

# **Experimental Evaluation of Black Olive oil as Water Repellent Admixture in Concrete**

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**ABSTRACT:** The effect of Black Olive Oil (BLO) on the properties of concrete was investigated in five different proportions of 0%, 0.3%, 0.5%, 0.7% and 1.0% by weight of cement binder. Addition of BLO showed to have different effect on the properties of the fresh and harden cement paste depending on the amount of BLO added. Transport properties measured in terms of water absorption, sorptivity and coefficient of water permeability were improved greatly with the addition of BLO in the concrete, however; the mechanical properties were slightly compromised. The Oil addition into cement matrix was found to be significantly decreasing the amount of pores which are easily accessible to water. This was affirmed by the clear lower total porosity value of BLO/OPC concrete mixes compared to the plain OPC conventional mixes. The observed performance of BLO addition in improving the permeability properties of concrete mixes investigated indicates that the durability of concrete may be improved; as a consequence of reduced water absorption induced, the rate of detrimental reactions needing liquid as a reaction medium is reduced. Also, the ingress of water born aggressive such as chlorides will be minimized and corrosion rates may be reduced.

**KEYWORDS:** Concrete, Black olive oil (BLO), Durability, Compressive strength, Permeability.

## **I. INTRODUCTION**

The wide spread use of concrete in construction makes it increasingly important to understand its behavior and to improve its performance. At the present context, durability and sustainability are key areas for development. The construction industry has advanced so much that today attention is being shifted to the production and use of materials that are greener and ecologically friendly. Sustainability of concrete includes not only using either “green” or recycled products, but also improving construction durability to maximize useful service life. Therefore Durability is a subject of increasing importance for concrete design, where longer life cycles of concrete are demanded for more sustainable development.

It is well- known that the lack of adequate durability of current concrete infrastructures is responsible for the poor condition of roads and concrete structures around the world and is causing maintenance problems. It is reported that in developed countries, over 40% of the total resources of the building industry are applied to repair and maintenance of existing structures[1]. Apart from the socio-economic implications of durability, there is also a clear link between durability and the environment, such that, by extending the life cycle of construction materials, we conserve valuable natural resources [2].

The introduction of high strength concrete was thought to solve the dilemma of poor durability in concrete. But high strength concretes in comparison to normal strength concretes exhibits greater cracking tendencies because of increased thermal and drying shrinkage [3,4]. These cracks results in ingress of corrosives down to the reinforcing steel bars and eventually spalling off of the concrete cover. It is argued that based on strength, it is rare for concrete structure to fail

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due to lack of intrinsic strength; Concrete has been specified principally on the basis of its characteristics compressive strength at 28 days, and reinforced concrete structures are usually designed with a sufficiently high factor of safety. However, gradual deterioration caused by lack of durability reduces the safety margin of concrete structure that serious concerns have been raised. Hence, there is an affirmation that the most severe durability problems associated with mortar and concrete always involves the penetration of water with corrosives agents into the concrete. This claim is supported by Justnes [5], who reported that durability issues for mortar and concrete are associated with the access of external water since all detrimental chemical reactions need water as a reaction medium. Durability of concrete is therefore related to the ease of ingress of water and chemicals.

Hence, to maximize the performance of concrete structure, they need to be constructed such that they will be relatively impermeable to moisture. This study therefore is embarked on with the aim to improve the permeability aspect of concrete durability.

## II. RELATED WORK

Numerous literatures made mention of vegetable oils and fats as water repellent material but very few experimental researches have been carried out to evaluate the effect of these vegetable oil and fats addition on concrete/mortar. Vegetable oils and fats are more commonly used as water-repellent admixtures as a protective coat applied on a hardened concrete/mortar. But Mortar Industry Association [6] stated that water repellents applied to the surface of a render/mortar may have a limited life as these types of materials only reduce ingress of water, not making the mortar impermeable. Moreso, UV light can oxidize the fatty acids, thus reducing the waterproofing ability near the surface[9]. Therefore, for a water repellent material to be effective, it is necessary that it should be in a form that it can be readily and uniformly distributed throughout the mix; it should be permanent in the hardened mass [7].

The fundamental criteria for selection of any vegetable oil as a water repellent admixture is based on its mono-unsaturated fatty acid content; as a high mono unsaturated fatty acid vegetable oil performs better in a cementitious matrix [19]. Unsaturated fatty acids have at least one double bond (=) between carbon atoms, they are more reactive with lower melting temperatures and they tend to be liquid at room temperatures[10,11]. And Black olive oil has been confirmed to possess a high mono unsaturated fatty acid closely relative to that of olives[12,13]. It is in this regard that black olive oil is selected as the choice material in the research.

A research conducted on seven (7) different vegetable oils from sunflower, olives, soya beans, peanuts, linseeds, corn and rapeseeds as admixtures in mortar ascertain that vegetable oils with high content of monounsaturated fatty acids like olive, peanut and rapeseed is more effective. The 4 day water absorption was reduced by more than 1/3 by 1% of the rapeseed oil, the water vapor coefficient in the interior was not reduced more than to the level of the cement paste skin of the reference mortar [5]. The influence of these same seven vegetable oils on long term water repellency and other durability aspects of mortar lasted for more than three years at moist conditions[18]. The water suction was found to be dependent on the oil concentration. The strongest effect was observed between the reference and the 0.5% oil concentration. Further increase of oil concentration resulted in further reduction in the water uptake, but the effect was not as strong. The reference mix was reported to exhibit no significant reduction in strength both at 1-day nor 28-days. However, the 3-year compressive strength was reduced by approximately 30% compared to the reference sample, but increase in strength was observed from 28 days. The research also indicated that 0.5% oil addition was sufficient in reducing chloride penetration. And that the addition of oils reduced in a substantial increase of carbonation depth compared to the reference mix samples [18].

Soy bean oil was also used as an admixture with the aim of improving the durability of concrete pavements. The test result indicated that the soybean oil emulsion provided moisture retention when surface applied or integrally mixed. Soy bean oil substantially reduced moisture loss from fresh concrete and provides greatly improved deicer scaling resistance to the concrete. A reduction in shrinkage was also reported with the addition of soy bean oil as concrete admixture compared with the control samples. However, a decrease in the compressive strength was observed [17].

On the other hand, an experiment on the influence of processed (waste) sunflower oil on the properties of cement; compressive strength, water demand, and moisture absorption established 0.2% by weight of cement of the processed sunflower oil to be the optimal content of the admixture. At 0.2% optimal content of the oil, 10% reduction in water

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demand of the mortar was deduced, increase in flowability was also observed, and 23% increase in grade strength was reported. The admixture gave the cement hydrophobic properties and caused moisture absorption to decrease by 34% (at optimal content of 0.2% of the oil). The admixture was observed to be a multi functional plasticising-waterproof admixture. [8].

Furthermore, the effect of linseed oil on the properties of lime-based restoration mortars was investigated at concentrations of 1% and 3% by weight of binder. The addition of 1% linseed oil was reported to have a positive effect on mechanical characteristics, and water absorption into the mortar was limited without significantly affecting the total open porosity or decreasing the degree of carbonation. On the other hand, 3% addition of linseed oil practically made the mortar to be almost hydrophobic by reducing the value of capillary coefficient by approximately 90%. But a dramatic decrease in mortar strength was observed compared to the unmodified mortars. However, all the tested lime-based mortars with the oil addition showed a significant decreased water and salt solution absorption by capillary rise. The proportions of pores which are easily accessible to water were reduced. Based on the result obtained, 1% addition of linseed oil was recommended for use in mortar meant for repair or replacement of historic mortars. The result also affirmed that oil addition delays setting [11].

### III. EXPERIMENTAL PROGRAM

The experimental program was conducted to investigate the mechanical and permeability-related characteristics of OPC concrete made with different dosages of black olive oil. The mechanical property was examined as a function of compressive and flexural strength of concrete. While the permeability characteristics of the concrete were assessed by studying the total porosity, water absorption, sorptivity and coefficient of water absorption (permeability) through capillarity. The effect of the oil addition was studied with different percentage proportions of 0, 0.3, 0.5, 0.7, and 1.0 by weight of cement binder. The data collected were mainly based on the prepared samples in the laboratory.

The materials used includes: ordinary Portland cement, non-reactive river sand (fine aggregate), machine crushed coarse aggregate having maximum size of 20mm diameter, and clean water suitable for drinking. The black olive fruit from which the oil was extracted was procured from Barikin Ladi local government in Plateau state Nigeria. Traditional (local) method of oil extraction was employed in the extraction of the oil from the fruit mesocarp.

Concrete mix design specifications according to British standard were used for the selection of suitable ingredients of concrete and determining their relative quantities. The design stipulations and the data considered for the mix design includes:

Characteristic Strength,  $f_{ck}$  of C20, 5% proportion defective materials,  $k$ -value = 1.64, 20mm maximum size of coarse aggregate (Crushed), zone one (1) uncrushed fine aggregate, 0.5 W/C ratio, 10 – 30mm slump range, 3.15 cement specific gravity and 2.7 relative density of aggregates (SSD).

The concrete specimens prepared in the Laboratory consist of concrete cubes of 100mm x 100mm x 100mm and 100mm x 100mm x 500mm steel beams. This experimental investigation was carried out on Grade 20 concrete. A total of 5 mixes were prepared containing 0, 0.3, 0.5, 0.7, and 1% proportion of BLO by OPC cement weight. A constant w/c ratio of 0.5 was used throughout the experiment for all the concrete mixes. Mixing of the ingredients was done on a clean and non-absorbent surface manually. The dry ingredients of concrete mix were initially mixed together before adding the mixing water. The black olive oil admixture was added to the mixing water (stirring with a metal rod) prior to adding it to the dry ingredients. Thereafter, the whole ingredients were thoroughly mixed together to obtain a homogenous, uniform in colour and consistency of the concrete mix. Test for air content was carried out immediately after mixing, following slump and compacting factor tests. The fresh concrete mix was cast into the appropriate moulds and vibrated for 3 minutes using an electrically operated vibrating table. After 24 hours, all specimens were removed from the moulds, weighed and completely immersed in water for curing at room temperature. The concrete cubes were cured inside the water at testing ages of 3, 7, 28, 60, 90, and 180 days respectively, before various tests were conducted on the hardened concrete cubes. The ambient room temperatures during the curing of the specimens ranges from 23 to 30°C.

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## Test Procedures

Workability tests and air entrainment test were conducted on the fresh concrete samples immediately after mixing. Workability was tested using the slump cone test and compacting factor test. The Air Entrainment meter apparatus used is calibrated to show the air content in percent when the standard operating pressure is applied (1 kg/cm<sup>2</sup> or 1 bar). The air entrainment values measured in percent values on fresh concrete are shown in Table 2.

The essential properties of the hardened concrete investigated are categorized into two; the mechanical and the durability characteristic properties. The mechanical property of the concrete was examined as a function of compressive strength, flexural strength, and density. While permeability (durability related) characteristics of the concrete were assessed by studying the water absorption, porosity, coefficient of water absorption (permeability) by capillary action and the rate of water flow through their surfaces exposed to water (surface areas only) using sorptivity approach. These various tests on the hardened concrete cubes were conducted after curing for 3, 7, 28, 60 and 90 and 180 days. For the permeability related tests, the concrete cube specimens were dried in an electrical oven at a temperature of 100°C (control specimen), but at 60±5°C (specimen with the black olive oil) until a constant weight was attained and weighed prior to the testing.

### 1. Water Absorption

The water absorption parameter is derived from Equation 1 and is measured in kg/m<sup>2</sup>.

$$WA = \frac{(w_s - w_d)}{A} \dots \dots \dots (1)$$

Where, WA = the water absorption of the concrete cube specimen (kg/m<sup>2</sup>),  
w<sub>d</sub> = the weight of oven dried sample cube; after removal from curing (kg),  
w<sub>s</sub> = the weight of saturated sample cube; after removal from oven (kg), and  
A = summation of all the surface areas of the cube specimen (m<sup>2</sup>)

### 2. Total Porosity

Total porosity was determined by vacuum saturation method developed by RILEM, CP113 [14], at ages 3, 7, 28, 60, 90 and 180 days for concrete cubes. And the total porosity of the samples was calculated using Equation 2.

$$P(\%) = \frac{(w_s - w_d)}{(w_s - w_w)} \times 100 \dots \dots \dots (2)$$

Where, P is the total porosity in percentage  
W<sub>s</sub> is the weight of saturated sample measured in the air  
W<sub>d</sub> is the weight of oven-dried samples measured in the air, and  
W<sub>w</sub> weight of saturated samples measured in water.

### 3. Coefficient of Water Absorption

Coefficient of water absorption, a measure of permeability of concrete is determined by measuring the water uptake in dry concrete/mortar in a time of one (1) hour. The cube specimens after curing were heated in an oven at 100°C (control specimen), but at 60°C (specimen containing black olive oil admixture) until a constant weight was attained at 14 days or more. The cubes were allowed to cool at room temperature for 24 hours. The sides of the cube specimen were coated with silicon sealant up to 30mm depth to allow the flow of water on only one surface of the cube. The initial weight of the sample is taken at time 0. The cube samples were immersed in water to a depth of 10mm. The weights of the samples were taken after one hour and the coefficient of water absorption of the concrete cube specimens was calculated using equation 3 presented by Ganesan [15].

$$Ka = \left(\frac{Q}{A}\right)^2 \times (1/t) \dots \dots \dots (3)$$

Where Ka is the coefficient of water absorption (m<sup>2</sup>/s) = permeability,  
Q is the quantity of water absorbed (m<sup>3</sup>),  
t is the time taken to absorb the water (1.0 hour = 3600 seconds), and

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A is the surface area (m<sup>2</sup>) through which water was absorbed.

#### 4. Sorptivity

Sorptivity is the rate of absorption of water into an unsaturated surface of concrete by capillary action [16]. Sorptivity measures how much water and how quickly it gets absorbed into a concrete material. For determining the sorptivity, the surfaces of designated concrete cube specimens were exposed to capillary absorption test, as described earlier for coefficient of water absorption. The initial weight of the cube was taken at time zero and at time intervals of 2, 4, 8, 10, 20, 30, 60 and 90 minutes, the samples were then removed from water at each time interval and the excess water blotted off and the sample weighed. It was then placed back in water and the process repeated at the same selected time intervals. The sorptivity of the specimens were then calculated using the data recorded from capillary absorption test. The sorptivity (S) is the slope of the cumulative volume of water absorbed per unit area (i) against the square root of time (t). Therefore, the sorptivity value of the specimen for one dimensional flow is calculated using Equation 4 [16].

$$i = S\sqrt{t} = S t^{1/2} \quad \dots\dots\dots (4)$$

Where,

S = the sorptivity (m/√s = m/s<sup>1/2</sup>).

t = the elapsed time in minutes, and

i = the cumulative water absorption per unit area of the surface (m<sup>3</sup>/m<sup>2</sup>), expressed as  $i = \Delta w / A d$

$\Delta w$  = Change in weight =  $W_2 - W_1$

$W_1$  = oven dry weight in grams

$W_2$  = weight of sample after capillary suction

A = surface area of the specimen through which water penetrates m<sup>2</sup>

d = density of water = 10<sup>-3</sup> g/mm<sup>3</sup>

### IV. RESULTS AND DISCUSSION

#### 1. Properties of Fresh Concrete

The aggregate and w/c ratio of 0.5 was kept constant for all the mixes. The results in table 1 show the consistency, initial and final setting time for each percentage of the black olive oil (BLO) addition. From the table, the value of consistency increases with increase in percentage of BLO admixture. The increase in consistency ranges from 26.65% - 28.50% for 0%-1% BLO. This is within the range (26-33%) specified for normal consistency.

Table 1. Consistency and Setting Time Results of BLO/OPC paste

Property	0%	0.3%	0.5%	0.7%	0.1%
Consistency (%)	26.65	27.25	27.50	27.75	28.5
Initial Setting time (mins)	123	147	161	161	188
Final setting time (mins)	185	181	205	210	240

It was observed that, during the mixing process at the first instant when water was added to the dry BLO/OPC sample the paste became very stiff (compact), plastic, but later becomes sticky when placing on mixing thoroughly with time. This indicates that the BLO/OPC paste requires more amount of work-done in kneading or more water to attain a



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standard consistency. Explanation of this phenomenon could be that the oil being a hydrophobic substance tends to soak into the solid phase, covering particles of the binder and thus increases cohesion of the binder paste. Consequently, as the percentage of the oil increases, cohesion also increases. The increase in cohesion results into particles been glued together (stiff paste) and consequently, requires more mixing water to reach the standard consistency.

The setting time also recorded an increase both in the initial and final set time as the percentage of BLO increases. The reason for the delay may be due to the fact that hydrophobic oil tends to adhere to binder grains and thus limiting water molecules access.

## 1.1. Workability Results

The values of slumps measured in millimetres (mm) and the compacting factors measured in degree of compaction, resulting from the application of a standard amount of work values are shown in Table 2. The slump and the compacting factor value of the OPC concrete increases with increasing the dosage of BLO induced in the OPC mixes. The increment in the slump value by percent ranges from 0%, 9.01%, 18.18% and 36.36%. at the various percentages of 0.3, 0.5, 0.7 and 1% BLO content respectively. An increase in the compacting factor was also recorded from 0.82 - 0.89 at 1% BLO content. This infers that workability property of concrete is improved as the percentage of BLO admixture increases. The oil in the concrete acts as a lubricant making the concrete paste more workable. The black olive oil investigated therefore can possibly act as a water reducing agent or a chemical plasticizer. It is imperative to note that plasticizing admixture causes a decrease in the early strength along with increasing workability.

Table 2 Properties Of Fresh Concrete.

Percentage of BLO	Slump (mm)	Compacting Factor	Air Entrained %
0%	11	0.82	3.4
0.3%	10	0.85	4.9
0.5%	12	0.88	5.0
0.7%	13	0.88	5.4
1.0%	15	0.89	6.1

## 1.2. Air Content

The effect of inducing BLO admixture into OPC concrete mixes on the air content investigated is illustrated in fig 1. It is noticed from fig 1 that the air content increases with increasing oil addition. So it can be stated that BLO can also be considered as an air entraining admixture. According to researches, the use of air entraining agents in concrete results in improved workability; hence the observed increase in workability property may be attributed to changes in the concrete air entrained.

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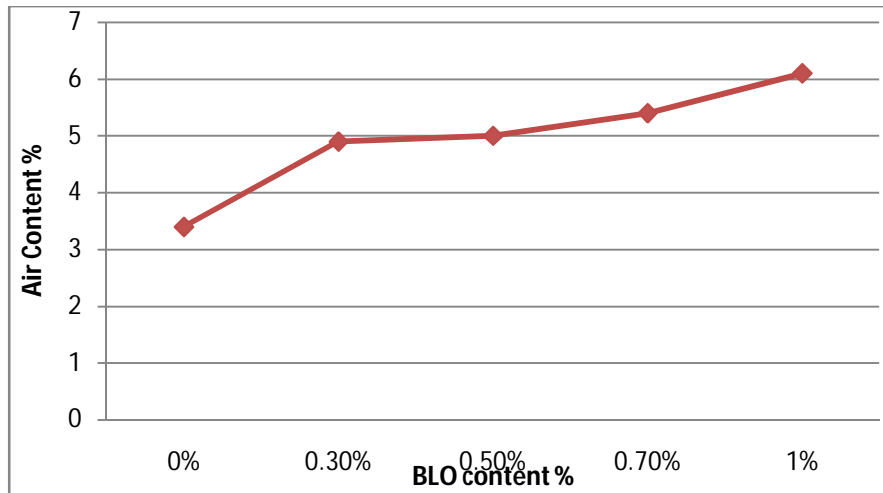


Figure 1. Effect of BLO on air content of concrete

### 2. Mechanical Characteristics of Hardened Concrete Incorporating Black Olive Oil

Table 3 shows the compressive strength of OPC concrete containing various dosages of black olive oil (BLO) at 0%, 0.3%, 0.5%, 0.7% and 1% by cement weight.

Table 3. Compressive Strength of BLO/OPC Concrete

Percentage of Olive oil Admixture	Compressive strength N/mm <sup>2</sup>					
	3 days	7 days	28 days	60 days	90 days	180 days
0%	12.33	16.63	23.25	25.50	31.50	33.17
0.3%	11.00	14.00	23.88	24.50	29.38	30.10
0.5%	13.50	10.00	19.63	22.75	25.50	33.00
0.7%	8.83	9.75	18.50	21.33	24.00	28.00
1.0%	8.00	9.50	18.00	18.63	20.50	21.50

Figure 2 presents the compressive strength development of concrete with the age of curing, and it shows a gradual increase in strength as curing proceeded as expected of OPC concrete/mortars. The effect of BLO on the compressive strength of concrete is illustrated in figure 3.

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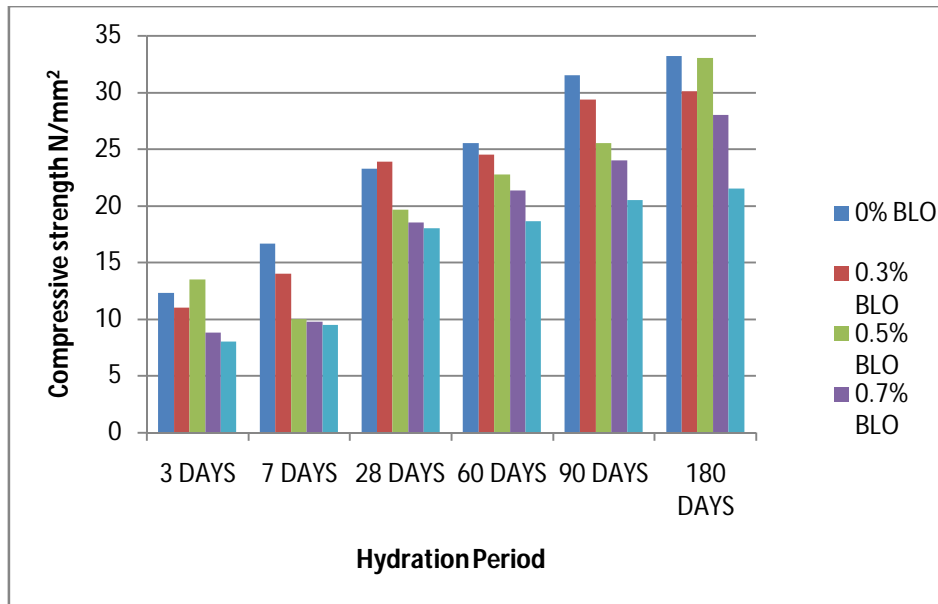


Figure 2. Compressive Strength of BLO/OPC Concrete with hydration period.

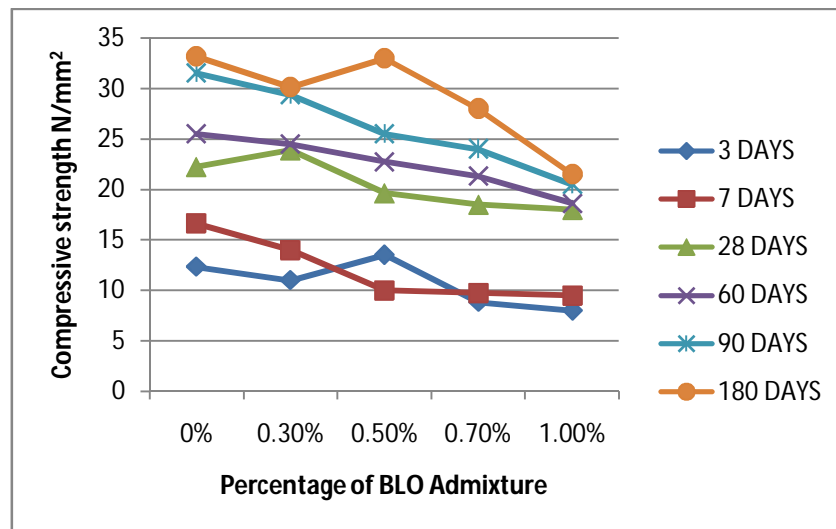


Figure 3. Compressive Strength of Concrete corresponding to Percentage of BLO Admixture.

The result presented in fig 3 revealed that introducing BLO into OPC decreases the strength of concrete. Although the 28 day compressive strength of the concrete mix containing 0.3% BLO showed a slight increase in strength by 1.89% from 23.25N/mm<sup>2</sup> (0% BLO control mix) to 23.88 N/mm<sup>2</sup>, but the increase was not progressive as the curing ages proceeds. At 180days of curing, the 0.5% BLO also recorded a good strength value of 33N/mm<sup>2</sup> closely related to the 33.17N/mm<sup>2</sup> strength of the reference sample, the decrease is insignificant.

Besides the 0.3%BLO at 28days and 0.5% BLO at 180days concrete strength which showed a good strength valve, all the other sample cubes containing BLO exhibited a low compressive strength comparable with that of the reference mix (0% BLO) throughout the hydration period.



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The behaviors of the density and flexural strength are generally close to that obtained earlier when the compressive strength of specimen made with BLO admixture was considered. Density of the reference mix (0%BLO) recorded as  $2.535\text{Kg/m}^3$  decreased to 2.478, 2.464, 2.383 and  $2.352\text{kg/m}^3$  as BLO percentage content increased from 0.3, 0.5, 0.7 and 1% respectively. The 28days flexural strength also showed a progressive decrease in strength from  $3.09\text{N/mm}^2$  to  $2.88\text{ N/mm}^2$ ,  $2.39\text{ N/mm}^2$ ,  $1.83\text{ N/mm}^2$  and  $1.97\text{ N/mm}^2$  at the various percentages of BLO respectively.

From theoretical view, decrease in strength of concrete may be caused by factors such as lower degree of hydration, lowered degree of carbonation, increase porosity, air content and workability. Therefore it is suggested that the above mentioned affects may be attributed to the significant role of the oil admixture on altering the air content, which in turn affects the hardened properties of concrete [17]. Another reason for lesser strength development explained by Vikan and Justnes [18] was that the transport of water from one part of the microstructure to another may be obstructed when the hydration has proceeded far enough to enrich the oil concentration to become an important phase in the liquid. Hence, lower degree of cement hydration may be due to the blocking of micro-pores by oil droplets, or may be caused by the diffusion of oxygen over time through the sample which oxidizes the liquid unsaturated fatty acids to form a solid saturated fatty acid. Also, it was reported that the carboxyl acids derivatives, occurring in solution during the decomposition of oil in basic environment coordinates strongly with Ca-sites. The absorption of the carboxyl acid derivatives on the cement particles might alter the hydration both by delaying it and changing the morphology of hydration products such as  $\text{CaCO}_3$ , gypsum and hydrated cement. Encapsulation of carboxyl acid derivatives might therefore have changed the morphology of the hydrated cement phase in a way which has weakened the strength of the paste. The morphology of later products may be more affected than the early ones since the concentration of fatty acid increase as the water is consumed [19].

## III. PERMEABILITY PROPERTIES OF BLO/OPC CONCRETE AND MORTAR

### 3.1 Water Absorption Test Results

The results in table 4 demonstrate a decrease in water absorption for all the concrete mixes containing BLO admixture. A reduction in water absorption naturally is anticipated with the use of oil due to the hydrophobic nature of the material used. Figure 4 emphasized that the amount of water absorbed by the concrete made with BLO decreased linearly with additional increments of BLO. From table 4, the water absorption of the concrete with 0.3%BLO at 28 days samples is  $1.550\text{kg/m}^2$  compared to  $1.789\text{kg/m}^2$  for reference mix (0% BLO). This further decreased to  $1.2\text{kg/m}^2$  at 1% BLO content. Decrease was also recorded in 90days sample, where the amount of water absorbed decreased from  $1.711\text{kg/m}^2$  to  $1.011\text{kg/m}^2$  at 1%BLO content. The minimum amount of water absorbed for all the mixes as shown in figure 4 is at 180days, implying that reduction in water absorption progresses with hydration period.

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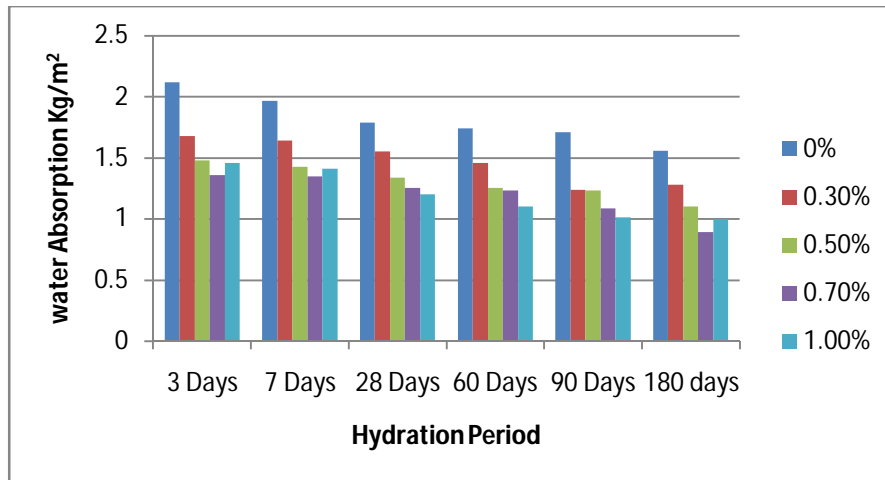


Figure 4. Water absorption of BLO/OPC Concrete

Table 4. Water Absorption and Porosity Result

	Percentage of Blk olive Admixture	Hydration Period					
		3 days	7 days	28 days	60 days	90 days	180 days
Water absorption kg/m <sup>2</sup>	0%	2.117	1.967	1.789	1.739	1.711	1.555
	0.3%	1.678	1.639	1.550	1.456	1.239	1.278
	0.5%	1.478	1.428	1.339	1.250	1.233	1.100
	0.7%	1.356	1.345	1.250	1.233	1.083	0.889
	1.0%	1.455	1.411	1.200	1.100	1.011	0.994
Porosity (%)	0%	11.68	11.06	10.62	10.40	9.67	9.22
	0.3%	9.75	9.76	8.90	8.74	7.04	6.86
	0.5%	9.07	9.00	8.52	8.28	6.42	6.42
	0.7%	7.19	7.21	7.14	6.92	6.10	5.57
	1.0%	8.98	8.29	7.70	6.41	5.99	5.88

### 3.2 Total Porosity Test Result

The effect of the BLO addition on the porosity property of OPC concrete illustrated in fig 5 reflects a clear decrease in this property, especially in specimens containing higher percentages of the oil admixture. The result revealed that the BLO/OPC concrete at 180days yielded lower porosity compared with the 90days result. And the 90days sample yielded a lower result compared with the 28 days samples. At 90 days the porosity of the OPC concrete mix was reduced sequentially with the addition of BLO by 2.63%, 3.25%, 3.57% and 3.68% for BLO concrete mixes of 0.3, 0.5, 0.7, and 1% respectively. The observed improvement in porosity is anticipated to result in a dense (well packed) material with

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increased density and strength. In this study however, a decreased in strength of the cement matrix with BLO admixture was observed while porosity decreased. Hence it can be inferred that the decrease in strength recorded may not be related to the porosity; rather could be due to lack of strong bonding of the cement matrix. It is suggested that addition of the oil to OPC paste might have reduced the bonding strength between aggregate and C-S-H gel. This suspicion however is not verified, laboratory investigation is required to justify this claim.

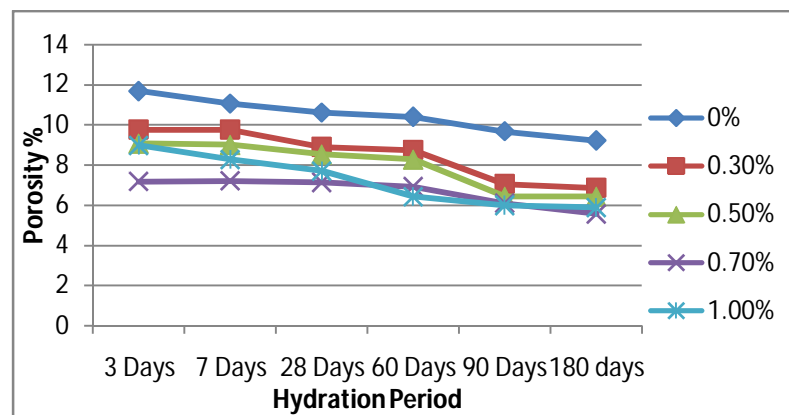


Figure 5. Total Porosity of BLO/OPC Concrete

### 3.3 Capillary Actions

The addition of BLO causes a significant decrease in the concrete coefficient of water absorption; the permeability coefficient of the conventional OPC concrete showed the greatest value as recorded in table 5. And it is evident that the higher the BLO content, the lower the coefficient value. . By adding only 0.3% BLO cured beyond 28days, the coefficient of water absorption value was 2 times less than the reference OPC concrete mix. Likewise with the highest content of 1% BLO, the value at 90days and 180days is approximately 7 times less than the reference mix. This result demonstrates that the concrete absorbs less water when the percentage of oil is increased.

Table 5. Capillary Sorption of the BLO/OPC Concrete

	Percentage of Blk olive Admixture	Hydration Period					
		3 days	7 days	28 days	60 days	90 days	180 days
Permeability coefficient $K_a$ ( $\times 10^{-4}$ )	0%	4.481	2.778	2.250	1.639	1.500	1.380
	0.3%	1.713	1.000	1.018	0.916	0.796	0.629
	0.5%	0.527	0.527	0.527	0.398	0.379	0.444
	0.7%	0.379	0.315	0.250	0.379	0.250	0.250
	1.0%	0.204	0.204	0.204	0.205	0.204	0.204
Sorptivity $m/t^{0.5}$	0%	0.169	0.123	0.123	0.095	0.088	0.083
	0.3%	0.084	0.070	0.070	0.060	0.063	0.053
	0.5%	0.053	0.049	0.049	0.046	0.042	0.036
	0.7%	0.046	0.046	0.035	0.035	0.032	0.025
	1.0%	0.032	0.032	0.035	0.032	0.032	0.032

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The sorptivity of OPC concrete recorded in table 5 decreased proportionally with increased BLO content for all the mixes. This may be attributed to the improvement observed with the porosity induced by the BLO admixture. The result of coefficient of water permeability and sorptivity which presented reduction in values indicates that the OPC reference cement matrix is more permeable than the BLO/OPC modified mixes. It can therefore be concluded that the use of black olive oil (BLO) in concrete reduces permeability and as a result, the deterioration may be delayed; the reduction in water absorption depths improves the resistance of concrete to chemical attack and protects the steel reinforcement.

## V. CONCLUSION

In summary, utilization of BLO admixture resulted in a significant alteration in the performance of OPC concrete during its fresh and hardened state. The addition of BLO has proved to have positive effect on concrete permeability related properties by reducing the water absorption into the concrete but their mechanical characteristics are slightly decreased. The BLO test admixture investigated has the potential to be used in the construction industry as a multifunctional plasticizing – water proofing admixture. It can be used as water repellent admixture for concrete and mortar in rather small amounts; ranging from 0.3 – 1% by weight of the binder because of the adverse negative effect on the strength. The negative effect on the strength properties of BLO/OPC mixes attributed to increased air content and workability can be offset by lowering the w/c ratio.

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