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# PROPERTIES AND MORPHOLOGICAL OF MORTAR CONTAINING USED ENGINE OIL

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**Abstract**

Engine oil has an important role in the design and operation of all automotive engines. Used engine oil is a waste product produced in high quantity in the workshop garage which commonly found in most cities in Indonesia. The utilization of used engine oil has shown potential as retarder by reduce the setting time of mortar. In this study mortar was made by mixing cement, light aggregate, water, and engine oil both new and used as admixture ranged 0-1% of cement weight. Mortar sample treatment is carried out at room temperature. The samples were tested for setting time and compressive strength after 3, 7, and 28 days curing. Density test also carried out to analyses the engine oil addition to the mass density of mortar. Scanning Electron Microscope characterization was carried out to to find out the morphological structure of resulting mortar. Results shown that the mortar with the addition of 0.75% used engine oil has the highest compressive test result of 9.31 MPa compared to mortar without engine oil addition has a compressive test result of 7.54 MPa, both were tested at 28 days, respectively. SEM images shown there are more ettringite presents in mortar with used engine oil addition.

*Keywords*: Used Engine Oil, Mortar, Retarder, Ettringite

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## 1. Introduction

The rapid development of industry and the number of motorized vehicles has triggered an increase in the quantity of used oil waste. Indonesia produces 75 million liters of lubricant per year. Engine oil is one of the petroleum products that still contains aromatic compounds with a low viscosity index. This fluid is used to prevent direct contact between two surfaces that rub against each other. This type of oil has a certain period of use, depending on the work of the machine. Engine oil used in motorized vehicle engines can be referred as lubricants. Used engine oil in daily life is basically lubricating oil which in its use has experienced various kinds of friction and is mixed with dirt from engine components, combustion residues and dust that are acidic, corrosive, deposits, and contain carcinogenic heavy metals including organic and inorganic main contaminants[1]. This causes the effectiveness of the lubricating oil to decrease and contaminants that accumulate in it that when left for too long, it will become abrasive and harmful particles. If viewed from this point of view, by removing a number of contaminants and restoring its lubricating properties, lubricating oil has the potential to be recycled[2-5]. One liter of used engine oil is estimated to contain millions of liters of fresh water from groundwater sources[6].

If not managed properly, this is a potential source of contaminants such as iron and lead that harm living things and the environment[7]. Recycling used engine oil is not only an alternative in the context of efficiency and savings in petroleum consumption, but also helps to reduce pollution. One of the methods used in refining used oil is the acid and clay method[8-10].

The main objective of this study was to investigate the addition of new and used engine oil as chemical admixture to setting time, compressive strength, and morphological of mortar by using scanning electron microscope (SEM), thus enhancing some properties of mortar while serving as a method of utilizing the oil waste.

## 2. Experimental and Procedures

### 2.1 Materials

Portland cement composite (PCC) was used for binder material conformed to SNI 7064-2014. The light aggregate was natural sand obtained from Sukamahi store in Cikarang, Indonesia screened through #4 sieve (less than 4.75mm). Water for mixing was obtained from Catania Cluster, Deltamas, Indonesia from general tap water

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(PDAM).

New engine oil (brand AHM oil MPX2) and used engine oil from motorcycle workshop around Cikarang, Indonesia was used as chemical admixture.

### 2.2 Experiment

Nine mortar mixes were prepared according to Table 1. In all mixes, PCC was used and the water/cement ratio was 0.6 while the ratio of PCC and light aggregate was kept 1:2.75.

*Table 1. Mix design in this study*

| No. | Sample Name | Admixture (%) |
|---|---|---|
| 1 | M-Control | 0 |
| 2 | NEO-0.25 | 0.25 |
| 3 | NEO-0.5 | 0.5 |
| 4 | NEO-0.75 | 0.75 |
| 5 | NEO-1 | 1 |
| 6 | UEO-0.25 | 0.25 |
| 7 | UEO-0.5 | 0.5 |
| 8 | UEO-0.75 | 0.75 |
| 9 | UEO-1 | 1 |

note
NEO: New Engine Oil
UEO: Used Engine Oil

The dosage of new and used engine oil as chemical admixture measured as percentage of cement weight ranged from 0-1%. The methods explain clearly how the author carried out the research. Mixing of cement, light aggregate, water, and new/used engine oil was conducted in Chemistry Laboratory, Institut Teknologi Sains Bandung. Setting time test was conducted using Vicat apparatus according to ASTM C191 "Standard Test Methods for Time Of Setting Of Hydraulic Cement By Vicat Needle"[11]. The 50x50x50 mm cubical mold used to test the compressive strength of mortars. Then, the slurry was curing with ambient method before testing. The mechanical test uses a universal testing machine (UTM) with a capacity of 100 tons at the Center for Infrastructure and Built Environment (CIBE), Faculty of Civil Engineering, ITB, Bandung. Compressive test was conducted at 3, 7, and 28 days. The test is conformed to ASTM C109 "Compressive Strength of Hydraulic Cement Mortars using 2-in. or [50-mm] Cube Specimens"[12]. Density test also carried out to analyses the engine oil addition to the mass density of mortar. scanning electron microscope (SEM) characterization brand HITACHI SU3500 was conducted to study the morphological of mortar with addition of new and used engine oil. This test was conducted at Center of Advanced Sciences (CAS) ITB.

## 3. Results and Discussion

### 3.1 Density

Mass density is measured conformed to ASTM C642 "Standard Test Method for Density, Absorption, and Voids in Hardened Concrete"[13]. This test was conducted to determine the effect of engine oil addition to density of mortar. Resulting value were presented in Table 2 and Fig. 1.

*Table 2. Resulting density of mortar with engine oil addition*

| No. | Code | Density (g/cm$^3$) | | |
|---|---|---|---|---|
| | | 3 days | 7 days | 28 days |
| 1 | M-Control | 1.86 | 1.92 | 1.97 |
| 2 | NEO-0.25 | 1.83 | 1.84 | 1.93 |
| 3 | NEO-0.5 | 2.06 | 2.06 | 2.15 |
| 4 | NEO-0.75 | 2.07 | 2.08 | 2.15 |
| 5 | NEO-1 | 1.97 | 1.97 | 2.11 |
| 6 | UEO-0.25 | 1.92 | 2.08 | 2.18 |
| 7 | UEO-0.5 | 2.05 | 2.07 | 2.14 |
| 8 | UEO-0.75 | 2.04 | 2.04 | 2.09 |
| 9 | UEO-1 | 2.07 | 2.08 | 2.13 |

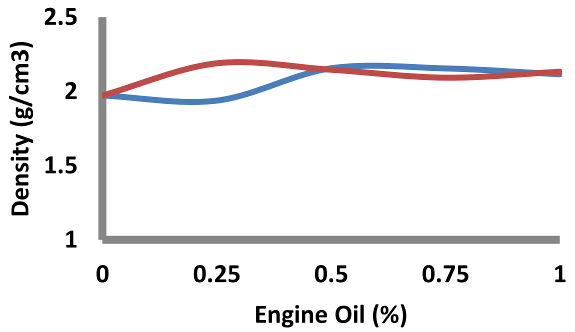


*Fig. 1. Density of mortar with addition of new engine oil (blue) and used engine oil (red)*

Fig. 1 shows that the new engine oil increase the density of mortar by 6-10% while used engine oil increase the density of mortar about 3-10%. According to SNI 03-2847-2002, addition of engine oil makes the mortar can be classified as normal density (2.001 – 2.500 g/cm$^3$).

### 3.2 Setting Time

The results of the setting time test can be seen in Table 3 and Fig. 2. Based on the results of the test experiment, addition new engine oil and used engine oil delay the setting time of mortar. This result is in accordance with the ASTM C191 test. For concrete mixtures containing added materials to slow the binding, the required penetration time is longer than the control time for the control concrete mixture.

This causes the cement to be sensitive to acid so that it can affect the hydration rate to be slower[14-

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16]. Several research also has studied the effect of chemical admixture to setting time[17, 18].

*Table 3. Initial and final set of slurry*

| No | Code | Initial set (min) | Final set (min) |
|---|---|---|---|
| 1 | M-Control | 180 | 390 |
| 2 | NEO-1 | 195 | 735 |
| 3 | UEO-0.25 | 225 | 675 |

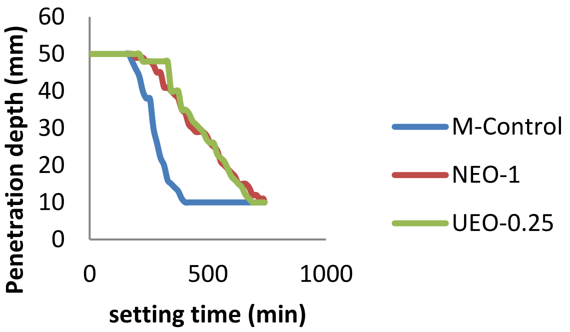


*Fig. 2. Setting time of mortar with addition of new and used engine oil*

Table 3 shows both initial and final set of mortar were longer setting time with addition of engine oil were longer than without. This is due to extra viscous fluid from hydrocarbon and detergent in engine oil composition, hence it will act as a deflocculating agent for cement particles and delays the setting time of mortar.

*3.3 Compressive Strength (fc)*

The resulting compressive strength of mortar at 3, 7, and 28 days with addition of new and used engine oil were represented at Table 4, Fig. 3, and Fig. 4.

*Table 4. Compressive strength of mortar with addition of new and used engine oil*

| No | Code | Compressive strength (MPa) | | |
|---|---|---|---|---|
| | | 3 days | 7 days | 28 days |
| 1 | M-Control | 3.14 | 5.88 | 7.55 |
| 2 | NEO-0.25 | 6.12 | 7.41 | 8.82 |
| 3 | NEO-0.5 | 2.55 | 3.14 | 6.27 |
| 4 | NEO-0.75 | 6.19 | 6.86 | 8.13 |
| 5 | NEO-1 | 6.33 | 9.31 | 10.00 |
| 6 | UEO-0.25 | 4.02 | 8.43 | 9.60 |
| 7 | UEO-0.5 | 4.31 | 4.78 | 6.76 |
| 8 | UEO-0.75 | 4.37 | 5.45 | 7.35 |
| 9 | UEO-1 | 2.94 | 5.68 | 7.25 |

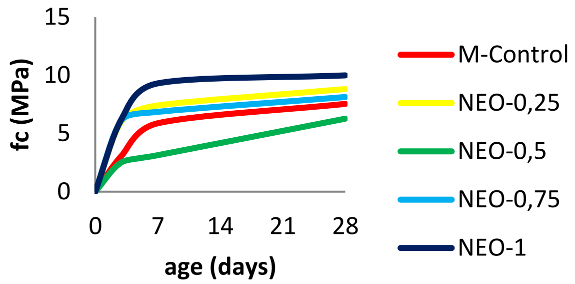


*Fig. 3. Compressive strength of NEO mortar*

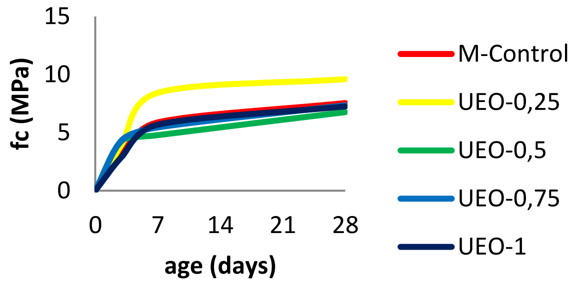


*Fig. 4. Compressive strength of UEO mortar*

Engine oil consists of hydrocarbon, which can protect the mortar from contamination, preventing the water content from being affected, and thus the hydration process can carry on as normal. This explains the strength increase after addition of engine oil to mortar. Various oxide contained in engine oil such as $SO_3$, CaO, $Fe_2O_3$, ZnO, and $P_2O_5$. Compared to M-Control, in some mix design (NEO-0.25, NEO-0.75, NEO-1, and UEO-0.25) the compressive strength is increased. This is due to presence of CaO which is main compound that affect the compressive strength of material. Compressive strength of mortar with used engine oil above 0.25% will decreased since the used engine oil viscosity is higher than new engine oil, and the contaminants in used engine oil had negative effect on compressive strength of mortar.

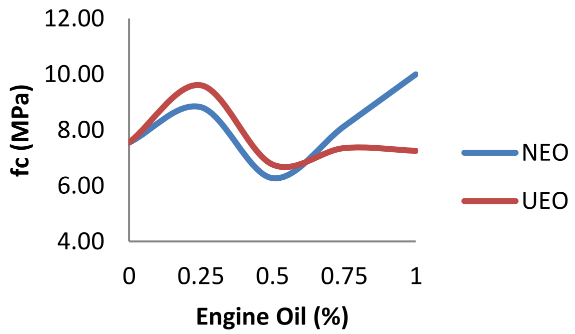


*Fig. 5. Compressive strength (fc) mortar related to percentage of new and used engine oil*

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Fig. 5 shows the correlation of engine oil percentage and compressive strength of mortar. Engine oil at low amount (0.25% by weight of cement) can increase the compressive strength of mortar due to the addition of CaO compound will speed up the hydration process. Engine oil at above 0.25% percentage affect the compressive strength as the cement particle repelled each other due to increase of engine oil, results in lower compressive strength of mortar.

### *3.4 SEM Images*

Figs. 6, 7, and 8 represent the SEM images of M-Control, NEO-1, and UEO-0.25, respectively. NEO-1 and UEO-0.25 were selected to explains the increase in compressive strength.

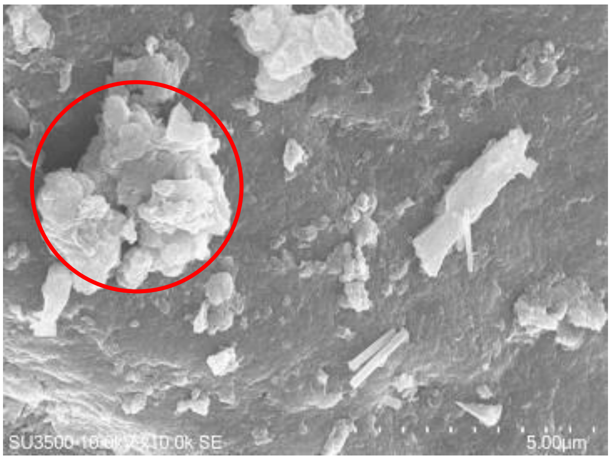

*Fig. 6. SEM images of M-Control (magnification 10000X). Red circle mark is the calcium silicate hydrate (C-S-H) formation*

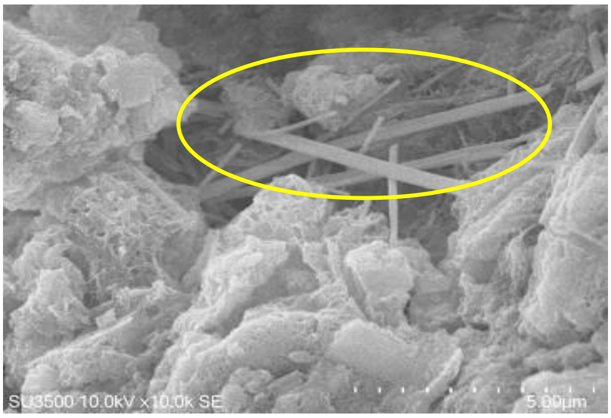

*Fig. 7. SEM images of NEO-1 (magnification 10000X). Yellow circle mark is the delayed ettringite formation*

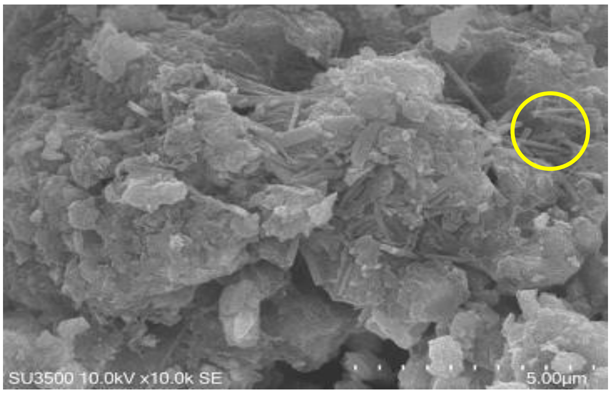


*Fig. 8. SEM images of UEO-0.25 (magnification 10000X). Yellow circle mark is the delayed ettringite formation*

NEO-1 and UEO-0.25 has two similarities compared to M-Control, which has delayed setting time and increase in compressive strength. This can be explained by morphological analysis from SEM. From Figs. 7 and 8 there are rod like structure which marks the delayed ettringite formation (DEF). There is high amount of DEF in NEO-1 and UEO-0.25 that explains the retardation in setting time.

$SO_3$ compound from both engine oil will increase the formation of DEF. The increase of compressive strength value is due to increase in calcium-silicate-hydrate (C-S-H) formation. This compound plays major role in compressive strength of cement-based material[19]. Several research also add supplementary material to increase the C-S-H formation[20, 21].

## 4. Conclusions

In summary, there was a difference between cement paste at 3, 7, and 28 days of age due to the water content in the paste visually. The color change experienced by the paste is due to the effect of the hydration reaction. Addition of engine oil affect the compressive strength of mortar at the age of 28 days. Generally, both new and used engine oil addition increase the compressive strength of mortar. The highest strength at 28 days was achieved by mortar with the addition of 1% new engine oil (10.00 MPa) compared to the control mortar (7.54 MPa). Based on the results of setting time, mortar with the addition of engine oil has a longer setting time than the control mortar due to engine oil slowing the rate of hydration which classified engine oil as potential retarder chemical admixture. SEM characterization shows both engine oil will form more ettringite.

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