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Solidification/Stabilization of Lubricant Waste Initial Setting Time and Compressive Strength Analyses

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Abstract. Lubricant waste contains hazardous material that may harm human being and environment. This research was aimed to observe the effect of lubricant waste, represented in ratio of O/W, designated as W_o, were control 0/100, O/W 15/85 and O/W 25/75 , to initial setting time and compressive strength by solidification/stabilization process physically and chemically. It was mixed with portland cement as binder and fine aggreate into mould of casting cube cement of 50mm x 50mm x 50mm. The test includes vicat test for initial setting time and unconfined compressive strength for compressive strength value. The result noted that the initial setting time and the compressive strength was dependent on ratio O/W. The higher the lubricant waste dosage, the lower initial setting time, the lower compressive strength. The initial setting time for control, O/W 15/85 and O/W 25/75 was 104.31 minutes, 87.12 minutes and 70.15 minutes respectively. Meanwhile, the compressive strength value of 28-days curing time for control, O/W 15/85 and O/W 25/75 was 229.7 Kg/cm^2, 209.9 Kg/cm^2 and 204.1 Kg/cm^2 respectively. The results showed that the initial setting time and the compressive strength excluding for the ratio O/W 25/72 meet qualification regulated by USEPA, Indonesian-EPA, SNI-15-7064.2004 and ASTM C-150-02.

Keywords: compressive strength, initial setting time, lubricant waste, solidification/stabilization

1. Introduction

Lubricant waste is classified as hazardous waste due to its potentially hazard content which is toxic, corrosive, and carcinogenic. It contains organic and inorganic parameter, such as heavy metals and total petroleum hydrocarbon (TPH) that may be harmful for human being and environment. To address this issue, the safe disposal of lubricant waste has been concerning on reducing its toxicity, solubility and mobility. Some treatment method or technology have been developed but still failed to solve this problem because of high cost, high maintenance and long period of treatment. The other recommended technology for hazardous waste treatment is solidification/stabilization (s/s). S/S has been effectively demonstrated as a treatment technique to immobilize hazardous wastes for 57 hazardous wastes from the environment [1].

Solidification/stabilization is a emerged technology for potential hazardous wastes, involving the mixing of a waste with a binder to decrease the contaminant or pollutant leachability physically and chemically. It converts the hazardous waste into an environmentally acceptable waste form for land disposal and construction use. Solidification is an encapsulation process of a waste to restrict contaminant or pollutant migration, then completed by a chemical reaction between a waste and binding (solidifying) reagents or by mechanical processes. Stabilization is a process involving chemical reactions that reduce the leachability of a waste [1]-[3]. Common binder used in S/S is portland cement. It is the main component used in the process of concrete production to get chemically and physically stable product and widely used to treat more contaminated wastes [2], [4]-[11].

Solidification/stabilization (S/S) is interfered by physical and chemical factors, of which are setting time, chemical stability, and strength. These are often common cited as evidences of S/S process in treating hazardous wastes. Initial setting time was measured to ensure the appropriateness cement used as a binder for

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solidification/stabilization process. The ease of cement application for expected final forms will depend on its workability and setting time. The workability of cement was determined by normal consistency test which is usually done before setting time test. According to the normal consistency test, the ratio of water to cement was confirmed. Compressive strength was tested to verify the s/s product meet the requirement standardized in ASTM or SNI (Indonesian Standard) for construction purpose. Thus, the objectives of this research was to investigate the effect of lubricant waste to initial setting time and unconfined compressive strength in solidifying waste by Portland composite cement.

2. Material and method

2.1. Materials

Lubricant waste was oily sample retrieved from local vehicle repair shop. Lubricant waste contains organic and inorganic organic contaminants. Similar to petroleum waste, inorganic contaminants of lubricant waste are in the form of metal compound such as arsen, cuprum, zinc, and nickel. Heavy metals may cause problems to human health and aquatic organisms. According to Indonesian government regulation (PP) no.101/2014, only 16 heavy metals are more likely to be present and considered as potential environmental health concern in hazardous waste. Binder used in this experiment was portland composite cement (PCC) in accordance with Indonesian Standard SNI 15-7064-2004. Its main component are 64,67% of calcium oxide, CaO and 21,23% of silica oxide, Si_2O according to weight percentage.

2.2. Experiments

Lubricant waste was cement-based solidified, and casted into cube-mould mortar, designated as solidified mortar. This solidified mortar process was completed in three subsequent stages, which were determining of mixture composition, casting, curing and testing. Prior to S/S process, initial setting time was conducted to determine the appropriate of mixture composition. The effect of lubricant waste – oily waste – to hydration process of cement was observed. Two main interfered factors were initial setting time and compressive strength. Lubricant waste was mixed into distilled water with ratios of lubricant waste to water (O/W), designated as W_o were 0% (controll), 15% (15/85) and 25% (25/75) of weight accordingly.

Initial setting time of solidified mortar was conducted in cement paste based on ASTM C 191-04b test methods by Vicat Needle [2], [12]. The initial setting time was tested on cement paste with water to cement ratio (W_o/C) of 0.51. Water (lubricant waste + distilled water) to cement ratio was obtained from normal consistency test. The initial setting time was defined as the elapsed time required to achieve a depth of penetration (DOP) of 25 mm. The cement, tricalcium silicat (C3S) reacts with water forming crystalline calcium dihydroxide $Ca(OH)_2$ and C-S-H gel spearhead the setting of cement hydration. The calcium dihydroxide produced by the reaction caused alkaline pH of cement of about 12.5 [9], [13], [14]. The initial setting time of portland cement specification should be ≥ 45 minutes using Vicat method referred to ASTM C 191 [12], [15]. The Compressive strength test was measured by mould used for casting unconfined compressive strength cube was 50x50x50 mm based on Indonesian standard of portland composite cement in SNI 03-6825-2002 and SNI-15-7064.2004 [9], [16]. Then, solidified mortars were cured in room temperature.

The strength test was done after being cured 7 days, 14 days and 28 days. The composition proportion for solidified mortar is presented in Table 1. All variants was being triplicated based on curing time and lubricant waste to water (O/W) ratio.

Table 1. Composition of solidified mortar

Variant	Composition					
	Cement (gr)	Sand (gr)	O (%)	W (%)	O (gr)	w (gr)
1 (control)	250	687.5	0	100	0	127.5
2	250	687.5	15	85	19.1	108.4
3	250	687.5	25	75	31.9	95.6

o =lubricant waste, w = water

The compressive strength test was measured using a universal compression testing machine. The strength test was calculated using equation 1.

$$f'm = \frac{P}{A} \qquad (1)$$

3. Result and Discussion

3.1. Effect of Ratio of (O/W) to Initial Setting Time

The initial setting time is configured in Figure 1. The three curves illustrate the initial setting time of three variants showed better in polynomial model. The result obtained indicates the influence of addition of lubricant waste, designated as ratio of O/W, were 0/100; 15/85; 25/75. Based on figure 1, result indicates that the increased O/W, the decreased the initial setting time. The partial replacement of water with lubricant waste influenced the hydration of cement process which presented by the initial setting time. The reduced water shortened the initial setting time, whereby the oil containing in Wo (lubricant waste + water) might hardened the cement paste faster than that of standardized or normal condition.

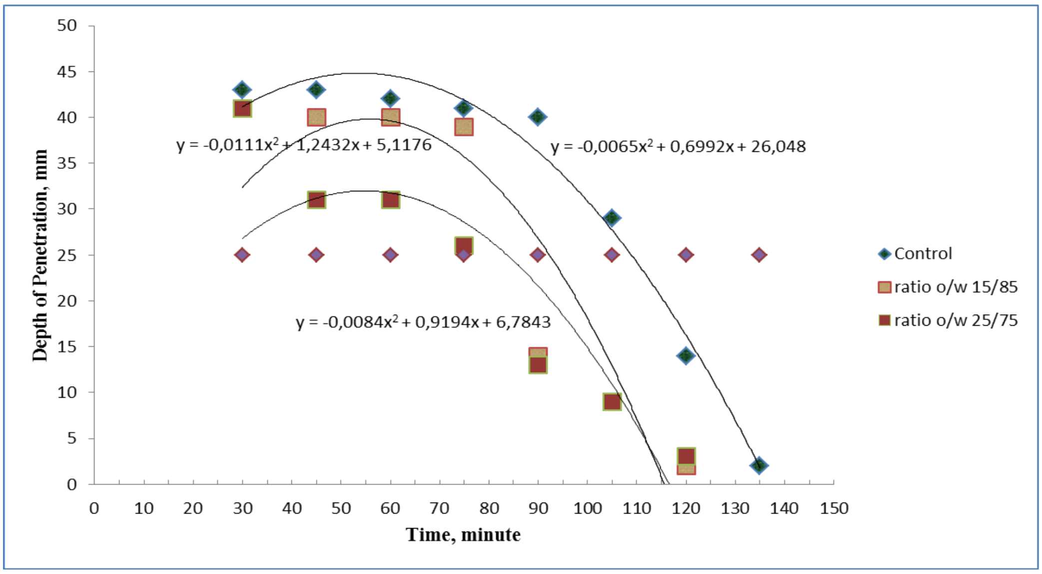

Fig. 1: Portland Composite Cement Depth of Penetration againts Initial Setting Time

The initial setting time of control (0/100), ratio O/W 15/85 and ratio O/W 25/75 was 104.308 minutes, 87.117 minutes and 70.153 minutes respectively. The presence of lubricant waste was supposed to increase reactivity of aluminate and sulfate contained in Portland Composite Cement. Meanwhile, at normal condition of cement paste, initial setting time occurs in 1 to 2 hours for high reactivity aluminate and sulfate content. Otherwise the set is delayed about 2 to 4 hours if both minerals are in low reactivity or availability [1], [3], [5], [6], [13], [17]. Similar to Asna reported, the hydration process of cement in crystalline model was started by nucleation and hexagonal calcium hydroxide crystall growth. Then, it filled up the pores or space between cement grain, leaving layer of rich silicate on the surface. The filling of cement space by lubricant waste would reduce the water movement and release the calcium and silicate ions from cement [1], [3], [5], [6], [13], [17].

3.2. Effect of Ratio of (O/W) to Compressive Strength

Results of compressive strength (UCS) tested at 7-days, 14-days and 28-days of curing time for control and treated solidified lubricant waste are illustrated in Fig. 2. The compressive strength was indicated highly depended on curing time and lubricant waste dosage (ratio O/W). Generally, the longer curing time, the higher compressive strength value. On the contrary, the higher dosage of lubricant waste, the lower compressive strength. Results showed that the highest value was observed for the control sample in 28-days curing time. The value of compressive strength for control, ratio O/W 15/85, 25/75 in 28-days curing time was 229.7, 209.9 and 204.1 Kg/cm2 respectively. The hydration process of cement in solidified lubricant waste was chemically and physically interfered by the properties of lubricant waste and curing period.

Chemically, lubricant waste was oily waste containing organic and inorganic contaminant which is dominated by total petroleum hydrocarbon and heavy metals. These contaminants probably prevent the formation of main cement hydration products such as Calcium Silicate Hydrates (CSH) and portlandite (Ca(OH)2) crystals. Of which impacted the mechanical forces i.e compressive strength [3], [14]. The properties of aggregates used in the mixture of solidified lubricant waste, e.g. specific surface area and organic content, possibly has physically effect. The addition of lubricant waste was supposed to fill in the void or pore of cement grain, so that prevent the water adsorbed into cement thoroughly. Consequently, the hydration process which was indicated by the adhesion of cement paste and aggregates incompletely occured [3], [9]. This behaviour influenced the compressive strength of solidified lubricant waste, that would be decreased by higher lubricant waste dosage. Reasonably, fracture of solidified lubricant waste occurs faster due to the decrease of compressive strength.

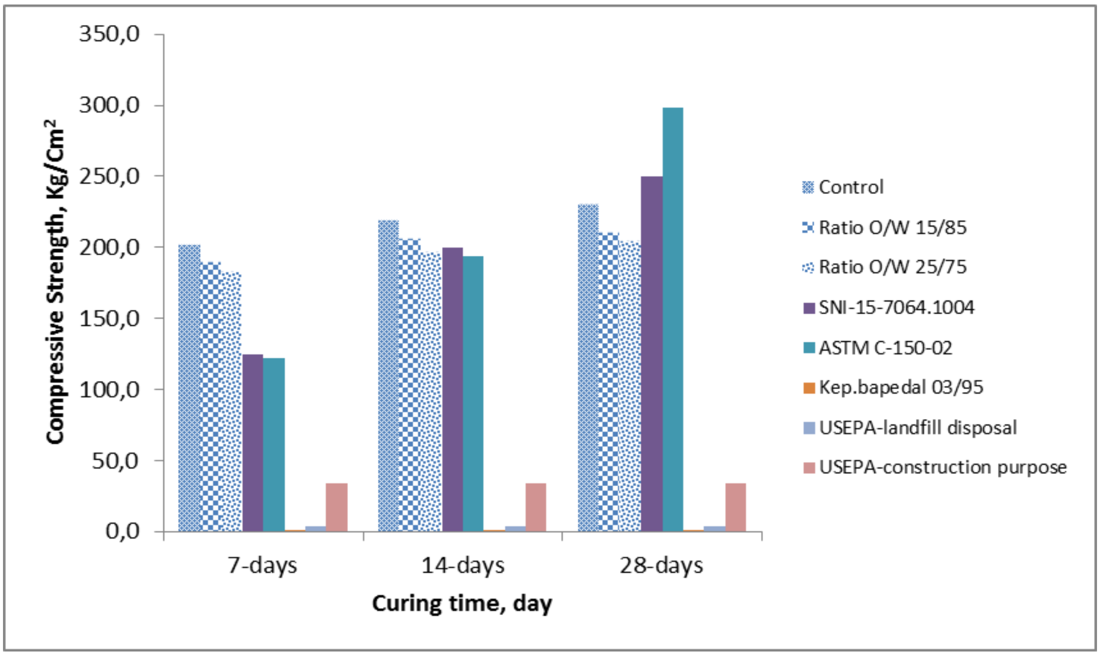

Fig. 2: Compressive Strength againts Curing Time

These facts were confirmed by the initial setting time recorded, whereby better compressive strength of treated lubricant waste was obtained by higher setting time. The lower intial setting time caused the disturbance of adhesion of cement paste, aggregates and water in hydration process of cement. However, the overall value of compressive strength was more than restricted value of USEPA and Indonesian EPA regulatory (Kep.Bapedal 03/1995), equal to 3.5 Kg/cm^2 and 1 Kg/cm^2 respectively. Moreover, the results compared to Indonesian Standard of Portland Composite Cement (SNI-15-7064.2004) and ASTM C-150-02, excluding for the compressive strength at 28-days curing time were satisfied.

4. Conclusion

According to the initial setting time and the compressive strength, solidified lubricant waste meet the restricted value in standard regulated hazardous waste for treatment and construction purpose including ASTM, Indonesian Environmental Protection Agency (Indonesian EPA - Kep.Bapedal 03/1995), USEPA [18] and SNI (Indonesian Standard). The results showed that the initial setting time of cement paste was higher than 45 minutes which noted that the addition of lubricant waste accelerated the hydration process so that the initial setting time became lower. The decreased initial setting time value influenced the compressive strength, whereby the lower initial setting time, the lower compressive strength due to the lubricant waste dosage and curing time.

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