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EFFECTIVENESS OF USED ENGINE OIL ON IMPROVEMENT OF PROPERTIES OF FRESH AND HARDENED CONCRETE

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Abstract: Use of mineral admixtures, processed and unprocessed industrial by-products and domestic and agricultural wastes as raw materials in cement and concrete is becoming popular. This has a positive environmental effect as the cost of safe disposal of waste is significantly higher and there are strict environmental regulations. Some references indicate that the leakage of oil into the cement in older grinding units resulted in concrete with greater resistance to freezing and thawing. This effect is similar to adding an air-entraining chemical admixture to the concrete. However, the hypothesis is not backed by significant research study reported in the available literature. This research study was conducted to investigate the effects of used engine oil on properties of fresh and hardened concrete. The main variables included the type and dosage of an air-entraining agent (SIKA AER commercially available air entraining agent, used engine oil, and new engine oil). Results showed that used engine oil increased the slump between 18 to 38% and air content between 26 to 58% with respect to the control mix containing no admixture, used engine oil reasonably reduced the porosity and did not adversely affect the strength properties of hardened concrete.

Introduction

Lubricants are generally produced from the base-stocks refined from the heavy fractions of crude oil or other hydrocarbons, to which various additives are blended. Lubricants are used for a wide range of applications, including: engine and transmission lubricants, hydraulic fluids, metal working fluids, insulating and process fluids and greases. During service in these applications, part or all of the lubricant may be consumed in the process. The balance tends to become contaminated with substances such as water, metal particles, rust, dirt, carbon and lead, and with other by-products of the combustion or the industrial process[1].

The hazards associated with used oil result from the various additives used in its manufacture and from the heavy metal contaminants picked up from use in the internal combustion engine. Oil poured down household drains, or directly onto the ground, can work its way into the waterways and ground waters. Illegally disposed of oil can pollute the groundwater with contaminants such as lead, magnesium, copper, zinc, chromium, arsenic, chlorides, cadmium and polychlorinated biphenyls. One quart of oil can pollute 250,000 gallons of drinking water. Used oil from a single oil change can ruin a million gallons of fresh water, which is sufficient for one year's supply for 50 people. One quart of used oil can pollute up to 40,730 square feet of soil, making it non-productive for farming or plant growth for up to 100 years. Although there are concerns and awareness about the safe and legal disposal of used engine oil in various parts of the world, however, the reality is that about 40% of the used engine oil illegally disposed of, which ultimately goes to rivers and seas[2].

The leakage of oil into the cement in older grinding units has been reported to result in concrete with greater resistance to freezing and thawing. This implies that adding used engine oil to the fresh concrete mix could be similar to adding an air-entraining chemical admixture, thus enhancing some durability properties of concrete while serving as another technique of disposing the oil waste. However, experimental data to support this hypothesis appear to be lacking[3].

Principal objective of this research study was to investigate the properties of fresh concrete i.e. slump and air content and hardened concrete i.e. compressive strength, flexural strength and porosity containing used engine oil. The significance of this research was to determine whether the used engine oil behaves like an air entraining agent as well as it enhances the slump value of a given concrete. Properties of concrete containing used engine oil were compared with the properties of concrete containing new engine oil and concrete containing commercially produced air entraining agent.

Experimental Investigation

Materials and Mix Proportions

A detailed experimental program was prepared to determine the slump value and air content of fresh concrete mixes and also to investigate the properties of hardened concrete such as compressive strength, porosity at the age of 3, 7, 28, and 90 days and flexural strength at the age of 28 days. A control mix without any chemical admixture and 6 different concrete mixes containing an amount of 0.15% and 0.3% used engine, new engine oil and commercially available air entraining agent were prepared.

Ordinary Portland cement, OPC from Lafarge Cement Malaysia that complied with the requirements of BS 12[4] was used. Sand and the gravels conforming to BS 882:1992[5] were used as fine and coarse aggregates respectively. Used engine oil was collected from Proton Edar Service Station at Jalan Lahat, Ipoh Perak, Sythium 800 standard grade new engine oil and commercially available air entraining agent SIKA AER 50/50 supplied by SIKA Malaysia Sdn Bhd were used in this investigation. By weight mix proportion of 1:2.33:2.5 was used for proportioning of cement, sand and gravel, the mix proportion was adopted based on previous research[6] on concrete mix proportion, water and admixture were measured in percentage by weight proportion of cement used. Details of 7 concrete mixes are listed in Table-1.

Table-1: Details of concrete mix proportion

Mix Type	OPC	Sand	Gravel	Water	Used Oil	New Oil	Sika AER
	Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3	%	%	%
Control	350	820	1230	158	-	-	-
0.15 used oil	350	820	1230	158	0.15	-	-
0.3 used oil	350	820	1230	158	0.30	-	-
o.15 new oil	350	820	1230	158	-	0.15	-
0.3 new oil	350	820	1230	158	-	0.30	-
0.15 sika	350	820	1230	158	-	-	0.15
0.3 sika	350	820	1230	158	-	-	0.30

Mixing, casting and curing

Mixing of concrete ingredients was performed in the laboratory using a 100 liter capacity concrete mixer. Dry ingredients; cement, sand and gravel were first mixed for 1 minute in the mixture prior to water addition. Admixtures such as use oil, new oil and Sika AER were diluted in water before it was added to the dry ingredients in the mixer. After addition of water to dry ingredients it was mixed for 2 minutes in order to achieve homogenous concrete. After homogeneous mixing of fresh concrete, it was tested for determination of slump and air content. Slump value was measured in accordance with the British standard BS 1881 part 102, 1983[7] and air content was measured in accordance with ASTM C231.

Concrete cubes were cast in standard steel mould of dimensions 150x150x150mm, concrete in moulds was laid in two layers of approximately the same thickness, after laying each layer the compaction was done by applying vibration according to the specifications defined in BS 8110 1997[8]. Similarly plain concrete prisms were cast in steel mould of the dimensions 100x100x500mm and layering and vibration procedure was same as applied for casting of cubes. Plain concrete planks of 400x400x40mm dimensions were cast in wooden moulds that were fabricated in concrete technology laboratory in the department of civil engineering at university technology PETRONAS, 50mm diameter cores were drilled out for porosity measurement from the planks.

After casting the specimens in the moulds, they were covered with black plastic sheets and left for 24 hours, after that all specimens were striped-out and transferred into the water-bath at room temperature for curing until the desired age of testing such that 3, 7, 28 and 90 days.

Testing of Specimens

Concrete cubes at the ages of 3, 7, 28, and 90 days were tested in accordance with the procedure defined in BS 1881: part 116, 1983[9], a universal hydraulic testing machine with a maximum capacity of 500 kN was used to test the specimens. Total porosity of concrete was determined by vacuum saturation method that was developed by RILEM[10]. At the age of 3, 7, 28, and 90 day, three 50mm diameter discs were cored-out from concrete planks. Total Porosity of the samples was determined using equation as below:

$$P(\%) = \frac{W_s - W_d}{W_s - W_w} x100 \qquad (1)$$

Where, P is the total porosity in percentage, W_s is the weight of saturated samples measured in the air; W_d is the weight of oven dried samples measured in the air, and W_d weight of saturated samples measured in water, all weight measurements are in grams, g.

Results and Discussion

Experimental results as obtained during testing on fresh and hardened concrete are discussed as below:

Fresh concrete properties

Slump value is the measure of fluidity and consistency of concrete; for control mix it was obtained as 130 mm. When used engine oil was added to concrete, the slump value of 0.15 used oil and 0.30 used oil concrete mixes was obtained as 150 mm and 180 mm respectively. Similarly the slump of o.15 new oil and 0.3 new oil mixes was obtained as 155mm and 190mm respectively and 170mm slump was measured for 0.15 sika and 200 mm for 0.30 sika concrete mixes. The above results showed that admixtures either new and used engine oil or SIKA AER improved the slump value as compared with the slump value of the control mix. The enhancement in slump value with the addition of admixture (used oil, new oil, and SIKA AER) was in the range of 15% to 54% as compared with the slump of the control mix, the results are shown in Figure-1.

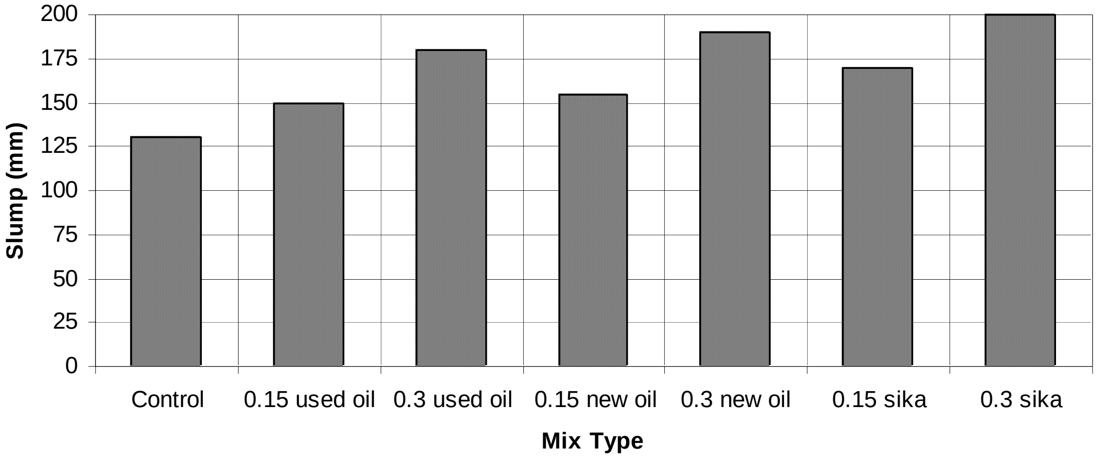

Figure-1: Variation of slump, mm of concrete mixes containing different admixtures

The amount of entrapped air in the control mix with no air-entraining agent was measured as 4%. The use of Sika, the chemical air-entraining admixture, increased the amount of entrained air to a value ranging from 7.3 to 8.4%. When used engine oil was added, the amount of entrained-air was obtained as 5.3 and 6.6% respectively with 0.15% and 0.3% dosage. When new engine oil was used, the amount of entrained air rose to 6.9% only when a dosage of 0.15% the amount was 8% when a dosage of 0.30% was use, the amount of entrained air is shown in Figure-2.

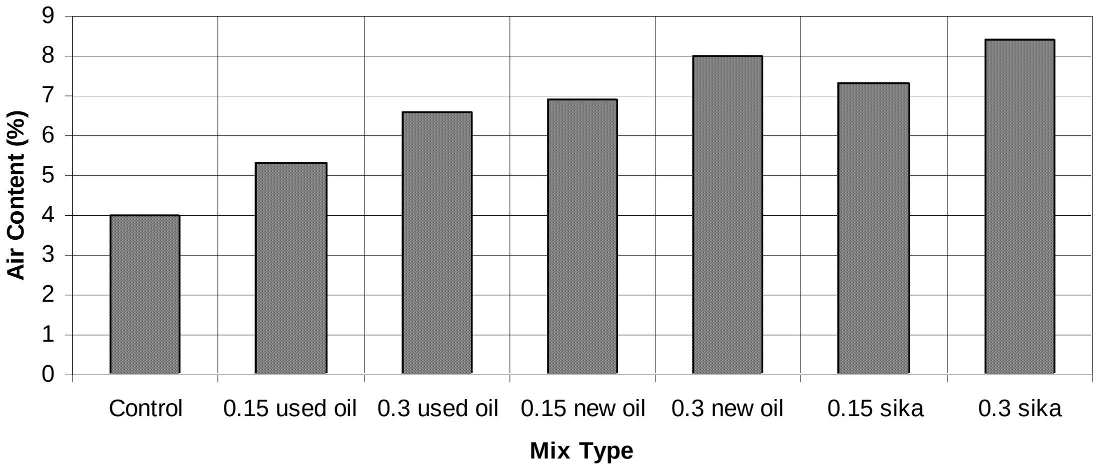

Figure-2: Variation in air content, % in concrete mixes containing different admixtures

Hardened Concrete Properties

Porosity of Concrete

At the age of 3 days total porosity of concrete was measured as 16.8%, it was obtained as the highest values as compared to the porosity value at the same age of 6 other mixes made of used engine oil, new engine oil, and sika air entraining agent. The porosity of those 6 mixes was obtained in between 9.55 and 12.85%. Total porosity of all mixes was lowered with ages, higher rate of reduction with ages was observed in the control mix. The porosity of control mix at the age of 7 days was measured as 11.61% and at the age of 90 days it was measured as 10.03%. The maximum reduction in the porosity of control mix was achieved up to 7 days of age, at this age when up to 70% of cement hydration takes place. At the age of 7, 28, and 90 days porosity of all concrete mixes containing admixtures was obtained less than the porosity of control mix measured at the corresponding age except the porosity of 0.3 sika mix which was obtained more than the porosity of control mix at the corresponding ages at 7, 28, and 90 days. Porosity of concrete mixes with different admixtures at 3, 7, 28, and 90 days is plotted in Figure-3.

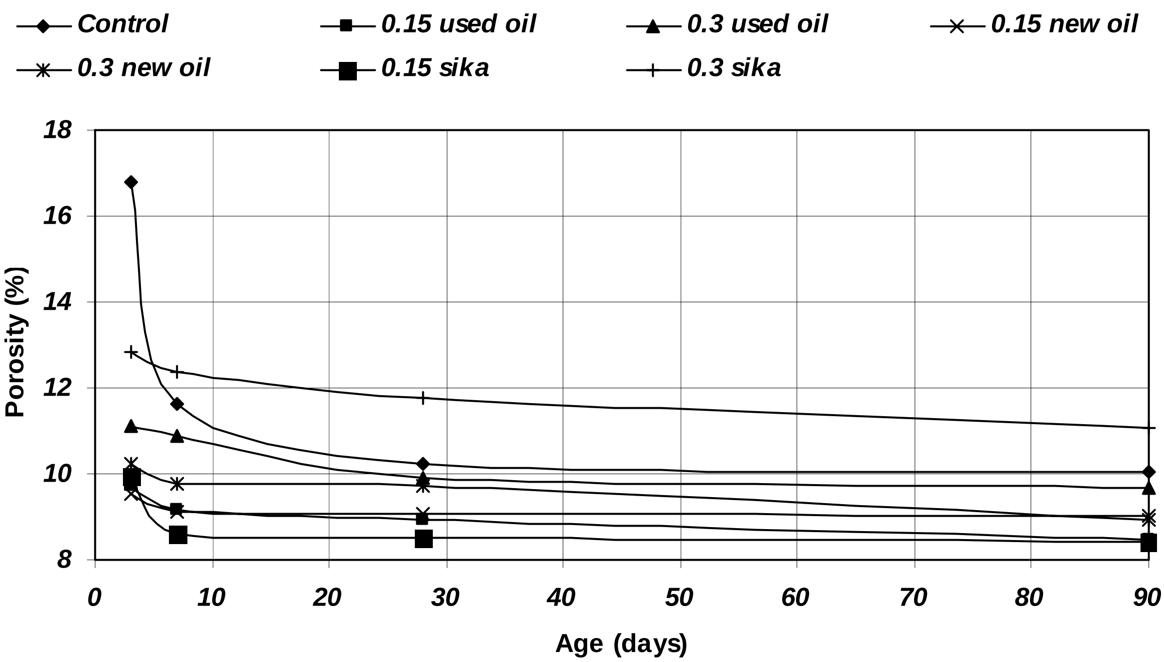

Figure-3: Porosity, % of concrete mixes containing different admixtures at different ages

Compressive strength

The concrete compressive strength was measured for each mix at four different ages: 3, 7, 28 and 90 days. When the dosage of 0.15% of the chemical air-entraining admixture Sika was used, the reduction in the concrete compression strength as compared with the control mix was approximately 1/3rd at all ages. While with 0.3% dosage of Sika admixture at the age of 3 and 7 days the two third reductions in compressive strength was obtained as compared to the strength of the control mix, at 28 and 90 days about 60% lower compressive strength of sika mix was observed. Compressive strength at different ages of all concrete mixes are plotted in Figure-4. The compressive strength of concrete mixes containing 0.3% dosage of used engine oil and the new engine oil was obtained about 25% lower than the compressive strength of the control mix at all the ages, however, when a dosage of 0.15% of used and new engine was used, almost identical value of compressive strength at 28 and 90 days was measured as the values of the compressive strength of the control mix.

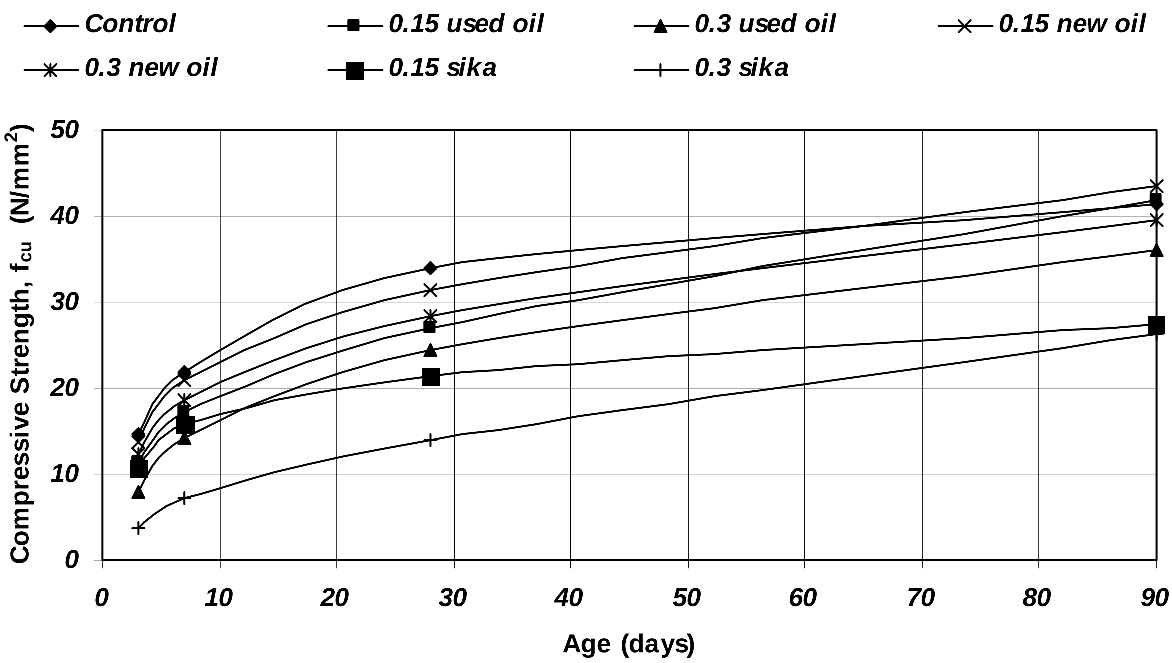

Figure-4: Variation of compressive strength, f_{cu} (N/mm^2) of concrete mixes at different ages

Flexural Strength

In general and regardless of the type or dosage of the air-entraining agent used, the flexural strength or modulus of rupture measured only at the age of 28 days dropped slightly with respect to the flexural strength of the control mix. The average values of the flexural strength for different dosages of the air-entraining agent were 3.27, 2.73, 2.9 and 2.77 N/mm^2, for concretes with no air entraining agent, with Sika, with used engine oil, and with new oil, respectively. The reduction in the average flexural strength relative to the control mix was 20, 10 and 16%, respectively. The corresponding variation is shown in Figure-5.

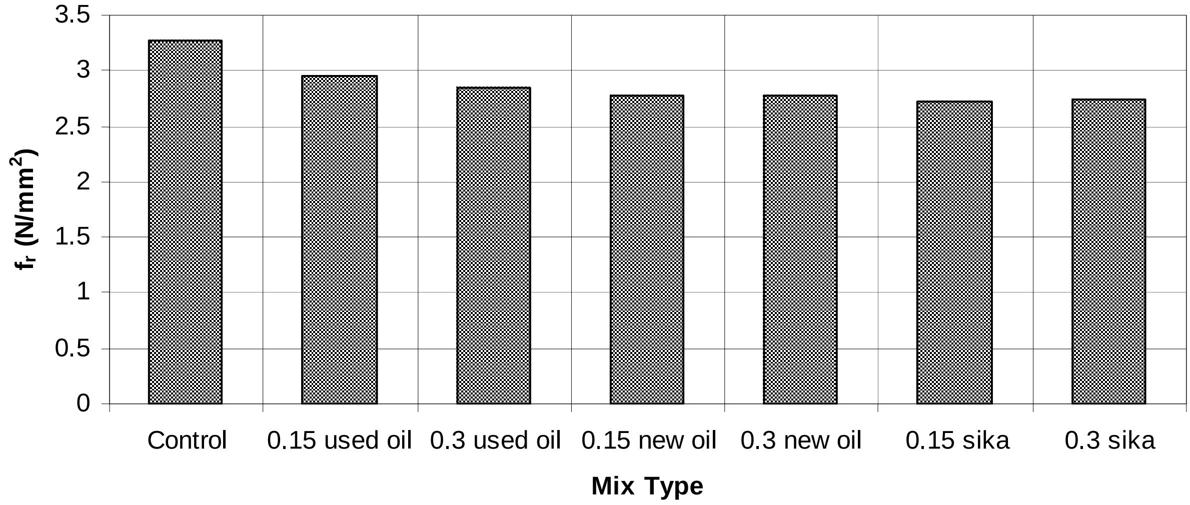

Figure-5: Variation of flexural strength, f_r (N/mm^2) of different concrete Mixes

Conclusions

Based on the results and discussion the following conclusions were made:

1. The performance of the used engine oil and the new engine oil mixes were more or less similar.
2. Used engine oil behaved as a chemical plasticizer in concrete by improving the fluidity and increasing the slump of the concrete mix.
3. Used engine oil increased the air content of the fresh concrete mix to about 30 to 50% as compare to the air content of the control mix, whereas the commercial chemical air-entraining admixture, SIKA AER almost doubled the air content.
4. Used engine oil reduced the total porosity of concrete to an average of 25% with respect to the total porosity of the control mix, where as 0.3% dosage of SIKA AER increased the porosity of concrete; hence low porosity of used engine oil may result in enhanced durability.
5. Used engine oil resulted in average loss 10% in the values of the flexural strength, the corresponding loss 30% when the chemical air-entraining admixture was used.
6. Used engine oil maintained the concrete compressive strength whereas the chemical air-entraining admixture caused approximately 50% loss in compressive strength at all ages.

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