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Effects of used engine oil on slump, compressive strength and oxygen permeability of normal and blended cement concrete

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HIGHLIGHTS

- Finding the effects of used engine oil on fly ash and rice husk blended cement concrete.
- Effects of used engine oil on concrete durability.
- Investigation of oxygen permeability of concrete.

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ABSTRACT

Used engine oil (UEO) is recognized as a hazardous waste produced during engine servicing. Its disposal in an environmentally friendly manner is a big challenge. This paper presents the experimental results of an investigation of the effects of UEO on slump and hardened concrete properties. Three concrete groups; 100% cement (OPC) concrete, concrete with 60% OPC + 40% fly ash and concrete with 80% OPC + 20% rice husk ash were prepared. Each of the groups composed of a control mix and a mix with 0.15% dosage of UEO (this dosage was selected from previous studies). Slump measurement of fresh concrete confirmed that a small dosage of UEO reasonably improves the slump of concrete. Lignosulfonate molecule (a common class of water reducing admixture) consists of aromatic rings containing one of the ionic groups viz., OH^-, COO^-, SO_3^{2-}. The chemical composition of used engine oil showed the presence of 37% SO_3 content that may be the reason for the plasticizing effect. Used engine oil caused variation in the compressive strength in the range of ±20% as compared to the control mix. The compressive strength at 28, 56, and 180 days of 100% OPC concrete with UEO reduced by about 17%. In general, a small dosage of used engine oil caused a substantial reduction in coefficient of oxygen permeability and porosity of all concrete mixes, which is an indicator of enhanced long-term durability.

1. Introduction

For the last few decades, some of the industrial wastes and by-products have been widely used as concrete constituent materials that substantially improved its properties. Commonly used wastes and industrial by-products in concrete contain a high amount of amorphous silica. These materials are used for partial replacement of cement in concrete to enhance its mechanical properties and durability. Fly ash and silica fume are now widely accepted by the global construction industry for producing high-performance concrete and are recognized as green products. For example, until the mid-twentieth century, fly ash (waste ash generated from burning of coal in thermal power stations) was considered a waste material and an environmental burden [21]. Fly ash generated in power plants is now almost entirely utilized as cement replacement material in producing a significant amount of concrete [17]. Apart from industrial by-products, a considerable amount of wastes generated during processing of many agricultural products such as rice husk and sugarcane bagasse are also explored as cement replacement materials. Concrete containing rice husk ash or sugarcane bagasse ash (when produced under controlled burning and grinding) showed better properties in both the short and long terms [23] and [16].

Used engine oil (UEO) is usually classified as a hazardous liquid waste, which is collected during servicing of an automotive engine. Every year, a substantial amount of UEO is produced worldwide. It usually includes various contaminants such as lead, copper,

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magnesium, zinc, chromium, chlorides, arsenic, cadmium and polychlorinated biphenyl, which pose severe concerns for its safe disposal [1,2]. Therefore, it is necessary to dispose-off used engine oil in a safe manner that complies with the relevant environmental regulations or according to recommended practices. Hamad et al. [12] reported that about 55% used engine oil is illegally disposed of worldwide every year. It is ultimately discharged into rivers and seas and hence, is one of the major causes of marine pollution [1,22]. Hamad et al. [12] reported an observation that a few drops of engine oil leaked from a motor into fresh concrete increased its slump and air content. This effect of leaked oil on fresh concrete prompted researchers to investigate further the potential of UEO as an admixture in concrete. Hamad et al. [12], among the earlier researchers, conducted an experimental study to investigate the effects of used engine oil on the air content in fresh concrete and on the compressive strength of hardened concrete. They added UEO dosages of 0.075%, 0.15%, and 0.3% in concrete and observed up to 80% increase in the slump of concrete compared to that of the control mix. The study confirmed the hypothesis that was formed by observing the effects of the leaked motor oil on fresh concrete. In an experimental study, Assaad [3] used 0.2%–0.9% dosages of UEO in concrete, and found 0.2% dosage as the optimum, whereas, more than 0.5% dosage caused adverse effects on the slump. He compared the results of the slump of concrete with optimum UEO dosage with the slump of concrete containing commercially produced water reducing admixture, and found similar slump values for the two. Investigation of the chemical composition of UEO is useful to understand its effects on fresh concrete compared to commercially produced water reducing admixtures. Lignosulfonates group is a commonly used class of water reducing admixture in concrete. The lignosulfonate molecule consists of aromatic rings containing functional groups in 3 positions, with alkoxy groups (OCH_3), ether groups (–O–) or polar upload substitutes or ionic groups (OH^-, COO^-, SO_3^{2-}). Lignosulfonate is a polymer with hydrophobic and ionizable groups [9]. Existing studies on investigation of the effects of UEO are limited to 100% OPC concrete. Whereas, in current practices, cement replacement materials (fly ash, silica fume, and ground granulated slag) are commonly used in concrete mix design. The addition of cement replacement material significantly enhances the compressive strength and long-term performance of concrete. Previous research studies by Hamad et al. [12] and Assaad [3] focused on investigating the effects of UEO on fresh and hardened concrete properties were limited to 100% cement concrete. The studies concluded that lower dosage of UEO such as 0.15%–0.3% showed better effects on the properties of concrete.

Therefore, the primary objective of this experimental study was to investigate the effects of 0.15% dosage of UEO on the properties of fresh and hardened concrete containing 100% cement and blended cement using fly ash and rice husk ash. The cement types comprised of 100% OPC, 60% OPC with 40% fly ash, and 80% OPC with 20% rice husk ash. Slump test was adopted as the fresh-concrete test, whereas, hardened concrete properties were measured by performing the compressive strength, total porosity and coefficient of oxygen permeability tests.

2. Research significance

Favorable effects of UEO on the properties of fresh and hardened concrete have been recognized in many research studies. However, all such studies were limited to assessing the effects of UEO on the slump and mechanical properties of 100% cement concrete. In modern concrete production, partial substitution of cement using industrial by-products such as fly ash, silica fume, and ground granulated blast furnace slag is becoming popular. Similarly, prediction of concrete durability for achieving long-term performance is being specified in the concrete mix design. The significance of this experimental research is that the scope of research included the investigation of the effects of used engine oil on the slump, compressive strength and durability of blended cement (fly ash and rice husk ash) concrete. Fly ash is commercially used in concrete mixing; many cement factories are producing composite cement using 20% or more fly ash content. The coefficient of permeability (water or oxygen) is usually specified as the indicator of the potential durability of concrete.

3. Material properties and research methodology

YTL cement Malaysia supplied ordinary Portland cement type CEM-1 conforming to BS EN 197-1 [8] for this study. Coarse aggregate of maximum gravel size 14 mm was used as acquired from a gravel processing plant located in Ipoh, Perak, Malaysia. Natural sand, for use as fine aggregate, was obtained from a sand pit near Kampar, Perak, Malaysia. The supplied coarse and fine aggregates conformed to the Eurocode specifications, BS EN 12620 [7].

Fly ash and rice husk ash were used as the cement replacement materials in this research study. ASTM Class-F fly ash was supplied by Manjung power station, Perak Malaysia. Whereas rice husk ash (RHA), was produced in the concrete technology laboratory, Universiti Teknologi PETRONAS (UTP). Rice husk was burnt in a high-temperature microwave incinerator at 800 °C for 3 h. Upon cooling, the burnt ash was ground in a Los Angeles (LA) ball mill to achieve the desired specification.

UEO for the study was collected from a single batch of oil produced in one of the service stations in Ipoh, Perak, Malaysia. As part of the funded research (the grant was secured from the ministry of science and technology, Malaysia) conducted during 2007–2012, various samples of engine oil (synthetic and semi-synthetic) were collected from 40 multiple locations from all over West Malaysia. All samples showed different effects on the properties of concrete. Synthetic based used engine oil samples showed a better impact on the slump of concrete. Therefore, in this research study, synthetic based used engine oil sample was collected from a car service station in Ipoh, Perak Malaysia. The sample was sent to SIRIM Bhd (Leading body for certification, testing, and inspection), Malaysia for chemical analysis and the results are shown in Table 1.

In the experimental investigations; three groups of concrete mixes (100% OPC, 60% OPC + 40% fly ash and 80% OPC + 20% rice husk ash) were prepared. Selection of 40% fly ash content and 20% RHA content as partial replacement of cement was made based on the results of an earlier research [19]. Two sets of concrete mixes; one without UEO and the other with a dosage of 0.15%

Table 1
Chemical compositions and physical properties of OPC, fly ash, rice husk ash and used engine oil.

Chemical Composition	Ordinary Portland Cement (%)	Fly ash (%)	Rice husk ash (%)	Used engine oil (%)
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	0.43
CaO	61.55	5.57	1.03	15.9
MgO	4.27	2.40	0.84	–
SO_3	2.19	0.88	0.41	37.0
K_2O	1.04	1.14	4.65	–
Na_2O	0.11	2.12	–	–
P_2O_5	–	–	–	8.95
ZnO	–	–	–	17.7
Cl^-	–	–	–	15.9
Others	1.94*		–	4.12
LOI		6.1	3.93	–

* Note: In cement others were equivalent alkalis and free lime.