International Journal of Engineering Sciences & Research Technology

(A Peer Reviewed Online Journal)
Impact Factor: 5.164

IJESRT

Chief Editor
Dr. J.B. Helonde

Executive Editor
Mr. Somil Mayur Shah

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

ASSESSMENT OF VOLCANIC ROCKS, IN EAST JEDDAH - SAUDI ARABIA, AS AGGREGATES

Hussin A. M. Ahmed
Mining Engineering Dept, Faculty of Engineering, King Abdulaziz University, Saudi Arabia
Permanent address: Central Metallurgical Research and Development Institute (CMRDI), Helwan, Cairo, Egypt

DOI: 10.5281/zenodo.2549891

ABSTRACT
This paper aims at evaluating some Saudi volcanic rocks, 30 km to the east of Jeddah city, as pavement and concrete aggregates. A series of standard tests were implemented. This included; Absorption Index, Abrasion Resistance, Deleterious Materials, Specific Gravity, Gradation, Soundness, Particle shape and Surface Texture, in addition to moisture content and Fineness modulus. Geological investigation results showed that the area contains two main formations: Quartz Diorite + diorite formation and Monzogranite formation. The sample picked from Quartz Diorite + diorite formation was named in this paper "Black Sample". The sample named in this study "white sample" was selected from Monzogranite formation. Results of the standard tests depicted that both black and white samples have different characteristics especially concerning abrasion resistance. Comparing the obtained results with standard specifications showed that both samples can produce aggregates that are suitable for pavement but only black sample can produce concrete aggregates. It was also found that there should be a technical control in the crushing circuit to produce the required gradation.

KEYWORDS: Quartz Diorite, Construction aggregates, Monzogranite, pavement aggregates, concrete aggregates.

1. INTRODUCTION
Aggregate is a term for the mineral materials such as sand, gravel and crushed stones that are used with a binding medium (such as water, bitumen, Portland cement, lime, etc.) to form compound materials (such as asphalt concrete and Portland cement concrete) (Al-Abdul Wahhab et al., 1994). By volume, aggregate generally accounts for 92 to 96 percent of hot mixed asphalt (HMA) and about 70 to 80 percent of Portland cement concrete (PCC). Aggregate is also used for base and sub-base courses for both flexible and rigid pavements (Pawar et al., 2016).

Aggregates can either be natural or manufactured. Natural aggregates are generally extracted from larger rock formations through an open excavation (quarry). Extracted rock is typically reduced to usable sizes by mechanical crushing. Manufactured aggregate is often the byproduct of other manufacturing industries. This is the case in our study, where rocks formations exist in the area under study are to be tested as a source for producing pavement and concrete aggregates **(**Rached et al., 2009).

Aggregates have different applications. Approximately one-third of aggregates usage is for road construction. The principal specification for Roads and Bridges in the UK is the Specification for Highway Works (SHW) prepared by the Highways Agency of the Department of Transport and published by HMSO, 1998 (Crouch et al., 2007).

However, Table 1 shows the different types, applications and the standard tests applied for evaluating the produced quarry aggregates. Some of these standard tests are necessary for evaluating aggregates application in pavement while others are necessary to judge the applicability of aggregates in concrete production. It is clear that Aggregate physical properties are the most readily apparent aggregate properties and they also have the

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

most direct effect on how an aggregate performs as either a pavement material constituent or by itself as a base or sub-base material. Meanwhile, Tables 2 and 3 shows Gradation Specifications for Aggregates applied on asphaltic pavement and concrete respectively.

Table 1. Standard tests applied for evaluating the produced quarry aggregates for different applications (Jose et al., 2007)

ID	Test	Applied Standard(s)	Specification limits and uses			
			Asphalt applications as pavement aggregates			**Concrete aggregates (PCC)**
			Sub-base	base	surface	
1	*Absorption Index*	ASTM-C 127/128	Less than 5%	Less than 5%	Less than 5%	1-2% max.
2	*Abrasion Resistance (after 500 rpm)*	ASTM C131, ASTM C535	Max. loss 40%	Max. loss 45%	Max. loss 45%	Max. loss 30%
3	*Deleterious Materials* - Clay lumps and Friable particles - Average sand equivalent	ASTM D2419/ ASTM C142 ASTM C142	Max. 1% From 25 to 35 %	Max. 1% From 25 to 35 %	Max. 1% From 25 to 35 %	Max. 1% From 25 to 35 %
4	*Specific Gravity*	ASTM-C 127/128	2.55-2.75	2.55-2.75	2.55-2.75	More than 2.65
5	*Gradation*	ASTM C136	See Table 2			See Table 3
6	*Soundness (Magnesium sulfate based after 5 cycles)*	ASTM C88	Max. loss 30%	Max. loss 20%	Max. loss 15%	Max. loss 12%
7	*Particle Shape and Surface Texture* *Particle index(I_a)*	ASTM D3398, ASTM D5821, ASTM C1252	*6-20%*	*6-20%*	*6-20%*	*6-20%*
8	*Fineness modulus*	ASTM C125	N.A.	N.A.	N.A.	2.7 -3.0 fine 7-9 coarse
9	*Moisture Content*	ASTM C70	N.A.	N.A.	N.A.	**
10	*Rock Drop Test*	ASTM C-131	Less than 5 %	Less than 5 %	Less than 5 %	Less than 5%

**high or law moisture contents are suitable but just only consider needed water for Portland cement concrete design

Table 2. Gradation Specifications for Aggregates applied on asphaltic pavement(Jose et al., 2007)

Sieve Size		Percent Passing		
		Sub-base Course (Grading A)*	Base Course (Grading B)*	Surface Course (Grading F)*
63 mm	2.5-inch	-	100	-
50 mm	2-inch	100	97 - 100	-
37.5 mm	1.5-inch	97 - 100	-	-
25.0 mm	1-inch	-	-	100
19.0 mm	0.75-inch	-	-	97 - 100

12.5 mm	0.5-inch	-	40 - 60 (8)	-
4.75 mm	No. 4	40 - 60 (8)	-	41 - 71 (7)
0.425 mm	No. 40	-	9 - 17 (4)	12 - 28 (5)
0.075 mm	No. 200	0 - 12 (4)	4 - 8 (3)	5 - 16 (4)

*Number in parentheses indicates the allowable deviations () from the target value.

***Table 3. Gradation Specifications for aggregates applied on concrete** (Jose et al., 2007)*

Sieve size mm	**Percentage passing for graded aggregate of nominal size**			
	40 mm aggregates	**20 mm aggregates**	**16 mm**	**12.5 mm**
80 mm	100	-	-	-
40 mm	95 -100	100	-	-
20mm	35 -70	95 -100	100	100
16 mm	-	-	90 -100	-
12mm	-	-	-	90 -100
10 mm	10 -35	25 -35	30 -70	40- 85
4.75 mm	0 -5	0 -10	0 -10	0 -10

This paper aims at evaluating some Saudi volcanic rocks, 30 km to the east of Jeddah city, as pavement and concrete aggregates.

2. EXPERIMENTAL WORK

The standard tests for the two selected samples were done at Mining Engineering Department, King Abdulaziz University. Figure 1 shows photographs for some of the used facilities. These facilities were used as stated in the required tests standards.

a) **Laboratory jaw Crusher**(Primary crushing for rock lumps)

b) **Buoyancy Balance**(Specific Gravity test)

c) Vibratory **lab shaker** (Small samples screening)

d) Soundness **bench test** (Chemical resistance test)

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

 e) Los **Anglos Machine**(Standard Abrasion test)	 f) Special **Varner** (Flakiness and shape test)

Figure 1 Photographs for Some of the used facilities to prepare and test the samples

3. RESULTS AND DISCUSSIONS

Area Location, Geology and Geochemistry

The Studied area is located 30 km to the east from Jeddah City, Kingdom of Saudi Arabia. Table 4 shows coordinates of the area corners. It reveals that the area is relatively small with differences in coordinates can be noticed in the seconds of the coordinates. On the other hand, Figure 2 shows geological map of the area together with its neighborhood localities. It is clear from Figure 2 that the area contains four different formations. These formations are numbered in the Figure as parts from one to four. The formation of each part can be explained as follows:-

- Zone 1, (Part no 1) (Fayddah Formation of Precambrian Layered Rocks), is small and mixed of more than one type of rocks (filsic and mafic rocks). It represents the southern eastern corner of crusher area.
- Zone 2, (Part no 2) (Talus Deposits) consist of unsorted angular rocks fragments of all sizes in fan -like accumulations this available in the southern western corner of the crusher area.
- Zone 3, (Part no 3), is a Diorite and Quartz Diorite rock of Precambrian intrusive rocks. It represents majority of crusher area. As a result in evaluating the crusher area a sample will be taken from this part for standard tests. The sample will be named as the black sample in this report.
- Zone 4, (Part no 4), is Rumayda granite of Precambrian Fatima group intrusive rocks. It consists of monzogranite and granite rocks. It also represents a major part in crusher area. As a result a second sample was taken from this part and was named as white sample.

Table 4. Studied area location shown by coordinates of studied area corners

Studied area Corner no.	North			East		
	Degree	Minutes	Seconds	Degree	Minutes	Seconds
1	37	21	37.88	34	39	39.258
2	37	21	40.2	34	39	9.33
3	37	21	48.68	34	39	5.136
4	37	21	34.88	34	39	5.1

In evaluating the studied area rocks, the black and white selected samples were firstly subjected to complete chemical analyses in Al-Amri Geotechnical Labs. The obtained results are shown in Table 5. The black sample in the geochemical analyses report is coded as Q-D-KH2 while the white sample is coded as GKH1. The chemical analyses of the two samples exhibit a partial difference regarding majority of the constituents which implies a different behavior regarding their physical properties and hence their possible uses. However, Major differences noted in the silica content are expected and can be attributed to the different formation conditions for each of the two selected samples. The high silica content of the black sample is attributed to the presence of finely disseminated quartz in the diorite matrix. This was noticed by naked eye in the freshly crushed sample. The shown chemical analyses make the investigators take the necessary precautions during the standard testing of the samples.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

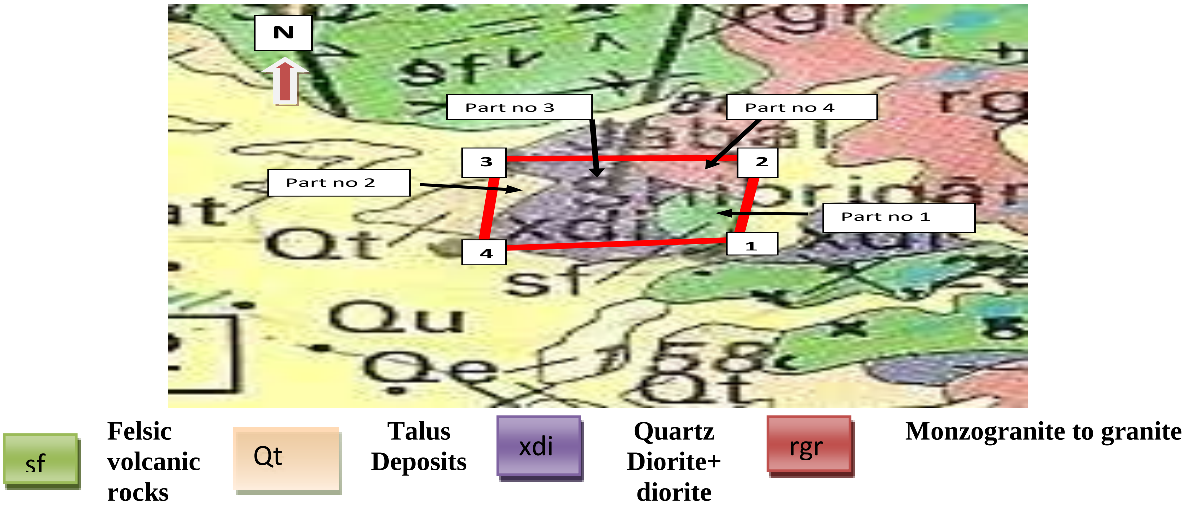

Figure 2. A map showing the geological settings existing in the studied area

Table 5. Chemical analyses of the rock formations existing in the studied area

Constituent, %	MgO	Al_2O_3	SiO_2	P_2O_5	CaO	TiO_2	MnO	Fe_2O_3	Na_2O	K_2O	LOI*
Black sample	0.42	13.42	73.23	0.05	0.28	0.83	0.07	3.99	3.66	3	1.02
White sample	2.33	15.56	61.63	0.27	3.32	0.72	0.1	7.68	3.44	2.71	2.23

*Loss on Ignition

Standard tests results

Results of the carried tests are included in Table 6 and Figure 3 (size distribution or gradation). However, summary of these results compared to needed specifications is articulated in the matrix shown in Tables 7a and 7b for black and white samples respectively.

Table 6 Results of the standard tests carried out to assess both white and black samples as aggregates

ID	Test	Results	
		Black sample	**White sample**
1	*Absorption Index*	1.071	2.177
2	*Abrasion Resistance (after 500 rpm)*	3.86	30.36
3	*Deleterious Materials* Clay lumps and Friable particles Average sand equivalent	 0.478 28.147	 0.575 26.815
4	*Specific Gravity*	2.742	2.625
5	*Gradation as coarse aggregates*	See Figure 3	See Figure 3
6	*Soundness (Magnesium sulfate based after 5 cycles)*	0.96	1.8
7	*Particle Shape and Surface Texture (Particle index(I_a))*	15.656	6.85
8	*Fineness modulus*	7.6%	3.8%
9	*Moisture Contents*	0.550%	1.5%
10	*Rock Drop Test*	0.521%	0.529%

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

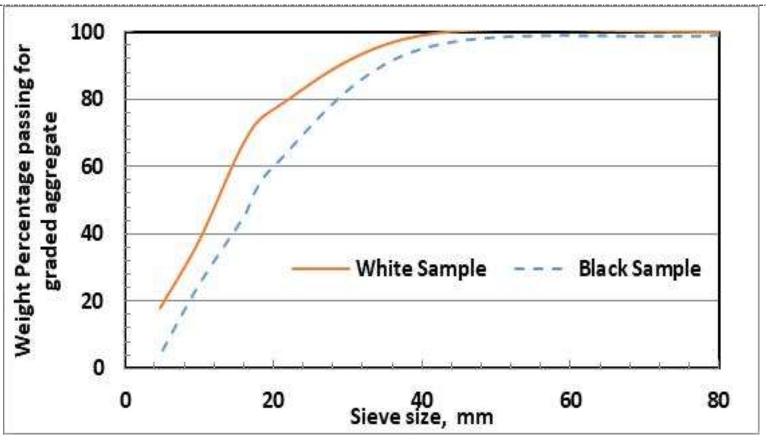

Figure3 Size distributions for white and black samplesas coarse concrete aggregates

From Table 7a, it can be seen that the black sample satisfies all the required specifications to be used as paving or concrete aggregates. However, some precautions should be taken into consideration for the crusher to work safely. For example, the abrasion resistance for this sample is 3.86 % which implies a very abrasive material that is not easy to be crushed using any normal crusher i.e. a special design for the crusher is a must to overcome the high abrasion resistance of the sample. Moreover, the specific gravity of the sample for asphalt applications is considered on the upper border and as a result mixing it with the white sample can give a more suitable blend. On the other hand,

Table 7a. Standard tests results and possible uses for aggregates produced from black sample

ID	Test	Specification limits and possible uses					
		Asphalt applications as pavement aggregates			**Concrete aggregates (PCC)**	**Black sample results**	**Remarks**
		Sub-base	base	surface			
1	*Absorption Index*	√	√	√	√	1.071	
2	*Abrasion Resistance (after 500 rpm)*	√	√	√	√	3.86	Needs attention in crusher design
3	*Deleterious Materials* Clay lumps and Friable particles Average sand equivalent	√ √	√ √	√ √	√ √	0.478 28.147	
4	*Specific Gravity*	√	√	√	√	2.742	In asphalt Sp. Gr. Is in the border limits
5	*Gradation*	See appendix			See appendix	See appendix	See appendix Needs attention in crushing circuit

6	*Soundness (Magnesium sulfate based after 5 cycles)*	√	√	√	√	0.96	Very safe
7	*Particle Shape and Surface Texture (Particle index(I_a))*	√	√	√	√	15.656	Needs attention in crushing circuit
8	*Fineness modulus*	N.A.	N.A.	N.A.	√	7.6%	
9	*Moisture Contents*	N.A.	N.A.	N.A.	√	0.550%	consider needed water for PCC design
10	*Rock Drop Test*	√	√	√	√	0.521%	safe

√ means suitable for stated application **x** means not suitable for stated application
N.A. means test results is not counted in deciding stated application

Table 7 b shows that the white sample can have a wide range of applications. It fails in application as gravels for PCC due to its low specific gravity (2.625 compared to a minimum needed of 2.65). Blending this sample with the black one may lead to suitable PCC gravel regarding its specific gravity. However, a special design for the crusher is a must to overcome the high abrasion resistance of the black sample some which if not done may lead to unsuitable specifications regarding grading. Due to the wide difference among the two samples, one can recommend to be worked concurrently in a blend to give a more suitable blend of aggregates that achieve the required specifications for both pavement and concrete. Moreover, a strict crusher operating conditions should be technically monitored to produce required gradation.

4. CONCLUSIONS

From the results presented in this report one can conclude the following:-

- The studied area contains a variety of existed volcanic intrusions mainly four different rock formations: Felsic volcanic rocks, Talus Deposits, Quartz Diorite+ diorite and Monzogranite.
- Nearly 78% of the area contains two main formations: Quartz Diorite + diorite (black sample) and Monzogranite (white sample).
- The black sample satisfies all the required specifications to be used as paving or concrete aggregates with minor specifications being on the border (specific gravity for asphalt applications)
- The black sample is a very abrasive material that is not easy to be crushed using any normal crusher
- The white sample is different from the black one and can have a wide range of applications but it fails in application as gravels for PCC due to its low specific gravity (2.625 compared to a minimum needed of 2.65)

Table 7b. Standard tests results and possible uses for aggregates produced from white sample

ID	**Test**	**Specification limits and possible uses**					
		Asphalt applications as pavement aggregates			**Concrete aggregates (PCC)**	**White sample results**	**Remarks**
		Sub-base	base	surface			
1	*Absorption Index*	√	√	√	√	2.177	
2	*Abrasion Resistance (after 500 rpm)*	√	√	√	√	30.36	
3	*Deleterious Materials*						

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

	Clay lumps and Friable particles Average sand equivalent	√ √	√ √	√ √	√ √	0.575 26.815	
4	*Specific Gravity*	√	√	√	x	2.625	In PCC Sp. Gr. Low (blending with black sample may produce suitable sp. Gr.)
5	*Gradation*						
6	*Soundness (Magnesium sulfate based after 5 cycles)*	√	√	√	√	1.8	Very safe
7	*Particle Shape and Surface Texture* *Particle index(I_a)*	√	√	√	√	6.85	Needs attention in crushing circuit
8	*Fineness modulus*	N.A.	N.A.	N.A.	√	3.8%	Adjustable by controlling crushing circuit
9	*Moisture Contents*	N.A.	N.A.	N.A.	√	1.5%	consider needed water for PCC design
10	*Rock Drop Test*	√	√	√	√	0.521%	safe

REFERENCES

[1] Jose F. Munoz, Karl J. Gullerud, Steven M. Cramel, M. Isabel Tejador, Marc A. Anderson, 2009 "Effects of Coarse Aggregate Coatings on Concrete Performance." J. Mater. Civ. Eng., 22(1), 96–103.
[2] Rached M, Mayo M.D and Fowler D.W, 2009 "Utilizing aggregate characteristics to minimize cement content in Portland cement concrete", International Centre for Aggregate Research (ICAR) Report No. 401
[3] CrouchL.K., Jordan Pitt, Ryan Hewitt 2007. "Aggregate Effects on Pervious Portland cement Concrete Static Modulus of Elasticity." J. Mater. Civ. Eng., 19(7), 561–568.
[4] Pawar, Chirag & Sharma, Palak & Titiksh, Abhyuday. (2016). Gradation of Aggregates and its Effects on Properties of Concrete. International Journal of Trend in Research and Development. 3. 2394-9333.
[5] Al-Abdul Wahhab, H., Ali, M. F., Asi, I. M. and Al-Dhubaib, I. (1994). Adaptation of SHRP Performance-Based Asphalt Specifications to the Gulf Countries. Project Number AR-14-60, Progress Report Number 2. King Abdulaziz City for Science and Technology. Riyadh, Saudi Arabia

CITE AN ARTICLE

Ahmed, H. A. (2019). ASSESSMENT OF VOLCANIC ROCKS, IN EAST JEDDAH - SAUDI ARABIA, AS AGGREGATES. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY*, *8*(1), 240-247.