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Effect of Grinded Oil Shale Inclusion on Some Properties of Concrete Mixtures

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Abstract. This study investigates the effect of cement replacement by oil shale grinded powder (OSGP) on the workability, mechanical properties, and durability of concrete. Four mixtures were prepared with OSGP ratios to cement of 0%, 10%, 20%, and 30%. OSGP was prepared by obtained oil shale from Wadi Al-Shallala at the north of Jordan, then grinded to fine particles and passed from 54 micro-meter sieve. X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF), and Scanning Electron Microscope (SEM) tests for OSGP were conducted and the results were displayed. Workability, through slump test, was conducted for fresh concrete specimens after mixing. Compressive strength, flexural strength, and tensile strength were performed at the age of 28 days. The results showed a significant reduction in workability, compressive, flexural, and splitting tensile strengths as oil shale increased in the concrete mixture.

INTRODUCTION

Jordan is ranked as the 6th country in the world with more than 70 billion tons of surficial proven reserves and the deep reserves are estimated tens of multiples thereof for the surface oil shale which located in more than 18 known surfaces and near surfaces deposits. Preliminary studies on Jordan oil shale by the Natural Resource Authority, the Ministry of Energy and Mineral Resources, and Jordan Electric Authority in collaboration with many specialized international companies are pointed toward the use of oil shale [1].

Geological, techno-economic, and pre-feasibility exploitation studies are concluded to use the Jordanian oil shale at both processing technologies: retorting for oil production and direct combustion for power generation [2]. An experimental study was performed on the mechanical and thermal properties of concrete contained oil shale ash (OSA). The results showed that the higher was the level of cement replacement by OSA; the lower was the compressive strength. Also, it concluded that Replacing cement with OSA, even in small amounts, is an effective way to improve the thermal conductivity of concrete mixtures [3]. In the concrete construction materials aspect, a previous study concluded that OSA could be used as an additive in Portland cement concrete to economically produce structural and non-structural concrete with the same range of design strengths as conventional concrete. Also, the use of OSA as a partial replacement of cement or sand in concrete or mortar would contribute to its compressive strength, especially at an optimum replacement level of 10% by weight [3].

Another study was investigated and tested the mechanical, physical, and chemical properties of OSA in various specimens of pastes of ash, cement, and their mixtures. X-ray diffraction and thermo-gravimetric analysis indicated that the ash consisted mainly of calcite, silica, and some calcium silicates, which possess cementations characteristics. The study concluded that OSA showed a good potential for use as an admixture in cement and concrete [4].

For choosing the best type of OSA from the 18 deposits which can be used as concrete cement replacement, this experimental study was performed to investigate the performance of concrete mixtures with 0%, 10%, 20%, and 30% of oil shale grinded powder (OSGP) cement replacement.

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EXPERIMENTAL WORK

Materials

In this experimental study, Ordinary Portland cement used was (OPC type I 42.5N) coming from Northern Cement Company (NCCO) and complying with Jordanian standard specifications (JSS. 30/1979) [5]. Fine aggregate used was locally available crushed aggregates coming from Al-Omari crashing plant which located in Irbid, at the north of Jordan and complying with Jordanian standard specifications (JSS. 96/1987) with particles smaller than 2mm, fineness modulus of 2.25, and specific gravity of 2.55g/cm^3. Coarse aggregate used was locally available crushed aggregates coming from Al-Omari crashing plant which located in Irbid in the north of Jordan and complying with Jordanian standard specifications (JSS. 96/1987) with particles smaller than 38mm, fineness modulus of 7.25, and specific gravity of 2.61g/cm^3. Water used in mixing and curing purposes was clean, fresh, taken from potable water supplies, and complying with Jordanian standard specifications (JSS. 1376/2003). OSGP was an oil shale obtained from Wadi Al-Shallala at the north of Jordan, then grinded to fine particles and passed from 54 micro-meter sieve as shown in Figure 1.

FIGURE 1. Oil Shale Grinded Powder (OSGP)

X-Ray Fluoresce (XRF) results for the chemical composition of OSGP are shown in Table 1.

TABLE 1. XRF results for the chemical composition of OSGP.

Form	Composition	Chemical name	Percentage (%)
C Ca	CaO	Calcium oxide	81.49
C Si	SiO_2	Silicon dioxide	10.41
C Fe	Fe_2O_3	Ferric oxide	1.46
C S	SO_3	Sulfur trioxide	1.37
C Cl	Cl	Chloride ion	0.47
C Sr	SrO	Strontium oxide	0.35
C Zn	ZnO	Zinc oxide	0.07
C Co	Co_3O_4	Cobalt tetraoxide	0.01

Table 1 showed that the content of CaO and SiO_2 were found to be approximately 96% of the total OSGP content. From Jordanian standard specifications (JSS. 30/1979) for OPC type I 42.5N, CaO ratio is more than standards (60% to 67%) while SiO_2 is less than standards (17% to 25%).

Figure 2 indicates X-Ray Diffraction (XRD) patterns for the microstructure of OSGP. Relation between intensity (counts) and 2-theta (degree) was obtained which shows different peaks of different minerals.

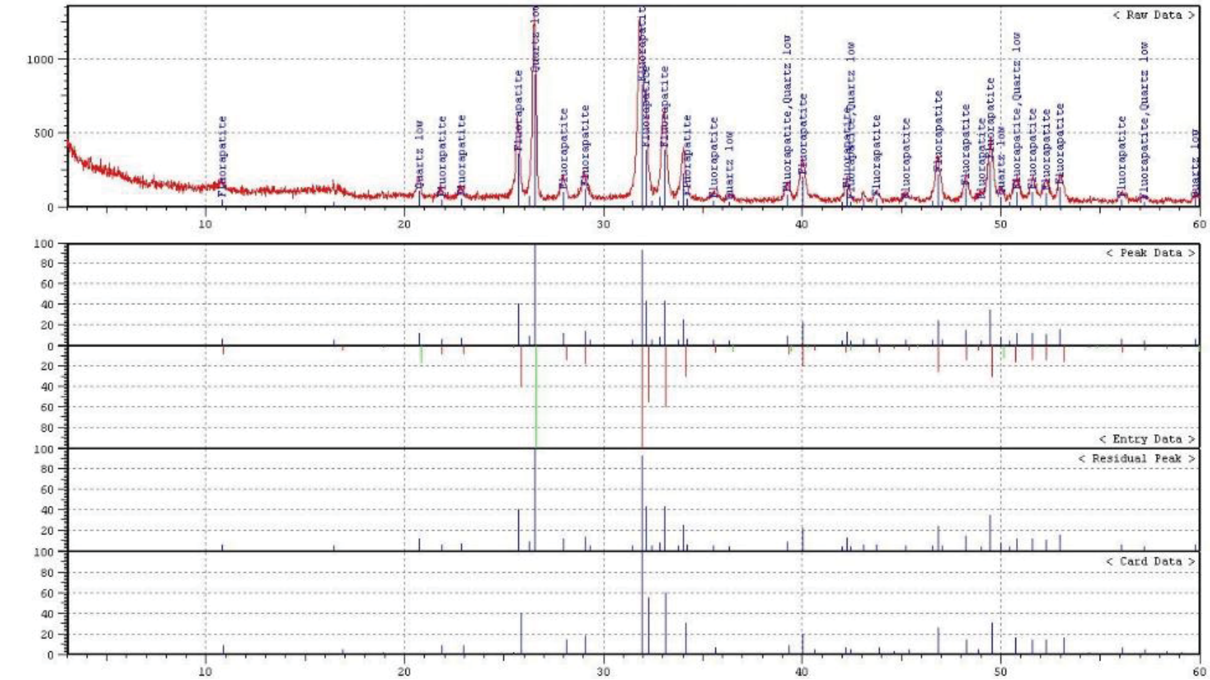


FIGURE 2. XRD patterns for the microstructure of OSGP.

It can be noticed from Figure 2 that the basic mineral phases were fluorapatite, marshite, hydroxylapatite, and silicon with small amounts of strontianite, zincite, and Cobalt III oxide.

Preparation of Concrete Specimens

The mix proportions were based on the absolute volume method according to Procedures outlined in ACI (211.4R) for mixture proportioning [6]. Employing the sequence outlined in that standard practice, the quantities of ingredients per cubic meter of concrete are given in Table 2.

TABLE 2. Mix proportion of concrete mix design.

Mix proportion (kg/m^3)			
Cement	**Fine Aggregate**	**Coarse Aggregate**	**Water**
407.3	537.5	1053.8	217.5

OSGP with a ratio of 0%, 10%, 20%, and 30% by weight of cement was used and the different concrete specimens are given in Table 3.

TABLE 3. Mix proportions of concrete specimens.

Concrete Designation	Mix proportion (kg)				
	Cement	**Fine Aggregate**	**Coarse Aggregate**	**Water**	**OSGP**
OS_0	18.74	24.73	48.47	10	0
OS_{10}	16.86	24.73	48.47	10	1.87
OS_{20}	14.99	24.73	48.47	10	3.75
OS_{30}	13.12	24.73	48.47	10	5.62

Mixing was carried out in a 60 kg revolving electric mixer of pan drum type for three minutes followed by three minutes of rest then two minutes of final mixing. In the mixing process, all dry ingredients were mixed first then the amount of water was added gradually while mixing continued.

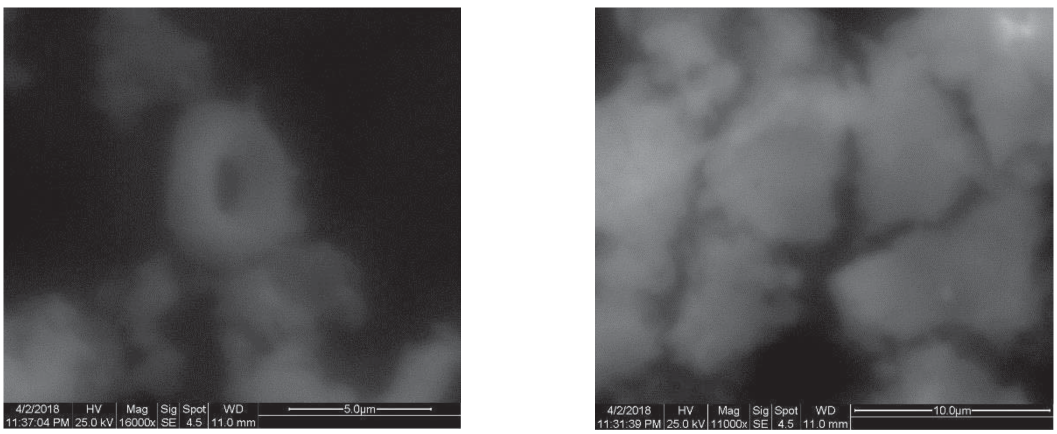
Then fresh concrete was cast into steel molds, before placing concrete the inside of the molds was cleaned and oiled to facilitate demolding. After mixing, slump steel mold was placed over its steel plate and filled with three layers of fresh concrete which tamped 25 times each before removing it and recording the amount of vertical slump [7]. The casting process was done immediately after slump determination. Fresh concretes were cast in cubes of size 15 x 15 x 15cm and in cylinders of size 10 x 20cm for testing in compressive strength [8] and prisms of size 10 x 10 x 50cm for the flexural testing (modulus of rupture) [9] and in cylinders of size 15 x 30cm for testing in splitting strength [10]. A vibrator table was used for compaction. The specimens were demolded after 24hrs then cured in fresh water at 23±2°C for 28 days until testing.

The microstructure of concrete was scanned using a scanning electronic microscope (SEM) JEOL-JSM5500LV and X-Ray diffraction (XRD) tests [11].

EXPERIMENTAL RESULTS

Microstructure Study

Figure 3 displays the SEM micrograph images for OSGP. The powder particles appeared to have structure nano-pores with irregular morphology and a varying particle size distribution due to the process of grinding.



(a) Nano pores (b) Irregular morphology

FIGURE 3. SEM micrograph for OSGP.

Table 1 indicates the X-Ray Fluoresce (XRF) patterns for OSGP. It can be noticed that the two major components in OSGP are calcium oxide (CaO) of Calcite form by 81% of chemical composition and silicon oxide (SiO_2) of Calcite form by 10% of chemical composition.

Workability

The workability of all concrete specimens was measured by the slump test [7]. Table 4 shows the center height decrease of the slumped concrete which contains OSGP.

TABLE 4. Slump test results.

OSGP (%)	Slump (cm)
0	7.6
10	1.7
20	1.4
30	1.0

The inclusion of OSGP reduced the workability of concrete specimens. Reduction in workability was observed from 10% OSGP substitution to 30% OSGP which confirmed the minimum workability among all mixtures.

Due to the calcite smaller particles of CaO (quick lime), more water was needed to slake it into $CaCO_3$ (hydrated lime). With the increase of OSGP concentration, more water decreased which reflects a great impact on concrete workability.

Compressive, Flexural, and Splitting Tensile Strengths

Table 5 designates the compressive strength test results for different concentrations of OSGP concrete cubes and cylinders ranged from 0% to 30% at the age of 28 days.

TABLE 5. Cube and cylinder compressive strength test results.

OSGP (%)	Compressive strength (MPa)	
	Cube	Cylinder
0	41.71	24.51
10	35.79	22.45
20	29.17	19.15
30	25.10	16.72

It can be indicated that the cube compressive strength decreased by 14%, 30%, and 40% of 10%, 20%, and 30% OSGP replacement, respectively.

Table 6 explains the flexural strength test results for different concentrations of OSGP concrete prisms ranged from 0% to 30% at the age of 28 days.

TABLE 6. Prism flexural strength test results.

OSGP (%)	Prism flexural strength (MPa)
0	5.21
10	5.07
20	4.54
30	4.10

It can be noticed that the modulus of rupture decreased by 3%, 13%, and 21% of 10%, 20%, and 30% OSGP replacement, respectively.

Table 7 shows the splitting tensile strength test results for different concentrations of OSGP concrete cylinders ranged from 0% to 30% at the age of 28 days.

TABLE 7. Cylinder splitting tensile strength test results.

OSGP (%)	Cylinder splitting tensile strength (MPa)
0	3.52
10	3.22
20	2.55
30	2.44

It can be seen that the splitting tensile strength decreased by 9%, 28%, and 31% of 10%, 20%, and 30% OSGP replacement, respectively.

DISCUSSION

The previous results showed a significant reduction in compressive, flexural, and splitting tensile strengths as OSGP increased in the concrete mixture. This can be attributed to the existence of the quick lime (CaO) by more than 80% as the major components in OSGP which tend to absorb a high amount of water to slake it into hydrated lime ($CaCO_3$) and reduce the amount of water that reacts with cement resulting with low workability and hydration of cement.

CONCLUSION

In this study, the performance of concrete mixtures with 0%, 10%, 20%, and 30% of oil shale grinded powder (OSGP) cement replacement, from Wadi Al-Shallala at the north of Jordan, was measured at the age of 28 days. According to the experimental results, the following conclusions could be shown:

- Based on fresh concrete results, workability decreased from 78% to 87% with increasing of OSGP.
- At the age of 28 days, concrete mix without OSGP replacement ratio had the highest value of compressive strength for cube and cylinder specimens by 41.71 MPa, and 24.51 MPa, respectively.
- For flexural strength prism specimens, concrete mix without OSGP replacement ratio had the highest value at the age of 28 days by 5.21 MPa.
- Concrete mix without OSGP replacement ratio had the highest value for splitting tensile strength cylinder specimens by 3.52 MPa at the age of 28 days.
- It is not recommended to use the OSA type obtained from Wadi Al-Shallala at the north of Jordan deposits in case of concrete cement replacement.

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REFERENCES

1. Ministry of Energy and Mineral Resources, (Mineral Status and Future Opportunity, Oil Shale, 2015).
2. M. Al-Hassan, "Behavior of concrete made using oil-shale ash and cement mixtures," (Estonian Academy Publishers, 2006), Vol. 23, No. 2, pp. 135-143.
3. M. M. Smadi and R. H. Haddad, "The use of oil shale ash in Portland cement concrete," (Cement and concrete composites, 2003), vol. 25, Issue. 1, pp. 43–50.
4. M. Smadi, A. Yeginobali, and T. Khedaywi, "Potential uses of Jordanian spent oil shale ash as a cementing material," (Magazine of concrete research, 1989), Vol. 41, Issue. 148, pp. 183–90.
5. A. H. E. Salama, "Effect of eggshell powder solution on some properties of cement mortar," Eighth international conference on advances in civil, structural, and mechanical engineering. (CSM, 2019), pp. 27-30.
6. ACI 211.4R-993, "Guide for selecting proportions for high-Strength concrete with Portland cement and fly ash," (ACI manual of concrete Practice), American concrete institute.
7. ASTM C143/C143M-12, "Standard test method for slump of hydraulic-cement concrete," (American society for testing and materials, Philadelphia, 2012).
8. ASTM C39/C39M-14, "Standard test method for compressive strength of cylindrical concrete specimens," (American society for testing and materials, Philadelphia, 2014).
9. ASTM C78-02, "Standard test method for flexural strength of concrete (Using simple beam with third-point loading)," (American society for testing and materials, Philadelphia, 2002).
10. ASTM C496-04, "Standard test method for splitting tensile strength of cylindrical concrete specimens," (American society for testing and materials, Philadelphia, 2004).
11. L. E. Copeland and R. H. Bragg, Anal. Chem. **30**, 196-201 (1958).