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The Performance of Concrete Containing Used Cooking Oil

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Abstract— **Implementing the sustainable materials become a trend nowadays including construction industry. As cocnrete usage become next two water, a more cost effective and economic new type of green admixtures may give positive impacts on the Malaysian construction building as well as worldwide concrete usage. Therefore, this paper focuses on the effects of used cooking oil as admixture in concrete. The objectives of this research are to determine effects of UCO interms of workability, mechanical properties and microstructure. The result obtained shows that UCO give positive effects of all properties presented in this research. It increases a workability, improve mechanical properties and decrease the ITZ and air voids size compared tocontrol mix. Hence, it can be stated that UCO can possibly act as admixture towards a good quality of concrete using sustainable products.**

Keywords— **Used Cooking Oil, workability, compressive strength, flexural strength, interfacial transition zones, air voids**

I. Introduction

Malaysia is generated about 1.35 billion gallon daily of used oil and has been disposed without proper disposal system. The are many type of cooking oil including palm oil, vegetable oil, peanut oil, olive oil, sunflower oil, grape seed oil and etc. Malaysia is the largest palm oil producer in the world

The used cooking oil (UCO) can be found in any home or cookery shop as it was a very common waste in Malaysia. The UCO always ended up in drainage system, sewerage system or drain. The harm of this waste could not be ignored as this will bring critical and long-lasting environment problem to the community. After all the cooking either at home or cookery shop, most of the UCO will be disposed straight to the sink or the drain. The chemical composition of the UCO depends of the different usage from the user, but the main composition will be saturated fatty acid, triglyceride, diglyceride, monoglycerid and the saturated fatty acid refers to palmitic acid and stearic acid [1]. According to the research, fatty acid in UCO will give effect to the genotypic and grown of the plants [2]. All the waste will then flow into the sewerage system at last and this lead to the environment problem later on. The grease was very high adhesion material, when it flowed into the piping system or sewerage system, it will stick on the pipe in the sewerage system. This will indirectly blocked the flow of the water; disturb the working of the sewerage system such as the grease traps will be affected and cause the maintenance problem. In other way, the UCO which disposed to the drain, most of the time it will enter the sewerage system and the river. The grease will harm the life in the agro system, marine and indirectly return the harm of used cooking oil to the humans.

The effects of used oil in cement has been conducted using a few types oil used oil such as used engine oil, soy bean,and waste paint. Research conducted by by Salmia et al. [3] stated that used engine oil (UEO) was introduced as admixture in concrete. Addition with certain dosage of used cooking oil will improve the performance of the concrete either fresh concrete or hardened concrete. The used engine oil enhanced the fluidity of fresh concrete, increase slump value, increase air content, reduce porosity of concrete. It can enhance high compressive strength and reduce the permeability to the coefficient of oxygen permeability of the concrete. Beside that, the porosity and permeability of the concrete can be also reduced by adding the UEO as admixture without affected the compression strength of concrete and supported by Hamad et al. [4]. Used engine oil research was performed to determine the optimum percentage of UEO that can be utilized in MIRHA [5] and SF [6] concrete as compared to superplasticizer. Chin et al. [7] also stated that the use of 0.15% of used engine oil in OPC concrete increase air content in the range of 40-63% compared to control mix and superplasticizer mix. Moreover, the air content of concrete with 20% replacement of fly ash (0.15% UEO) was almost similar to superplasticizer mix with the same percentage.

UEO also suggested by Aravind and Animesh [8] to be use in highway construction but requires well organized oil collection system. The further research is noteworthy to produce the good quality and performance of concrete.

Potential of soy bean oil as a curing agent explored by Kevern [9] to improve the durability of concrete pavements. He concluded that soybean oil substantially reduces moisture loss from fresh concrete and provides greatly improved deicer scaling resistance.

It was also found that waste paint shows the positive result in maintaining the concrete compression strength and without drying shrinkage. The waste paint also increase the workability and reduce viscosity of concrete compared to control mix. In order to affect the properties of the concrete such as the stiffness of the concrete, higher dosage of the waste paint can be used [10].

Han and Doo [11] investigated the effect of UCO on the engineering properties and durability of high volume admixture concrete. It was resulted that the increase of emulsified refining cooking oil resulted in decrease of slump and air contents. For compressive strength, the use of emulsified refining cooking oil led to decrease the compressive strength at 28 days, while it had similar strength or much higher strength than plain concrete at 180 days. Resistance to carbonation and chloride penetration was improved with the increase of emulsified refining cooking oil contents due to decreased pore distribution by saponification between emulsified refining cooking oil and concrete, while freeze-thaw resistance was degraded due to air loss.

Since there are potential of to act as an admixture to improve concrete performance, it is possible explore the effectiveness of UCO as an admixture in concrete.

II. Experimental Program

Six mixes were cast with fixed value of coarse aggregate, fine aggregate and water binder ratio (w/b) as tabulated in Table 1.

Ordinary Portland Cement (OPC) Type 1 was used in this research, in accordance to BS EN 197-1 2000. OPC Type 1 was preferred because the observation on concrete properties can be done in normal hydration process hence the advantages of UCO usage in concrete can be optimized. UCO were used as admixture in the mix. UCO in this research was collected randomly from COE food court, UNITEN. Generally, all the oil collected from stalls that do not have proper way of disposal.

The specimens were cast in accordance to BS1880. Slump test were conducted to determine the workability of concrete. The test was carried out conforming to BS 1881: Part 102: 1983. Compressive strength test was performed according to BS 1881-111:1983. Concrete cubes of 100x100x100 mm were cast and then water cured for 3, 7, 28 and 56 days.

Flexural test was using center-point loading method which is prescribed in ASTM C 293-79, for 28 days curing age.

SEM were carried out to determine the micro structural properties of the concrete such as interfacial transition zones (ITZ) and size of air voids inside the concrete. This test has been conducted at UKM-MTDC Smart Technology Center, Universiti Kebangsaan Malaysia under Quasi-S Company.

Table 1: Concrete Mix Design

Mix	OPC (kg/m^3)	CA (kg/m^3)	FA (kg/m^3)	w/c	UCO (%)
C	325	1137.5	757.3	0.55	-
CU-0.25	325	1137.5	757.3	0.55	0.25
CU-0.5	325	1137.5	757.3	0.55	0.5
CU-0.75	325	1137.5	757.3	0.55	0.75
CU-1.5	325	1137.5	757.3	0.55	1.50
CU-2.0	325	1137.5	757.3	0.55	2.00

III. Result and Discussion

A. Workability

Throughout this research, slump value of all concrete mixes were measured soon after their mixing. The result of the slump illustrated in Fig. 1.

From the result obtained, there are no significance in workability when adding 0.25% UCO. The slump started to increase 4% with addition of 0.5% UCO and keep increasing until 2% of UCO. The slump value increase almost double compared to control mix with additional of 2% UCO. The relationship of slump to the inclusion of UCO can be determined using the following equation:

$$S = 6.12UCO2 - 4.57UCO + 25.96 \quad (1)$$

Where;

$R^2 = 0.90$

S = Slump value (mm)

UCO = dosage of UCO in%

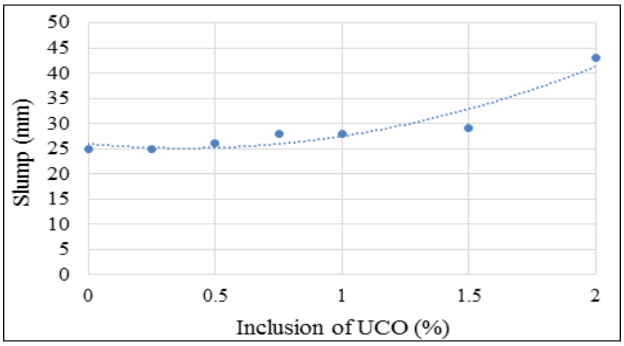

Figure 1: Slump value of concrete mixes with UCO as an admixture

It can be stated that UCO can possibly act as water reducer and lubricant that improve concrete workability. This behavior can relate with UEO obtained by Hamad et al. [4] and Salmia et al. [6] whereby used engine oil acted as chemical plasticizer by improving the fluidity of fresh concrete mix. Thus, there are possibilities that UCO has similarities as UEO [12] and superplasticizer to incerase fluidity that achieved by the addition of superplasticizer.

B. Compressive Strength

Fig. 2 shows the strength development up to the age of 56 days. The effects of UCO in strength development can be obtained by the following linear relationship extracted as below:

$$f'c = -0.007UCO2 + 0.65UCO + 16.14 \quad (2)$$

Where;
$R^2 = 0.99$
f'c = compressive strength on 28 days
UCO = dosage of UCO in%

It can be observed that almost all ages compressive strength reach more than 26 MPa. At the age of 28 days, control mix give the lowest compressive strength of 26.1 MPa. The compressive strength were kept increasing with the increment dosage of UCO which are at 3.24%, 7.26%, 9.22%, 11.36% and 16.79% with 0.25%, 0.5%, 0.75%, 1% and 1.5% increment of UCO respectively. The inclusion 2% UCO started to decrease to 3.3% of compressive strength, however the strength still comparable to the control mix.

The effects of UCO in 28 days curing age can be determine using the following polynomial relationship as presented in Fig. 3:

$$f'c(28d)= -3.15UCO4 + 9.72UCO3 – 9.85UCO2 + 6.44UCO + 26.04 \qquad (3)$$

Where;
$R^2 = 0.99$
f'c = compressive strength on 28 days
UCO = dosage of UCO in%

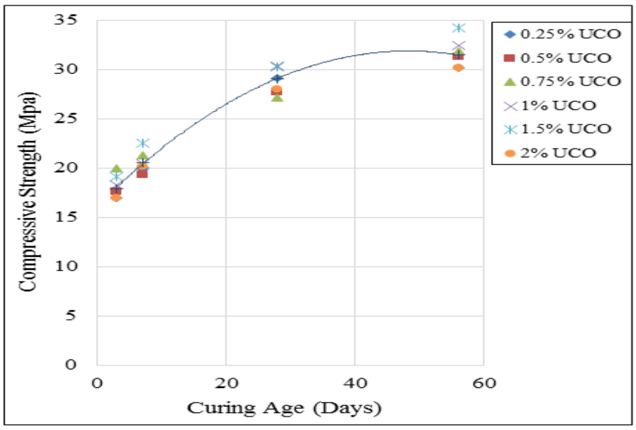

Figure 2: Relationship of UCO with strength development of concrete

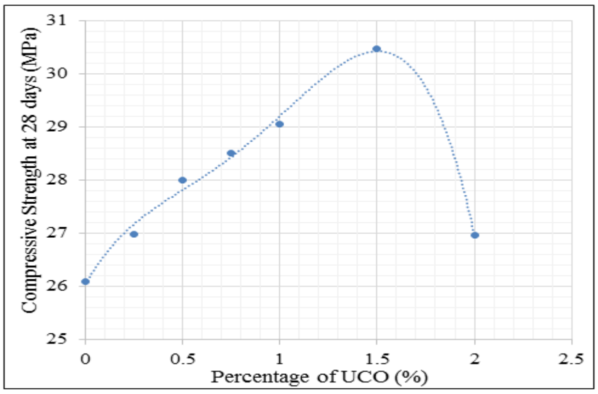

Figure 3: The effects of UCO in 28 days compressive strength

It can be stated that UCO able to increase concrete strength. UCO is generally a very 'slippery" material. Therefore, it can be act as a lubricant that could reduce the friction between fine and coarse aggregates with cement paste to make concrete workable. During mixing process, UCO generated a pressurized film between aggregate surfaces and cement paste that provided a slippery surface that could easily drove the aggregate and cement particle into the empty spaces. The behavior of UCO is comparable with UEO as reported by Chin et al [13] and also almost similar with superplasticizer mentioned by Tarun and Shiw [14], when superplasticizer dosage was increased beyond normal dosage, concrete performance start deteriorated. Furthermore, Mailvaganam [15] added that superplasticizer will not adverse effect to the compressive strength. The high packing density ability and reducing of water content which is directly affected by the superplasticizer is the high contribution to higher compressive strength.

C. *Flexural Strength*

From Fig. 4, it can be clearly seen that the flexural strength increase from 1.8MPa of 0% UCO to 2.01MPa of 1.5% UCO. The flexural strength is increased by 11.7%. Based on the graph, it shows that further addition of UCO had decreased the flexural strength from 2.01MPa of 1.5% UCO to 1.91MPa of 2.0% UCO. The flexural strength value had decreased by 5%. However, the flexural strength of 2.0% used cooking oil is still higher than control test (0% UCO). The flexural strength of 0% to 2.0% UCO is increased by 6%.

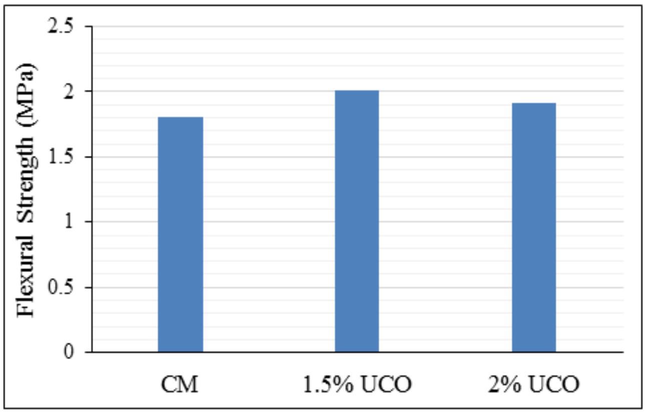

Figure 4: Flexural Strength of concrete containing UCO

Based on the results, it is positively shows that the addition of UCO in OPC concrete can actually increase the flexural strength of concrete. But this increasing will come to a limit where further additions of UCO can actually split the flexural strength. Thus, the strength started to decrease. The UCO added in OPC concrete has increased the flexural strength which at the same time has improved the stiffness of the concrete. It can be conclude that UCO can possibly increase viscosity of concrete therefore produce a good matrix in concrete and increase concrete ductility.

D. *SEM Analysis Test*

From Fig. 4, it can be clearly seen that the flexural strength increase from 1.8MPa of 0% UCO to 2.01MPa of 1.5% UCO. The flexural strength is increased by 11.7%. Based on the graph, it shows that further addition of UCO had decreased the flexural strength from 2.01MPa of 1.5% UCO to 1.91MPa of 2.0% UCO. The flexural strength value had decreased by 5%. However, the flexural strength of 2.0% used cooking oil is still higher than control test (0% UCO). The flexural strength of 0% to 2.0% UCO is increased by 6%.

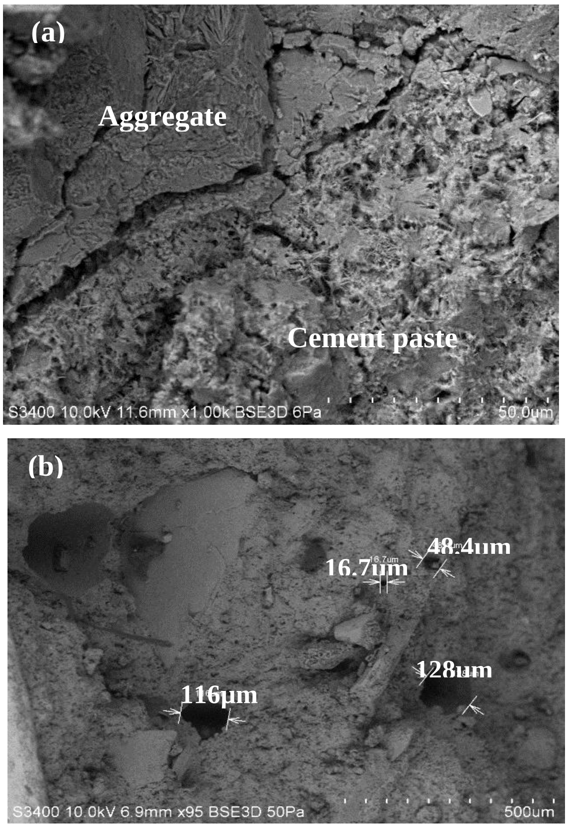

Figure 5: SEM Images of 0% UCO (a) Interfacial Transition Zone (b) Air Voids

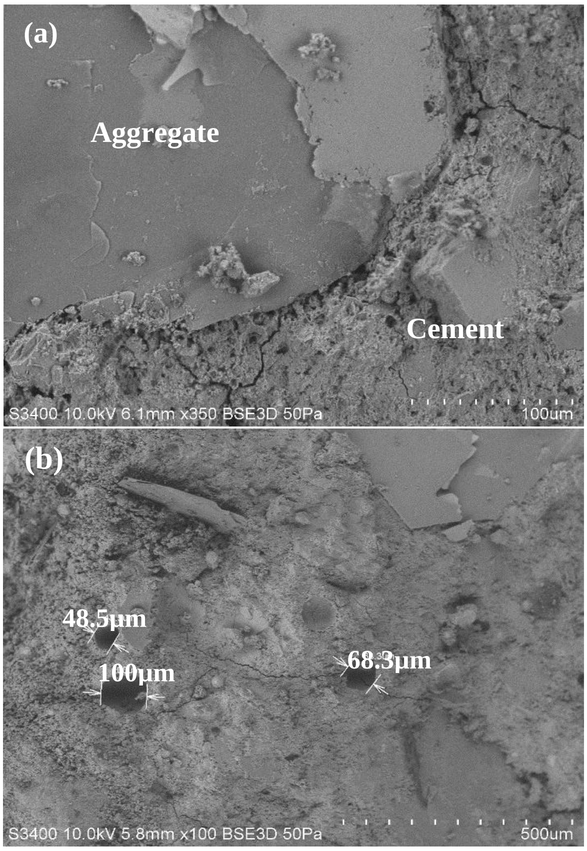

Figure 6: SEM Images of 1.5% UCO (a) Interfacial Transition Zone (b) Air Voids

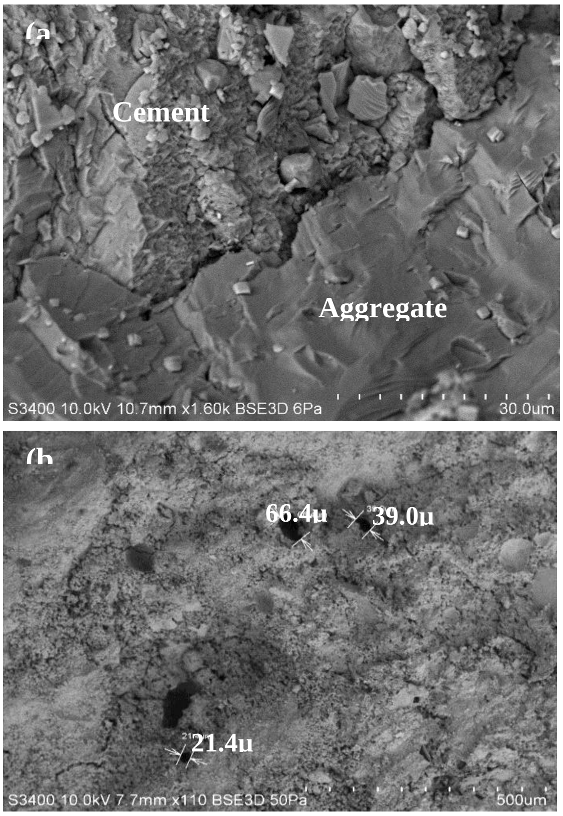

Figure 7: SEM Images of 2.0% UCO (a) Interfacial Transition Zone (b) Air Voids

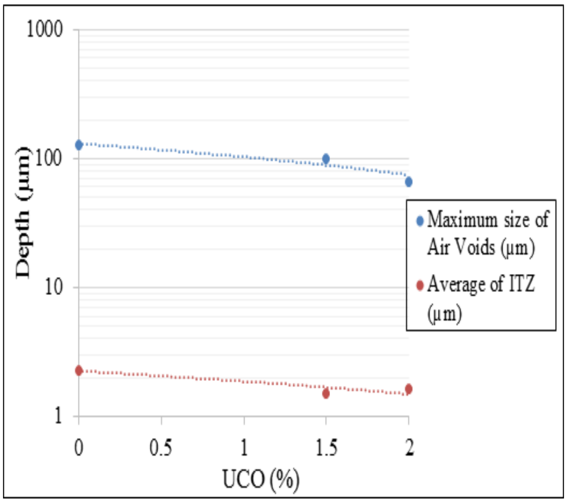

Figure 8: Relationship between ITZ and Air Voids Size with Inclusion of UCO

A statistical relationship of ITZ and air voids size with inclusion of UCO using linear function was obtained from Fig. 8 and the equation are given as below:

$$a = -28UCO + 130.8 \qquad (4)$$

Where;
$R^2 = 0.89$
a = maximum size of air voids (µm)
UCO = dosage of UCO (%)

$$i = -0.38UCO + 2.25 \quad (5)$$

Where;
$R^2 = 0.89$
i = average of ITZ (µm)
UCO = dosage of UCO (%)

The performance of concrete containing UCO summarized in Table 4. It can revealed that the properties of concrete conducted in this research is proportional to the inclusion of UCO. Thus UCO did not affect the properties of concrete.

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Table 4: Concrete Performance with UCO Addition

	Maximum size of Air Voids (µm)	Average of ITZ (µm)	Compressive strength at 28 days (MPa)	Flexural Strength at 28 days (MPa)
CM	128	2.3	26.1	1.8
1.5% UCO	100	1.5	30.5	2.01
2% UCO	66.4	1.63	26.9	1.91

IV. Conclusion

The important conclusions drawn from the present research are summarized as follows:

- UCO increases the concrete workability almost double compared to control mix, thus it can act as a water reducer or lubricant for concrete.
- The inclusion of UCO improve the concrete compressive strength. The highest compressive strength achieved with inclusion of 1.5% UCO. Inclusion of 2% UCO give lower compressive strength compared to 1.5% UCO but still comparable with control mix.
- UCO increases the flexural strength of concrete up to 11.7% compared to control mix.
- Based on the SEM analysis, the interfacial transition zone and the air voids reduced with incorporation of UCO.
- Based on the above points, it can be concluded that UCO improve concrete performance and all properties tested were proportional.

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