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Elaboration of an Experimental Method of Microconcrete Workability Measurements (Case of Dune Sand Concrete)

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Abstract: This study describes a new simple experimental method elaborated for measuring fresh microconcretes workability. To measure systematically this fresh characteristic for fine grained building materials, composed principally of small size aggregates, it is necessary to dispose only of small volumes of mixes, as additional fillers which are similar to powder, are not produced industrially but by means of traditional sieving. The principle of the proposed method consists in measuring, during fresh microconcrete mixing, of the absorbed electrical power of a laboratory mixer's motor connected to a differential wattmeter. This power increases since the microconcrete is dry; thus, the workability is indirectly measured at any time. The assembly description, its advantages, its specificity in relation to other experimental measurement methods of workability and its calibration are presented and analyzed in this study.

Key words: Workability, microconcrete, differential wattmeter, calibration, eleboration of experimental method

INTRODUCTION

Workability of concrete is, with its mechanical strength, the basic characteristic. Its indicates the consistency level of fresh concrete and allows to define the moulding mode of elements realized in concrete. It is measured on samples taken at the exit of mixer, more often by simplified tests. There is many normalized tests for measuring this characteristic, they have been all designed for gravels traditional concretes and they require generally great batch quantities for the tests. The slump test, the Vébé consistometer (which is a slump test version) and the flow test at the shock table require 6 L of fresh concrete, the LCPC concrete workabilimeter requires 30 L and the other techniques need intermediate volumes (LCPC is Laboratoire Central des Ponts et Chaussées, a French laboratory specialized on bridges an roads materials). The choice of a technique is most of the time imposed by the particularity of the mix (maximal size of the aggregates) or the batch volume of concrete required for achieving the test.

The microconcretes have been subject to many studies (Chauvin and Grimaldi, 1988; Beton, 1994; Ushikawa and Hamhara, 1996; Hadjoudja, 2001; Bederina *et al*., 2005) the ones envisaged for measuring the workability are quaternary materials composed of a skeleton of aggregates with maximum 5 mm size, an hydraulic binder (cement), additional fillers intended to improve their compactness and mixing water. The fillers have a fine grading (ϕ_{max} = 80 μm), they have been obtained by manual sieving in French AFNOR sieve N° 20, from crushing waste generated in Laghouat area (400 km in the south of Algiers, Algeria), AFNOR is Association Française de Normalisation (the French standard). Their production is poor, slow and tiring as no industrialized. The systematic study of such microconcretes requires great quantities of fillers. The classical means of measuring this characteristic turned out to be not adapted for these investigations. Stamapoulos and Kotzias (1971) have recourse to Casagrande apparatus (designated to determination of liquidity limits of soils) to carry out their experimental study in situ on the microconcretes consistency. They have preliminary calibrated the apparatus by means of slump cone. If this technique allows resolving the quantitative problem of fillers, it risks on the other hand creating a scale problem since it requires only 50 g of microconcrete for achieving the test.

The elaborated method usable just in both laboratory and in building site requires the use of a small mixer and a small quantity of microconcretes (~3 kg), which is approximately 1.6 L in volume. It furthers systematic studies on microconcretes. Other advantageous in close to its utilization are shown in following. In the follow up of this study, it is convenient to call this assembly a differential wattmeter.

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MATERIALS AND METHODS

Electrical device: The mixer's motor is connected in series with an ampermeter and a wattmeter and wired up in parallel with a voltmeter (Fig. 1). The wattmeter allows the direct reading of total power developed by the motor: power to turn empty and useful power to mix the microconcrete at different consistencies. The first is obtained by making mixer turning empty and the second by a simple subtraction operation. The amperemeter and the voltmeter allow reading of current intensity which crosses the circuit and the tension at motor terminals, respectively. Because of their presence, the regularity of developed power measures is checked at any moment.

Used mixer: Its volume capacity is 3 L. This volume relatively limited lends very well for mixing small quantities of microconcrete and allows avoiding the loss of fine elements (cement and fillers). Its paddle is equipped with 2 types of movements: A rotating movement with a speed of 139 t min^{-1} and a planetary movement with a speed of 65 t min^{-1}. It is obvious that the more size D of microconcrete is small, the more it is useful to carry out a mix with high speed. The mix gains plasticity appreciably for the same water quantity. For a traditional concrete (D = 20 mm), the rotating speed of the mixer is_about 15-20 t min^{-1}. Gorisse (1972) for his microconcrete (D = 1.6 mm) has proposed 160 sec of mixing time by batch, with 44 t min^{-1}speed during 120 sec and 84 t min^{-1}during the remaining time.

The rotating speed adopted for mixing the present studied microconcrete (maximal grain size = 0.63 mm) is thus completely suitable from this point of view.

Calibration process of the differential wattmeter: It was calibrated by means of slump cone. This one called rightly the king slump (Larrard, 1990) remains the most practical and the most widely used in the world as it has been thoroughly tested.

The formulation of adopted microconcrete for the calibration is the one of dune sand microconcrete without addition of fillers. This choice is justified by the concern of generalization and standardization. However, it is obvious that for a similar composition with fillers of different nature, the mixer's motor develops different powers. At this moment, the desired consistency is to be searched by varying the water- cement plus filler ratio.

Mix design for calibration tests: Twelve mixtures of dune sand based concrete of Laghouat area (400 km in the south of Algiers) having a constant proportioning of cement (350 kg m^{-3}) and W/C ratio varying from 0.40-120 (Table 1) have been confectioned for the differential wattmeter calibration. The dune sand employed has a continued grading and a maximal grain size of 0.63 mm (Fig. 2), its specific density is 2596 kg m^{-3}. The cement is a CPA CEM I 32.5 with specific density 2900 kg m^{-3} and Blaine specific surface area 407 m^2 kg^{-1}. Mixing water added to react with the cement is normal tap water with pH ~ 7.5. The obtained mixes possess workability varying from the most firm (W/C = 0.40) to the most soft (W/C = 1.20). They have been submitted to the slump test and the differential wattmeter consecutively and a systematic correspondence has been established between the slump cone measurement and the useful power developed by the mixer's motor. The total power measures of the mixer's motor have been systematically taken from the differential wattmeter after homogenization of the mixtures, 3 min after the beginning of the test.

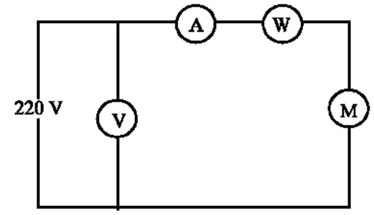

Fig. 1: Electrical device scheme

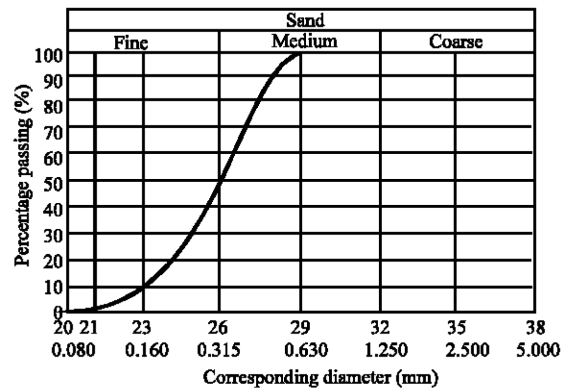

Fig. 2 : Dune sand grading curve

Table 1: Mix proportions per m^3 of the 12 calibration mixtures

Mixture	W/C	Cement (kg)	Dune sand (kg)	Water (kg)
M1	0.40	350	1690	140
M2	0.50	350	1655	175
M3	0.60	350	1620	210
M4	0.70	350	1585	245
M5	0.80	350	1550	280
M6	0.90	350	1515	315
M7	0.95	350	1490	333
M8	1.00	350	1480	350
M9	1.03	350	1470	360
M10	1.06	350	1459	371
M11	1.10	350	1445	385
M12	1.20	350	1410	420

We have noted that the obtained mixtures have been visibly homogeneous after the mixing.

RESULTS AND DISCUSSION

The systematic measurements of the current intensity crossing the mixer's motor, the tension at its terminals and the developed power have been noted for each mix and summarized in Table 2. The correspondence with slump cone values has been also noted in the same table.

The standard curve relating the slump cone to the useful power of the mixer is represented in Fig. 3.

The relationship is almost linear. The more slump decreases, the more concrete is wet and the more motor absorbs power. Consistency fields could be related according to the Table 3 hereafter.

The own knowledge of the stabilized useful power required to mix fresh microconcrete is sufficient to inform us on the field of its consistency.

Effect of W/C ratio on the mixer's useful power: This effect is represented in Fig. 4. The near linearity of the relation between the 2 parameters is established, notably for low and medium consistencies corresponding to W/C = 0.40-0.80. The increase of mixing water reduces the mixer's useful power until its annulation at W/C = 1.10.

Effect of W/C ratio on the slump cone: The curve of Fig. 5 characterizes this effect. The relation could be considered as almost linear. As for traditional concretes with coarse aggregates, the proportionality between the two parameters is obvious from W/C = 0.60.

Table 2: Quantified calibration results

N°	W/C	I (A)	T (Volt)	P_0 (Watt)	P_1 (Watt)	P (Watt)	Slump (cm)
M1	0.40	1.65	230	100	240	140	0.00
M2	0.50	1.65	232	100	220	120	0.00
M3	0.60	1.67	232	100	205	105	0.00
M4	0.70	1.65	232	100	192	92	1.00
M5	0.80	1.65	232	100	165	65	2.60
M6	0.90	1.65	235	100	170	70	4.20
M7	0.95	1.63	232	100	157	57	5.00
M8	1.00	1.65	232	100	142	42	9.00
M9	1.03	1.65	232	100	125	25	9.20
M10	1.06	1.65	230	100	112	12	11.80
M11	1.10	1.67	232	100	100	00	12.20
M12	1.20	1.65	232	100	107	07	15.00

I: Intensity of current, T: Tension at the terminals of mixer's motor, P_0: Initial Power (in neutral) supplied by the mixer's motor. P_1: Final Power (total) supplied by the mixer's motor, P: Useful Power = P_1 - P_0

Table 3: Correlation of fields consistency

Field consistency	Slump cone (cm)	Useful power in the mixer (W)
Wet concrete	0-5	> 61
plastic concrete	5-10	27-61
Fluid concrete	10-15	0-27

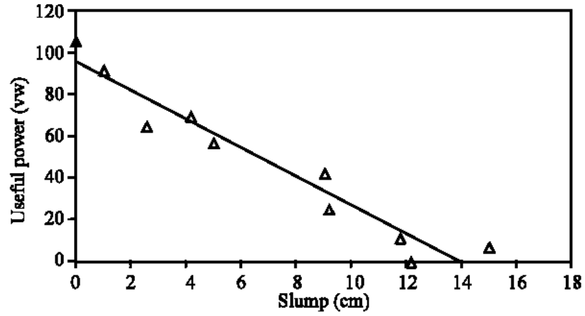

Fig. 3: Standard curve of measurements in differential wattmeter/slump cone

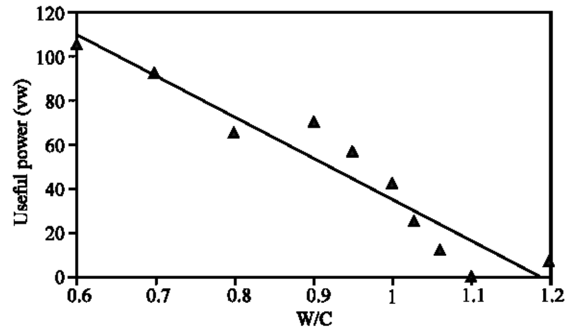

Fig. 4: Effect of W/C on the mixer's useful motor

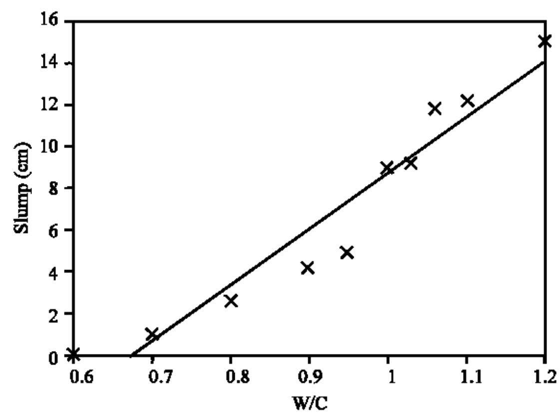

Fig. 5: Relation W/C-Slump cone

CONCLUSION

The proposed method of differential wattmeter allows to report with simplicity of microconcrete workabilities. The process requires few materials: 3 kg versus 14 kg for the slump test. This substantial saving of materials, particularly in fillers is very appreciable. It allows approaching systematic studies on microconcrete rheology.

On the other hand, the differential wattmeter gives additional information when the microconcrete consistency is firm or soft. For example, 2 firm microconcretes (slump cone = 0 cm) could be compactable or completely dry; this difference is appreciated by the suggested method.

We note at the end that the test carried out with the differential wattmeter is practicable by a few qualified personal and by only one person.

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