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# The Effect of using Olive Oil Mill Wastewater on Bending and Compression Properties of Cement Mortar

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**ABSTRACT: Huge amounts of olive waste residues are accumulated every year in olive-oil-producing countries, as in Jordan, that may in role impacted the environment. Olive oil mill wastewater contains various hazardous compounds and estimated to be 200,000 $m^3$/year in Jordan. This amount of resulted discharge is transported to landfills or discharged to surrounding environment causing serious environmental problems. This study investigates the utilization of olive oil mill wastewater in mortar mixes where the normal water was replaced with olive oil mill wastewaters in different percentages (2.5, 5.0, 7.5, 10.0, 15.0, 20.0, 30.0, and 40.0%) and the corresponding changes in compression and bending properties were tested at ages (7, 14, 21, 28) days. We have also tested compression and bending properties of mortar mixes after adding Alkali-resistance Glass fiber of 2.0, 2.5, 3.0 and 3.5% of the total cement weight and the maximum values of compression and bending properties has been registered for 3.0%. This percentage has been used for all samples that tested for finding the effect of adding Alkali-resistance Glass fiber in combination with olive oil mill wastewater on compression and bending strengths where olive oil mill waste water has been added in different percentages (2.5, 5.0, 7.5, 10.0, 15.0, 20.0, 30.0, and 40.0%). Maximum 28 curing days compression strength (35 MPa) has been registered for 7.5% replacement value, which was 17% higher than regular cement mortar at same curing day revealing that the use of olive oil mill wastewater may enhance compression strength of mortar mixtures. There was no substantial change in bending property for all samples at all replacement percentages but the 28 curing days bending strength has increased by 58% (15.40 MPa) in compare with the reference samples of same curing day after adding Alkali-resistance Glass Fiber by 3% of the cement weight. Mean value of 28 curing days Compression strength (32.40 MPa) has been increased by 12% after adding Alkali-resistance Glass Fiber by 3% of the cement weight and olive oil mill wastewater of 7.0% replacement percentage in compare with the reference samples.**

**Keywords**: Olive Oil Mill Wastewaters, Cement mortar, Glass Fibers, Compression strength, Bending strength**.**

## I. INTRODUCTION

Concrete still occupies the fore position in various building materials since its first use until the present time as the methods of production and manufacture have greatly improved and the types of concrete produced have varied according to the requirements of the purposes for which they are used and according to the different fields [1]. Due to the diversity of concrete components, the possibility to use additives, and the diversity of production methods, concrete appears as the important factor for building important facilities. Therefore, the materials are involved in concrete must be taken and their proportions in consideration and given appropriate importance [2].

Twelve billion tons of concrete has been estimated to be consumed in the world making concrete a significant contributor to air pollution and a major consumer of substantial quantities of freshwater [3]. Tons of greenhouse gases are released into the atmosphere during concrete production processes that in role impacted the environment. It has been estimated that about 1.4 billion tons of $CO_2$ are produced in 1995 forming 7% of the total produced $CO_2$ worldwide [3a]. Many studies have shown that the concrete industry produces an amount of green-house gases during cement production, required high energy, produces tons of solid wastes, and consumes a large amount of freshwater [4]. In semi-arid regions, where Jordan is located, freshwater resources are rarely available [5]. This in role making water reuse options an essential component of water resources management and sustainable development [6]. While the concrete industry consuming one trillion gallons of water each year worldwide excluding waters used for washing and curing, this amount of water boosts the stress on the available water resources in semiarid regions [7]. On the other hand, wastewater discharged from wastewater treatment plants, desalination plants, and olive oil mills affects surrounding streams and deteriorates surface and groundwater quality [8]. The cultivation of olive trees and the production and use of olive oil has been a well-known and established practice in the

Mediterranean region for more than 7000 years. The consumption of olive oil is rapidly increasing worldwide, due to its high dietetic and nutritional value. According to the IOOC (2004), the production of olive oil increased from 1.85 million tons in 1984 to 3.17 million tons in 2003 (70% increase). There are approximately 750 million productive olive trees worldwide, 98% of them located in the Mediterranean region among them is Jordan, where more than 97% of olive oil is produced [9]. These wastewater sources can be reused in many local practices to minimize their impact on the environment [10].

To our knowledge, the effect of using olive oil mill wastewater in cement mortar mixes on compression and bending properties have not been investigated before as well as in combination with Alkali-resistance Glass fiber. This research aims to find out the effect of using olive oil mills wastewater in the concrete mixture on its mechanical properties by replacing part of the regular water olive oil mills wastewater, as this topic has a great economic and environmental advantages.

## II. MATERIALS AND METHODS

During the traditional press extraction method there is three products are generated i) olive oil ii) wet solid waste called olive husk and iii) an olive mill effluent in the respective percentage of 20%, 30%, and 50%, respectively [9]. The effluent discharged from olive mills have shown to impact the surrounding environment and are many attempts to alleviate the problem in countries that producing a hug amount of olive oil [11].

We have collected olive oil mill wastewater samples from plant's discharge outlet located in nearest City Ajloun and transported in sealed-nonreactive containers to the laboratory. The olive oil mill wastewater has been used within three days after collection to ensure the properties are not changed and to avoid bio processes during incubation. Physico-chemical properties of samples are collected from the plant's laboratory database (Table 1).

**Table 1: Characterization of olive oil mill wastewaters.**

| Property | Value |
|---|---|
| pH | 5.37 |
| COD ($kgm^{-3}$) | 54.56 |
| BOD ($kgm^{-3}$) | 18.58 |
| PhC ($kgm^{-3}$) | 2.01 |
| TS ($kgm^{-3}$) | 46.47 |
| VS ($kgm^{-3}$) | 37.07 |

We have used sandy rocks composed of (quartz) granule with grain size ranging between 1.0 and 5.0 microns, and its purity reaches more than (98%). The chemical description for these rocks is ($SiO_2$) sand Silica that is widely used in silicic industries, and ceramic because it prevents the occurrence of cracks as it reduces shrinkage rate and plasticity decrease as well as help with exit gases released into the ceramic body. The volumetric analysis and chemical composition of silicate sand are presented in Table 2 & 3.

Ordinary Portland Cement (OPC), Type I (ASTM C 150) / BS 12 / CEM 1, has been used in preparing mixes. The silicates are responsible for the strength of hydrated cement paste where Tricalicium aluminate contributes to the early-stage strength of cement. When the sulfates attack the hardened cement, the calcium sulfoaluminate (ettringite) is formed and may cause disruption.

**Table 2: Sieve analysis of used silica sand.**

| Sieve (in) | Finer percent (%) |
|---|---|
| No. 4 | 100 |
| No. 8 | 99 |
| No. 10 | 98 |
| No. 16 | 97 |
| No. 30 | 81 |
| No. 40 | 65 |
| No. 50 | 40 |
| No. 100 | 5 |
| No. 200 | 2.9 |

**Table 3: Chemical properties of the sand (as provided by the Royal Scientific Society in Jordan).**

| Component | (%) |
|---|---|
| LOI | 2.84 |
| $SiO_2$ | 93.71 |
| CaO | 0.23 |
| $Fe_2O_3$ | 0.10 |
| $SO_3$ | 1.57 |
| MgO | 0.06 |
| $Al_2O_3$ | 0.95 |
| $Na_2O$ | 0.07 |
| $K_2O$ | 0.32 |
| $TiO_2$ | 0.15 |

Tetracalcium aluminoferrite contributes in a minor way to the behavior of cement, it reacts with gypsum to form calcium sulfoferrite to accelerate the hydration of silicate. The typical average values of the compound composition of ordinary Portland cement are presented in Table 4.

**Table 4: Approximate composition limits of Type I Portland cement.**

| Compound composition | Content, percent |
|---|---|
| **$C_3S$** | 59 |
| **$C_2S$** | 15 |
| **$C_3A$** | 12 |
| **$C_4AF$** | 8 |
| **$CaSO_4$** | 2.9 |
| **Free CaO** | 0.8 |
| **MgO** | 2.4 |
| **Loss of ignition** | 1.2 |

*A. Alkali-Resistant (AR) Glass Fibers Used*

Alkali-resistant (AR) glass fibers, made of a glass having minimum Zircona content of 16%, has been used in mixes preparation. The fiber composition lies within the critical region of the $Na_2O$ $CaO$ $ZrO_2$ $SiO_2$ system and has high durability when used in cement-based products with significantly increasing flexural and tensile strength. AR glass fiber meets the requirements of ASTMC-1116 with no negative impact on underground water and organisms. AR glass fiber is not harmful to human lungs due to its filament thickness which is (14 to 20 µm). The glass-fibers used in this study are cost-effective and can be obtained in Jordan. The length of glass-fibers (30mm), "chopped strand", and the physical and mechanical properties of the fibers are provided by the manufacturer (Fig. 1 and Table 5).

**Fig. 1.** AR glass fibers sample: 30mm length (A).

**Table 5: Physical and mechanical properties of the fibers (as provided by the manufacturer).**

| | |
|---|---|
| **Filament Diameter** | (0.1 mm) |
| **Fiber Length** | 12 mm, 30 mm |
| **Specific Gravity** | 2.7 |
| **Young's modulus of elasticity** | 72 to 74 GN/$m^2$ |
| **Tensile Strength** | 1700 MPa |
| **Flexural Strength** | 72 GPa |
| **Melting Point** | 1121° C |
| **Color** | White |
| **Water Absorption** | < 1% |
| **Alkali Resistance** | High |
| **Concrete Surface** | Not Fuzzy |
| **Corrosion Resistance** | High |
| **$ZrO_2$ content** | 16% by weight |

*B. Technical Preparation of Cement Concrete mixes*

The technical preparation of all mixes has been performed in 4 laboratory work stages. i) cement mortar production ii) model preparation, including molding, surface finishing, moved from molds and finally curing iii) testing the compressive and flexural strength iv) adding olive oil mill wastewater in different proportions (0%, 2.5%, 5%, 7.5%, 10%, 15%, 20%, 30%, 40%) to the optimum proportions of added AR to replace part of the regular water. Reference samples of a regular cement concrete were prepared and compared with samples after the addition of fiber in order to find the optimum proportions of added AR based on maximum obtained compression and flexural strengths. All the examinations took place in the materials laboratory of Ajloun National University.

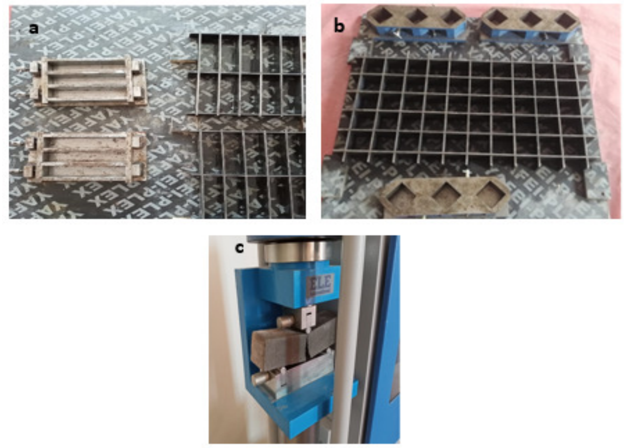

**Fig. 2.** The shape of the prisms, cubes and screening device.

Molds design were met the standard approved by (B.S.1881.part (116): 1989) and (B.S.1881. part (118): 1983), in which the molds used are made of a non-absorbable material that does not allow the passage of water and is not capable of interacting with the contents of the cement mortar [12]. Molds are cube shaped of 50.5×50.5×50.5 mm dimensions, and gauge prisms (beams) measure (40 x40 x 160) mm to perform bending resistance tests (Fig. 2a &b). The mixes ratio of tested specimens are shown in Table 6, noting that in the mixtures, part of the regular water has been replaced by proportions (2.5, 5.0, 7.5, 10.0, 15.0, 20.0, 30.0,40.0) %) with Olive oil mill wastewater and fiber with Olive oil mill wastewater.

Specimens preparation are met the US specifications (ASTM –C-192-1980) [13], where the cement concrete was placed in molds and stacked using electric vibrators for a suitable time (one minute for each layer) until the cement mortar inside the mold has been leveled and the sides of the mold being checked after each compaction [13]. Manual and accurate stacking process has applied for AR and AR-OOW specimens and the surface of the samples has modified and flattened after molds filling. All the samples were covered with nylon sheets to prevent water evaporation and to obtain a flatten surface for examination [14]. Forms were removed from the molds after 48 hours instead of 24 hours from the time of casting as specimens, which consist OOW, need longer time for solidification [14]. All samples were flooded with water until the testing date.

Compression and flexural strength tests were performed using used scan capacity, (250/25 KN, (ADR Touch control PRO 250/25 Auto Cement Machine the code: 39-7160/01)) (Fig. 2c), for reference mixtures and mixtures containing different proportions of olive oil mill wastewater and mixtures containing olive oil mill wastewater with AR. Mixtures were tested at curing ages (7, 14, 21,28) days, where three cubic models with dimensions (50.5×50.5×50.5) mm were examined for each age. In this examination, British specifications were approved (BS.1981.PART(116): 1983), in Table (10 and 11) the average results obtained from laboratory work for all mixes and every age. Prisms with dimensions (40×40×160 ) mm were used to check flexural strength following British specifications of (BS.1981.PART(118): 1983), and by using scan capacity 250/25 KN, (ADR Touch control PRO 250/25 Auto Cement Machine the code: 39-7160/01) (Fig. 2c).

**Table 6: Water and cement (W/C) ratio, Sand and cement (S/C) ratio, the percentage of added Olive Oil Mill Wastewaters (% of OOW) and the percentage of added glass fibers (% of AR) mixes.**

| Trail # | Mixture | W/C | S/C | % of OOW | % of AR |
|---|---|---|---|---|---|
| 0 | only mortar | 0.5 | 2.75 | 0 | 0 |
| 1 | OOW | 0.5 | 2.75 | 2.5 | 0 |
| 2 | OOW | 0.5 | 2.75 | 5 | 0 |
| 3 | OOW | 0.5 | 2.75 | 7.5 | 0 |
| 4 | OOW | 0.5 | 2.75 | 10 | 0 |
| 5 | OOW | 0.5 | 2.75 | 15 | 0 |
| 6 | OOW | 0.5 | 2.75 | 20 | 0 |
| 7 | OOW | 0.5 | 2.75 | 30 | 0 |
| 8 | OOW | 0.5 | 2.75 | 40 | 0 |
| AR1 | AR | 0.5 | 2.75 | 0 | 2 |
| AR2 | AR | 0.5 | 2.75 | 0 | 2.5 |
| AR3 | AR | 0.5 | 2.75 | 0 | 3 |
| AR4 | AR | 0.5 | 2.75 | 0 | 3.25 |
| F-OOW1 | OOW + AR | 0.5 | 2.75 | 2.5 | 3 |
| F-OOW2 | OOW + AR | 0.5 | 2.75 | 5 | 3 |
| F-OOW3 | OOW + AR | 0.5 | 2.75 | 7.5 | 3 |
| F-OOW4 | OOW + AR | 0.5 | 2.75 | 10 | 3 |
| F-OOW5 | OOW + AR | 0.5 | 2.75 | 15 | 3 |
| F-OOW6 | OOW + AR | 0.5 | 2.75 | 20 | 3 |
| F-OOW7 | OOW + AR | 0.5 | 2.75 | 30 | 3 |
| F-OOW8 | OOW + AR | 0.5 | 2.75 | 40 | 3 |

## III. RESULTS AND DISCUSSION

Maximum Compression strength has been registered for AR3 specimen's at all curing days. The percentage of added AR to specimens of 3% has compression and bending strength of 21.1MPa and 19.4 MPa, respectively. This percentage has been used for all experimentations aimed to investigate the effect of adding olive oil mill wastewater in combination with AR on the compression and bending strength of specimens (Fig. 3 and 4).

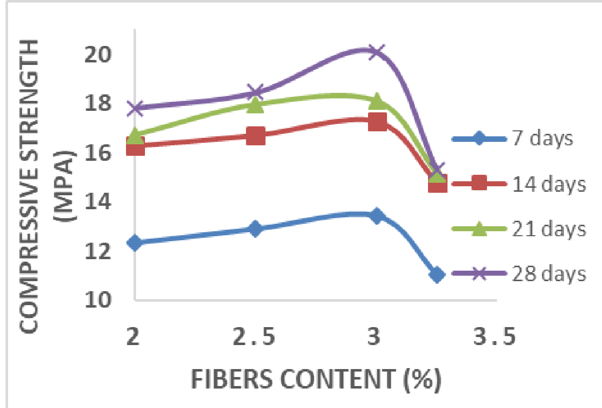


**Fig. 3.** Compressive strength (fiber-reinforced cement mortar).

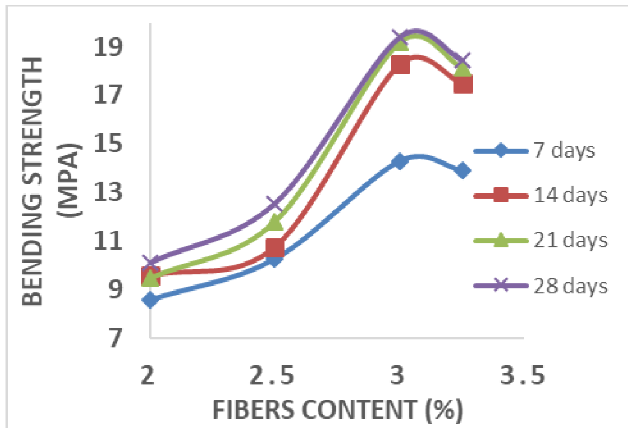


**Fig. 4.** Bending strength (fiber-reinforced cement mortar).

All mortars specimens that contain olive oil mill wastewater in their mixture had harder surfaces than the other specimens mixed with freshwater. We have noticed that specimens mixed with olive oil mill wastewater had also better workability than the other mixes; therefore, we did not use any additives when using the fiber in mixtures. However, surface color has also been noticed to change for specimens that mixed to be darker than the specimens mixed and cured in freshwater (Fig. 5 and 6). The failure molds of the Cubic's in presence of olive oil mill wastewater for all percentages differs from its regular concrete analogs known to us (Fig. 6).

**Fig. 5.** Cubic's with Olive Oil Mill Wastewater and fibers.

**Fig. 6.** Failure molds of the Cubic's with Olive Oil Mill Wastewater.

A substantial decrease in compressive strengths has been observed with the increase of olive oil mill wastewater percentage added to specimens. The rate of strength in all samples has increased with time and reached its maximum value at the curing day 28. Maximum 28 curing day compressive strength (34.9MPa) for OOW specimens has registered for the percentage of added OOW of 7.5% with 20% increase in compare with the compression strength for the reference samples. This percentage has also shown to have maximum compression strength for concrete mixes [15]. However, the rates of increase in all samples were still increasing after 28 days and the compression strength decreased for OOW percentage higher than 7.5%. The average percentage increase in compressive strength has been observed after 14 days of about 30% for all samples mixed with olive oil mill wastewater and the maximum average have been registered for a high percentage of added OOW. This refers to the low rate of gained strength a few days after curing for samples mixed with olive oil mill wastewater indicated that at the high percentage of wastewater the chemical reaction has inhabited. However, a slight increase in strength percentage has registered after 21 days of curing reaching its maximum of 22% for samples of higher than 15% of its water content in olive oil wastewater with an average increase of 12% (Fig.7). We don't see any decrease in compressive strength with curing time for all samples mixed with added olive oil wastewater indicating that maximum strength has not been reached. The addition of fiber material 3% was also determined (Fig. 3) with different proportions of olive oil mill wastewater did not increase the strength compression, The highest strength force was 32.4, which is due to an added ratio of 7.5%, but on the contrary, reduced it by 7%, The compressive strength of cement concrete with added olive oil mill wastewater (2.5, 5.0, and 10 ) % is good, but after that it begins to decrease, reaching 8.13 MPa, at 40% (Fig. 7).

We conclude from the laboratory work in (Fig. 8) adding the fiber to cement concrete (mortar) that contains olive oil mill wastewater has no effect on the compressive strength, but on the contrary, it reduced it by a percentage equal to 7%, which is the same for ordinary cement mortar.

**Bending strength -** The bending strength of concrete depends on several factors, including age; cement content, water-to-cement ratio, and olive oil mill wastewater to cement ratio, fiber-to-cement ratio, curing time, additives. The failure modes of the prisms with olive oil mill wastewater, and olive oil mill wastewater with AR, similar to the failure modes in regular concrete. Cracks have been shown in the middle of the samples at the place of loading (Fig. 9 &10).

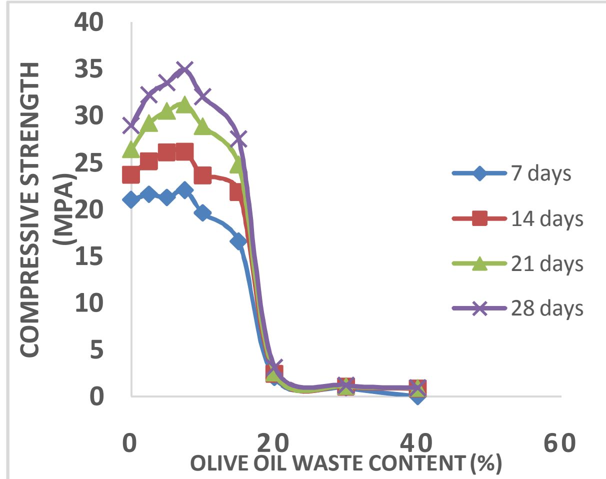


**Fig. 7.** Compressive strength (MPa) of cement mortar mixes of different olive oil mill wastewater at 7, 14, 21, and 28 days of curing.

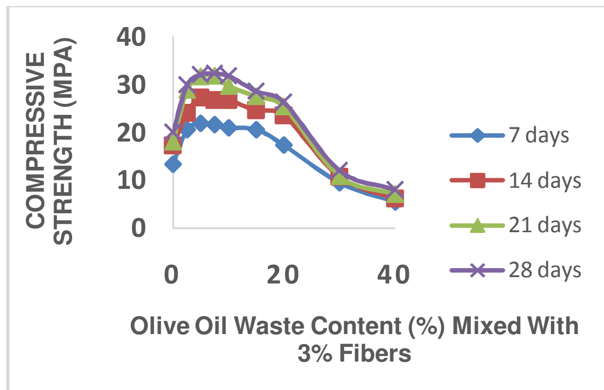


**Fig. 8.** Compressive strength (MPa) of cement mortar reinforced with 3% fibers and different percentage olive oil wastewaters for 7,14,21,28 curing day.

The addition of olive oil mill wastewater to cement mortar had negligible effect on the bending strength for percentages below 10%, where the highest strength was 6.5 MPa compared to 6.28 MPa for ordinary cement mortar. For the percentages higher 10, the bending strength began to decrease gradually until it reached 1.9 MPa after 28 curing days (Fig.11). So we can be sure that adding olive oil mill wastewater to cement mortar by up to 10% does not have a negative effect and it increases the strength of resistance. Adding fiber to cement mortar increases its bending strength by a percentage equal to 66% after 28 days, which confirms the quality of the fibers works on the bending. When adding fiber to cement mortar that contains different percentages of olive oil mill wastewater, it was found that the strength bending decreases by a percentage equal to 58%, and it returns to the best percentage 7.5 %, which gave the highest strength (Fig. 11 & 12).

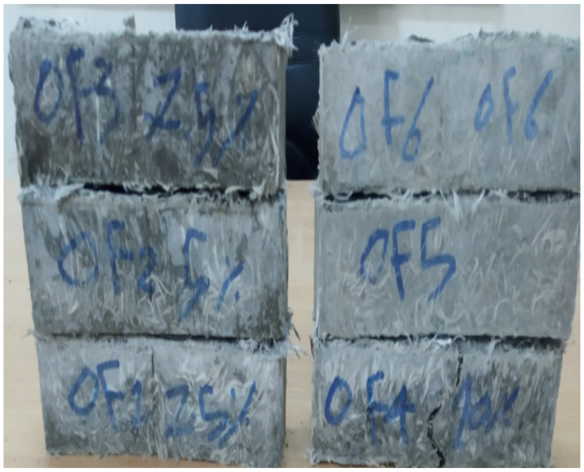

**Fig. 9.** The failure modes of the prisms with Olive oil mill wastewater and fibers.

**Fig. 10.** Prisms with Olive oil mill wastewater.

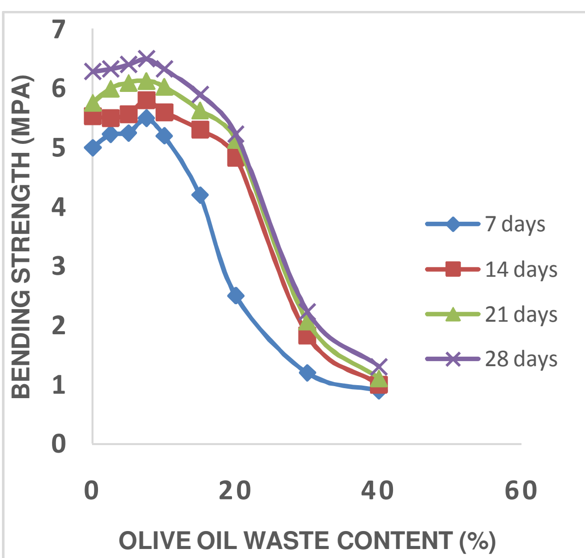


**Fig. 11.** Bending strength (MPa) of cement mortar mixes of different olive oil mill wastewater for 7, 14, 21, and 28 curing days.

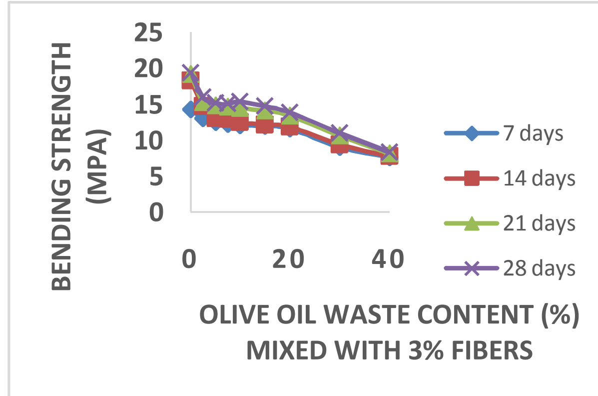


**Fig. 12.** Bending strength (MPa) of cement mortar reinforced with 3% fibers and different percentage olive oil mill wastewaters for 7, 14, 21, 28 curing day.

## IV. CONCLUSION AND RECOMMENDATION

During laboratory compression and bending strength tests for cement mortar specimens containing the addition of olive oil mill wastewater, the following actions can be concluded:

Cement concrete (mortar) of higher compression value in compare with the reference mixes can be produced by replacing part of the regular water with the proportions of olive oil mill wastewater.

Adding AR and olive oil mill wastewater to cement concrete (mortar) increase the bending strength.

The best percentage of olive oil mill wastewater that is added to the concrete mixture is 7.5%.

When preparing concrete with fiber and Olive Oil Mill Wastewater, no additives were used, as the Olive Oil Mill Wastewater performed the task of additions.

However, torsion and tensile properties of cement mortar may investigate for specimens after AR with olive oil wastewater addition as well as the effect of adding olive oil mill wastewater on steel reinforcement. Adding olive oil mill wastewater to specimens in presence of basalt sand need to be tested for compression and bending strength as basalt sand can absorb hazardous waste gases.


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