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Effects of used Engine Oil in Reinforced Concrete Beams: The Structural Behaviour

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***Abstract*—**In the modern construction practices, industrial wastes or by-products are largely used as raw materials in cement and concrete. These impart many benefits to the environment and bring-about an economic impact because the cost of waste disposal is constantly increasing due to strict environmental regulations. It was reported in literature that the leakage of oil onto concrete element in older cement grinding unit resulted in concrete with greater resistance to freezing and thawing. This effect was thought to be similar to adding an air-entraining chemical admixture to concrete. This paper presents an investigation on the load deflection behaviour and crack patterns of reinforced concrete (RC) beams subjected to four point loading. Ten 120x260x1900 mm beams were cast with 100% ordinary Portland cement (OPC) concrete, 20% fly ash (FA) and 20% rice husk ash (RHA) blended cement concrete. 0.15% dosage of admixtures (used engine oil, new engine oil, and superplasticizer) was used throughout the experiment. Results show that OPC and OPC/RHA RC beams containing used engine oil and superplasticizer exhibit higher capacity, 18-26% than their corresponding control mix.

***Keywords*—**by-products, RC beams, superplasticizer, used engine oil

I. Introduction

WASTES or better known as by-products obtained from the industrial, agricultural or any other process which has no economical demand and necessary to be disposed of properly. For the past decades, processed or unprocessed industrial wastes have been used as raw materials in cement manufacturing, components of concrete binder, aggregates or a portion of aggregate, or can be used as ingredients of manufactured aggregates [1].

A. By-products/Waste

Industrial wastes and by-products either solid or liquid based chemical are available in large quantities all over the world. Environmental agencies in most of the countries have laws and regulations regarding safe handling/disposal of the waste. However, huge amount of such waste are illegally disposed of, which may cause severe environmental problems. On the other hand, current trends in enhancing concrete properties are made by incorporating huge amount of wastes such as the use fly ash as partial cement replacement material.

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B. Used Engine Oil

Hazards related with used engine oil are resulted from various additives used in its manufacture and from heavy metal contaminants picked up from the internal combustion engine. Used engine oil poured into household drains or directly onto the ground, may leads into waterways and groundwaters. Illegally disposed of oil can pollute the groundwater with contaminants such as lead, magnesium, copper, zinc, chromium, arsenic, chlorides, cadmium and polychlorinated biphenyls. It is estimated that one quart of used engine oil can pollute 250,000 gallons of drinking water. Used engine 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 engine 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. Many countries in the world have imposed rules and regulations regarding the safe and legal disposal of used engine oil. However, the actual fact is that approximately 40% of the used engine oil is illegally disposed of, that eventually drops into the rivers and seas [2], [3]. It has been reported in the literature that the leakage of oil into the cement in older grinding units resulted in concrete with greater resistance to freezing and thawing. This means that adding used engine oil into fresh concrete mix could be similar to adding an air-entraining chemical admixture [1], [2].

C. Fly Ash

Fly ash is a by-product produced from burning of pulverized coal in thermal power plants. Its physical, chemical, and mineralogical properties are highly dependent on the type and source of coal, type of burning system, burning temperature, type of pollution control system used and so on. World utilization of coal for generating electricity in power stations is approximately 4800 million tons annually, which produces about 600 million tons of fly ash [4], [5]. Fly ash which has pozzolanic and cementitious characteristics in nature has made it a useful cement replacement material for producing high performance concrete. Its major component consists of SiO_2, $Al2O_3$, $Fe2O_3$, and CaO in which their relative percentages mainly depend on the type of coal burned at the power plant. Fly ash which obtained from burning of bituminous coals such as anthracite contains relatively low quantity of calcium oxide, CaO which known as low calcium fly ash. Burning of sub-bituminous coals like lignite results in ash with higher CaO content, better known as high calcium fly ash. ASTM classifies low calcium fly ash as Class F and the high calcium fly ash as Class C [4], [6]. Low-calcium fly ash with proper composition possesses pozzolanic properties, whereas high-calcium fly ash contains hydraulic properties. In the past decades, fly ash has been increasingly used as a major cement replacement material even though more than 80% is disposed of as waste material [4], [7]. At present, approximately 28% of electricity in Malaysia is generated by pulverized coal burning. It consumes about 8 million tons of coal annually and about 65% is generated by natural gas. To reduce the dependency on natural gas as a main fuel for electricity generation, in year 2004 the Malaysia government decided that by year 2010, the share of coal in the fuel mix for electricity generation would increase to about 40%. This increased in usage of coal burning in thermal power plants will indirectly increase the production of fly ash to an estimated 2.5 to 3 million tons per year.

D.Rice Husk Ash

Approximately 100 million tons/year of rice husks are available for disposal worldwide. This agricultural waste can be used as a combustion source for electrical power plants, from which rice husk ash (RHA) is obtained. The production rate of RHA is about 20% of the dried rice husks whereas the combustion of the rice husks produces approximately 20% high silica ash. This shows that there is a potential for producing 20 million tons of rice husk ash every year. The burning temperature of a rice husk ash combustion furnace must be controlled to keep silica in an amorphous state as crystalline silica is hazardous to human health. The burning process should be controlled to remove the cellulose and lignin portion while preserving the original cellular structure of rice husks. A very high pozzolanic activity can be achieved due to the microporosity and the high surface area of the product or even the material has not been ground to fine particle such as silica fume. In terms of engineering properties, there is substantial reduction in the permeability when non-crystalline rice husk ash was used as a mineral admixture in concrete [8], [9].

II. RESEARCH SIGNIFICANCE

This paper provides the results of an experimental program to investigate the behaviour of reinforced concrete beams containing used engine oil as chemical admixtures in ordinary Portland cement and cement replacement material under four point bending. Results of this experimental program may be useful to determine whether the durability properties of concrete could be enhanced by adding used engine oil as chemical admixture and at the same time as a method to dispose the oil waste.

III. EXPERIMENTAL PROGRAM

In the experimental program of this research, tests were conducted on RC beams under four point loading. The beams were tested to investigate their load deflection behaviour and cracking patterns.

A. Material Properties

The cementitious materials used in this study were typical ordinary Portland cement Type I which conformed to the requirements of BS 12 [10], fly ash (FA) and rice husk ash (RHA). Gravel as course aggregate used is 14 mm nominal maximum gravel. Sand as fine aggregate used is natural sand having a 3.35 mm nominal maximum size. Both aggregates conforming to BS 882: 1992 [11]. In this experimental program, 0.15% dosage of used engine oil, new engine oil and superplasticizer (naphthalene formaldehyde sulphonate) were used. Used engine oil was collected from a workshop at Tronoh, Perak. The ingredients which consist of cement, sand and gravel are proportioned by weight ratio of 1:2.33:3.5. The water/cement used was 0.55 (by weight) throughout the experimental studies. Water and admixture are measured in percentage by weight proportion of cement used. TABLE I lists the chemical composition of OPC, fly ash and rice husk ash. The chemical composition of used and new engine oil is shown in Table II.

TABLE I
CHEMICAL COMPOSITION ON OPC, FLY ASH AND RICE HUSK ASH

Chemical Composition	OPC (%)	FA (%)	RHA (%)
SiO_2	21.98	51.19	86.1
Al_2O_3	4.65	24.00	0.17
Fe_2O_3	2.27	6.60	2.87
CaO	61.55	5.57	1.03
MgO	4.27	2.40	0.84
SO_3	2.19	0.88	0.41
K_2O	1.04	1.14	4.65
Na_2O	0.11	2.12	-

TABLE II
CHEMICAL COMPOSITION OF USED ENGINE OIL AND NEW ENGINE OIL

Chemical Composition	Used engine oil (%)	New engine oil (%)
SiO_2	-	0.85
Fe_2O_3	0.43	0.18
CaO	15.9	21.0
SO_3	37.0	36.3
P_2O_5	8.95	13.4
ZnO	17.7	25.6
Cl^-	15.9	-

B. Material Preparation

Mixing of concrete ingredients was performed in the laboratory of Civil Engineering Department, Universiti Teknologi PETRONAS using a 100 liter capacity concrete mixer. The dry ingredients which include cement, sand and gravel was first mixed for 1 minute in the mixture prior to water addition. Admixtures such as used engine oil, new engine oil and superplasticizer are 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 1 minute in order to achieve homogeneous concrete. On the other hand, plywood formworks were fabricated and RC beams were cast with the dimension of 120 x 260 x 1900 mm. After 24 hours, the beams were removed from the formworks and cured at room temperature with wet gunny bags until a period of 28 days.

C. Test Setup

Tests were carried out on ten beam specimens. The beams with 120 mm x 260 mm cross section and 1800 mm clear span were simply supported and loaded in a four point arrangement with a constant moment region of 600 mm. The reinforcement of the beams is shown in Fig. 1. Steel stirrups of 6 mm diameter were used at 150 mm spacing along the beam length for all beams. The top and bottom steel reinforcements were 12 mm diameter size. The test setup is shown in Fig. 2.

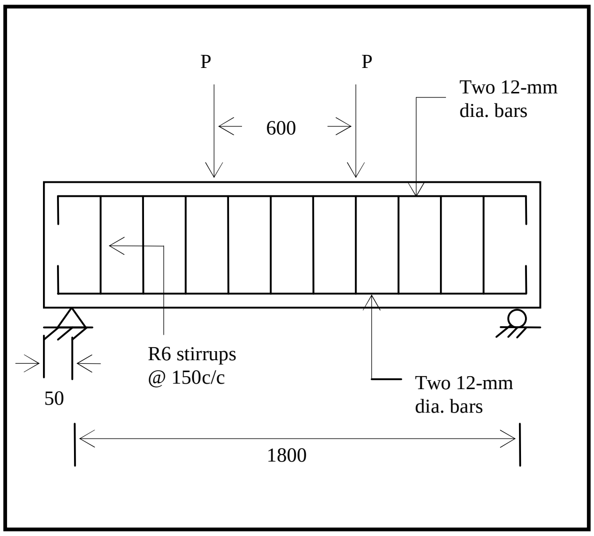

Fig. 1 Details of test specimen (unit in mm)

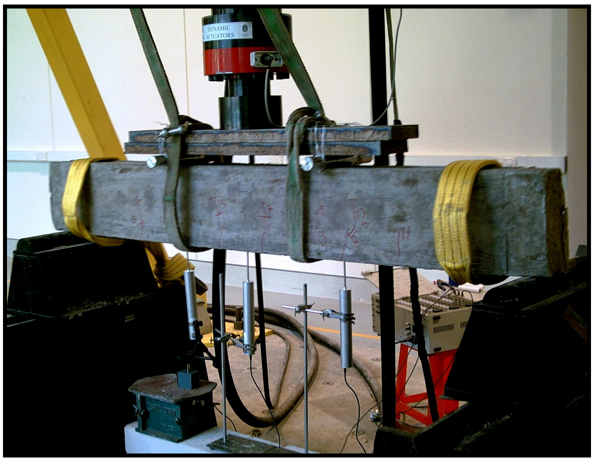

Fig. 2 Test setup

The four point flexural test of RC beams was performed on a Universal Testing Machine (UTM) with a maximum load capacity of 1000 kN under the displacement control mode. All beams were tested to failure in four point bending with an effective span of 1800 mm. The corresponding beam deflection was monitored by means of a linear variable displacement transducer (LVDT) mounted at the bottom soffit of the beam at the midspan. The development and propagation of cracks were marked and the ultimate load of the beams was recorded.

IV. Results and Discussion

A. Crack Patterns

Crack patterns of 100% OPC control beam, CM and 100% OPC contained 0.15% used and new engine oil and superplasticizer, OPC/UEO, OPC/NEO and OPC/SP are shown in Fig. 3 - 6 respectively. The numbers beside the cracks indicate the order of cracks appeared with the increment of load. It was observed that the first flexural crack was appeared in the constant moment region. As the load increased, cracks formed on the tension side along the entire beam length. Cracks were seen initiated from the point load towards the support which caused the peeling of concrete to occur. Just before failure, it was observed that tensile cracks close to the supports, propagated diagonally towards the location of load P and transformed into a diagonal shear crack. The failure was sudden and brittle. The cracking and failure patterns of CM, OPC/UEO and OPC/NEO beams were similar. However, the cracks inside the constant moment region were wider than outside due to the higher steel stresses of OPC/SP beam. After yielding and drop in the load capacity, the cracks increased in width until the test completed.

As for crack patterns of 20% fly ash blended cement concrete beams, it was observed that cracks formed along the entire length of the constant moment region as the load increased. Likewise in OPC concrete beams, before failure, the tensile cracks nearby to the support propagated diagonally towards the location of load P and transformed into a diagonal shear crack. It was observed that the failure was abrupt and brittle. The cracking and failure patterns of all fly ash concrete beams were observed the same. The crack patterns of fly ash concrete beams are depicted in Fig. 7- 8.

Meanwhile, crack patterns of 20% rice husk ash blended cement concrete beams were recorded. The results obtained were similar to the other two groups of the beams. When the load increased, crack patterns were formed along the entire length of the constant moment region of the beam. The beams exhibited patterns of tensile crack close to the support. These cracks then propagated diagonally towards the location of load P which eventually turned into diagonal shear cracks before failure occurred. The failure observed was sudden and brittle. The cracking and failure patterns of all the beams were identical. Fig. 9-10 show the crack patterns of rice husk ash concrete beams.

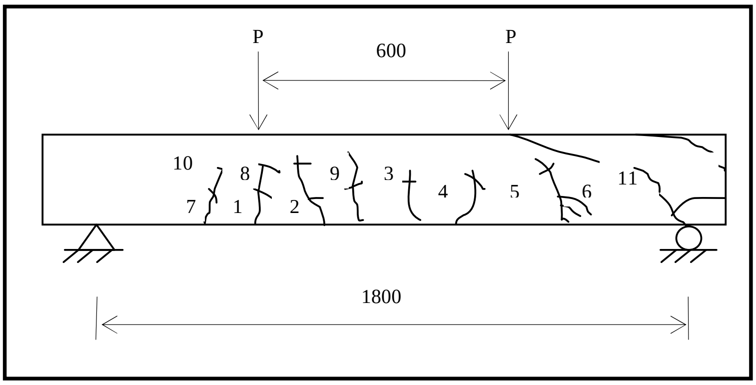

Fig. 3 Crack patterns of RC beam OPC control mix, CM

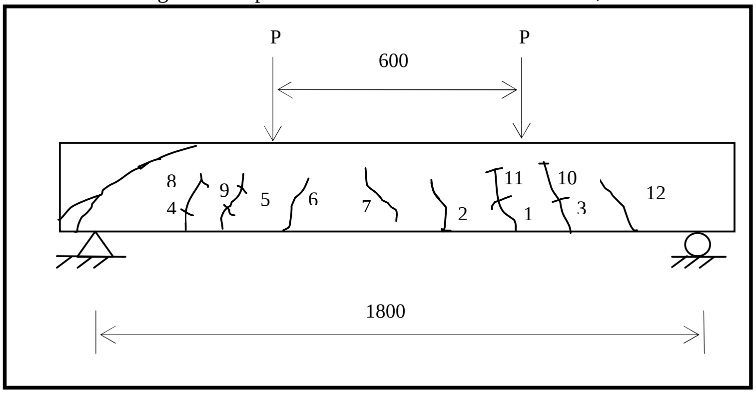

Fig. 4 Crack patterns of RC beam OPC contain 0.15% used engine oil, OPC/UEO

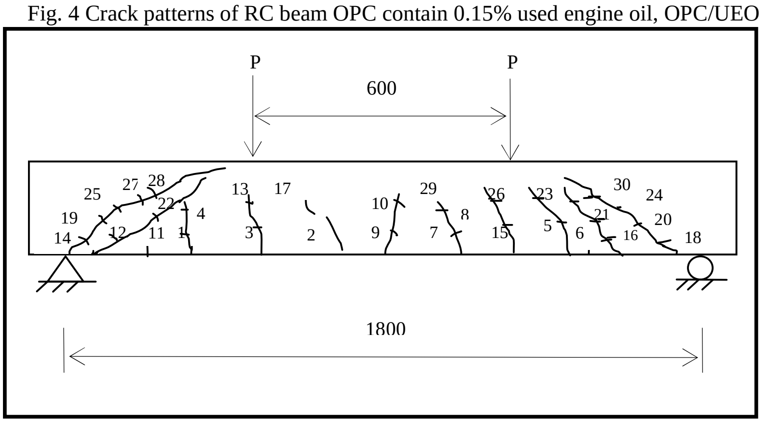

Fig. 5 Crack patterns of RC beam OPC contain 0.15% new engine oil, OPC/NEO

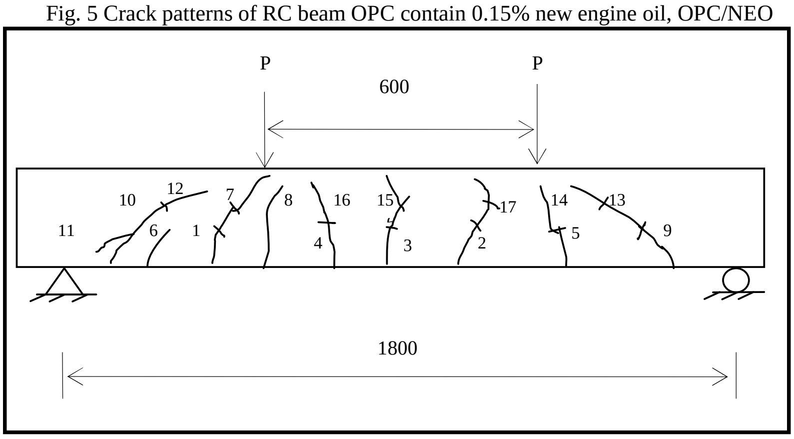

Fig. 6 Crack patterns of RC beam OPC contain 0.15% superplasticizer, OPC/SP

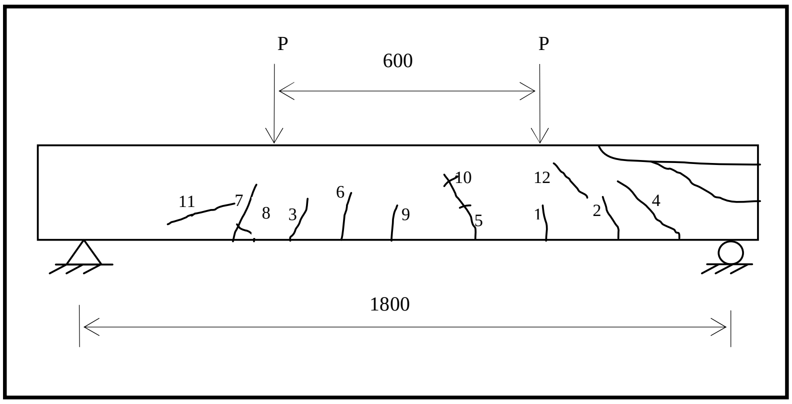

Fig. 7 Crack patterns of RC beam 20% fly ash contain 0.15% used engine oil, 20FA/UEO

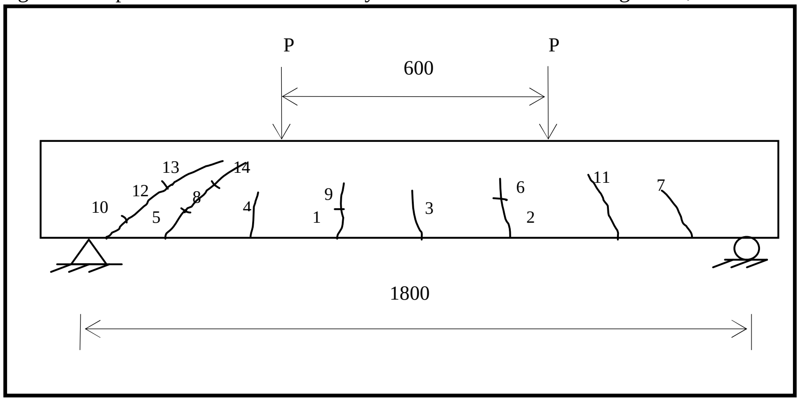

Fig. 8 Crack patterns of RC beam 20% fly ash contain 0.15% superplasticizer, 20FA/SP

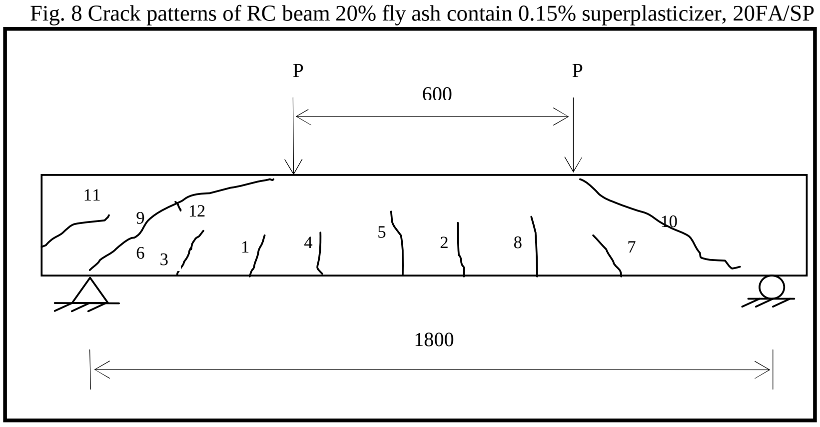

Fig. 9 Crack patterns of RC beam 20% rice husk ash contain 0.15% used engine oil, 20RHA/UEO

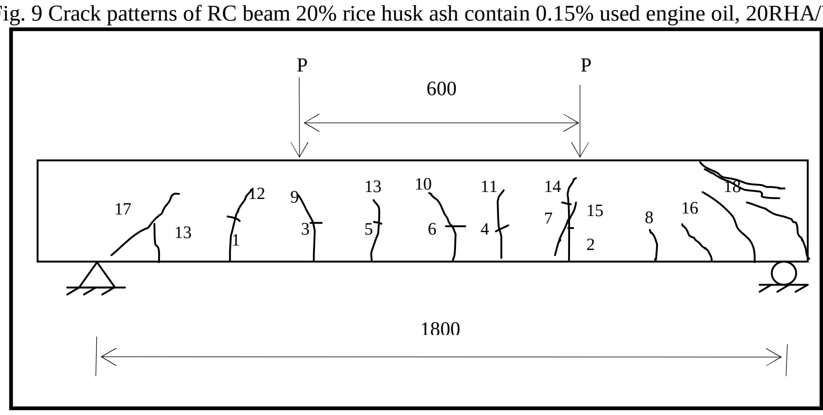

Fig. 10 Crack patterns of RC beam 20% rice husk ash contain 0.15% superplasticizer, 20RHA/SP

B. Load Deflection Curves and Ultimate Load

The load deflection curves of all OPC concrete mixes are illustrated in Fig. 11. It was observed that the ultimate load capacity of control beam, CM was obtained as 71.2 kN with a deflection of 10 mm. Superplasticizer in OPC concrete beam, OPC/SP showed the highest ultimate load capacity, 103.8 kN with a deflection of 13.5 mm whereas used engine oil in OPC concrete beam, OPC/UEO was obtained as 94.8 kN with a deflection of 31.6 mm. Both the beams showed 45% and 33% higher in ultimate capacity compared to the control beam, CM. The ultimate loads and deflections at midspan are listed in TABLE III.

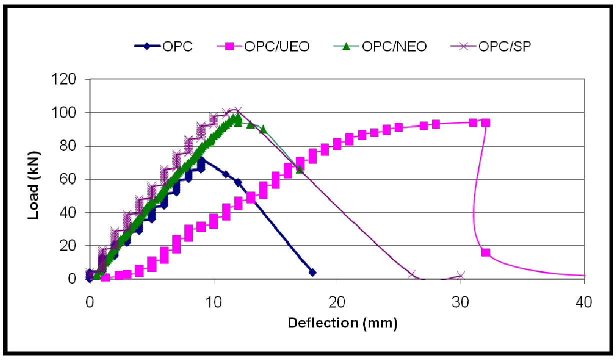

Fig. 11 Load deflection curves of 100% OPC concrete beams

On the other hand, load deflection curves of fly ash concrete mixes are shown in Fig. 12. It indicates that the ultimate capacity of concrete mixes 20FA/UEO and 20FA/SP were obtained as 83.2 kN and 68.6 kN respectively. The ultimate load capacity of 20FA/UEO and 20FA/SP beams was about 13 and 27% lower than the ultimate capacity of the control mix 20FA, which was obtained as 95.2 kN. The deflection of the three beams 20FA, 20FA/UEO and 20FA/SP was obtained as 15.5 mm, 10.6 mm and 9.5 mm respectively. The results are listed in TABLE III. This signifies that there is very little variation in the flexural stiffness of the three beams.

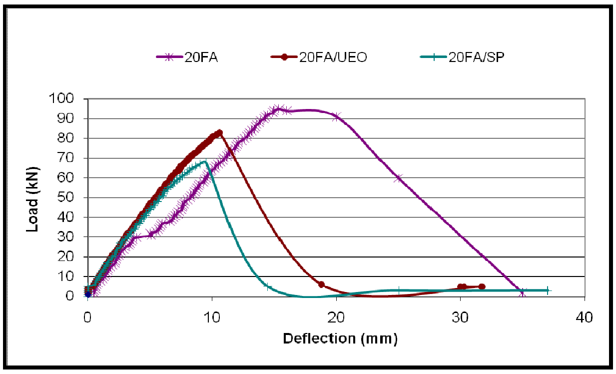

Fig. 12 Load deflection curves of 20% fly ash concrete beams

The load deflection curves of 20% RHA concrete beams which consists of 20RHA, 20RHA/UEO and 20RHA/SP are plotted in Fig. 13. It was observed that the concrete beams made of the mix 20RHA/SP and 20RHA/UEO have shown 24% and 21% higher ultimate load capacity compared to the ultimate capacity of 20RHA beam which was obtained as 72.1 kN. The maximum deflection of the beams made of 20RHA, 20RHA/UEO and 20RHA/SP was obtained as 14.2 mm, 15.1 mm and 16.7 mm respectively. The following results are listed in TABLE III. It is noted that RC beams made of used engine oil and superplasticizer have shown higher flexural stiffness than the control mix, 20RHA.

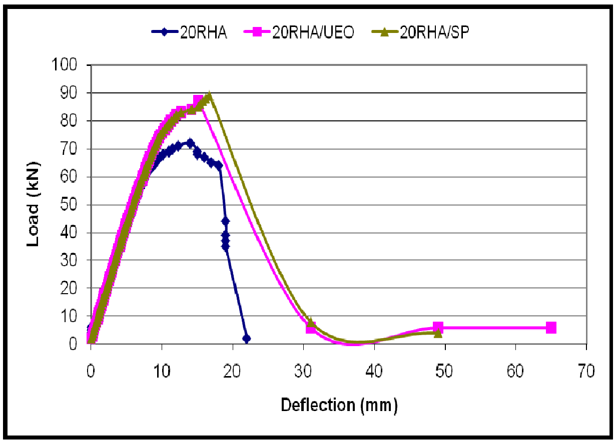

Fig. 13 Load deflection curves of 20% rice husk ash concrete beams

TABLE III
ULTIMATE LOAD OF OPC, FLY ASH AND RICE HUSK ASH CONCRETE MIXES

No.	Beam Notation	Percentage of Used Engine Oil , %	Measured Ultimate Load, kN	Deflection at Midspan, mm
1	CM	0	71.2	10.0
2	OPC/UEO	0.15%	94.8	31.6
3	OPC/NEO	0.15%	98.3	12.0
4	OPC/SP	0.15%	103.8	13.5
5	20FA	0	95.2	15.5
6	20FA/UEO	0.15%	83.2	10.6
7	20FA/SP	0.15%	68.6	9.5
8	20RHA	0	72.1	14.2
9	20RHA/UEO	0.15%	87.3	15.1
10	20RHA/SP	0.15%	89.3	16.7

C. Analysis of Results

In general, it is found that RC beams of 100% OPC, OPC/FA and OPC/RHA concrete failed in shear. This may due to overall concrete in the beams contributed mostly in shear. In group of OPC RC beams, used engine oil has shown almost similar ultimate load compared to the performance of new engine oil, with a difference of 4%. Used engine oil in OPC RC beam has demonstrated higher ultimate load, 25% compared to OPC control beam. Meanwhile, superplasticizer in OPC RC beam has shown the highest ultimate load, 103.8 kN about 9% more than the ultimate load of RC beam contained used engine oil and 31% compared to OPC control beam, CM. Although the performance of used engine oil in OPC RC beam is lower than superplasticizer, however, it exhibited higher ultimate load compared to CM and no harmful effects were traced in the reinforcement of the RC beams. The results of RC beams behaviour obtained supported the investigation available in literature [12].

As in OPC/FA RC concrete beams, 20% fly ash control beam, 20FA appeared to be the highest measured ultimate load, 95.2 kN compared to the ultimate load of both OPC/FA contained used engine oil and superplasticizer, with a difference of 13% and 28% respectively. This may due to the effects of concrete in the beams. LIkewise, in OPC RC beams, OPC/RHA control beam achieved an ultimate load of 72.1 kN, exhibited 18% less than OPC/RHA RC beam contained used engine oil and superplasticizer. The performance of used engine oil and superplasticizer in OPC/RHA beams were almost similar, with a difference of 2% in ultimate load.

New engine oil was not tested in OPC/FA and OPC/RHA RC beams as it is assumed to give almost similar or higher in load compared to used engine oil. It can be observed in OPC RC beam contained new engine oil and used engine oil; in which new engine oil exhibited 4% higher than the ultimate load of used engine oil. In general, for all categories of RC beams, the performance of used engine oil is comparable to the performance of superplasticizer, within a range of 2- 18%.

V. Conclusion and Recommendations

Based on the above results and discussion, the following conclusions are made.

1) The effect of used engine oil on the cracking pattern of RC beams in 100% OPC, OPC/FA and OPC/RHA were observed similar and the failure mode was in shear. The ultimate load achieved by all beams varied between 69 to 104 kN.
2) OPC and OPC/RHA concrete beams that contained used engine oil, new engine oil and superplasticizer showed higher capacity, 18-26% than their corresponding control mix. Fly ash concrete beams with admixtures showed a lower capacity than their corresponding control mix.
3) Reinforced concrete beams behaviour investigated in this study were in line with those investigated by other researchers and reported in the literature. Based on the experimental program of this study, used engine oil has potential to be used as superplasticizer without losing engineering and structural behaviour of concrete.
4) It is recommended that the researches in this area to be continued in order to investigate a number of different parameters which were not explore in this study, such as the effects of used engine oil on high strength concrete, effects on corrosion, fatigue and elastic properties.

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