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Characterization and Possible Industrial Applications of Tripoli Outcrops at Al-Karak Province.

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Abstract

Tripoli layers outcropping at the old village of Aynun, 10 km south of Al-Karak city is embedded within Wadi Um Ghudran Formation of lower Cretaceous age. The area has the richest deposits in Al-Karak province and is minable because of the uninhibited possible mining sites and low overburden thickness.

Tripoli layers varied in thickness from 3-12m.It is composed mainly of high SiO_2 (up to 93 wt%). Quartz is the essential component. The physical properties of tripoli (bulk density, specific gravity, water adsorption and size distribution) are suitable for its use as a filler and filter. The whiteness (82%) makes tripoli suitable for us in manufacturing external paint.

The effect of partial replacement of the components of ordinary Portland cement by tripoli on the compressive strength, setting time, soundness and normal consistency has decreased the compressive strength. Replacement of cement by tripoli in mass ratios of 10%, 20%, and 30% has decreased the 28-days compressive strength of mortar cubes by 6.2%, 14.7%, and 32.1% respectively. The volume of mix water required to produce a paste of normal consistency has increased with increasing the ratio of tripoli in the paste. The increasing ratio of tripoli in the paste did not affect the setting time nor the soundness of the paste.

Keywords: Tripoli;Al-Karak;Cement Paste; Compressive Strength; Soundness.

1. Introduction

The government of Jordan is encouraging the foreign investment in the sector of mining and natural products industry, because it is the type of investment that can generates large number of employments and increases the country export yields. Within this frame The main concern of this study is to investigate tripoli as a natural raw materials for possible use in various industries.

Tripoli is a soft, very fine grained, earthy material that is nearly pure silica. It is known in trade market as (soft silica) (Wileborn, 1994). The annual World production is about 30 million tons, 30-50% is used as an abrasive (Kogel et al., 2006). The largest deposits in the world are in USA at Missouri, Oklahoma and Illinois (Gensen & Bateman, 1981). Tripoli is also found in Europe such as France, Germany, and UK. Tripoli in Jordan is crypto-crystalline silica; white, very fine, soft powdery form, light-friable (Khoury, 2006). It is found as permeable and highly porous beds with some chert nodules (El-Hasan & Al-Hamaidah, 2011). Jeresat & Bashir, (1972), studied the tripoli occurrences in Madaba and Tafila. Al-Omari (1975), described the Tripoli deposits in El-Shahabiyah and Aynun at Al-Karak area. He found the SiO_2 content is more than 92%. Khoury (1986) analyzed samples from Al-Karak and Amman and reported the presence of amorphous silica phase. The adsorption capacities of Tripoli in removing heavy metal from aqueous solutions were studied by (Al-Omari, 2003; El-Hasan et al., 2009, and Al-Ghezawi et al., 2010). Khoury (1987) discussed the origin of Tripoli and concluded that tripolization of chert is another process associated with tripolization of limestone. Khoury (1990), explains the nomenclature overlap between tripoli and porcelanite, and concluded that tripoli is different from porcelanite in composition and texture. Alden, 2011 has mentioned that tripoli is high purity silica (SiO_2) that readily breaks and is easily reduced to fine powder. He the origin of tripoli as a result of leaching of calcium carbonate from the Upper Division of the Arkansas Novaculite leaving residual re-crystalline silica. Triploi is classified in the USA under the the natural abrasives sector based on a hardness less than 5.5 (Wileborn, 1994).

Tripoli outcrops at Al-Karak province bears economic quantities (Khoury, 2006, El-Hasan and Al-hamaideh, 2011). Tripoli reserves in central Jordan were estimated 1 million m^3 in the sheet area of Al-Karak alone (Technostone, 1983). However, they found that exploitation was not economic due to higher production cost comparing with revenues at that time. While according to (Kogel et al., 2006), the USA is the world number one in tripoli production of 68,800 ton/year this figures were in the year (2003), at an average price equal to 257$/tone. Therefore, under this World prices Al-Karak tripoli seems to be much feasible.

The following work aims to carry out geochemical and mineralogical characterization of the tripoli in at Aynun area. Tripoli was added as a cement paste replacing agent. The concrete was tested for engineering properties such as compressive strength, soundness, consistency, soundness and setting time.

2. Study Area Settings:

The investigated area of Aynun is located 10 km to south-southwest of Al-Karak city (Fig. 1). The geological map of Al-Karak area (map sheet No. 3152 III) indicates four main sites of tripoli deposits; El-Shahabiyah, Aynun, Rakeen and Tafilah road (Wadi Falqa) (Powell, 1987),. Aynun area was chosen as potential production area because it has higher outcropped thicknesses, lower overburden and relatively uninhibited areas.. The investigated site belongs to the upper Cretaceous Period and namely Wadi Ghudran Formation (WG) (Coniacian age) and Amman Silicified Limestone (ASL) of Coniacian – Santonaian age.

The detailed lithology of WG formation shows that it is composed of sequence of white-buff chalk; its thickness reaches up to 84m and composed of chalk, dolomitic and phosphatic siliceous sandstone, grey chert, chalky-laminated tripoli, and chalk with thin chert beds. The thickness of ASL Formation is 80 m and is composed of thick auto-brecciated chert, inter-bedded with phosphatic limestone, coquina limestone and phosphatic chert (Powell, 1987).

Tripoli outcrops (12 m thick) are bedded, finely laminated soft deposits with relicts or nodules of pale chert (Fig. 2). The soft tripoli spreads laterally and become bedded chert within few hundred meters. It is most likely to be of late diagenetic origin resulted after the alteration of chert with high proportion of carbonate, which might be due to slightly acidic groundwater flow (Khoury, 2006 and Alden, 2011).

3. Materials, Analyses and Experimental Design

Tripoli rock samples were collected from Aynun area and were analyzed geochemically using XRF instrument model (S4 Pioneer / Minibruker) at the Natural Resources Authority (NRA). The physical properties of tripoli were tested for size distribution, density, , specific gravity, water and oil absorption capacity Whiteness test was done using the instrument (Pincher PN-488) available at the NRA.

The mineralogical investigation was done to three tripoli samples from Aynun area by using XRD instrument model (XPERT MPD) available at the NRA.

The Ordinary Portland Cement (OPC= obtained from the Jordan cement industry company of Lafarge) was used. The cement is classified as CEM-1 42.50 N according to the specification of the European Committee for Standardization (CEN).

Sand filler used in the experiments is the same that is used for testing in Jordan cement industry. It is a natural sand standard, consisting of rounded particles and with silica content not less than 98%. The sand particle size distribution limits are defined according to the British Standards. The sand sample was delivered in plastics bags weight of (1350±5) grams. Tap water was used.

4. Experimental set up and procedure:

Cement paste was partially replaced by tripoli in three mixture ratios of 10, 20, and 30% by weight. Mortar cubes were made and their compressive strength and other parameters were determined with setting time of 2 and 28 days. OPC mortar cubes were made as reference samples. Each mortar mix was prepared from 1350 grams of standard sand and 450 grams of binder (cement and tripoli) as shown in Table (3). The mortar was mixed for 4 minutes in a laboratory ELE mixer. The weight ratios of (water: binder: sand) were (0.5: 1: 3) were kept constant for all samples. A total number of twelve mortar cubes, three cubes from each binder mixture were tested at each setting time to study the effect of tripoli addition and curing time on compressive strength and other parameters. The compressive strength of the mortar cubes was measured using ELE testing machine. The recorded value is the average of three values for each age. Before determining the setting time of the binders, the normal consistency for each binder paste was determined. Twelve binder paste samples (three samples from each mixture) were tested for setting time using vicat apparatus.

5. Results and Discussion

The results have indicated that the tripoli of Aynun has a very high SiO_2 % content which is above 92 wt%, with Al_2O_3, Fe_2O_3 and TiO_2 impurities. Moreover, the average CaO% is 2.57wt% (Table 1). The physical properties results have indicated that the bulk density of tripoli equals to 0.6 g/cm^3, the specific gravity equals 2.3-2.5, the water absorption capacity 48% - 61% and the oil absorption medium was good (30%), which makes it suitable to be used as a filler and filter.

Table 1. XRF analytical results for selected tripoli samples from Aynun area. (all are in weight %)

	Aynun-1	Aynun-1	Aynun-1	Max	Min	Mean
SiO_2	92.79	92.88	92.88	92.88	92.79	92.84
Al_2O_3	1.04	0.94	0.93	1.04	0.93	0.98
Fe_2O_3	0.06	0.08	0.10	0.06	0.10	0.08
TiO_2	0.006	0.006	0.006	0.006	0.006	0.006
Na_2O	0.21	0.23	0.25	0.25	0.23	0.24
K_2O	0.48	0.47	0.48	0.48	0.47	0.48
MgO	0.40	0.37	0.40	0.40	0.37	0.39
CaO	2.61	2.52	2.57	2.61	2.52	2.57
MnO	0.001	0.001	0.001	0.001	0.001	0.001
P_2O_5	0.06	0.06	0.06	0.06	0.06	0.06
LOI	2.38	2.42	2.40	2.43	2.38	2.41

The sieve analysis shows that the lower than 0.074 mm size fraction is 98.2%, the less than 0.01 mm is 76.1%. The size distribution makes tripoli suitable as abrasive material, ceramic and paint industries.

Tripoli of Aynun is not very white Table (2), but it has relatively high whiteness degree with an average of 81.77%, The high whiteness degree makes tripoli powder suitable for paint manufacturing, The higher bulk density makes it also suitable for the outdoor paints because of its high resistant to weathering. The XRD results have indicated that tripoli is composed of quartz as shown in (Fig. 3).

Table 2. Whiteness analysis for a selected tripoli samples from Aynun area.

Sample Name	Whiteness %
Aynun-Tripoli-1	82.6
Aynun-Tripoli-2	81.3
Aynun-Trpoli-3	81.4

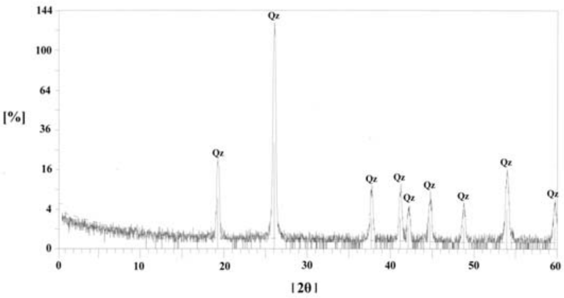

Fig. 3. XRD chart for a selected tripoli sample from Aynun study area.

The chemistry is quite different from OPC mainly in SiO_2, Al_2O_3 and CaO contents as shown in Table (4).

Table 4: Chemical composition of tripoli and Ordinary Portland Cement.

Component	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O
Cement	19.94	5.37	3.18	63.65	2.59	0.82	0.1
Tripoli	92.84	0.98	0.08	2.57	0.39	0.48	0.21

The addition of tripoli to the mixture will deviate its chemical composition from normal OPC. The estimated volume of water required to produce pastes of normal consistency for binders containing tripoli ratios of 10, 20, and 30% has increased by 2, 3.3, and 6.3 ml respectively compared with binders containing 0% tripoli (Fig. 4).

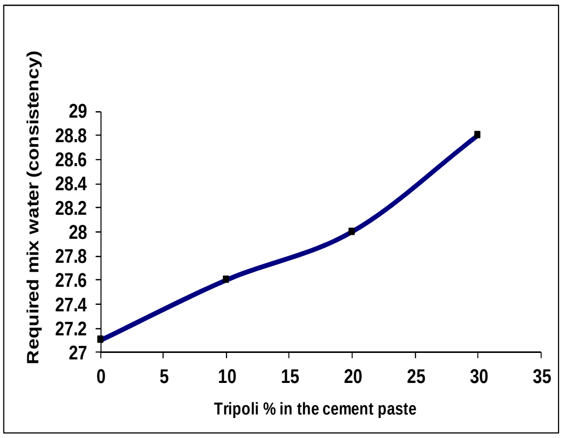

Fig. 4. The relation between tripoli % in cement paste and water consistency.

This is related to the presence of excessive quartz which is not soluble and not reactive as lime in the hydrated OPC. The effect of partial replacement of cement by tripoli on the compressive strength of the concrete can be established by comparing the measured values for a given curing time and ratios as indicated in (Fig. 5).

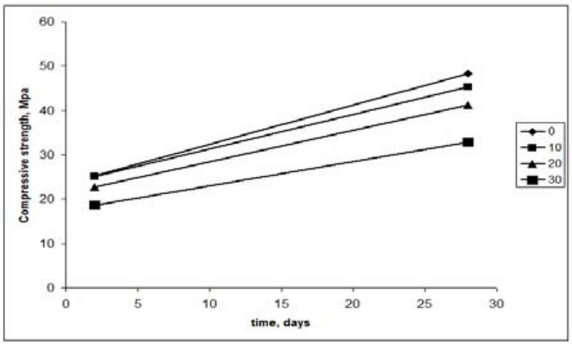

Fig. (5): Effect of replacing cement by tripoli on the compressive strength of mortar cubes

One can observe that the compressive strength increases with increasing curing time and decreases with increasing tripoli mix ratio. The increase of compressive strength with time is due to the continuous hydration reactions of cement. The addition of tripoli increases the silica content at the expense of lime which is responsible for the cementing and strength properties (Table 5).

Table 5: Chemical composition of binder containing different ratios of tripoli

TRIPOLI % In Cement paste	Components						
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O
0	19.94	5.37	3.18	63.65	2.59	0.82	0.10
10	27.23	4.93	2.87	57.54	2.37	0.79	0.11
20	34.52	4.49	2.56	51.43	2.15	0.75	0.12
30	41.81	4.05	2.25	45.33	1.93	0.72	0.13

Therefore, the replacement of cement by tripoli in mass ratios of 10, 20, and 30% has decreased the 28-days compressive strength of the concrete cubes by 6.2, 14.7, and 32.1% respectively. These results are in good agreement with previous results for oil shale ash replacing the OPC obtained by (Al-Hamaiedeh et al., 2010), where the compressive strength has decreased by 7.4, 11.7, and 23% due to replacement of cement by oil shale ash in ratios of 10, 20, and 30% respectively.

The reduction in the compressive strength caused by the addition of tripoli decreases with setting time. The compressive strength gaining of concrete with tripoli is slower than that of mortars without tripoli. The low development of compressive strength is probably related to the increase of silica content at the expense of lime. It is expected that an increase of compressive strength with tripoli might occur with longer curing time.

The presence of tripoli in the binder in ratios of 10, 20, and 30% did not increase the setting time (Fig. 6).

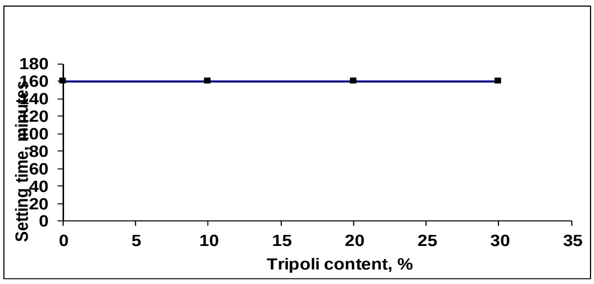

Fig. 6.The relationship between tripoli content in cement past and the setting time

This situation is related to the absence of reaction of water with tripoli in comparison lime. However, the increase of tripoli ratio decreases the amount of reactive CaO in binders (Table 5) that causes some negative effects on formation of calcium-silicate-hydrate (C-S-H). The Le Chatelier experiment was made to study the expansion of binder pastes (soundness) containing different ratios of tripoli. The results of the Le Chatelier experiment shows that the expansion of concrete containing tripoli was not significant and do not exceed the standard value of 10 mm stated by British Standards (BS, 1995) (Fig. 7).

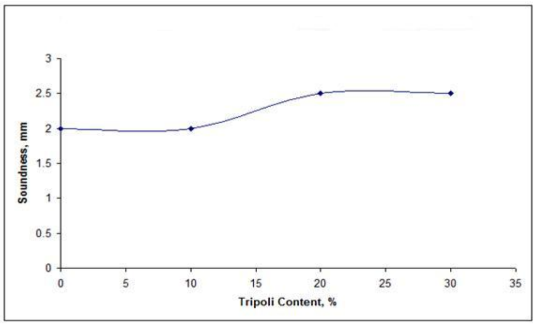

Fig. 7. The relationship between tripoli % in cement past and the soundness.

6. Conclusions

The results of the conducted experiments have indicated that the higher is the level of OPC replacement by tripoli, the lower is the compressive strength. The longer is the curing period, the higher is the compressive strength. Replacing cement by tripoli, did not affect the setting time of concrete. The increase of the tripoli cement ratio has slightly increased the soundness and did not exceed the allowable limits with tripoli content up to 30%. Therefore, the results of the conducted experiment proved the possibility of replacement of OPC by tripoli in ratios up to 20% without causing significant effects on the studied properties of cement. Comparing with oil shale ash, tripoli shows better compressive strength, setting time and good soundness, due to its lower sulfur content. The investigation showed that tripoli deposits at Al-Karak province and particularly Aynun area are feasible to undergo further mining and manufacturing for use as a filler and abrasive material due to its quantity, availability at surface (lower overburden), beside its preferable mineralogical and geochemical properties.

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References

[1] Alden, A. (2011): Abrasive minerals, http:// geologz.about.com/bio/Andrew-Alden-453.html.

[2] AL-Ghezawi, N., Al-Anber, M., Al-Anber, Z., El-Hasan, T. And Al-Momani, I. (2010): Decontamination and adsorption modeling of aqueous Pb+2 and Co+2 ions using natural inorganic materials: Tripoli (NT) and Bentonite (NB), Desalination and Water Treatment 24 (2010) 336–343.

[3] Al-Hamaidh, H., Maaitah, O. and Mahadin, S. (2010): Using Oil Shale in Concrete Binder. EJGE, 15:601-608.

[4] Al-Omari, H. (2003): Study of the Adsorption of (Ni) and Cu(II) by Tripol, Mutah Lil-Buhuth wad-Dirasat, Vol. 18, No. 1, 77-94.

[5] Al-Omari, K. (1975): The Triploi prospects of Ainun and El-Sh-habiyeh, NRA, Internal Report, Amman. Saadi , T.(1968): Tripoli, NRA, Internal report, Amman.

[6] El-Hasan, T., Al-Anbar, Z., Batarseh, M., Al-Naser, F., Al-Anbar, M, Ziadat, A.., Kato, Y. and Jiries, A (2009): Removal of Zn^{+2} Cu^{+2} and N^{+2} ions from aqueous solutions via Tripoli: Simple component with single phase model. Current World Environment. 3(1): 1-14.

[7] El-Hasan, T. & Al-Hamaidah, H. (2011): Occurrences, characteristics and possible industrial applications of Tripoli rock outcropping at Al-Karak province. 2^{nd} International Conference In Materials On Jordan, Abstract Book, Page 62.

[8] Gensen, M.L. and Bateman, A.M. (1981): Economic Mineral deposits Network. John Wiley & Sons.

[9] Jeresat, K. & Bashir, S. (1972): The Tripoli occurrences between Madaba and Tafila, NRA, Internal Report, Amman.

[10] Khoury, H (1990): The discovery of diatomite in Jordan, Unpublished Report, University of Jordan (in Arabic).

[11] Khoury, H. (2006): Industrial rocks and minerals in Jordan, Publication of the University of Jordan (in Arabic).

[12] Khoury, H. (1987): Tripolization of chert in Jordan, Sediment. Geol. 53:305-310.

[13] Khoury, H. N., (1986): The origin of tripoli in Jordan. Sediment. Geol., 48, 223-235.

[14] Kogel, J. E., Trivedi, N.C., Barker, J. M. and Krukowski, S.T. (2006): Industrial Minerals and Rocks, commodities, markets and uses. 7^{th} edition. SME, pp. 1570.

[15] Powell, J. (1987): The geology of the Karak map sheet area, NRA. Amman. Unpublished report.

[16] Technostone SpA, Carrara (MS) (1983): Project for the development of no-metallic minerals industry in Jordan – Italian Foreign Affairs Ministry Project.

[17] Wileborn, W.W., (1994): Abrasives. In: Industrial Minerals and Rocks, 6^{th} Ed. Edited bz D.D. Carr Littleton, Co, SEM. 497-507.