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Correlation between adhesion energy of release agents on the formwork and demoulding performances

Laurent Libessart [a,*], Pascale de Caro [b,c], Chafika Djelal [d], Isabelle Dubois [e]

[a] Laboratoire Génie Civil et géo-Environnement (LGCgE) – Lille Nord de France (EA 4515), Hautes Etudes d'Ingénieur, 13 Rue de Toul, F-59046 Lille Cedex, France
[b] Université de Toulouse, INP, LCA (Laboratoire de Chimie Agro-Industrielle), ENSIACET, 4 Allée Emile Monso, F-31030 Toulouse, France
[c] INRA, UMR 1010 CAI, F-31030 Toulouse, France
[d] Laboratoire Génie Civil et géo-Environnement (LGCgE) – Lille Nord de France (EA 4515), IUT de Béthune, 1230 Rue de l'Université, F-62400 Béthune, France
[e] Centre de Recherche Lafarge, 95 rue de Montmurier, F-38291 Saint Quentin Fallavier, France

HIGHLIGHTS

- Correlation established between interfacial properties and demoulding performances.
- The influence of the composition of the oil formulations was studied.
- Surface state of the formwork (new, used, and polished) was taken into account.
- Interfacial properties of vegetable oils are favourable to the criteria of demoulding.
- A minimal level of adhesion energy was found to get aesthetical facings.

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ABSTRACT

To ensure an easy demoulding of the concrete, the release agent must form a homogeneous film on the formwork to resist the casting concrete. The adherence of oil with the support was studied via the solid/liquid energy adhesion. This energy was calculated using the Zisman equation involving the angle of drop and the surface tension. Various formulations were studied, in order to establish correlations between their composition and the interfacial properties. Formwork release tests were performed to assess cladding aesthetics; it was possible to define a minimal level of adhesion energy to meet the facings quality after concrete demoulding.

1. Introduction

Architects nowadays have become more demanding and request only the highest quality concrete cladding. Control over cladding appearance implies a suitable selection of formwork release conditions (relative to concrete composition, demoulding oil and formwork characteristics). The role of a release agent applied on a formwork surface is critical since it involves three interfaces: oil/concrete, oil/formwork, and oil/air. The formwork release agent prevents concrete from adhering, while displaying perfect adherence to the formwork and eliminating air bubbles trapped at the surface during concrete casting.

These three functionalities serve to avoid a number of appearance flaws on the cladding (dusting, stripping, micro-bubbling, anchoring points).

The adherence of concrete to the formwork surface [1] is due to two distinct causes: meshing and capillary forces. By virtue of its extremely fine structure and high lubricity, the cement paste generated spreads along the formwork surface and becomes embedded in even the smallest surface irregularities, thus creating an actual bond. As the level of contact between cement paste and surface improves, this bond becomes more solid and the ultimate adherence more effective [2]. Yet, such contact between cement

* Corresponding author. Tel.: +33 (0)361762346; fax: +33 (0)328384804.
E-mail address: laurent.libessart@hei.fr (L. Libessart).

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paste and surface is not always identical and declines in the presence of a water film.

Capillary forces develop within water-filled pores where contact surfaces lie very close to one another. These forces may be tremendous at first and then taper off slowly as the concrete is setting. The bond shows greater strength when the two components are more tightly spaced and less permeable.

Capillary forces are also at work between two less perfect surfaces, though more specifically in spots where the minimum spacing conditions may be perfectly achieved.

Surface treatment using a formwork release agent offers one means for reducing the level of adherence between concrete and formwork, in taking advantage of a complex lubrication mechanism. Two mechanisms may in fact be acting at the interface [3]. For mineral based oils, a physical water-repellent film prevents the concrete from adhering to the formwork, providing a so-called "barrier" effect. For vegetable based oils on the other hand, soap formation facilitates formwork release.

The guide [4] specifies two categories of cladding:

- Concrete surfaces subject to requirements regarding appearance quality (visible concrete surfaces).
- Other surfaces only subject to dimensional accuracy requirements.

According to this guide, claddings are defined by three classifications corresponding to quality ratings of both the surface condition and appearance, with specifications becoming more stringent for each classification:

- Simple raw cladding out of the formwork, whose appearance is only subject to a regularity requirement, plus the possibility of additional specifications like compliance with a general colour scheme or with the appearance of a suitable concrete poured at the beginning of the project.
- A more refined cladding subject to requirements relative to its texture, shade and geometric shapes.
- Structural cladding subject to a decorative requirement, either prefabricated or cast-in-place.

Several standards [5–7] specify the main requirements for the colour, texture and shape tolerances, for these three classes of cladding. It also indicates the set of prescriptions to be met with respect to formwork, concrete components and the quality assurance approach. These recommendations however do not prevent the occurrence of flaws.

Moreover, flaws may be magnified by the use of poor quality formworks (Figs. 1 and 2). The type of formwork is taken into account for the present study.

With the same oil, the cladding aesthetic may be quite different according to the formwork (used or new) as shown in Figs. 3 and 4.

The affinity of the oil with the support is a significant property, since the oil film acts as a protective coating for the formwork and a lubricant during the concrete casting [3]. Therefore, we propose to calculate the solid/liquid adhesion energy (ω_{SL}) derived from the Owens–Wendt model [8]. From Young's equation [9], the resulting Zisman's equation [10] inputs two experimental measurements, the droplet (or contact) angle and liquid/vapour surface tension (Fig. 5).

Young's equation is expressed in the following form:

$$\gamma_{LV}\cos(\theta) = \gamma_{SV} - \gamma_{SL} \Longleftrightarrow \gamma_{SL} = \gamma_{SV} - \gamma_{LV}\cos(\theta) \quad (1)$$

where θ is the contact angle, γ_{SV} is the solid surface energy, γ_{LV} is the liquid–vapour surface tension and γ_{SL} is the interfacial energy solid/liquid.

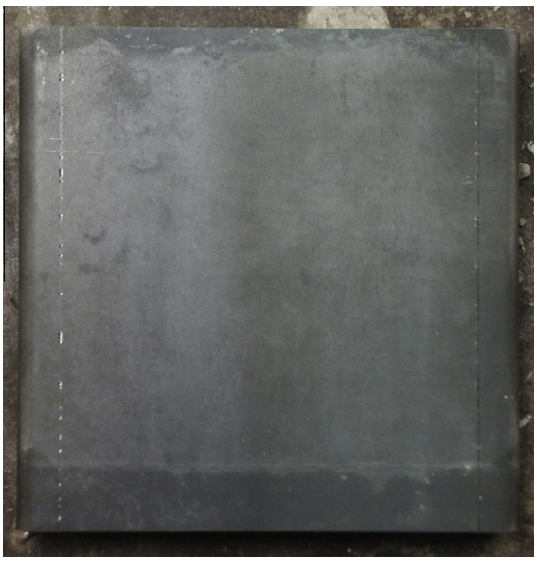

Fig. 1. New formwork surface.

Fig. 2. Used formwork surface.

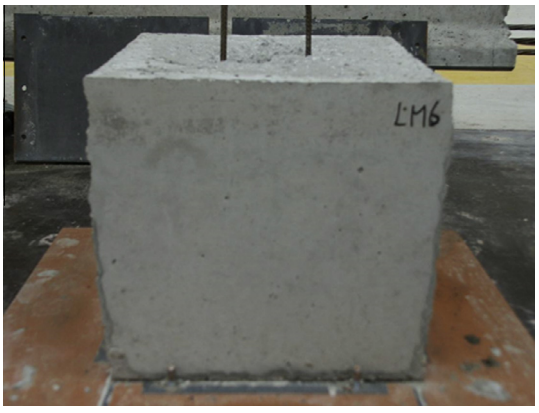

Fig. 3. Facing aspect with new formwork surface.

The liquid/solid adhesion energy ω_{LS} provides an indication of the adhesive force between a liquid and its support. Adhesion energy values are determined according to Zisman's equation, i.e.: