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Effect of Natural Release Oils on Concrete Wettability

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Abstract. Special formulations of biodegradable, non-toxic release oils based on edible oils have been developed. The unique edible oil formula has physico-chemical properties similar to diesel fuel and is a renewable and biodegradable product. Due to its hydrophobic properties, it can be used to produce release agents. In this study, ultrasound was used to properly combine the liquid phase of edible oil and the liquid phase of glyceryl trioleate and/or water. Based on PN-B-19305:1996 standard, six component configurations were designed and then tested. The wettability of the concrete was determined by contact angle (CA) analysis. The ordinary concrete retained good absorbency, the CA was less than 30°, indicating good hydrophilicity. The release oils did not seal the concrete structure. The O65T35 concrete (65% unique edible oil formula and 35% glyceryl trioleate) had the best absorption, in this case, the CA was 20° after oil application and 19° before.

INTRODUCTION

One of the problems occurring in the construction and production of building elements are damages to the surface of products directly adhering to the molds or formworks. Such damages are the result concrete adhering too strongly to the mold or formwork surface during the concrete setting process. A common cause of this situation is not using release oils, using the wrong oils or using them in excess, and using contaminated molds [1]. In practice, there are three basic types of release agents for releasing concrete from molds: for direct use as oil, for use in the form of water-oil emulsions, or for use in the form of a gel. The classification of releasing agents has not yet been developed by ISO. The PN-B-19305:1996 standard [2], which has been withdrawn classifies concrete release agents as oil release agents, designated by the symbol (O), and emulsion release agents, designated by the symbol (E).

New generation release oils must meet stringent environmental requirements, among which biodegradability is the most important [3]. Therefore, natural or chemically modified vegetable oils can be used as biocomponents for the production of release agent [4, 5]. So far, no detailed normative requirements for the quality of this type of oils have been developed.

Biodegradation of oils is a process induced by microorganisms' enzymes, thanks to which, by transforming the chemical structure of compounds constituting an oil composition, microorganisms obtain metabolites that are incorporated into natural energy-generating and biosynthetic pathways occurring in their cells. The progress of biodegradation depends both on the qualitative and quantitative composition of microflora capable of carrying out the decomposition processes and on environmental factors occurring in a given ecosystem, as well as on physicochemical properties of decomposed substances, including their structural structure. Vegetable oils tested in respect of their susceptibility to quick biodegradation in the natural environment, in comparison to all other base oils used for the production of lubricating materials, show the biggest biodegradability falling in the range of 70–100%, independently of origin and conditions of plant cultivation from which they are obtained. This results from the fact that they are materials synthesized by nature, but also used next to carbohydrates and proteins by heterotrophic organisms as a high-energy source of carbon and energy.

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The research presented in this paper deals with new biodegradable oil-based release agents. The most advantageous, from the point of view of environmental protection, functional feature of vegetable oils is their ability to biodegrade, i.e. to decompose spontaneously to CO_2 and H_2O. Due to their hydrophobic properties, they can be used in the production of release agents for concrete molds. The starting materials for the study were natural oils and glyceryl trioleate. This innovative combination has not been tested yet, so there are no reports on this topic in the literature.

MATERIALS AND METHODS

The material used in this study was ordinary concrete (grey) made from CEM I 42.5R cement, gravel aggregate, with w/c = 0.45, water absorption rate 5.2%, volumetric density 2275 kg/m^3, compressive strength 52 MPa [6]. The mold release agents were prepared in the following configurations (Table 1):

TABLE 1. The compositions of form release agents.

Name	Unit	Natural oil	Glyceryl trioleate	Water
O65T35	%	65	35	–
O65T33W2	%	65	33	2
O65T31W4	%	65	31	4
O65T29W6	%	65	29	6
O70W30	%	70	–	30
O80W20	%	80	–	20

The vegetable oils used are higher carboxylic acid ethers which are compositions of natural ester compounds derived from canola oil. The physical characteristics of the natural oils were as follows: density 1.0 g/cm^3, dynamic viscosity 0.022 Pa·s. The viscosity coefficient was determined by the Stokes method. The tests were carried out at room temperature of 22.5 °C. Five measurements were taken as the authoritative number. The second ingredient was glyceryl trioleate, which is formed as a waste product during the esterification of higher fatty acids. Both products are claimed by a patent application, and until a patent is obtained, both products are covered by the manufacturer's confidentiality. The density of glyceryl trioleate was 1.28 g/cm^3. A UP400S ultrasonic sonicator from Hielscher Ultrasound Technology was used to properly combine the liquid phase of natural oils and the liquid phase of glyceryl trioleate and/or water. The ultrasound was used as one of the effective methods to change the viscosity and surface tension of the liquids. The most optimal mixing time was 10 minutes at an amplitude of 30%. Based on many trials involving analysis of ultrasonic power and stirring time, the optimum time and power were determined so that the new product would not overheat as the solution temperature rose rapidly, and so that no precipitate would form at the bottom of the container.

In this study, research related to the effect of new release oils on concrete wettability was conducted. The water contact angle (CA) was carried out on using distilled water. Drops of constant volume liquid (approximately 2 mm^3) were applied to the dry surface of the concrete samples using a micropipette. Five drops were applied to each specimen at a temperature of about 22.5 °C. The water absorption coefficient due to capillary rise was performed according to PN-EN 1015-18 [7] standard on rectangular-shaped specimens with dimensions of 40 mm × 40 mm × 160 mm. After 24h, the weight gain was determined and the water absorption coefficient was calculated. The water vapor diffusion test was conducted to see if the new release oils have a negative effect on the movement of water vapor through the concrete sample. According to paragraph 2.3.2 of PN-B-19305:1996 [2] standard, the release agent should not cause a change in the color of the concrete (stains, crystalline efflorescence) on any of the tested samples. After the concrete specimens were unmolded, their surface condition was evaluated - it was checked for possible defects on the surface of the samples caused by the new release oils.

RESULTS AND DISCUSSIONS

The density and viscosity of new biodegradable-oil-based release agents were determined first. The results are shown in Table 2.

TABLE 2. The viscosity and density of release agents.

	O65T35	O65T33W2	O65T31W4	O65T29W6	O70W30	O80W20
Dynamic viscosity, Pa·s	0.025	0.032	0.037	0.035	0.022	0.03
Kinematic viscosity, mm^2/s	25.30	32.0	33.6	31.9	21.7	27.9
Density, g/cm^3	1.0	1.0	1.1	1.1	1.1	1.1

The newly produced agents had a density of 1.0 – 1.1 g/cm^3. The water at a temperature of about 1 °C has a similar density. The measurements of the viscosity showed that the highest dynamic/kinematic viscosity was characterized by the agent O65T31W4, while the lowest by the agent O70W30. For comparison, the kinematic viscosity of rapeseed oil methyl ester at 20 °C is 7 mm^2/s [8]. The obtained viscosity caused the newly produced release agents to have less tendency to run off the sloping and lateral surfaces of the molds.

The measurements along with CA results performed during the droplet application are shown in Fig. 1.

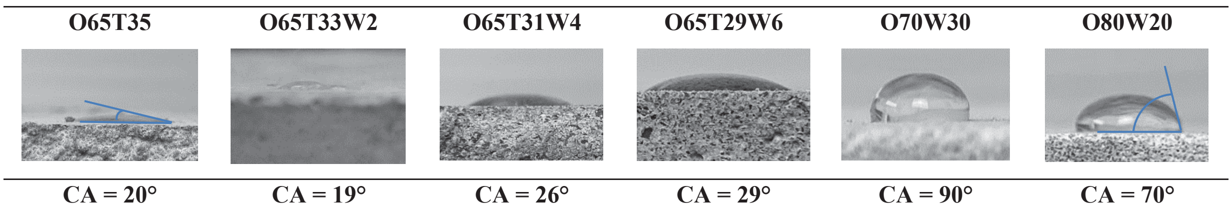

FIGURE 1. The CA of the concrete during the application of the drop.

The analysis of Fig. 1 shows that the CA depends on the type of biodegradable-oil-based release agents used. Materials' CA is an indicator of their wettability. Higher wettability occurs at low CA <90° [9].

The highest CA of water $\theta_w = 90°$ and 70°, at the beginning of the test, was obtained by the O70W30 and O80W20, respectively. CAs lesser than 90° mean good wetting of materials such as concrete. Similar wettability of the concretes was obtained for typical mold release agents, which was 24.8° [10] or 40° depending on the type of concrete [9]. The layer of oil (O70W30 and O80W20) that remained on the concrete surface caused the surface to become slightly hydrophobic, which is an undesirable phenomenon.

The results of the water absorption coefficient are presented in Fig. 2.

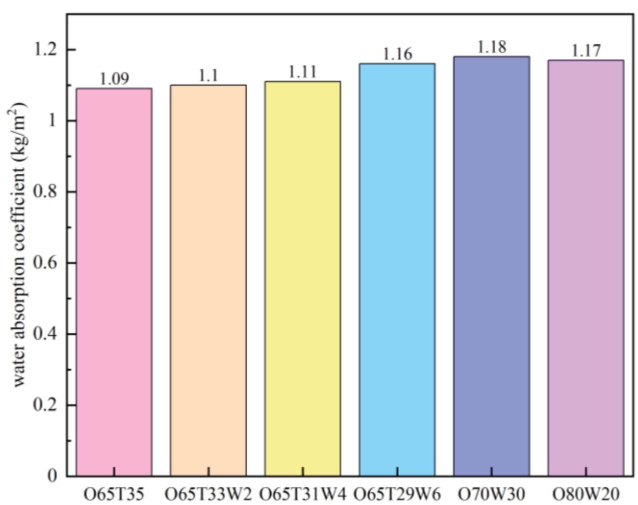

FIGURE 2. Water absorption coefficient due to rising capillary action after 24 hours.

It was observed that as the amount of water in the mixture increases, the water absorption coefficient due to capillary rise increases. It differs by a maximum of 7% between the agent without water O65W35 and with the highest water content O70W30. These values are typical for normal concrete and do not deviate from the standard, indicating that there is no negative effect of oils on water retention in concrete. The results do not coincide with the CA test, because the CA test involves applying small drops to the concrete surface, which in the case of O70W30, O80W20 was covered with oil in some areas of the samples. In the longer period of the water absorption coefficient test, these concretes did not show hydrophobic properties as during the CA test.

The results of water vapor diffusion measured by the decrease in moisture content over time are presented in Fig. 3.

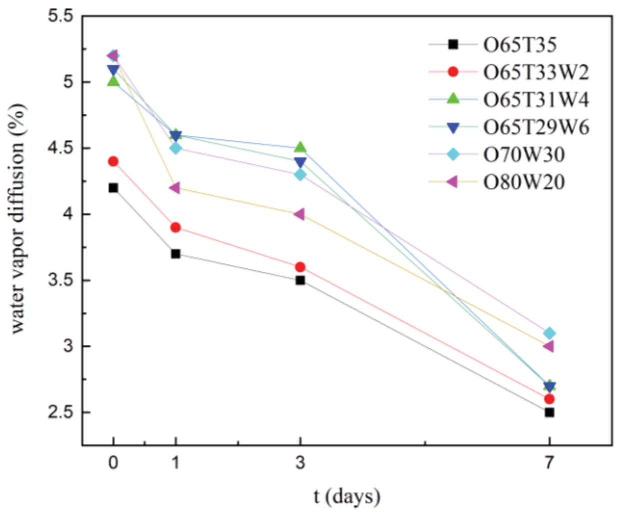

FIGURE 3. Moisture as a function of time during water evaporation from the concrete structure.

The tests showed that the tested release agents did not inhibit water vapor diffusion from the tested samples (Fig. 3). The moisture content after 7 days for all concretes ranged from 2.5% to 3.1%. Concretes with formulations O70T30 and O80W20 had the lowest diffusion. Compared to the formulations without water or with 2% water content (O65T35 and O65T33W2), diffusion was 19.3% lower after 7 days.

Figure 4 shows the surface condition of the selected concrete specimens after unmolding the samples. The relationship between pores on the concrete surface and the type of release oil was studied by Ichimiya et al. [11]. They compared a water-based release agent with a commercially available oil product. The ordinary concrete specimens cast molded with the water-based release agent had fewer surface voids compared to specimens that were molded with the oil-based release agent. Gram [12] stated that the varying surface quality is due to altered cement hydration. This is due to the fact that release agents, such as water emulsions, retard the hydration of cement near the mold. In our study, the situation was the opposite, oil with water resulted in larger pores and voids on the concrete surface (Fig. 4). Linder [13] pointed out that during fresh concrete compaction, it is easy for the compaction energy transferred to the concrete to cause partial deposition of the applied release agent layer in the edge zone and partial, irregular, deposition on the surface.

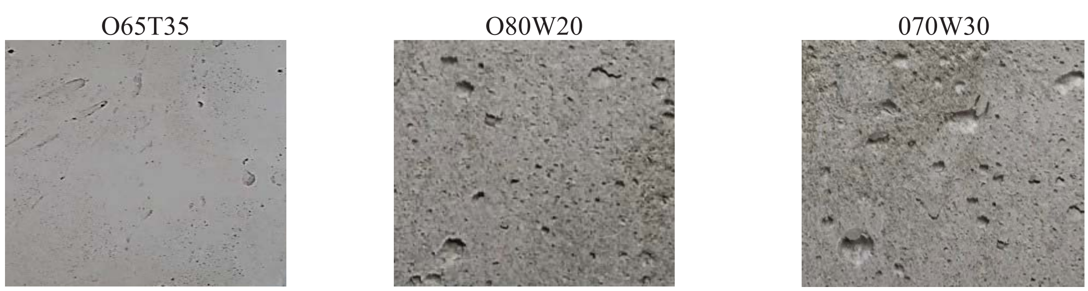

FIGURE 4. The surface condition of concrete specimens after demolding.

The performance tests carried out showed that the unmolding of the specimens using biodegradable-oil-based release agents was easy and the agent did not cause adverse effects on the mold and concrete. No staining, streaking, crystallization, efflorescence were observed on the surface of the unmolded concrete specimens for almost all the analyzed release agents except the oils which contained 30% (O70W30) and 20% (O80W20) water. A certain amount of oil soaks into the concrete by reacting with the surface layer of the concrete. It is satisfactory that the new release oils, with little or no water (up to 6%), do not cause streaks or yellow stains, a very desirable feature.

When special surface cleanliness is required of the concrete product, e.g. for concretes that will not be coated with paint or cladding, light-colored, non-staining release oils, such as O65T35 or O53T33W2, should be used. It will prevent uneven staining of concrete [14]. However, in the case of painting or cladding applications, O80W20 and O70W30 could also be used.

CONCLUSIONS

In this study, the influence of biodegradable-oil-based release agents on concrete wettability was evaluated. The study showed that higher fatty acids derived from vegetable oils can be used as release oil for steel molds used in the production of ordinary aggregate concrete elements, meeting the normative requirements for this type of oil.

The good rheological properties, resulting from the relatively low viscosity of the oil, have a beneficial effect on the use-values, as it can be applied to steel mold surfaces by typical methods.

The newly developed release agents do not seal the concrete structure, allow free moisture migration, and do not form a greasy film on the concrete surface except for O80W20 and O70W30.

The best results were obtained for O65T35 mixture.

In conclusion, the new approach developed in this work shows good application prospects of the investigated release agents in the field of concrete technology.

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