A comprehensive overview about the reality of investment in the mining sector of Aggregates in Jordan

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Abstract

It is impossible to construct a city without using natural aggregate sand, gravel
and crushed stone. The amount of these essential construction materials we use
each year is likely to surprise you. Annual production of aggregate worldwide
totals about 16.5 billion tons (15 billion metric tons). This staggering volume
valued at more than $70 billion makes aggregate production one of the most important mining industries in the world. In view of the urban and infrastructure
development and the package of tax exemptions on the property during the past years as well as banking facilities and political reasons experienced by the region, which led to the influx of a large number of displaced people to this hospitable country, which increases demand for residential buildings in particular and the accompanying Which leads to an increase in the demand for the production of aggregates as the volume of investment in the housing sector increased.

Although potential sources of sand, gravel, and crushed stone are widespread and large, land-use choices, economic considerations, and environmental concerns
may limit their availability. Making aggregate resources available for our country's increasing needs will be an ongoing challenge. Understanding how aggregates are produced and how the related environmental impacts are prevented or mitigated can help citizens, communities, and our nation meet this challenge.

Given the right information and access to suitable resources in appropriate geologic settings, aggregate producers can meet the nations demand for aggregate without causing undue harm to the environment.

Aggregates

ASTM (**A**merican **S**ociety of **T**esting and **M**aterials) C 125 & D 8 are standard definitions

Granular material such as:

- Sand & Gravel (~900,000,000 tons per year)
- Crushed stone (~1,200,000,000 tons per year)
- Iron ore blast furnace and other slags
- Manufactured (lightweight and heavy weight)
- Reclaimed (Crushed portland cement concrete, clay bricks, etc.)

Aggregates Types

GRAVEL

- Naturally occurring, water born pieces of rock, in buried or current stream beds.
- Normally rounded with smooth surfaces, other properties dependent on parent rock. See figure (1)
- Crushed gravel is larger gravel particles that have been reduced in size by a crusher
- May be washed to remove undesirable material
- May be screened to divide into desired size groupings

Sand

- Naturally occurring, water or wind born pieces of rock in buried or current stream beds or dunes
- Often rounded with smooth surfaces, other properties dependent on parent rock
- May be washed to remove undesirable material
- May be screened to divide into desired size groupings

Figure (1)

Crushed Stone or Manufactured Mineral Aggregate
Rock layers quarried and processed through a crushing and screen plant to reduce to desired size and divide into desired size groupings. See figure (2).
Limestones and dolomites (~ 70%, Hard to Soft)
Granites (~15%, Hard)
Sandstones (~2%, Soft)

figure (2)

Normal Weight
Gravels, Sands, Normal Crushed Stone, Bulk Specific Gravity - 2.4 to

2.9, Bulk Density (of Bulk Unit Weight) - 1520 to 1680 kg/m3 (95 to 105 pcf), Most commonly used.

Light Weight
Manufactured or Natural, Bulk Density Less than 1120 kg/m3 (70 pcf), Most commonly used in lightweight concrete, many must be screened to get the desired size distribution, and some must be crushed.

Concrete Aggregates ASTM C33-16

Aggregate, recycled, n—granular material that has been diverted, separated, or removed from the solid waste stream, and processed for use in the form of raw materials or products.

Fine aggregate figure (3) shall consist of natural sand, manufactured sand, or other recycled aggregate, or a combination thereof.

figure (3)

Coarse aggregate figure (4) shall consist of gravel, crushed gravel, crushed stone, air-cooled blast furnace slag, or crushed hydraulic-cement concrete ,or other recycled aggregate ,or a combination thereof, conforming

to the requirements of this specification.

figure (4)

Aggregates Importance

It is economical to put as much aggregate into a concrete mix as possible while not
Sacrificing other properties. However, Economy is not the only reason for using aggregate; it also confers greater volume stability and better durability than
Cement paste alone. Influences dimensional stability, elastic modulus, Durability, workability, and cost of concrete.

Geological Formations mostly used for aggregate production in Jordan

Most of the quarries operating in the Kingdom, especially the capital province, are produced by the excavated limestone rocks, which are mostly found within the formation of Wadi Al-Sir , where good thicknesses are available from limestone layers up to 80-90 meters of Varying hardness and appropriate for the production of aggregates.

A number of crushers produce the dolomite and dolomite limestone aggregates from the Na'ur formation, which consists of the succession of different levels of limestone not exceeding 30 meters. According to Boyle's description 1989, this composition was divided into four main units: the first unit is the lower and contains a group of kurnub, The second unit is the real beginning of the formation of Na'ur and consists of dolomite, dolomitic limestone and limestone with a little chert nodules, the third unit is a soft unit consisting of green marl, and a small quantities of dolomitic limestone

with thickness ranges 20-40 m, the fourth unit consists of carbonates in general from gray dolomite, dolomitic limestone, limestone and some chert nodules.

See figure (5)

Some quarries work on the production of natural debris from the wadi and flood plains in some areas of Zarqa, Aqaba and the Jordan Valley.
In the province of Aqaba, the crushers are working on the production of aggregates of granite rocks, which are characterized by good engineering characteristics.
In recent times there has been a tendency of some investors to produce the aggregates of basalt located in the eastern and northeastern regions where laboratory tests proved its quality for concrete and asphalt mixtures.

Era	Period	Group	Formation	Dom. Lith.
Cenozoic	Quaternary		Superficial sediments	
			Lisan Marl/halat Ammar/ Azraq	LM
	Tertiary		Dana Conglomerate	DC
		Belqa	Wadi Shallala Chalk	WSC
			Umm Rijam Chert Limestone	URC
Mesozoic	Cretaceous		Muwaqqar Chalk Marl	MCM
			Al Hisa Phosphorite	AHP
			Amman Silicified Limestone	ASL
			Wadi Umm Ghudran	WG
		Ajlun	Khurayj Limestone	KL
			Wadi As Sir Limestone	WSL
			Shua'yb	S
			Hummar	H
			Fuhays	F

			Na'ur Limestone	*NL*
		Kurnub Sandstone		*KS*
	Jurassic	*Azab*	*Mughanniyya Limestone*	*MUG*
			Hammam Sandstone	*HA*
			Ramla Sandstone	*RM*
			Dhahab Limestone	*DH*
			Silal Sandstone	*SL*
			Nimer Limestone	*NR*
			Hihi Claystone	*HI*

figure (5)

Places of current aggregates production, and production size

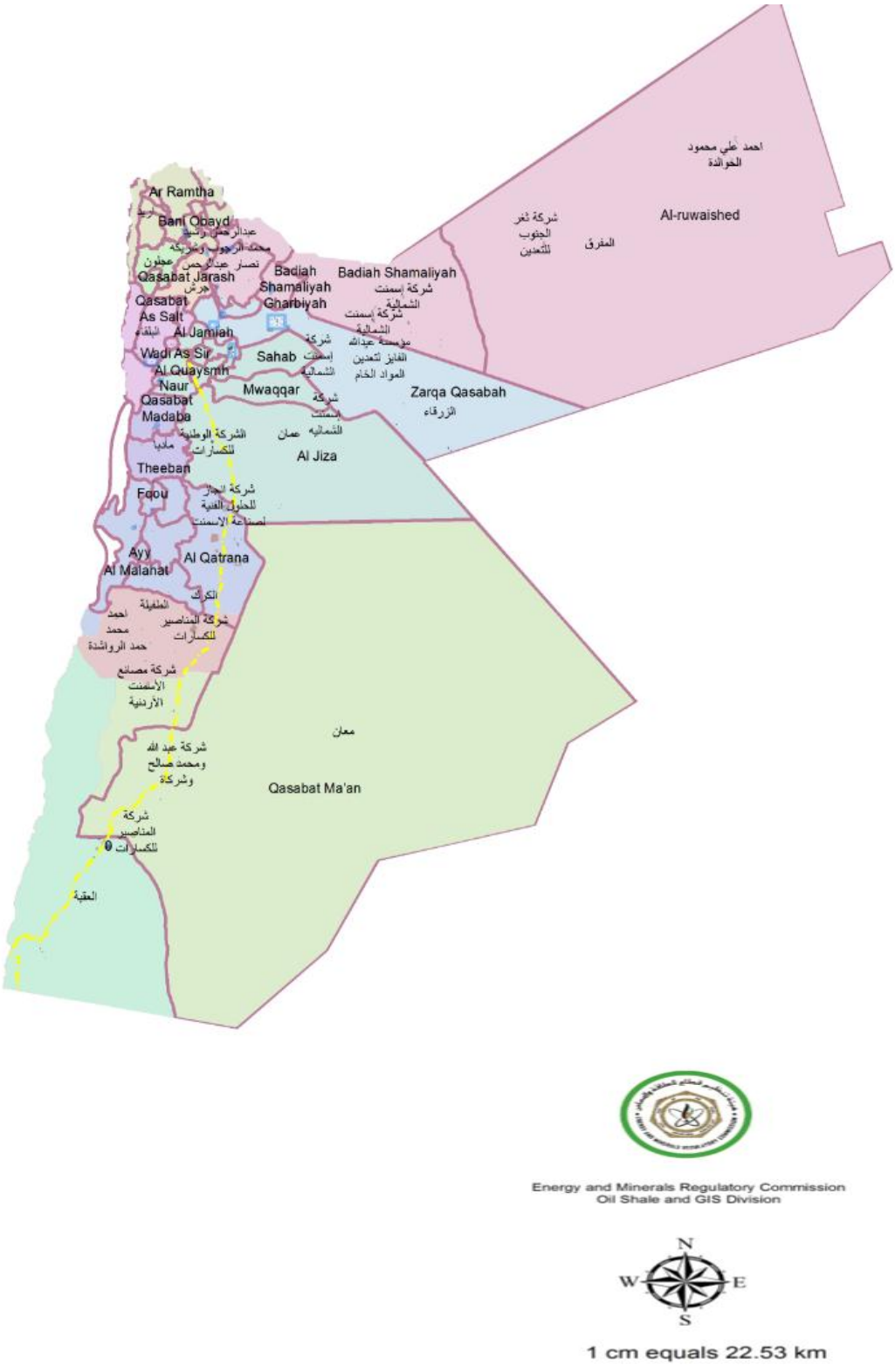
The aggregates are produced in most of the Kingdom's governorates. Most of them are concentrated in the capital. The number of quarries operating in the Kingdom is 124 quarries see table (1), distributed according to the map (1)The amount of aggregate production in theKingdom is estimated to be about 15 million cubic meters annually.

Number of quarries, of which samples are taken

Number of Quarries	city
35	Amman
11	Irbid
12	Albalqa
13	AlKarak

6	Ma’an
20	Alzarqa
7	Almafraq
7	Altafila
4	Madaba
2	Jerash
1	Ajloun
6	AlAqaba

Table (1)



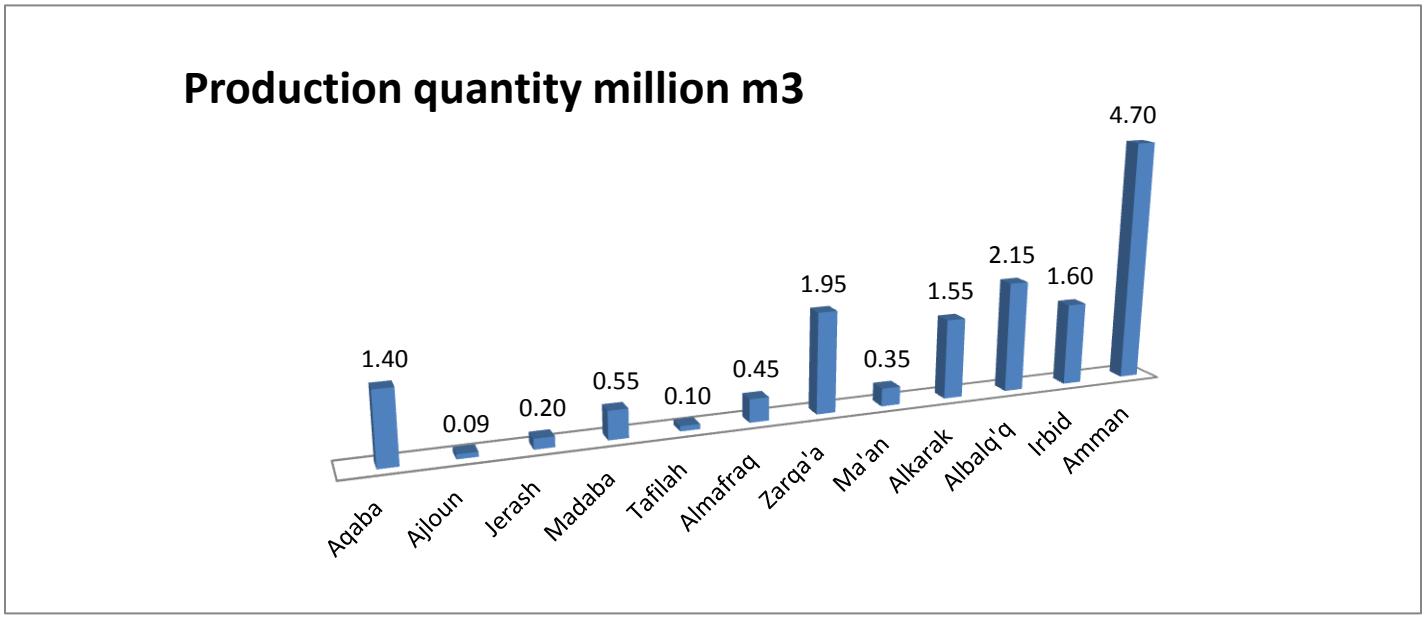
Map (1)

Production quantity in million m3 of aggregates in 2016

The amount of aggregate production inthe Kingdom is estimated to be about 15 million cubic meters annually. Shown in table (2), figures 6and 7.

Total	Aqaba	Ajloun	Jerash	Madaba	Altafila	Almafraq	Alzarqa	Ma'an	AlKarak	Albalqa	Irbid	Amman	
15,090	1,400	0,090	0,200	0,550	0,100	0,450	1,950	0,350	1,550	2,150	1,600	4,700	Production in m3

Table (2Figure (6)



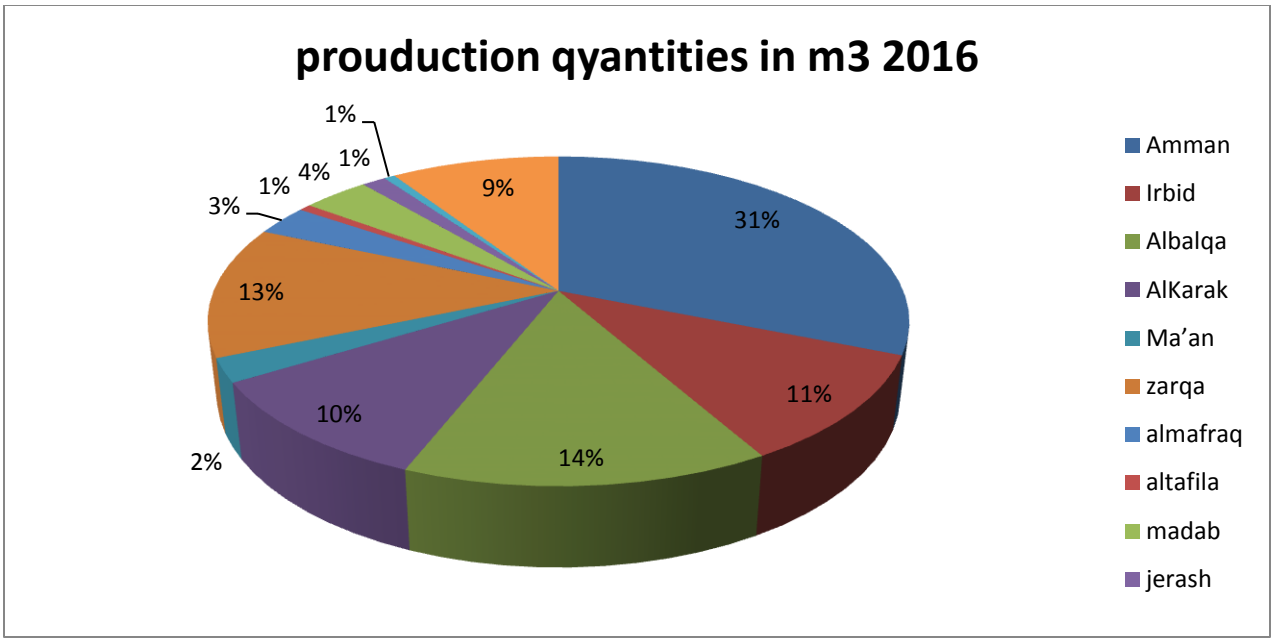


Figure (7)

Standard specifications for quarry aggregates

Aggregates can be divided in terms of size into two main types:

Fine Aggregate

It is the aggregate most of which passes 4.75 mm IS sieve and contains only so much coarser as is permitted by specification.

Coarse Aggregate

It is the aggregate most of which is retained on 4.75 mm IS sieve and contains only so much finer material as is permitted by specification.

All in Aggregate

It is the aggregate composed of both fine aggregate and coarse aggregate. According to size All-in-aggregate is described as all-in-aggregates of its nominal size, i.e. 40mm, 20mm etc.

The Jordanian Standard No. 2065 of 2016 has set the approved requirements for the grain size of aggregates of various types used in ordinary and reinforced concrete, as specified in the following tables:

TABLE 1 Grading Requirements for Fine Aggregate

Sieve (Specification E11)	Percent Passing
9.5-mm (⅜-in.)	100
4.75-mm (No. 4)	95 to 100
2.36-mm (No. 8)	80 to 100
1.18-mm (No. 16)	50 to 85
600-µm (No. 30)	25 to 60
300-µm (No. 50)	5 to 30
150-µm (No. 100)	0 to 10
75-µm (No. 200)	0 to 3.0[A,B]

[A] For concrete not subject to abrasion, the limit for material finer than the 75-µm (No. 200) sieve shall be 5.0 % maximum.
[B] For manufactured fine aggregate, if the material finer than the 75-µm (No. 200) sieve consists of dust of fracture, essentially free of clay or shale, this limit shall be 5.0 % maximum for concrete subject to abrasion, and 7.0 % maximum for concrete not subject to abrasion.

TABLE 3 Grading Requirements for Coarse Aggregates

Size Number	Nominal Size (Sieves with Square Openings)	Amounts Finer than Each Laboratory Sieve (Square Openings), Mass Percent																		
		100 mm (4 in.)	90 mm (3½ in.)	75 mm (3 in.)	63 mm (2½ in.)	50 mm (2 in.)	37.5 mm (1½ in.)	25.0 mm (1 in.)	19.0 mm (¾ in.)	12.5 mm (½ in.)	9.5 mm (⅜ in.)	4.75 mm (No. 4)	2.36 mm (No. 8)	1.18 mm (No. 16)	300 µm (No. 50)
1	90 to 37.5 mm (3½ to 1½ in.)	100	90 to 100	...	25 to 60	...	0 to 15	...	0 to 5	...	...	...	...	...	...
2	63 to 37.5 mm (2½ to 1½ in.)	...	...	100	90 to 100	35 to 70	0 to 15	...	0 to 5	...	...	...	...	...	...
3	50 to 25.0 mm (2 to 1 in.)	...	...	...	100	90 to 100	35 to 70	0 to 15	...	0 to 5	...	...	...	...	...
357	50 to 4.75 mm (2 in. to No. 4)	...	...	...	100	95 to 100	...	35 to 70	...	10 to 30	...	0 to 5	...	...	...
4	37.5 to 19.0 mm (1½ to ¾ in.)	...	...	...	...	100	90 to 100	20 to 55	0 to 15	...	0 to 5	...	...	...	...
467	37.5 to 4.75 mm (1½ in. to No. 4)	...	...	...	...	100	95 to 100	...	35 to 70	...	10 to 30	0 to 5	...	...	...
5	25.0 to 12.5 mm (1 to ½ in.)	...	...	...	...	...	100	90 to 100	20 to 55	0 to 10	0 to 5	...	...	...	...
56	25.0 to 9.5 mm (1 to ⅜ in.)	...	...	...	...	...	100	90 to 100	40 to 85	10 to 40	0 to 15	0 to 5	...	...	...
57	25.0 to 4.75 mm (1 in. to No. 4)	...	...	...	...	...	100	95 to 100	...	25 to 60	...	0 to 10	0 to 5	...	...
6	19.0 to 9.5 mm (¾ to ⅜ in.)	...	...	...	...	...	...	100	90 to 100	20 to 55	0 to 15	0 to 5	...	...	...
67	19.0 to 4.75 mm (¾ in. to No. 4)	...	...	...	...	...	...	100	90 to 100	...	20 to 55	0 to 10	0 to 5	...	...
7	12.5 to 4.75 mm (½ in. to No. 4)	...	...	...	...	...	...	...	100	90 to 100	40 to 70	0 to 15	0 to 5	...	...
8	9.5 to 2.36 mm (⅜ in. to No. 8)	...	...	...	...	...	...	...	...	100	85 to 100	10 to 30	0 to 10	0 to 5	...
89	9.5 to 1.18 mm (⅜ in. to No. 16)	...	...	...	...	...	...	...	...	100	90 to 100	20 to 55	5 to 30	0 to 10	0 to 5
9[A]	4.75 to 1.18 mm (No. 4 to No. 16)	...	...	...	...	...	...	...	...	...	100	85 to 100	10 to 40	0 to 10	0 to 5

[A] Size number 9 aggregate is defined in Terminology C125 as a fine aggregate. It is included as a coarse aggregate when it is combined with a size number 8 material to create a size number 89, which is a coarse aggregate as defined by Terminology C125.

Aggregates testing

Aggregates testing play an important role in assessing new material sources, in situ behavior, compliance and quality control. All aggregate testing is undertaken by directorate of laboratory –ministry of energy and mineral resources experienced technical staff operating from our well equipped independent test facilities.

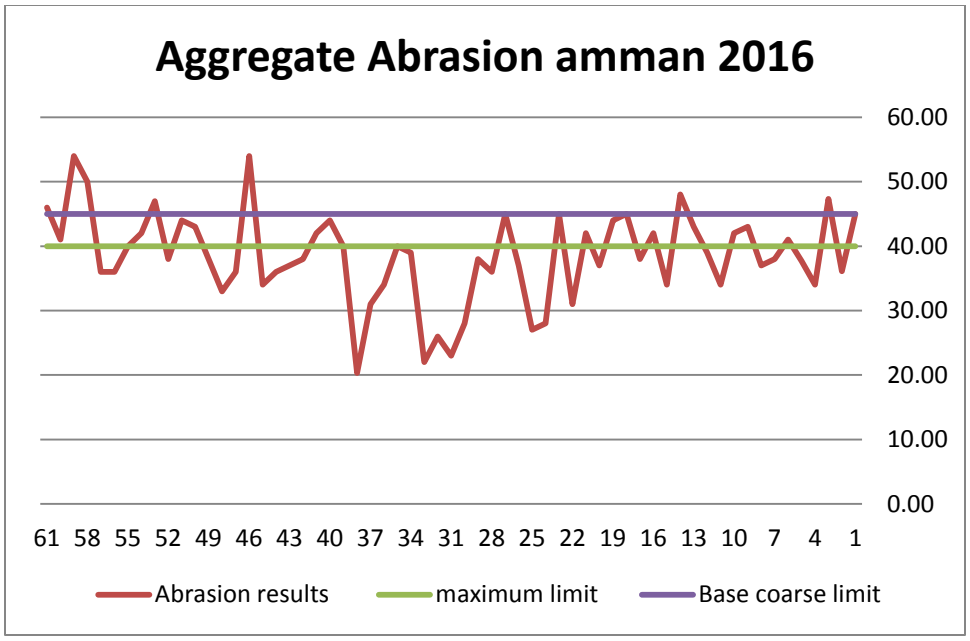
Testing of Aggregate Properties As a vital and wide ranging element of construction it is important to accurately evaluate all aggregate characteristics whether used as sub-base or capping material or for more specialized purposes such as track ballast, backfill and many more. Our aggregate tests include valuable information about:

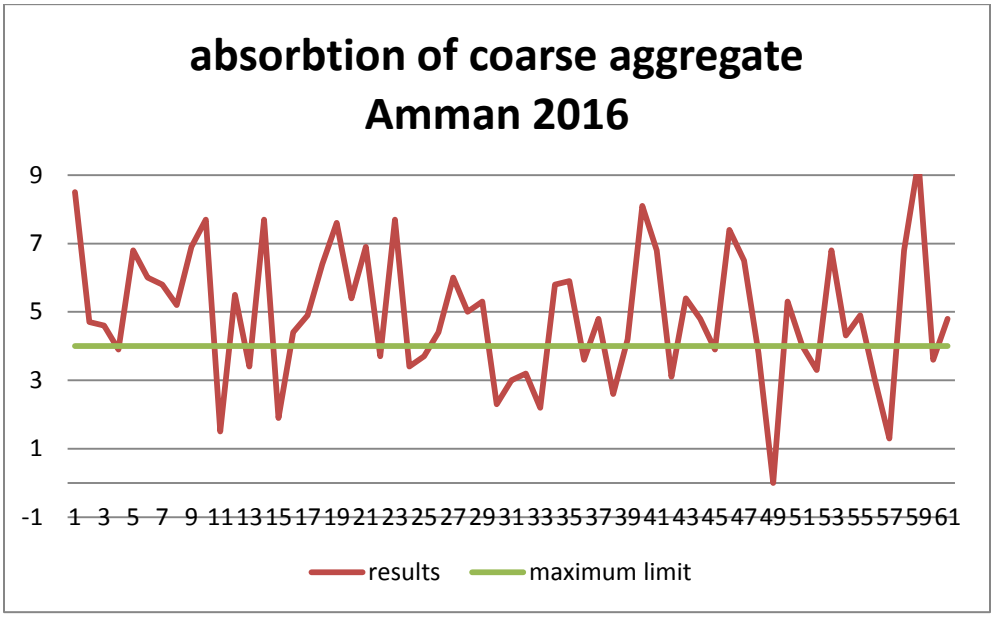
- Geometrical properties
- Physical properties
- Thermal and weathering properties, see the tables below.

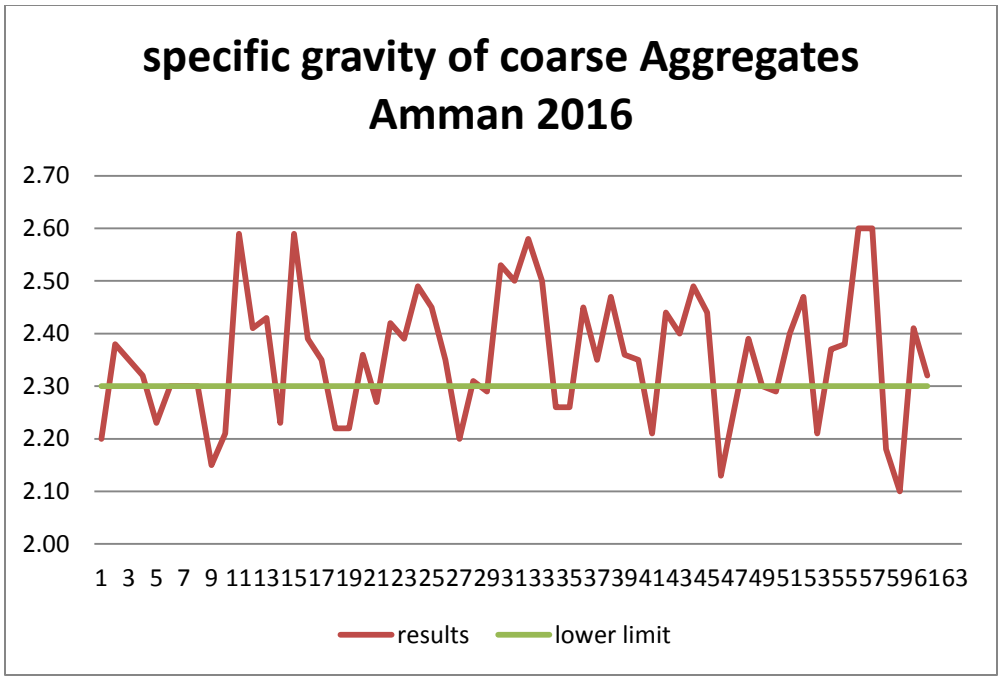
Characteristic	Test
Abrasion resistance	ASTM C 131 (AASHTO T 96), ASTM C 535, ASTM C 779
Freeze-thaw resistance	ASTM C 666 (AASHTO T 161), ASTM C 682, AASHTO T 103
Sulfate resistance	ASTM C 88 (AASHTO T 104)
Particle shape and surface texture	ASTM C 295, ASTM D 3398
Grading	ASTM C 117 (AASHTO T 11), ASTM C 136 (AASHTO T 27)
Fine aggregate	ASTM C 1137

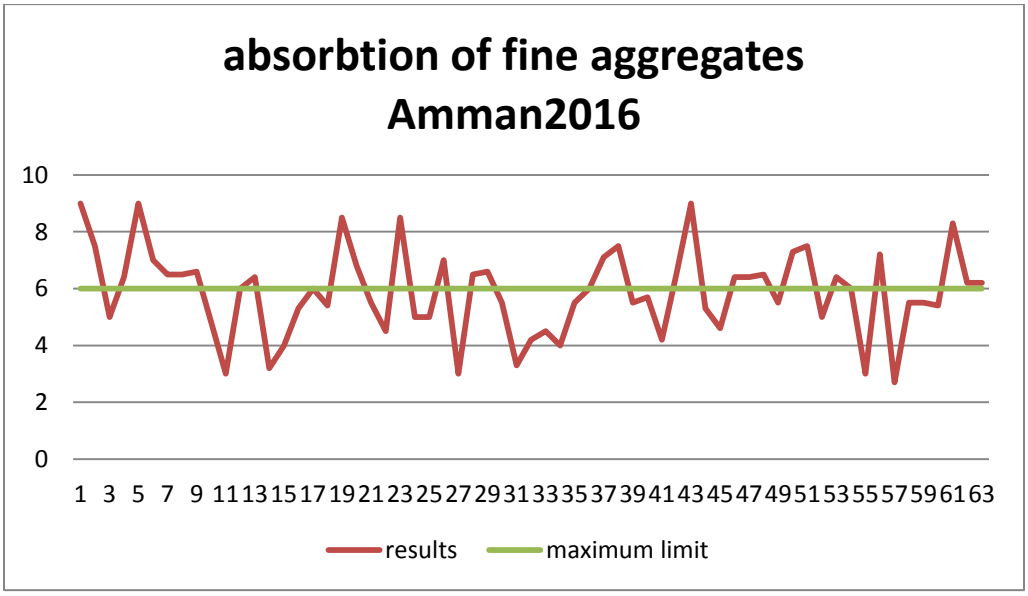
Characteristic	Test
Relative density	ASTM C 127 (AASHTO T 85)—fine aggregate ASTM C 128 (AASHTO T 84)—coarse aggregate
Absorption and surface moisture	ASTM C 70, ASTM C 127 (AASHTO T 85), ASTM C 128 (AASHTO T 84), ASTM C 566 (AASHTO T 255)
Strength	ASTM C 39 (AASHTO T 22), ASTM C 78 (AASHTO T 97)
Def. of constituents	ASTM C 125, ASTM C 294
Aggregate constituents	ASTM C 40 (AASHTO T 21), ASTM C 87 (AASHTO T 71), ASTM C 117 (AASHTO T 11), ASTM C 123 (AASHTO T 113), ASTM C 142 (AASHTO T 112), ASTM C 295
Alkali Resistance	ASTM C 227, ASTM C 289, ASTM C 295, ASTM C 342, ASTM C 586, ASTM C 1260 (AASHTO T 303), ASTM C 1293

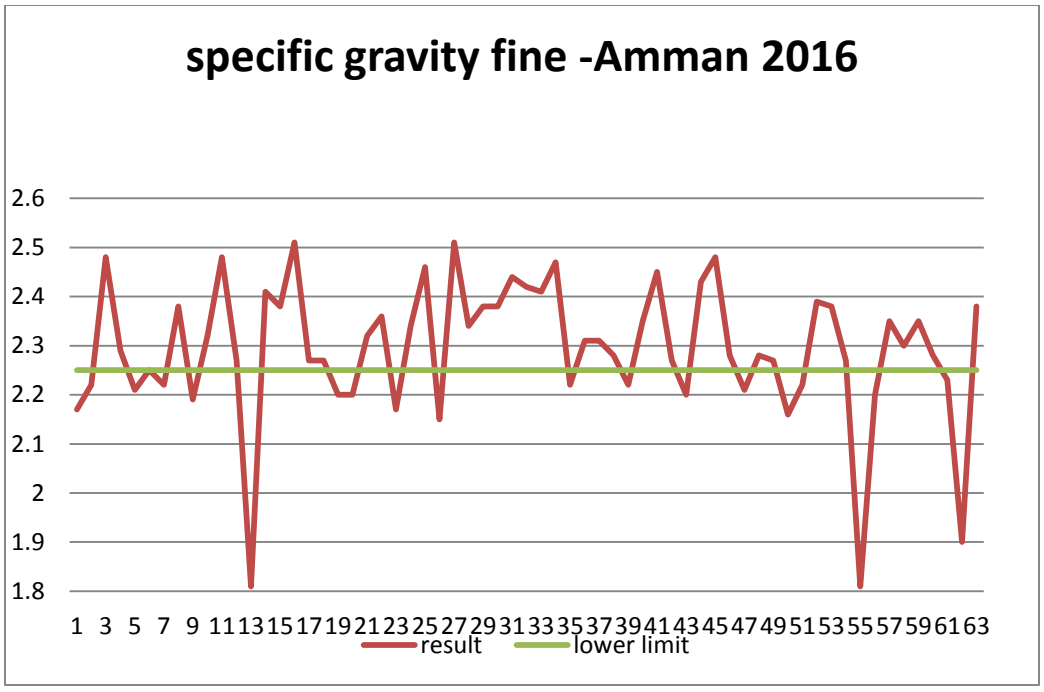
The results of aggregate testing in Amman are shown in the following diagrams

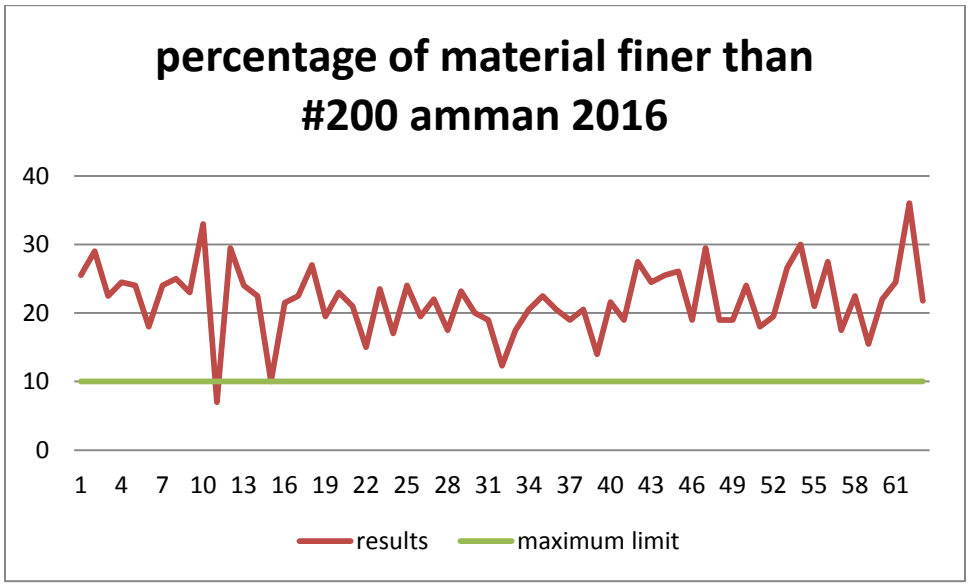

Aggregate Abrasion amman 2016
60.00
50.00
40.00
30.00
20.00
10.00
0.00
61 58 55 52 49 46 43 40 37 34 31 28 25 22 19 16 13 10 7 4 1
Abrasion results
maximum limit
Base coarse limit


absorbtion of coarse aggregate
Amman 2016
9
7
5
3
1
-1
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61
results
maximum limit


specific gravity of coarse Aggregates
Amman 2016
2.70
2.60
2.50
2.40
2.30
2.20
2.10
2.00
1 3 5 7 9 11131517192123252729313335373941434547495153555759616 3
results
lower limit


absorbtion of fine aggregates
Amman2016
10
8
6
4
2
0
1 3 5 7 9 11131517192123252729313335373941434547495153555759616 3
results
maximum limit





Mining and production methods currently followed

Aggregate production essentially turns big rocks into little rocks and carefully sorts them by size. Excavating crushed stone or sand and gravel is

dependent on the geologic characteristics and the extent and thickness of the deposit. Open-pit mining and quarrying methods commonly are used, although some stone is mined underground. Quarrying and mining stone generally requires drilling and controlled blasting before the rock is extracted with power shovels, bulldozers, and draglines. Sand and gravel deposits

Commonly are excavated with conventional earth-moving equipment such as bulldozers, front-end loaders, and tractor scrapers, but may be excavated from streams or water-filled pits with draglines or from barges that use hydraulic or ladder dredges. Processing of quarried rock and large gravel may require crushing, depending on the requirements for the final product. After crushing, the aggregate is sorted to size. Silt and clay are removed by washing. At this stage, aggregate commonly is moved by conveyors to bins or is stockpiled by size. Finally, aggregate is loaded on trucks, railcars, barges, or freighters for shipment to the site of use.

Most of the crushers follow the method of digging deep trench wells without taking into account the quality of the rock layers and the interconnections between them, for reasons including:

•The desire of the owners of the quarries to produce the largest quantity of materials at the lowest cost.

•They believe that the mining of soft layers with hard layers saves the consumption of spare parts and prolongs the life of the equipment and machinery used.

Laws and regulations related to aggregates mining

•Law No. 8 of 2017 Law of the Regulatory Authority for the Energy and Minerals Sector
• Law on the regulation of natural resources and its amendments No. 12 of 1968
Systems
• Mining System No. 131 of 1966

• System No. (64) for the year 2016 - an amended system of quarrying and mining fees
• An amended system for quarrying and mining fee system - No. 66 of 2013.

Environmental impacts of industrial operations including aggregate extraction.

Properly designed and operated aggregate production minimizes the impact on landscape, wildlife, surface and groundwater, and surrounding communities. The extraction and processing techniques and the natural site conditions determine which specific impacts may occur, how widespread they will be, and how long they will last. Mining aggregate, building a house, or building a highway all impact the environment. In comparison, the land disturbed to build a community or a highway is about 100 times greater than the land disturbed to provide the aggregate for those purpose .An aggregate operation is a temporary land use, and when mining is completed, the site is likely to be converted into another beneficial use. Consequently, the overall environmental impact of aggregate extraction is usually relatively small over the long term. Aggregates are environmentally inert materials and their processing commonly requires only crushing, screening, and washing. Environmentally sound and safe aggregate operations effectively manage physical disturbance, protect ground and surface waters, control noise and dust, use safe blasting procedures, and have long-term operation and closure plans that recognize habitat and community needs. Modern technology and scientific investigation methods have made it possible to reduce the environmental impacts from aggregate mining and to manage those impacts at acceptable levels. In addition, a variety of local regulations designed by the ministry of environment which assign a general committee for giving the license to a quarry which ensures the availability of the requirements to limit environmental impacts of industrial operations including aggregate extraction.

Reasons that lead to poor product quality

- During excavation work rock layers are not separated.

-The presence of unlicensed crushers which doesn't use explosive materials.

- The presence of layers of marly limestone, chalky limestone and earth cover with thin layers of chert overlapped with hard limestone layers leads to a low quality of the resulting aggregates.

- In the province of the capital, specifically (Valley of Al-ish and the Valley of Al qattar), the owners of the crushers do not remove the soft and harmful layers to the quality of the aggregates, but they mix it with the limestone and dolomitic rocks of good quality for aggregate production, where these crushers work in the layers of the of the Upper Wadi As Sir formation , which is topped by Umm Ghudran formation of soft marlstone With a thickness reaches up to (20) meters and some locations topped by the formation of Amman Silicified Limestone with different thicknesses and these two layers must be removed.

- The results showed a decrease in the quality of the resulting aggregates (Abrasion test) in the Amman (Wadi Al-Ish) and Al Zarqa'a (AlHalabat) and the fluctuation of the results in Mafraq Governorate.

- The results showed that the percent passing of sieve 200 exceeds the permissible limit, especially in Amman, Zarqa, Mafraq, Tafileh.

-The results indicates that the natural aggregate quarries in AL Balqa'a and Al-karak in addition of granite quarries in Aqaba produce aggregates that conforms to the specifications and is suitable for the use of Class A concrete with an erosion rate not exceeding (30%).

-Some crushers are still using sieves with openings less than or greater than what is stated in the specifications and standards, which leads to the production and sorting of aggregates in shapes and sizes that do not conform to the specification.

-The inability to follow up the progress of the work in the quarries of the Governorate of Aqaba correctly to the existence of an agreement with the authority of the region does not allow to exercise control only after the

completion of all licensing procedures from the authority of the region note that most of them work without a license.

-(9) Crushers in the capital Governorate / Al-Hiazm Road operate without any legal authorization from any party and bring the materials from the nearby abandoned quarries and the remains of the stone saws and the dangerous here is that they are sold for the use of concrete in addition to the tiles with no control over the quality Materials.

- Some crushers categorized as base coarse producers sold aggregates not conforming to the approved specifications.

Conclusion and recommendations

The best methods of mining are to control the depth of the blast wells in accordance with the quality of the rock layers and to oblige the quarry owners to remove the soft layers, including the soil cover above the rock layers and to reuse it in the landfill and rehabilitation.

- To find alternative areas for the production of limestone aggregates with good specifications and to work on diversifying the sources of aggregates to include (granite, basalt , natural aggregates of floodwaters and valleys), which are available in many areas of the Kingdom.

Activation of article 8 paragraph (a) of the quarry system and address the Ministry of Public Works, the Ministry of Municipal Affairs, the Amman Municipality and the armed forces not to submit any tender without presenting a document proving that the bidder uses materials from licensed quarries.

The owner of the licensed base coarse crusher must have a steel plate with dimensions (1.5-1), indicated by the required instructions, in addition to the phrase - the aggregate is not suitable for the concrete .

Coordinate with the authority of the Aqaba Region for the necessity of supervising the on all quarries operating in the Governorate of Aqaba license

and control according to the law of natural resources no. (12) 1968 in the Kingdom.

Addressing the Amman Municipality to form a joint committee to solve the problem of road belt crushers, which have been operating for more than eight years without any actual control over the quality of the aggregates.

- The need to sort the aggregates within the crusher yards by size and not to sell the mixed aggregates.

-Work on the appointment of engineers and geologists specialized in the crushers, whose daily production exceeds 600 m 3 for actual supervision and help to improve the quality of the produced materials.

-Encouraging researches and innovations related to improving the quality of Aggregates ,finding alternative places for extraction, preserving the environment and rehabilitation.