of the concrete structures and estimate their remaining life, the tests by the indirect methods are particularly interesting and represent the quality control of the structure. Among the advantages of these tests, we can mention the economy of materials, time and testing tools. Some characteristics of concrete are essential in the design and the control of structures. From these characteristics, we have the longitudinal elasticity modulus, the transversal modulus of elasticity, and Poisson's ratio. The transversal modulus of elasticity and the Poisson's ratio form in the case of traverse strain or shear and appear in the calculation rules (EUROCODE, CBA, BAEL, and RPA) precisely in the verification of cutting effort, when the longitudinal elasticity modulus step in the calculation of deflection and effect from creep and shrinkage of concrete .the dynamic modulus of elasticity is considered equal to the tangent modulus of elasticity at the origin determined by the static tests .The dynamic modulus of elasticity is easy to measure, the static module knowledge of which is necessary for the conception of concrete structures. To know the relation and check the influence of the addition of natural pozzolan and crushed limestone, we followed a non-destructive approach based on the measurement of the resonance frequency on cylindrical specimens 16x32 cm [BOU 12].

2. CHARACTERIZATION OF USED MATERIALS:

The cement that we have used in this study is a CPJ CEM cement type, that belongs to the Algerian standard NA44 from the cements society of BENIE SAF in AIN TEMOUCHENT. For making deferent types of concrete, we used potable water that is distributed by public service network of CHITOUANE DAIRA of TELEMCEN city. Aggregates and fillers used are of a great career of TELEMCEN region, named career DJBEL ABIOD SIDI ABDELI which belongs to the national company of aggregates (ENG), these crushed limestone aggregates are marketed as grading: sand 0/3 and gravel 3/8; 8/16 and 16/25. Pozzolan used is also from BENIE SAF.

The analyses of the chemical composition of cement, natural pozzolan, and limestone fillers are recorded in table 1, those concerning the properties of aggregates were performed in our laboratory [BOU 07], [BOU 09,], [BOU 10,].

Table1. Chemical characteristics of natural pozzolan, limestone and cement

CODE	SIO_2	AL_2O_3	FE_2O_3	CAO	MgO	Na_2O	Cl	P_2O5	Tio_2	loi	Densité	SS.Blaine
CEM2	22.17	6.18	3.62	59.45	1.05	0.19	0.004	0.18	0.43	2.62	3.15	3597
F.C	0.06	0.29	0.22	52.63	0.84	0.08	0.005	0.02	0.02	42.77	2.75	2416
P.N	37.84	14.74	14.1	5.34	3.03	0.75	0.05	0.68	3.37	4.57	2.87	2567

3. EXPERIMENTAL PROGRAM:

The Concretes are generally formulated on the basis of the granular skeleton optimized [BOU, 10], by varying the E / C ratio (0.5, 0.55, 0.6, 0.65) with fillers in a percentage of 10% and a percentage of 10% from pozzolan. 36 (16x32 cm) cylindrical test pieces were conducted to determine the resonance frequency of a different times (3, 7, 14, 28 days).

The created concretes were made in accordance with standards [AFN 02], [NOR 92] and cylindrical specimens were stored after preparation and removal and a total water immersion (NA 426).

3.1 Measurement of dynamic characteristics:

We find that we can determine the dynamic modulus of elasticity by the frequency of resonance, while the method is only valid for homogeneous and isotropic material (considered). It can also be applied to the concrete if the sample size is bigger than the size of the constituents [HUN 04], [GIN 12].

We have the following equation:

$$N= ((m^2K) / (2\pi L^2)) \sqrt{((E/P))} \quad (1)$$

From equation 1 we found E:

$$E = ((4\pi^2L^4N^2P)/(K^2m^2)) \quad (2)$$

E: Dynamic modulus of elasticity

P: material density

L: length of the sample

NL: the longitudinal resonance frequency

NT: the transversal resonance frequency

K: Radius of gyration of the section about an axis perpendicular to the plane of bending

m: a constant (4.73 for the fundamental mode of vibration).

The dynamic modulus of elasticity is calculated from the fundamental frequency of longitudinal vibration of the sample by the following equation:

$$E = 4\,L^2 P N L^2 \tag{3}$$

The two equations (1) and (3) obtained, are used for solving the differential equation of motion [12 HAS].

The dynamic shear modulus is calculated using the same way as the dynamic modulus of elasticity (Equ.3), simply replacing NL by NT representing the transversal resonance frequency which is given by the following equation:

$$G = 4L^2 P N T^2 \tag{4}$$

4. RESULTATS AND DISCUSSION:

4.1 Influence of W/C ratio on longitudinal elasticity modulus:

Figures 1, 2 and 3 show the evolution of dynamic modulus of elasticity versus time for the four W/C ratios corresponding to 0.5, 0.55, 0.6 and 0.65, and this for the three types of realized concrete: the reference concrete, concrete with the addition of 10 % natural pozzolan and concrete with the addition of 10 % of crushed limestone. We note that the three figures showed similar results. The evolution of dynamic modulus of elasticity is fast in the first 10 days, then the speed of this evolution decrease in the last 18 days. Also, we note that the increase in the W / C ratio which leads to a reduction in the resistance according to the literature, leads to decrease in the dynamic modulus of elasticity.

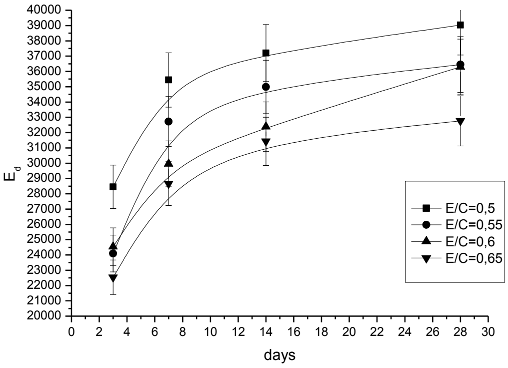

Figure1: influence of W/C ratio on longitudinal elasticity modulus (ordinary concrete)

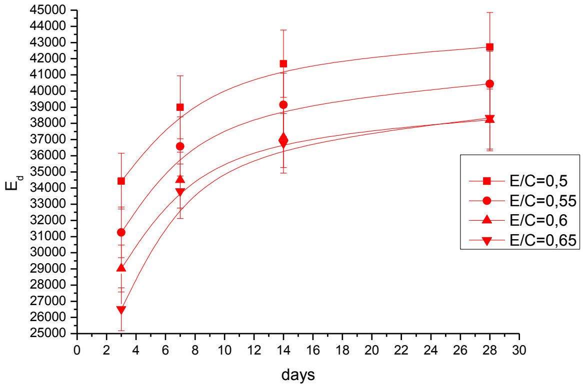

Figure2: influence of W/C ratio on longitudinal elasticity modulus (concrete with 10% limestone)

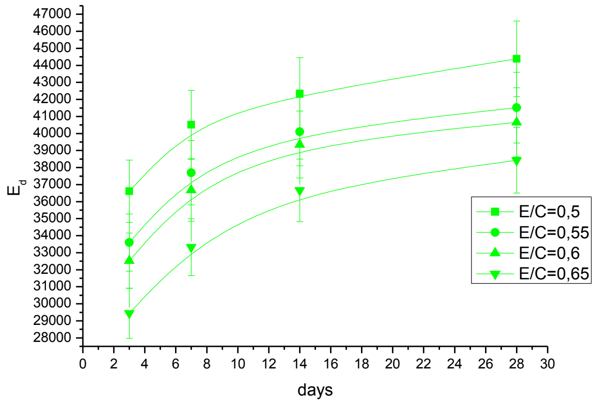

Figure3: influence of W/C ratio on longitudinal elasticity modulus (concrete with 10% pozzolan).

4.2 Influence of W/C ratio on the transversal elasticity modulus:

With the same, figures 4, 5 and 6 show the evolution of dynamic modulus of rigidity versus time for the four W/C ratios corresponding to 0.5, 0.55, 0.6 and 0.65 and this for the three types of realized concrete. We note that the three figures show the same identical results to those of the dynamic modulus of elasticity. The dynamic modulus of rigidity reach 80% of its value in the first 14 days and its evolution is so fast during those 14 days.

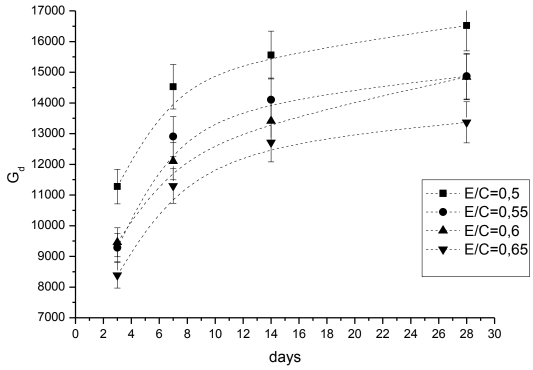

Figure4: influence of W/C ratio on the transversal elasticity modulus (ordinary concrete)

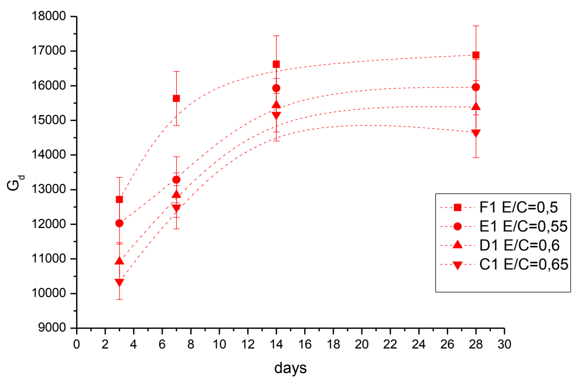

Figure5: influence of W/C ratio on the transversal elasticity modulus (concrete with 10% limestone)

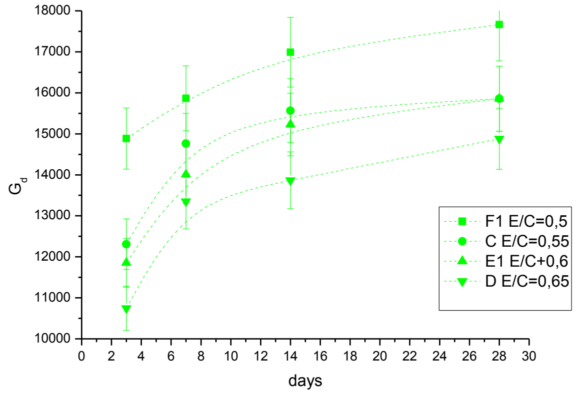

Figure6: influence of W/C ratio on the transversal elasticity modulus (concrete with 10% pozzolan)

4.3 Influence of supplementary addition on the longitudinal transversal elasticity modulus:

Figures 7 and 8 show the influence of cement additions on the dynamic modulus for W/C ratio equal to 0.5. These figures show that the greatest value of the dynamic modulus of elasticity and rigidity is obtained from concrete containing 10% pozzolan followed by concrete with 10% crushed limestone, and finally comes the reference concrete. Trend lines give great scatter plot, which can be justified by the coefficients of determination that exceed the 0.9 in all cases. The curves presented in figures 7 and 8 can be represented by an exponential equation type:

Ed=A*exp (-X/B) + C

Where X: number of days A, B and C: integer numbers

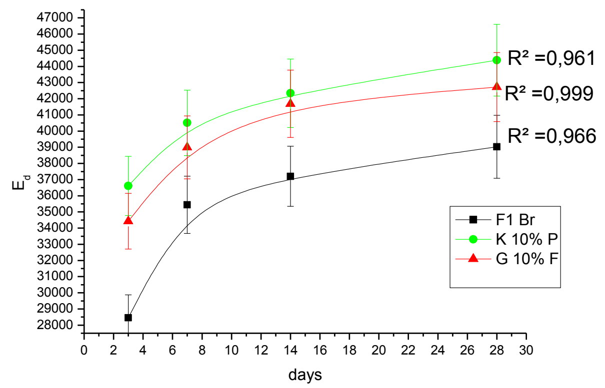

Figure7: Influence of supplementary addition on the longitudinal elasticity modulus

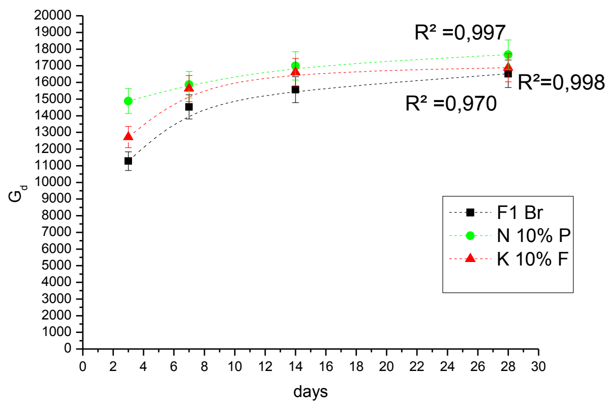

Figure7: Influence of supplementary addition on the transversal elasticity modulus

5. CONCLUSION:

In This article we have adopted a non-destructive experimental approach for dynamic characterization of concrete. We have reached to the following main results:

- When the dynamic modulus of elasticity and the dynamic modulus of rigidity increases, the W/C ratio decreases. They reach the 85% of their final values in the 7th day and the 95% in the 14th day.
- The type of addition presents a direct influence at the dynamic modulus.
- The pozzolan gives an elasticity modulus and a rigidity modulus greater then the limestone and the reference concrete.

Acknowledgement

The authors would like to thank the University Aboubekr Belkaid for providing the financial support while undertaking the research work.

REFERENCES

[AFN 02] AFNOR; Béton et constituants du béton. Tome 1 : Spécifications du béton et de ces constituants, 5e édition, Paris, 2012, 431 p.

[AFN 02] AFNOR; Béton et constituants du béton. Tome 2 : Méthodes d'essai du béton, 5e édition, Paris, 2012, 510 p.

[BOU 07] BOUKLI HACENE M.A., GHOMARI F. "Study of the compression resistance of local concretes", Twelfth International Colloquium on Structural and Geotechnical Engineering, ICSGE, Cairo, Egypt, 10-12 December, 2007, pp.1005-1014.

[BOU 09] BOUKLI HACENE M.A., GHOMARI F., KHELIDJ A., "Compressive Strengths of Concrete Formulated with Algerian Local Materials", Jordan Journal of Civil Engineering, Volume 3, No. 2, 2009, April, pp.103-117.

[BOU 10] BOUKLI HACENE M.A.," Contribution a l'etude de la resistance caracteristique des bétons de la région de tlemcen ", Doctorat thesis in Civil Engineering, Université Abou Bekr Belkaid Tlemcen, Algeria, 2010, 194 p.

[BOU 12] M. A. Bouakkaz, "Caractérisation du béton par les méthodes non destructives-application de la méthode de la fréquence de résonance", Magister thesis in Civil Engineering, Université Abou Bekr Belkaid Tlemcen, Algeria, 2012, 87 p.

[GIN 12] V.T. Giner, F.J. Baeza, S. Ivorra, E. Zornoza, O. Galao, "Effect of steel and carbon fiber additions on the dynamic properties of concrete containing silica fume" Materials and Design, Vol. 34, 2012, p. 332–339.

[HAS 12] A.M.T. Hassan a, S.W. Jones a," Non-destructive testing of ultra high performance fiber reinforced concrete (UHPFRC): A feasibility study for using ultrasonic and resonant frequency testing techniques" Construction and Building Materials, Vol. 35, 2012, p. 361–367.

[HUN 04] Sang-Hun Han, Jin-Keun Kim, "Effect of temperature and age on the relationship between dynamic and static elastic modulus of concrete" Cement and Concrete Research, Vol. 34, 2004, p. 1219–1227.

[NOR 92] NORMES ALGERIENNES; édition et diffusion Abou Hamou Moussa, Alger, 1992.