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Harmful Materials in Scoria Lightweight Aggregates, Harrat Rahat, Al Akhal area, South of Al Madinah Al Monawarah, West Central Arabian Shield, Saudi Arabia.

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Abstract-The study aims to clarify the effect of the fine harmful clay fractions in the engineering characters of the scoria deposits. The study is based on mineralogical data and engineering measurements of scoria collected from four main area. The results of the clay minerals identification revealed that, one sample from Jabal al Khayalah contain clay minerals (montmorillonite and kaolinite), the clay minerals are common in the samples from Gabal Umm Furayqayn and Umm al Amad and the lowest clay minerals occurrence is reported in the samples from Jabal al Khayalah and Gabalal Hirshan. The results of the study also confirm the presence of montmorillonite in the black scoria of Gabal Umm Al Amad. The obtained results of clay minerals identificationas well as the associated friable particles revealed that, the values are within the acceptable standard specification limits except that of Gabal Umm Al Amad where it contains montorillonite. Except Gabal Umm Al Amad aggregates, all the samples of the other areas are complying with the specification limits as the materials passing sieve No 200 should not exceed 1% and 3% for the coarse and fine aggregate. The obtained result of the sand equivalent can be considered acceptable as the sand equivalent value should exceed 75% for the fine aggregate. The scoria aggregate from the four sites are free from organic impurities. The results of study revealed that, the amounts of harmful materials are within the acceptable specification limits for three of the four selected sites. It is strongly recommended that weathered zones of scoria should be avoided.

Index Terms- Harrat of Saudi Arabia, Scoria, insulating masonry bricks, Structural/Insulating concretes, Lightweight aggregates.

1 INTRODUCTION

THERE is a huge quantities of scoria lightweight aggregates were used in the production of insulating masonry bricks, and structural or insulating concretes. These new products find a great demand from public and government, in order to reduce the cost of energy. It was decided to study the possibility of the existence of clay-like materials and organic impurities within the source of fresh layers of scoria as failure in these products will occur due to the existence of plastic fines because these minerals expand and contract upon moisture fluctuations.

The use of weathered and altered scoria lightweight aggregates in constructions may cause premature failures in-service. Many authors .i.e. [1], [2], [3], [4], [5] relate this failure to the presence of smectite minerals in the used aggregates. Smectite is a fairly common secondary product in the basalt, resulting from low- grade alteration and weathering. The presence of smectite increases drying shrinkage of mortar samples when present in aggregates that were used in concrete [6].

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The studied scoria lightweight aggregate samples were collected from the harrat domains south of Al madinah Al Monawarah (Fig. 1 and Fig. 2A). The samples were collected from four isolated cones, namely Gabal Umm al Amad, Gabal al Hirshan, Gabal Umm Furayqayn and Gabal al Khayalah (Figs. 2B and Figs. 3, 4). The satellite images of the studied areas shows the presence of more than one volcanic episodes. The studied samples are from the younger ones (red color on the satellite images of Figs. 2, 3, 4).

Methods of study

The scoria deposits are carefully described in the field and the samples are selected according to the variation in color and grain size variation. The samples are used in the preparation of thin sections and for the identification of the clay minerals by XRD analyses. The samples are also subjected to the other engineering tests and measurements.

The reported failure mechanisms include the release of plastic fines and the potential of these minerals to expand and contract upon moisture fluctuations. The soundness of aggregates, i.e. existence of smectite minerals and organic impurities for four selected sites were assessed as well the amount of these minerals was determined by using thin sections, XRD analyses, loss on ignition, clay lumps and friable particles, materials finer than sieve No.200, sand equivalent and organic impurities tests.

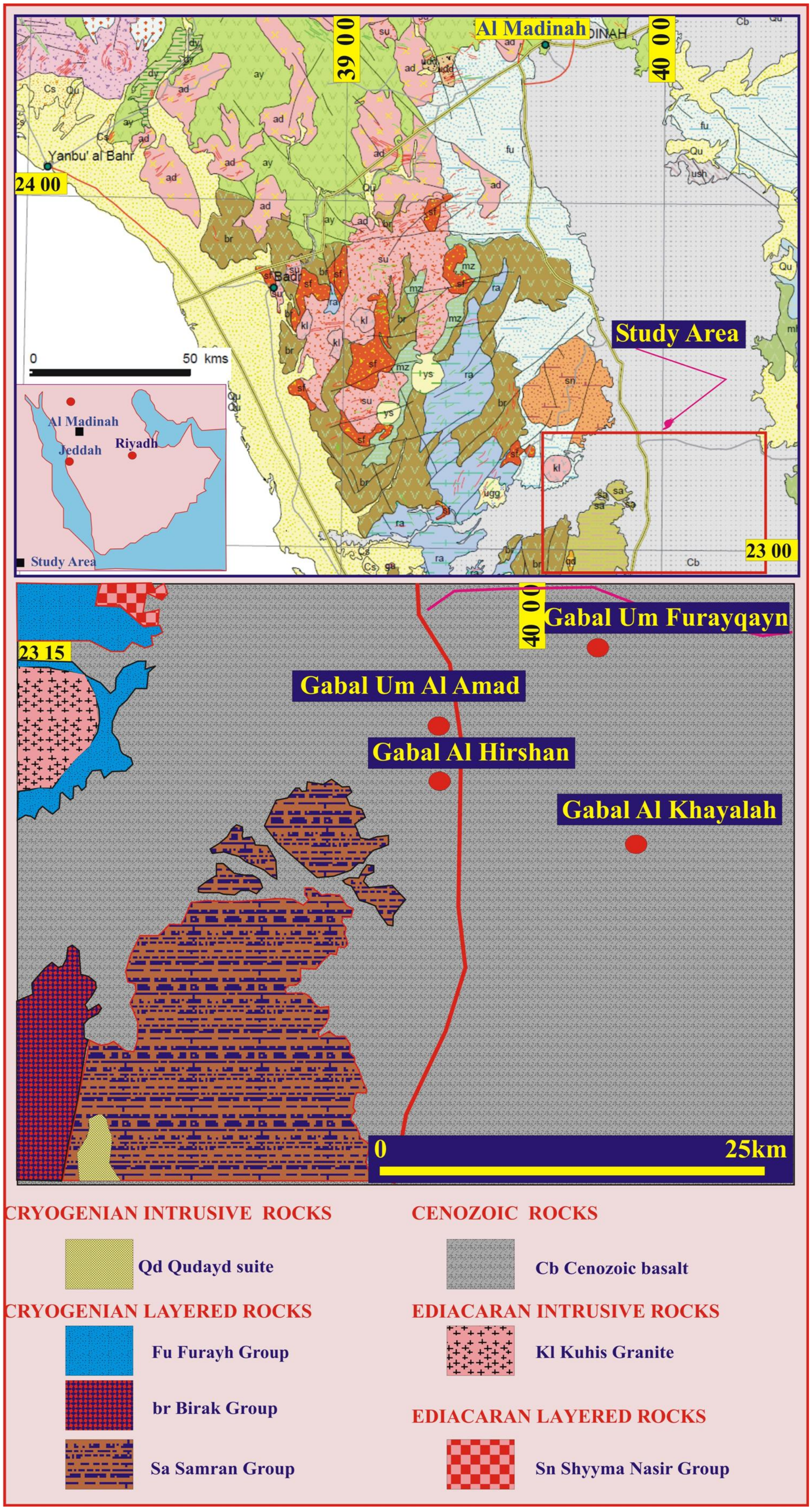

Fig. (1): Geologic map of the study area showing the locations of the studied scoria sites [7].

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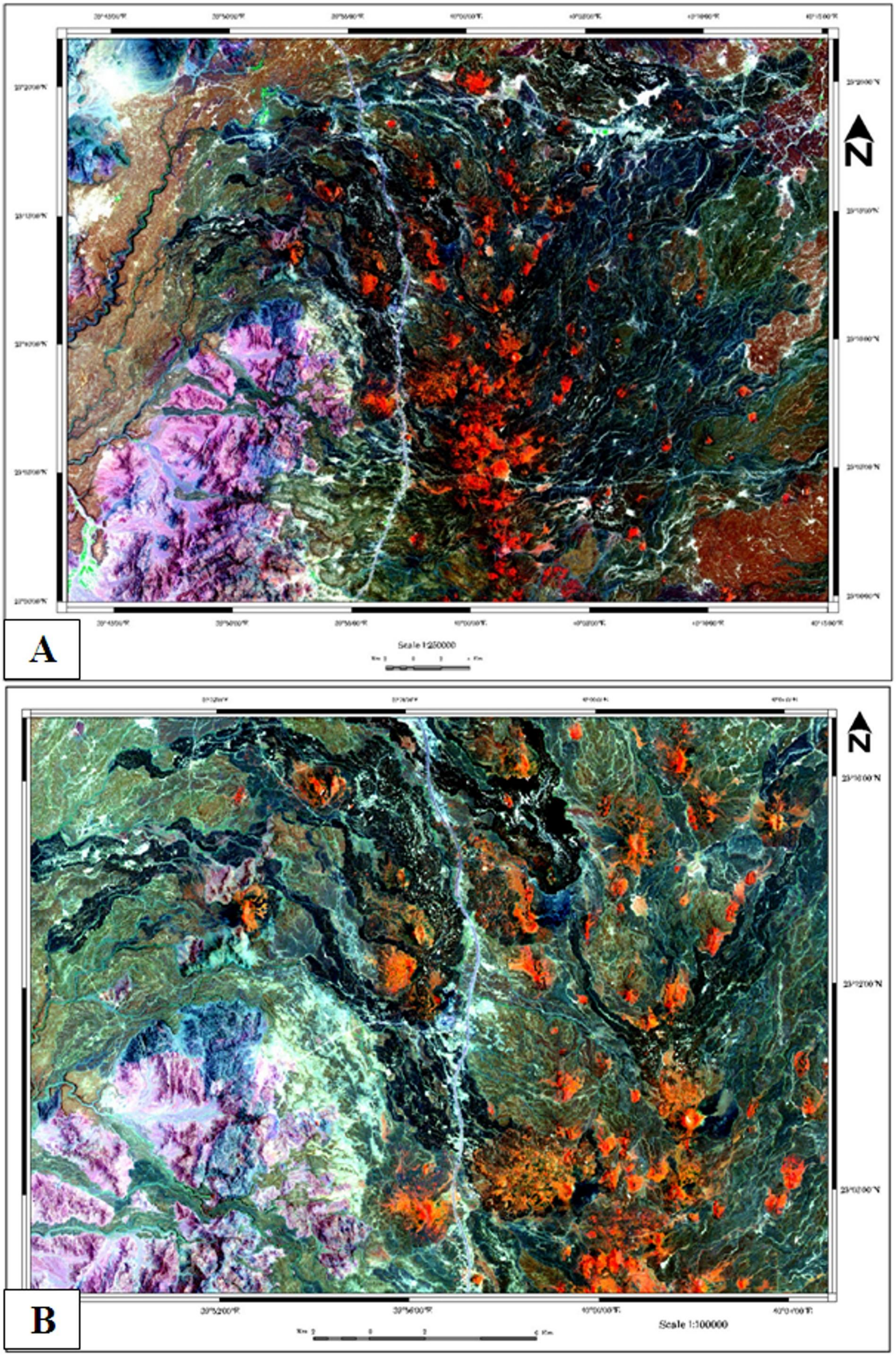

Fig. (2): A= Satellite image of the study area; B= Close-up satellite image of Gabal Al Hirshan area.

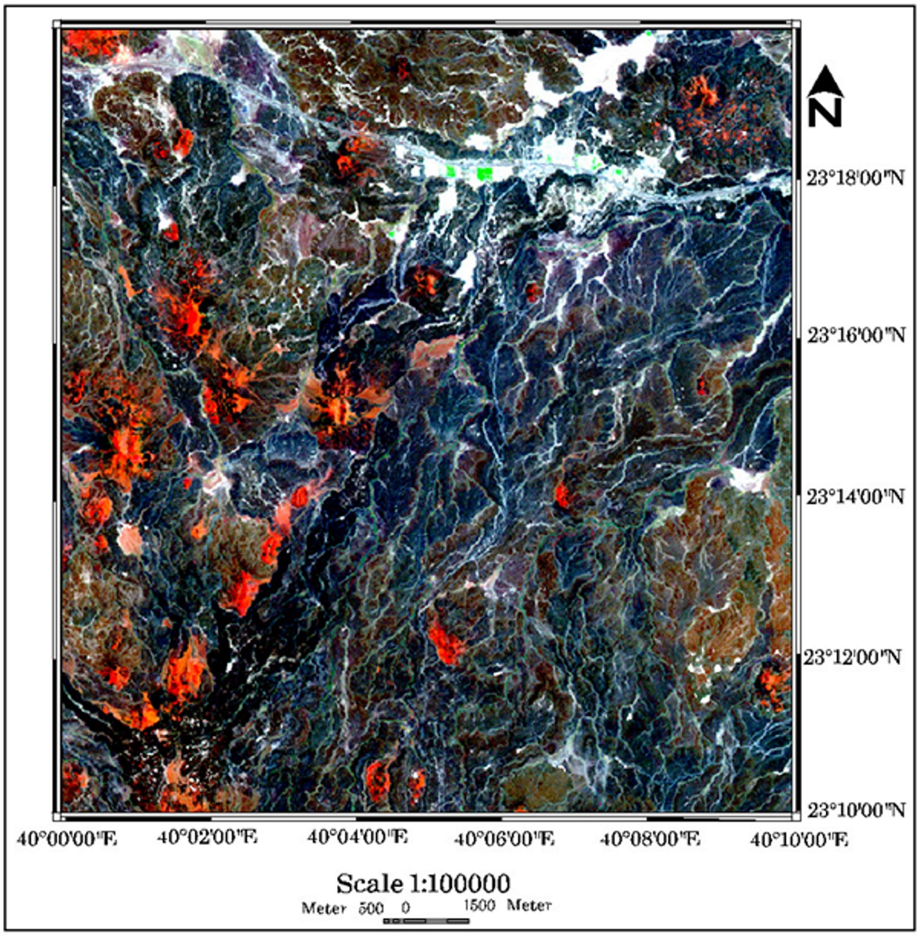

Fig. (3): Close-up satellite image of Gabal Um Furayqyan.

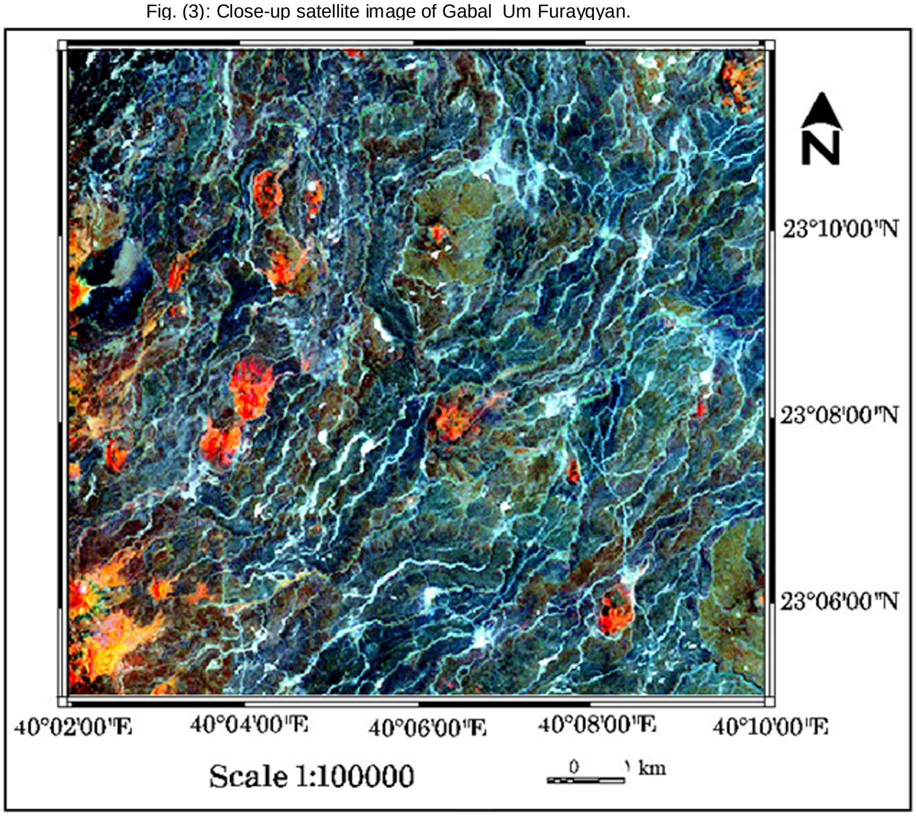

Fig. (4): Close-up satellite image of Gabal Al Khayalah.

2. Mineralogical characteristics of the investigated scoria

The scoria samples used for mineralogical investigations are also used in the engineering geological tests.

2.1. Petrographic description of scoria

Aiming to characterize the investigated samples mineralogically, the samples were subjected to a detailed microscopic study in addition to their analyses by the X-ray diffractometer (XRD). The scoria samples are classified on petrographic basis into vesicular porphyritic basalt and porphyritic basalt, respectively as given in Table 1. The description of these types is given below as follow:

Black Scoria

This type of scoria is of black and brown or yellowish brown color on the weathered surfaces. The scoria contains large vesicles and consists mainly of glassy matrix; the matrix is in the form of sporadic crystals of plagioclase and pyroxene. The vesicles constitute more than 60% of the rock and are of rounded, sub-rounded, ovoid and lobate shapes. They vary in size from 1mm to 3mm. The vesicles are usually isolated but some are connected (Fig. 5A). The groundmass is composed of reddish brown volcanic glass. The vesicles are usually partially filled with carbonates, quartz and amorphous tuffaceous material (Fig. 5B). Some microlites of plagioclase and few crystals of clinopyroxene are present.

Vesicular Porphyritic Basalt

The vesicular porphyritic basalt is the most abundant rock type in the studied scoria. It is composed from glassy groundmass contains abundant plagioclase and clinopyroxene phenocrysts with less frequent opaques (magnetite and ilmenite). The vesicular texture is the most dominant where the vesicles are filled with calcite and quartz (Fig. 5C). The plagioclase is present either as fine-grained euhedral to subhedral prismatic to lathic crystallites or as large crystal forming phenocrysts within the vesicular glassy groundmass. The plagioclase feldspar is twinned and few of them show zoning and reaction boundary (Fig. 5D).

Vesicular Porphyritic Olivine Basalt

The vesicular porphyritic olivine basalt is hemicrystalline and it is composed from a glassy vesicular groundmass contains phenocrysts of olivine, clinopyroxene, calcic-plagioclase (Fig. 5E). The plagioclase feldspar crystals are fine-grained, subhedral with prismatic to lathic shape and are twinned with few displaying patchy and oscillatory zoning (Fig. 5F). The pyroxene crystals (augite) are almost very fine-grained, rarely as subhedral to anhedral phenocryst.

Vesicular Trachytic Basalt

The vesicular trachyitic basalt is fine-grained and it is composed mainly from glassy groundmass contains phenocrysts of plagioclase, pyroxene, and opaques (magnetite and ilmenite) with less frequent small vesicles. The plagioclase feldspar crystals are parallel to each other imparting to the rock a trachytic texture (Fig. 6A). Most of the pyroxene crystals are very fine- grained although some of them form small phenocrysts with anhedral to subhedral outline. Most of the pyroxene crystals occur in the groundmass with yellowish orange interference colors.

Porphyritic Hornblende Basalt

The porphyritic hornblende basalt is composed from a glassy groundmass with abundant phenocrysts of plagioclase, hornblende and microcrystalline crystals of plagioclase, few pyroxene, and opaque minerals (mainly ilmenite and magnetite). Vitrophyric texture is the most common in this rock type (Fig. 6B). Plagioclase occurs in two distinct forms, the first type is fine grained, subhedral to euhedral with prismatic to equant crystals. This type shows both oscillatory zoning. The second type is very fine grained microlites with acicular to prismatic form, and unzoned. Pyroxene crystals are almost very fine anhedral grains. Most of the pyroxene crystals occur in the groundmass and have yellowish orange or yellowish grey interference colors and oblique extinction in the longitudinal section. Hornblende crystals rarely occur as phenocrysts in the groundmass and are observed as irregular brown coarse-grained highly resorbed crystal, (Fig. 6C).

Scoriaceous Basalt

The scoriaceous porphyritic basalt is hemicrystalline with grayish black to black color. It contains abundant rounded to sub-rounded vesicles which give the rock a sieve-like texture. The rock consists of phenocrysts of plagioclase and microphenocrysts of clinopyroxene embedded in a hemicrystalline groundmass of plagioclase, clinopyroxene, magnetite and glassy materials. The plagioclase crystals are present in two distinct forms; the first form is very fine-crystals and is euhedral to subhedral with prismatic to lathic shape. The second form is present as large crystal (phenocrysts) clearly twinned and rarely display zoning (Fig. 6D). The clinopyroxene crystals occur as phenocrysts and as very fine-grained constituent of the groundmass.

2.2. XRD investigation of scoria from the four investigated areas

The use of XRD analyses for the study of extremely fine-grained volcanic rocks is greatly recommended here in order to verify the occurrence of ultra-fine mineral species such as zeolite minerals and feldspathoids, when present. XRD data of all the collected samples are presented in order to have a detailed configuration about the difference in mineralogy among samples from the four investigated areas. In fact, such detailed investigations are a necessity because the presence of some accessory minerals (if present in appreciable percentages) may be harmful for the manufacturing of scoria-based pozzolanic concrete as an insulating material.

Prior to the analysis of samples by the XRD technique, some of the investigated samples were subjected to mineral separation using the heavy liquids and magnetic separators. The purpose of such separation is the exclusion of heavy minerals that mainly comprise forsteritic olivine, pyroxenes and spinels. Because of the great abundance of magnetic minerals (spinels) up to 15 % of the total rock constituents, the yielded light fractions

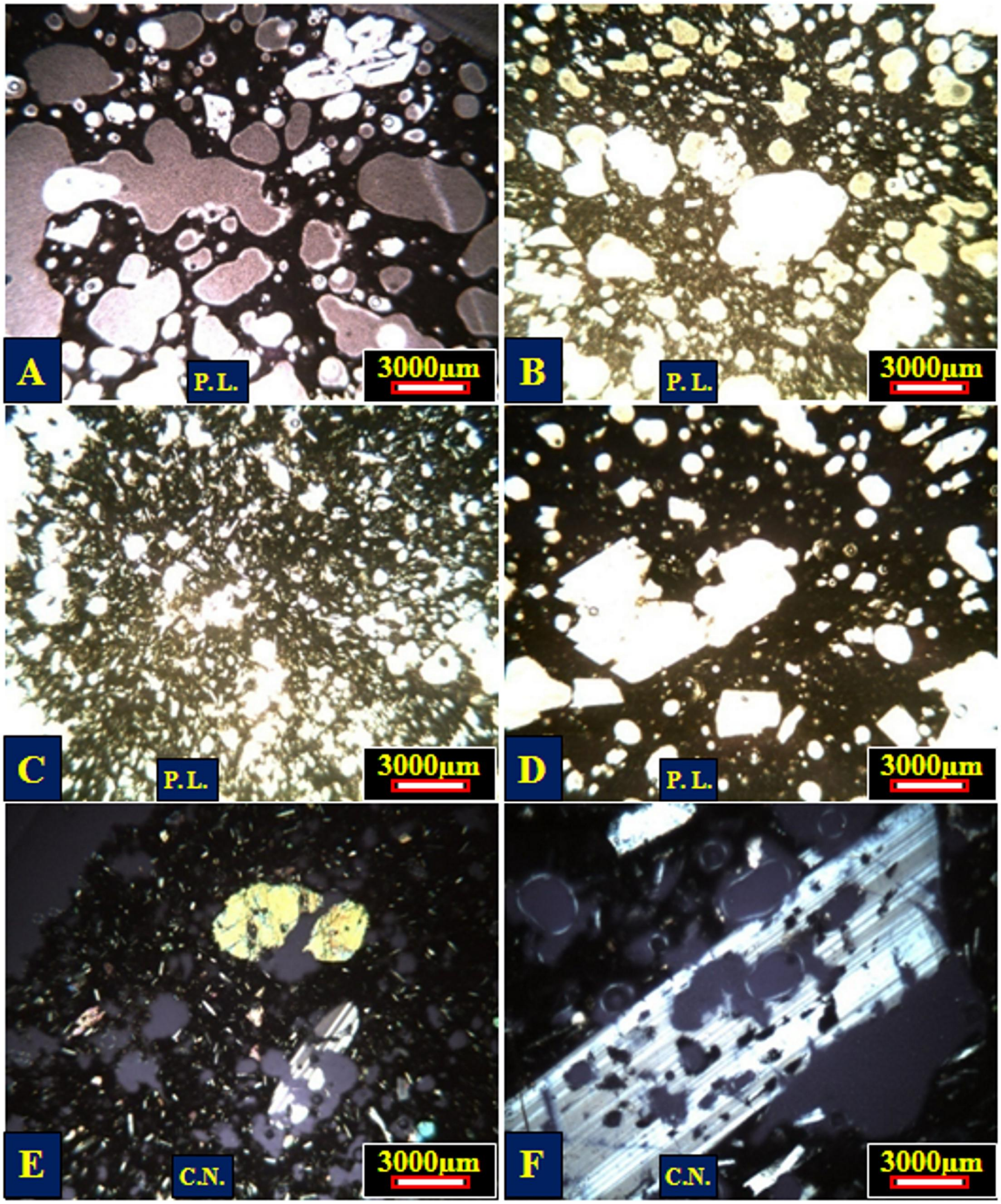

Fig. (5): A= Connected and isolated vesicles in reddish brown glassy groundmass, black scoria; B= Isolated and connected vesicles in black scoria. Reddish brown volcanic glass is the abundant dusty iron oxide forms the groundmass; C= Pyroxene and plagioclase microlites in the vesicular porphyritic basalt; D= Phenocryst of plagioclase with numerous clinopyroxene in the groundmass of the vesicular porphyritic basalt; E= Plagioclase, Olivine, and pyroxene phenocrysts in vesicular porphyritic olivine basalt; F= A reaction rim surrounded a plagioclase phenocryst in vesicular porphyritic olivine basalt. P.L.= Plain Polarized Light; C.N.= Crossed Nicols.

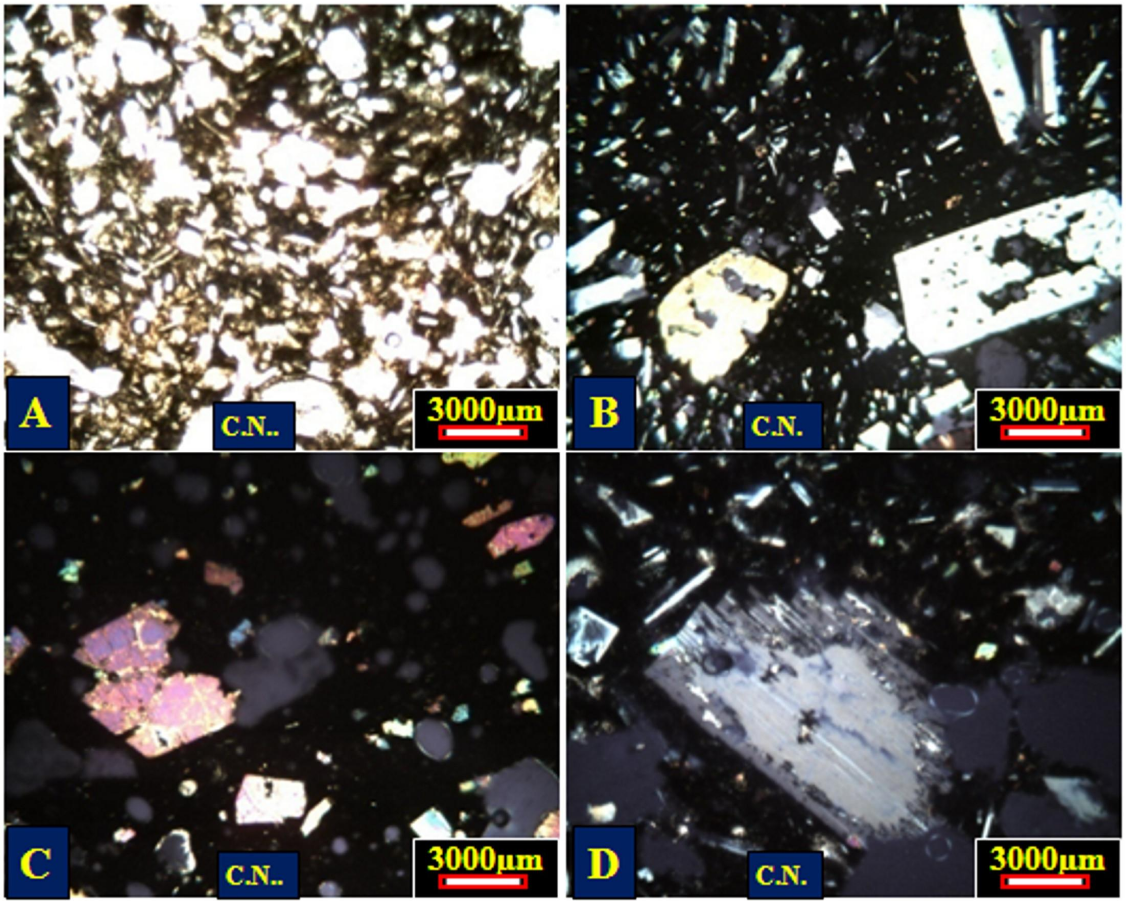

Fig. (6): A= Vesicular, porphyritic and trachyitic textures in vesicular porphyritic trachytic basalt; B= Different shapes and sizes of plagioclase crystals, some bearing-iron minerals and glassy material are placed in a porphyritic to vitrophyric textures, hornblende basalt; C= Coarse-grained highly resorbed hornblende crystal associated with augite and plagioclase crystals in hornblende basalt; D= Plagioclase phenocryst, microlites in scoriaceous porphyritic basalt.

were nearly devoid of magnetic minerals. Nevertheless, the obtained light fractions contain few magnetic minerals, e.g. Ni-bearing pyrite (bravoite, Table 2) that could not be eliminated because its occurrence as minute specks inside light minerals such as labradorite. Table 2 also confirms the occurrence of hematite traces as mineral staining for the felsic components in some samples from the four investigated areas. A single sample from Umm al Amad area (Ua 8) shows traces of chalcocite that may represent an alteration of primary chalcopyrite by oxidation. The transformation of chalcopyrite to chalcocite by low-T oxidation might result in the liberation of iron that gets into solution giving rise to the hematitic staining.

2.2.1. Clay minerals

Table 3 summarizes the occurrence of the recorded clay minerals in the scoria and scoriaceous basaltic samples from the four areas. Based on the tabulated XRD data, it is noticed that the proper black scoria samples from Jabal al Khayalah (Kh 3) and Gabalal Hirshan (Hi 7) contain neither montmorillonite nor kaolinite. On the other hand, the proper scoria sample from Umm al Amad (Ua 1) contains some montmorillonite. The scoria samples and the rest of scoriaceous samples are kaolinite-free with the exception of two samples from Jabal al Khayalah (Kh 2 &Kh 8). The survey of clay minerals from the XRD data indicates hence the following observations:-

1- Only one sample from Jabal al Khayalah (Kh 8) contain both clay minerals (montmorillonite and kaolinite).

2- Clay minerals are common in the samples from Gabal Umm Furayqayn and Umm al Amad.

3- The least clay minerals occurrence is reported in the samples from Jabal al Khayalah and Gabal al Hirshan.

4- Montmorillonite is only recorded in the black scoria sample from Umm al Amad.

2.2.2. Zeolite group minerals

Minerals of the zeolite group are sometimes recorded in the studied volcanic samples (Table 4), especially in the amygdals. From this table, the following aspects can be extracted:

1- No zeolites are recorded in all samples from Jabal al Khayalah.

2- The samples from Jabal Umm Furayqayn show relative enrichment in the zeolite minerals, namely chabazite, heulandite and natrolite.

3- Only one sample from Gabalal Hirshan (Hi 8) contains natrolite.

4- Only one sample from Jabal Umm al Amad (Ua 8) contains Phillipsite .

5- None of the zeolite-group minerals are recorded in the black scoria samples (Kh 3, Hi 7 & Ua 1).

The literature review documented that zeolite-based lightweight concrete gives tremendous flexibility in meeting the engineering requirements, both structurally and non-structurally.

2.2.3. Smectite–group minerals

When dealing with concretes, the effect of smectite on the cohesion must be taken in consideration. In accordance, the present work sheds more light on the abundance and nature of the smectite-group minerals in the raw volcanic samples. Such account aims principally to show the rock varieties with possible shrinkage due to the presence of smectites. The data given in Table 4 show the following remarks:

1- With no exception, the four investigated sites contain smectites, as saponite and nontronite.

2- None of the proper black scoria samples (KH 3, Hi 7 & Ua 1) contain smectites.

The microscopic investigations indicate that, nontronite in the studied samples occurs as an amygdaloidal phase. On the other hand, saponite appears to replace olivine due to low-temperature alteration that might lead to the formation of Fe-Smectite at 60-80°C. Saponite and intrastratified chlorite/saponite are common alterations for continental basalts.

3. Clay Lumps and Friable Particles

The clay lumps and friable particles in coarse aggregate are not allowed in the concrete mix because; they can break up during mixing and thereby absorb some of the mixing water causing pop outs in hardened concrete. It affects the durability and wear resistance. The clay lumps and friable particles content in the coarse aggregate were determined according to ASTM C-142 Designation [8].The results of this test are given in Tables (3).

It has been found that, the clay lump content in the scoria samples for Jabal Umm al Amad ranges between 2.52 % and 2.64 % with an average of about 2.57 %, for Jabal Umm Furayqayn it ranges between 1.52% and 1.72% with an average of about 1.64%, for Jabal al Khayalah it ranges between 1.2% and 1.31% with an average of about 1.26%, while for Gabal Hirshan it ranges between 0.84 % and 1.49 % with an average of about 1.06%.

These obtained values are within the acceptable standard specification limits except in Jabal Umm al Amad samples that are a little higher than the specification limits. Some deleterious substances that are possible in concrete aggregate are listed in Table (4). (WACASPEC, ISG, EM 1110-3-135-84, 2003) [9].

3. 1. Materials Finer than Sieve No. 200

Materials finer than sieve No.200 silt and clay may form a coating on the aggregate particles. Even thin coatings of silt or clay on gravel particles can be harmful because it might weaken the bonds between the cement paste and the aggregate. The test for detecting the presence of materials finer than sieve No.200 was carried out according to ASTM C-117 Designation (ASTM, 2002. The results of this test are given in Table (5).

It has been found that, the materials finer than sieve No. 200 for Jabal Umm al Amad ranges between 2.94 and 5.02 within an average of about 4.15, for Jabal Umm Furayqayn it ranges between 1.04% and 1.92% within an average of about 1.52%, for Jabal al Khayalah it ranges between 1.1% and 1.4% within an average of about 1.267, while for GabalAl Hirshan it ranges between 0.55 and 1.17 within an average of about 0.86. The obtained results indicate that, the scoria samples except Jabal Umm al Amad aggregates are complying with the specification limits as the materials passing sieve No 200 should not exceed 1% and 3% for the coarse and fine aggregate respectively as given in Table (6) (WACASPEC, ISG, EM 1110-3-135-84, 2003).

4. Sand Equivalent

This test is intended to serve as a rapid field correlation test. The purpose of this test is to indicate, under standard conditions, the relative proportions of clay-like or plastic fines and dusts in granular soils and fine aggregate that pass sieve No.4 (4.75mm). Sand equivalence values below 75 % increases the chance of plastic fines being present in the fine aggregate. As the percentage of plastic fines increase the water demand for the mix may increase, potentially reducing concrete strength and durability. The very fine nature of this material puts it in the size range of cementitious materials, thereby competing for the same pore space as the cementation materials potentially reducing strength and durability. Plastic fines can also chemically interfere with the hydration process.

The sand equivalent value test was carried out according to ASTM D-2419 Designation, ASTM, 1995. The results of this test are given in Table (6).

It has been found that, the sand equivalent for Jabal Umm al Amad ranges between 88.76 % and 91.18 % with an average of about 89.59 %, for Jabal Umm Furayqayn between it ranges between 89.52% and 94.2% with an average of about 92.46%, for Jabal Al Khayalah it ranges between 89.64% and 92.75% with an average of about 91.27%, while that for Jabal Al Hirshan it ranges between 97.14% and 98.55% with an average of about 97.89%.

The obtained result can be considered acceptable as the sand equivalent value should exceed 75% for the fine aggregate (WACASPEC, ISG, EM 1110-3-135-84, 2003).

5. Organic impurities

The presence of organic impurities in the scoria aggregate was tested according to ASTM-C 40 Designation, ASTM, 2002. The test method covers the procedure for an approximate determination of the presence of injurious organic compounds in the fine aggregates that are to be used in cement mortar or concrete. The tested specimens indicated that scoria aggregate from the four sites are free from organic impurities.

6. Loss on ignition

The use of weathered and altered scoria as lightweight aggregates in constructions may cause premature failures in-service. Several researchers such as Scott 1955; Van Atta & Ludowise 1976; Wylde 1976; Van Rooy 1991; Lagerblad & Jacobsson 1997 relate this failure to the presence of smectite minerals in the aggregates used. Smectite is a fairly common secondary product in the basalt, resulting from low-grade alteration and weathering. The presence of smectite increases drying shrinkage of mortar samples

Area	Sample No.	Petrographic Name
Jabal al Khayalah (Kh)	Kh 1	Vesicular porphyritic olivine basalt
	Kh 2	Vesicular porphyritic olivine basalt
	Kh 3	Black scoria
	Kh 4	Scoriaceous porphyritic basalt
	Kh 5	Vesicular porphyritic basalt
	Kh 6	Scoriaceous porphyritic basalt
	Kh 7	Vesicular porphyritic olivine basalt
	Kh 8	Vesicular porphyritic olivine basalt
	Kh 9	Vesicular porphyritic trachybasalt
	Kh10	Vesicular porphyritic trachybasalt
Jibal al Hirshan (Hi)	Hi 1	Porphyritic olivine trachybasalt
	Hi 2	Porphyritic basalt
	Hi 3	Porphyritic olivine trachybasalt
	Hi 4	Porphyritic olivine trachybasalt
	Hi 5	Porphyritic olivine trachybasalt
	Hi 6	Porphyritic hornblende basalt
	Hi 7	Black scoria
	Hi 8	Porphyritic basalt
Jabal Umm Furayqayn (Uf)	Uf 1	Vesicular porphyritic trachybasalt
	Uf 2	Vesicular porphyritic olivine basalt
	Uf 3	Vesicular porphyritic trachybasalt
	Uf 4	Vesicular Porphyritic basalt
	Uf 5	Vesicular Porphyritic basalt
	Uf 6	Vesicular Porphyritic basalt
	Uf 7	Vesicular Porphyritic basalt
	Uf 8	Vesicular Porphyritic basalt
	Uf 9	Vesicular Porphyritic basalt
	Uf 10	Black scoria
Jabal Umm Al Amad (Ua)	Ua 1	Black scoria
	Ua 2	Vesicular porphyritic olivine basalt
	Ua 3	Vesicular porphyritic olivine basalt
	Ua 4	Black scoria
	Ua 5	Vesicular porphyritic trachybasalt
	Ua 6	Vesicular porphyritic trachybasalt
	Ua 7	Vesicular porphyritic basalt
	Ua 8	Vesicular porphyritic basalt
	Ua 9	Vesicular porphyritic olivine basalt
	Ua 10	Scoriaceous basalt

Table 1: Petrographic classification of the analyzed scoria lightweight aggregate samples.

		XRD Results		Zeolite and Smectites group minerals						Non-magnetic and poorly magnetic opaque minerals		
Area	No.	Montmorillonite	Kaolinite	Zeolite				Smectites		Hematite	Chalcocite	Bravoite
				Phillipsite	Chabazite	Heulandite	Natrolite	Saponite	Nontronite			
Jabal al Khayalah (Kh)	Kh 1											
	Kh 2		•						•			
	Kh 3											
	Kh 4											
	Kh 5											
	Kh 6											
	Kh 7											
	Kh 8	*	*						•	•		
	Kh 9											
Gabal al Hirshan (Hi)	Hi 1											•
	Hi 2	*						•	•			
	Hi 3											
	Hi 5											
	Hi 7											
	Hi 8	*					•	•		•		
Gabal Umm Furayqayn (Uf)	Uf 1	*			•				•			
	Uf 2	*				•			•	•		
	Uf 3	*					•					
	Uf 5											
	Uf 7											
	Uf 8	*								•		
	Uf 9								•			
Gabal Umm al Amad (Ua)	Ua 1	*										
	Ua 2								•	•		
	Ua 3	*										
	Ua 5	*										
	Ua 7	*										
	Ua 8	*		•				•		•	•	
	Ua 9								•			

Table 2: Clay minerals in the studied scoria lightweight aggregate samples; the occurrence of minerals from the zeolite and smectite groups in the studied samples and the non-magnetic and poorly magnetic opaque minerals.

Sample No.	Size of test sample	Selected Sites			
		Umm Al Amad	Umm Furayqayn	Al Khayalah	Al Hirshan
		Percentage of clay lumps and friable particles			
1	3/8 – No.4	2.52	1.68	1.2	1.49
2	3/8 – No.4	2.64	1.52	1.31	0.84
3	3/8 – No.4	2.56	1.72	1.28	0.84
Average %		2.57	1.64	1.26	1.06

Table (3): Results of clay lumps and friable particles in aggregates for the four selected sites.

Materials	Percentage by weight	
	Coarse aggregate	Fine aggregate
Clay lumps	2.0	1.0
Material finer than No. 200 sieve	1.0	3.0

Table (4): Maximum allowable percentage of some deleterious substances in coarse and fine aggregate (After [9]).

Sample No.	Selected Sites			
	Umm al Amad	Umm Furayqayn	Al Khayalah	Al Hirshan
	Percentage of materials finer than sieve No.200			
1	2.94	1.04	1.4	1.17
2	4.48	1.92	1.1	0.55
3	5.02	1.6	1.3	0.85
Average %	4.15	1.52	1.267	0.86

Table (5): Results of materials finer than sieve No.200 test for the four selected sites.

Sample No.	Selected Sites			
	Umm al Amad	Umm Furayqayn	Al Khayalah	Al Hirshan
	Sand Equivalent %			
1	88.76	93.65	92.75	98.55
2	91.18	89.52	91.43	97.14
3	88.83	94.2	89.64	97.98
Average %	89.59	92.46	91.27	97.89

Table (6): Results of sand equivalent test for the four selected sites.

when present in aggregates that were used in concrete [6]. The reported failure mechanisms include the release of plastic fines and the potential of these minerals to expand and contract upon moisture fluctuations. The soundness of aggregates, i.e. existence of smectite minerals was assessed as well the amount of these minerals using a combination of thin section, XRD analyses and loss on ignition. Loss on ignition method measures the proportion of hydrated minerals in the aggregates. This is probably also a measure of the amount of minerals with a swelling potential.

The loss on ignition, for the lightweight aggregate was carried out by pulverizing the fraction passing test sieve No.4 (4.75 mm) and sub samples then heated from 110 to 1100 °C. Mass loss from 110 °C was calculated. The results of loss on ignition test for the four selected sites are given in Table (7)

It can be seen that, the loss in ignition for Jabal Umm al Amad lightweight aggregates ranges between 0.223% and 0.534% with an average of about 0.335%, loss on ignition for Umm Furayqayn ranges between 0.766 % and 1.286 % with an average of about 0.964 %, for Al Khayalah it ranges between 1.55 % and 2.081 % with an average of about 1.771 %, while for Jabal Al Hirshan it ranges between 0.376 and 1.566 with an average of about 0.907.

According to ASTM C-114, 2001 loss on ignition of aggregates, consisting of end products of coal or coke combustion, shall not exceed 12 %, while loss on ignition of other aggregates shall not exceed 5 %, which indicates that, the scoria lightweight aggregates are within acceptable specification limits.

7. Staining of Concrete Aggregates

Concrete structures are subject to deterioration over time due to environmental exposure. Contributors to degradation include salts, moisture, and atmospheric gases. Rust staining, cracking and spalling are often visible sign that the concrete has been damaged. The potential degree of staining attributable to the presence of iron compounds in the lightweight aggregate of the four selected site samples was evaluated according to ASTM C-641, 98. The method involves exposure of a portion of the aggregate to a steam bath for 16 hours, after which the degree of stain resulting from the liberation of iron compounds is evaluated primarily by means of a visual classification method in accordance with the photographic stain index reference standards. The proportion of such compounds is determined by chemical analysis method as required by ASTM Specifications C 330 and C 331 for lightweight aggregate. The results of this test are given in Table (8).

According to ASTM C-641, 2001 an aggregate producing a stain index of 60 or higher shall be rejected when the deposited stain is found upon chemical analysis to contain iron content, expressed as Fe_2O_3 equal to or greater than 1.5 mg/200 g of sample. It has been found that, the concentration of Fe_2O_3 for Jabal Al Hirshan ranges between 2.03 to 8.29 mg/200g with an average of about 6.11.; for Jabal Al Khayalah, it ranges from 0 to 1 mg/200g; with an average of about 0.68 mg/200g, for Jabal Umm Furayqayn it ranges between 0.01 and 1.52 with an average of about 0.96 mg/200g, while that for Jabal Umm al Amad as it can be seen that, two of the three samples were free from Fe_2O_3, while the third one contain (Fe_2O_3) about 1.49 mg/200g. The obtained results indicate that all of the lightweight aggregates are within acceptable limits except the samples of Jabal Al Hirshan.

8. CONCLUSIONS

The scoria samples can be classified on petrographic basis as vesicular porphyritic basalt and porphyritic basalt, respectively as given in Table (1), while Table (3) shows that:-

1- Only one sample from Jabal Al Khayala (Kh 8) contains montmorillonite and kaolinite).

2- Clay minerals are common in the samples from Jabal Umm Furayqayn and Umm al Amad.

3- The least clay minerals occurrence is reported in the samples from Jabal al Khayalah and Jabal Al Hirshan.

4- Montmorillonite alone is present in the black scoria sample from Umm al Amad.

Sample No.	Selected Sites			
	Umm al Amad	Umm Furayqayn	Al Khayalah	Al Hirshan
	Loss on ignition %			
1	0.248	0.766	1.550	0.779
2	0.534	0.840	2.081	1.566
3	0.223	1.286	1.682	0.376
Average %	0.335	0.964	1.771	0.907

Table (7): Results of Loss on ignition test for the four selected sites.

Sample No.	Selected Sites			
	Umm al Amad	Umm Furayqayn	Al Khayalah	Al Hirshan
	(Fe_2O_3) mg/200g			
1	—	1.34	—	8.01
2	—	1.52	1.05	8.29
3	1.49	0.01	1.0	2.03
Average %	—	0.96	0.68	6.11

Table (8): Results of Staining of concrete aggregates test for the four selected sites.

The zeolite group are sometimes recorded in the studied volcanic samples (Table 4), especially in the amygdals. From this table, the following aspects can be extracted:

1- No zeolites are recorded in all samples from Jabal al Khayalah.

2- The samples from Jabal Umm Furayqayn show relative enrichment in the zeolite minerals, namely chabazite, heulandite and natrolite.

3- Only one sample from Jabal AL Hirshan (Hi 8) contains natrolite.

4- Only one sample from Jabal Umm al Amad (Ua 8) contains Phillipsite .

5- None of the zeolite-group minerals are recorded in the black scoria samples (Kh 3, Hi 7 & Ua 1).

6- With no exception, the four investigated sites contain smectites, as saponite and nontronite.

7- None of the proper black scoria samples (Kh 3, Hi 7 & Ua 1) contain smectites.

The microscopic investigation indicated that nontronite in the studied samples occurs as an amygdaloidal phase. It has been found that, the clay lump content in the scoria samples for Jabal Umm al Amad ranges between 2.52 % and 2.64 % with an average of about 2.57 %, for Jabal Umm Furayqayn it ranges between 1.52% and 1.72% with an average of about 1.64%, for Jabal Al Khayalah it ranges between 1.2% and 1.31% with an average of about 1.26%, while for Jabal Al Hirshan it ranges between 0.84 % and 1.49 % with an average of about 1.06%. These obtained values (Table 5) are within the acceptable standard specification limits except Umm al Amad samples that are a little higher than the specification limits.

It has been found that, the materials finer than sieve No.200 for Jabal Umm al Amad ranges between 2.94 and 5.02 within an average of about 4.15, for Jabal Umm Furayqayn it ranges between 1.04% and 1.92% within an average of about 1.52%, for Jabal Al Khayalah it ranges between 1.1% and 1.4% within an average of about 1.267, while for Jabal Al Hirshan it ranges between 0.55 and 1.17 within an average of about 0.86. The obtained results (Table 5) indicate that, the scoria samples except Jabal Umm al Amad aggregates are complying with the specification limits as the materials passing sieve No 200 should not exceed 1% and 3% for the coarse and fine aggregate respectively as given in Table (4).

It has been found that, the sand equivalent for Jabal Umm al Amad ranges between 88.76 % and 91.18 % with an average of about 89.59 %, for Jabal Umm Furayqayn it ranges between 89.52% and 94.2% with an average of about 92.46%, for Jabal Al Khayalah it ranges between 89.64% and 92.75% with an average of about 91.27%, while that forGabalAl Hirshan it ranges between 97.14% and 98.55% with an average of about 97.89%. The obtained result (Table 6) can be considered acceptable as the sand equivalent value should exceed 75% for the fine aggregate.

The tested specimens indicated that scoria aggregate from the four sites are free from organic impurities, and further tests should be made before approving the sand for the use in concrete. It can be seen that, the loss in ignition for Jabal Umm al Amad lightweight aggregates ranges between 0.223% and 0.534% with an average of about 0.335%, loss on ignition for Halat Umm Furayqayn ranges between 0.766 % and 1.286 % with an average of about 0.964 %, for Al Khayalah it ranges between 1.55 % and 2.081 % with an average of about 1.771 %, while for Gabal al Hirshan it ranges between 0.376 and 1.566 with an average of about 0.907. As the loss on ignition of aggregates (Table 7) did exceed 12 %, the scoria lightweight aggregates are within acceptable specification limits.

It has been found that, the concentration of Fe_2O_3 for Jabal Al Hirshan ranges between 2.03 to 8.29 mg/200g with an average of about 6.11.; for Jabal Al Khayalah, it ranges from 0 to 1 mg/200g; with an average of about 0.68 mg/200g, for Jabal Umm Furayqayn it ranges between 0.01 and 1.52 with an average of about 0.96 mg/200g, while that for Jabal Umm al Amad as it can be seen that, two of the three samples were free from Fe_2O_3, while the third one contain (Fe_2O_3) about 1.49 mg/200g. The obtained results (Table 8) indicate that all of the lightweight aggregates are within acceptable limits except the samples of Gabal Al Hirshan.

REFERENCES

[1] Scott L.E., 1955: Secondary minerals in rock as a cause of pavement and base failure. Proc. Highw.Res. Board, 34th Ann. Meet., p412-417.

[2] Van Atta R.O. and Ludowise H. 1976: Causes of degradation in basaltic aggregates and durability testing. 14th Eng. Geol. and Soils Eng. Symp., p241-254.

[3] Wylde L.J., 1976: Degradation of road aggregates. Australian Road Research 6(1), p22-29.

[4] Van Rooy J.L., 1991: The influence of the mineralogy on the durability of Drakensberg basalts. In.Blight et al: Geotechnics. in the African Environment, p383-92.

[5] Lagerblad B. and Jacobsson B. 1997: Smectite clays and concrete durability. Proc.19 Int. Conf. Cement Microscopy, p151-162.

[6] Sveinsdottir E.L., Magnusdottir B., Hardardottir V., Holmgeirsdottir Th., Kristmannsdottir H. and Tryggvason N., 1999: The effect of alteration minerals on the quality of construction aggregates (in Icelandic). IBRI

Report no. 99-01, 53 pp + appendices

[7] Johnson PR (2006) Explanatory notes to the map of Proterozoic geology of western Saudi Arabia, technical report SGS-Tr-2006- 4.

[8] ASTM, 2000. Annual Book of Standards-Construction, Concrete and Aggregate. V. 04.02, Philadelphia, PA, USA.

[9] Washington Aggregates and Concrete Association, ISG., 2003. Ready mix concrete guide and commentary. (WACASPEC, ISG, EM 1110-3-135-84, 2003).