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Impact of temperature on the demoulding of concrete elements with a polarization process

N. Goudjil [a,*], C. Djelal [a], Y. Vanhove [a], H. Kada [a], N. Heloun [b]

[a] Laboratory of Civil Engineering and geo-Environment, IUT – Civil Engineering Department 1230, rue de l'Université – BP 819, 62408 Béthune Cedex, France
[b] Outinord, 392, Rue de millonfosse, 59732 Saint Amand les Eaux Cedex, France

HIGHLIGHTS

- Development of a new demoulding process.
- Applying of the polarization for demoulding of reinforced concrete.
- Avoid the use of release agents.
- Protect the environment and users from the risks related to the use of release agents.

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ABSTRACT

A recent study proposed a new process for demoulding concrete elements based on the principle of electro-osmosis, consisting of applying an electric potential between the reinforcement and formwork which causes the water displacement towards the concrete/formwork interface where a film of water is formed avoiding the adhesion of the concrete on the formwork. The quality of facing and demoulding has been shown to be dependent on the polarization parameters (voltage value, time and duration of its application) and therefore optimal parameters were assessed. However these parameters were found in a very limited condition of temperature, only at 20 ± 2 °C. In this new study we consider the parameters optimization scheme in other room temperature conditions. In this respect an experimental device was developed in order to quantify the amount of displaced water at (20 ± 2 °C) and (8 ± 2 °C) according to the voltage value and duration of its application. We showed that, under the same polarization conditions, the quantity of water transported decreases with decreasing room temperature. This decreasing of water quantity caused the alteration of demoulding and facing quality. To overcome this issue, the optimal polarization conditions have been revisited in order to take into account the temperature. When transposed in situ, our method performed successfully at 20 ± 2 °C and at 8 ± 2 °C as well and it could be a better choice than the previous demoulding methods like those using vegetable oils, developed recently to replace mineral oils, they cannot be used at low temperatures.

1. Introduction

Taking into account its malleability, concrete is the most used material in the making of formworks which have varied aspects and forms. To facilitate its demoulding and protect formworks from corrosion, the applying of a release agent turns out to be essential. A release agent aims at preventing the adhesion between the concrete and the formwork walls. At the moment two main types of release agents are used: mineral-based oils and vegetable-based oils. The first ones are commonly used, however they are not very compatible with the environment and cause respiratory and skin diseases and even skin cancers among users [6]. If vegetable-based oils can overcome these disadvantages, their viscosities are unfortunately not adapted to cold weather [16]. Users and the environment are always exposed to risks associated with the use of these products. Moreover, the choice of a release agent is not always obvious. Its mode of applying and the thickness of the oil film are not always mastered [8] and the facing quality is not always satisfactory because of color defects, bubbling and the presence of stains on the facing. Recently, in order to free from these products and thus to compensate their disadvantages, a new demoulding process based on polarization was developed [9] and has led to a patent N ° FR2948711 by Outinord. The principle of this process which depends on the electric osmosis phenomena consists in applying an electric current between the reinforcement and formwork wall thus inducing a migration of the water coming from the concrete at the concrete/formwork

* Corresponding author. Tel.: +33 626887609; fax: +33 321684957.
E-mail address: goodjilnassi@yahoo.fr (N. Goudjil).

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interface. The displaced water makes a film which is able to form a separator screen between the concrete and the formwork thus ensuring demoulding. But the quantity of transported water must be sufficient without being excessive since it would induce a raise of the water/cementitious ratio at the concrete/formwork interface and it would alter the facing quality. The thickness of the water film at the concrete/formwork interface depends on several parameters including the ambient temperature. Optimal conditions for demoulding and facing quality at a temperature of 20 ± 2 °C were studied in a previous study [11]. The duration of polarization and the value of voltage to be applied were established. At the moment, for low temperatures, mineral-based demoulding oils keep on being used because of the problems met with the high viscosity of the vegetable-based oils. Therefore, this document proposes to study the water flow from a polarized concrete for two ambient temperatures (20 ± 2 °C and 8 ± 2 °C) using an experimental device specially designed for these tests so as to optimize the demoulding conditions. Several steps were necessary. After the conductivity monitoring tests which enable us to determine the moment of the applied voltage, an experimental device was settled so as to quantify the displaced water according to the value of the voltage, its applying duration and the ambient temperature. The parameters influencing the facing quality, the demoulding and the optimization of the facing were studied by using molds with $30 \times 30 \times 20\ cm^3$ dimensions for both temperatures. This process was then transposed in situ on 2.8 m high formwork.

2. Electro osmosis

The relative displacement of the liquid (neutral water, anions and cations) in relation to the solid skeleton electrically charged constitutes the phenomenon of electro-osmosis at a macroscopic scale. This phenomenon was highlighted in 1952 by Casagrande who determined the law of water displacement in clay soil. This method was also used for soil by Mitchell [17] and Camberfort [5] and more recently by Djelal [7] to lubricate a wall during the extrusion of clay pastes. On the microscopic scale, the contact between a negatively charged solid and water creates an electric double layer in which electro-osmosis has its origin. In the case of concrete, this electric double layer is essentially formed by electrically charged cement grains.

The most soluble constituents of the cement dissolve quickly during the manufacture of concrete and cause a rapid saturation of ions in the solution. These ions and water molecules are then attracted by the charges of the cement grains surface. Ions of the same sign as the surface's charge are repulsed while those of opposite sign are attracted thereby forming a cloud of loads around the particle. It is the combination of these charges which form the electrical double layer. The application of an electric current through the concrete (in the electric double layer) causes cations displacement near the diffuse layer (Fig. 1) [20]. When the cations migrate from the anode to the cathode they bring about water by viscosity effect with them.

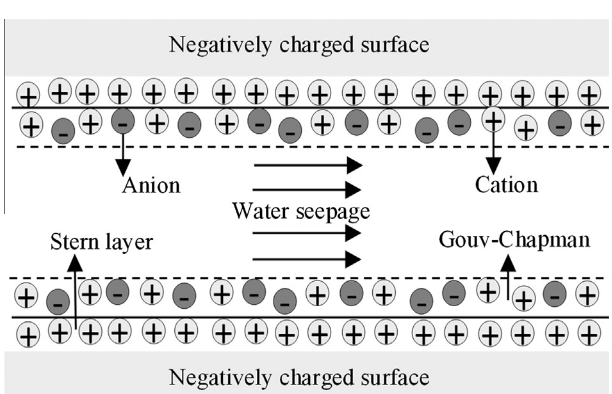


Fig. 1. Water displacement caused by electro-osmosis in a porous environment (microscopic scale).

The new technique of demoulding based on the polarization uses the properties of this electrical double layer formed after water/cement contact.

Before starting the study of demoulding and facing quality, some preliminary tests are necessary in order to determine the hydration reactions of concrete for both temperatures and the quantity of water which is transported from the concrete to the formwork. The tests were conducted with an ordinary concrete class C 25/30 (European standard).

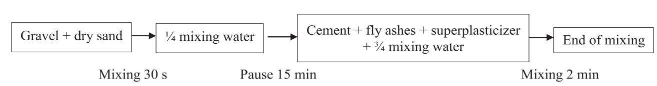
3. Materials

The concrete consistency class S3 is made with cement CEMIII. The composition of concrete is given in Table 1.

The cement, which is used, is a CEMIIIA 42.5 N containing 45.5% clinker (C3A, 8.5% C3S 61%, C4AF 11%) and it represents the most unfavorable case considering the low rate of hydration reactions it engenders. Adding pulverized fly ashes, considering their rounded shapes, improves the workability of the concrete while reducing the needed quantity of mixing water and thus could reduce the quantity of carried water under the effect of the electrical polarization. The physical and chemical characterizations of the cement and the fly ashes are given in Table 2.

The sands which are used in the composition of the concrete have a density of 2.59 and a coefficient of absorption of 0.7%. The density and the absorption coefficient of the gravels 4/12.5 and 11.2/22.4 are respectively of 2.54% and 0.7%. The admixture is a plasticizer made with lignosulfonates which reduces the need of water while improving the workability of the concrete. Its characteristics are given in Table 3.

For the production of concrete, a vertical axis mixer with a tank was used at a constant speed. The process of mixing concrete, in accordance with the standard NF P 18-404, is the following:



The absorption done by the aggregates of the water necessary to the hydration of the cement could cause a modification of the rheological characteristics of concrete. To avoid this alteration, a pause of 15 min (pre wetting) was necessary after the first phase of mixing which consists of mixing bits of gravel and dry sand with 25% water. For every trial, the tests of fresh concrete were performed immediately after the manufacturing of concretes. The results show that concretes slump is of 12 ± 2 cm (very plastic concrete). Before starting the demoulding tests, it is needed to determine the initial setting time of the concrete in order to determine the moment of voltage application and also to study the flow water in the fresh concrete.

4. Determination of the initial setting time

To minimize the disruption of the concrete hydration, it is necessary to start the polarization of the sample before the end of the

Table 1
Concrete composition.

	Composition (kg/m^3)
Cement CEM III A 42.5 N	280
Fly ash	45
Sand 0/4	863
Gravel 4/12.5	291
Gravel 11.2/22.4	641
Water	185
Water reducing plasticizer	0.62
E/L[a]	0.57
G/S	1.08
Paste volume (%)	30

[a] L = Cement + pulverized fly ash.