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Quality evaluation and loss estimation at gravel quarries around the Qena Governorate, Egypt: A case study

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Abstract

Purpose. In recent years in Egypt there has been a significant increase in the demand for building materials, particularly gravel which is employed in buildings, the base layer for road construction, and other industries. The quality of gravel that is deemed suitable for different purposes depends on the physical, chemical, and mechanical properties of the gravel; these aspects are determined according to the Egyptian Code, depending on the required application.

Methods. Representative samples were collected from two working sides of the quarries, then they were processed in a laboratory to characterize the samples depending on the location and evaluate their properties with respect to the corresponding concrete and road codes.

Findings. The findings indicate that the gravel tests were simple to conduct and that the gravel from these locations were suitable for constructed roads and to be used in mixture of asphalt and cement.

Originality. The samples were collected from five quarries around the Qena Governorate, Egypt; each of these locations occupied areas ranging from approximately 100×100 or 200×100 m^2.

Practical implications. The loss of gravel at the studied quarries was found to be 32.88-44.06%. Abo-Teshet 1 exhibited the highest loss of gravel deposits with thicknesses ranging from 0.5 to 1.50 m, which was attributed to the fill layers.

Keywords: *gravel characterization, construction materials, gravel quarry, gravel chemical properties*

1. Introduction

Gravel serves as a construction and building materials that plays an important role in the development of infrastructure and roads. Investments in Egypt have increased significantly, particularly those pertaining to the construction of roads and new buildings. In this study gravel samples were collected from five different locations and evaluated in terms of their physical, chemical and mechanical properties. The surface of the significant thick and widely distributed sedimentary succession around Qena is used as a raw material for building purposes. The application of gravel in building construction is mainly dependent on the physical and mechanical properties of the gravel; these properties are generally determined by research laboratories and industries [1], [2]. A previous study evaluated the quarries located around the Nile valley; gravel from these quarries is sued as the base layer for highway pavements [3], [4]. Therefore, it is essential to determine the properties of gravel, given that the applicability of gravel in construction mainly depends on its physical and mechanical properties, which typically determined by research laboratories and organizations. Figure 1 depicts the study area and the quarry locations.

Physical properties of gravel, such as the density, porosity, and water absorption capacity were determined. Density is defined as the ratio of the mass of a dry specimen to its apparent volume. The weight of a unit volume of rock in its natural state differs from that of the same volume of rock containing the solid phase alone. Porosity of stone is directly related to important characteristics such as the mechanical strength and the behavior in liquids. A higher porosity indicates a lower mechanical strength and that liquids can be absorbed more easily by the stone. Absorption capacity refers to the ability of a stone to absorb liquids and gases. In this study, tests are conducted on specimens with dimensions of 50×50×50 mm [5], [6]. To determine the absorption capacity of the samples, the specimens were dried at 105°C for 24 h. subsequently, they were immersed in distilled water at 20°C ±2°C for 24 h. These samples were removed from water, their surfaces were dried, and they were weighed to the nearest 0.001 gm. Absorption capacity is expressed as gm/cm^2 for the polished surface of the specimens [7].

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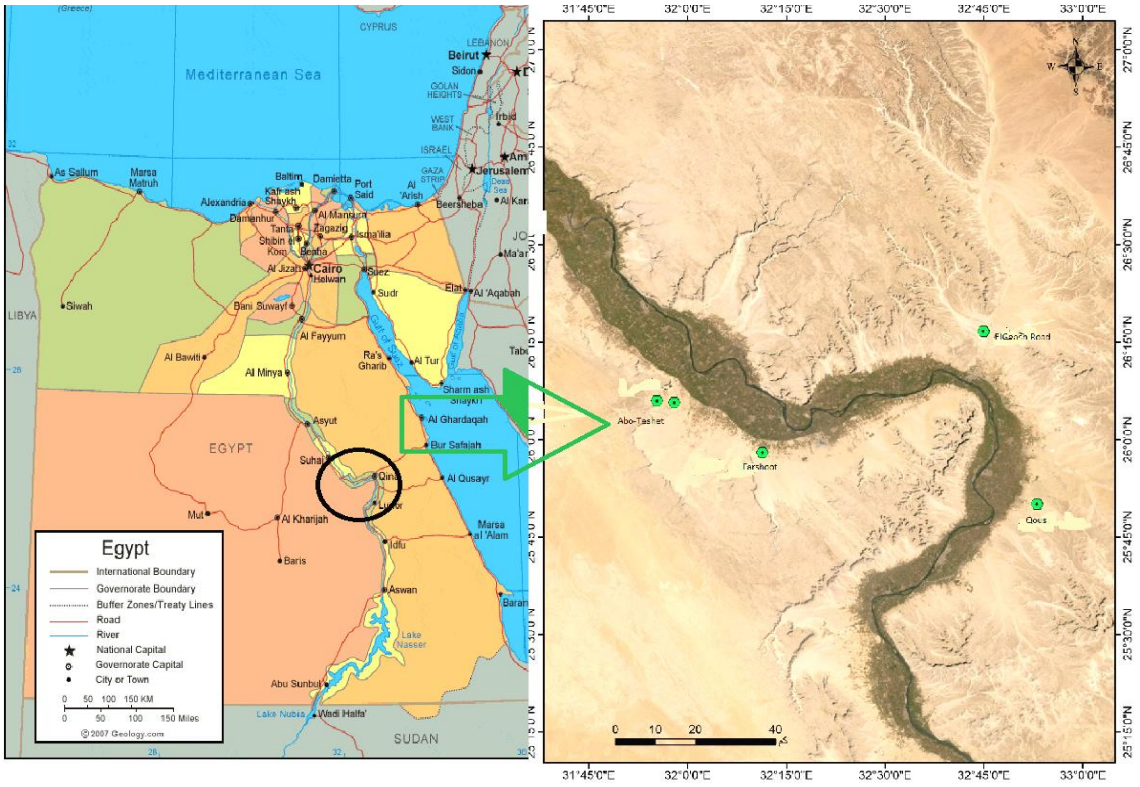


Figure 1. Quarry locations in the study area

Mechanical properties such as the uniaxial compressive strength, and abrasion were determined using the Los-Angeles test. The chemical compositions of all samples were evaluated to determine the main competencies of quartz or carbonate and all other minerals [8]. There are numerous natural aggregates in the soil in Egypt, particularly gravel quarries lie in the eastern desert, which is an economy. These can be used for various industrial applications such as construction roads and also be used in concrete and asphalt mixtures. For this purpose, however, their geotechnical behavior must be evaluated to ensure that they are suitable for use in various engineering applications. The exposed gravel quarries along the eastern bank of the Nile Valley afford significant important building materials in Qena; this improves the economic growth and facilities the construction of new towns, such s the new town of Qena.

For determining the quality and economic importance of gravel deposits, their geotechnical behavior, alkaline reactivity, and the percentage of gravel deposit loss are highly significant parameters. Many previous studies have focused on the geological nature of the area considered in this research, including the sediments and mineralogy of this area [9]. High Cretaceous-low Tertiary rocks covered Qena region, which contain gravel and sand, form the main plateaus in this region. In addition to the cellar complexes in the east, the studied quaternary sediments in the Qena area are covered by the Upper Cretaceous-Lower Tertiary successions from the east and west [10], [11].

The main objective of this study is to evaluate quarry samples to determine their suitability for different applications, such as construction, cement concretes, and asphalt mixtures, according to the Egyptian Code; the study also aimed at estimating the losses related to clay covering the gravel in order to present the results to the Quarry administration of the Qena Governate. The results of this study are expected to help elucidate the gravel losses in all similar quarries.

2. Data collections

Business trips were arranged to collect all samples from different quarries, in cooperation with the quarry administration of the Qena governorate. Five different locations were investigated, representative samples were collected from two working sides of the quarries. The experiments were conducted at the Mining and Petroleum Department, Faculty of Engineering, Qena, Al-Azhar University. Samples were collected from Abo-Teshet 1, 2, Farshoot, Qus and Elgeash Road. A total of 26 samples were collected from the working side faces of the quarries, these samples weighed 30-45 kg. The thickness of the working faces reached 4-5 m, and the entire surface area was coated with fine materials, with a thickness similar to the gravel that cover the thickness of gravel layers.

The quarry-ground deposits of Qus were covered with thin layers featuring a thickness of 0.30-1.50 m (fine seeded soils). Gravel grains should be investigated and clarify that grain composition were consisted of silicone or calcareous. Some of the examined grains were significant rough quartz flint [12], [13]. Figures 2, 3 illustrate the working side for the Abo-Teshet 1, 2 quarry and the locations from which the samples were procured.

Figure 4 highlights these locations for the Farshoot quarry, while Figure 5, 6 depict the locations for Qus and Elgeash Road respectively. The second location is the Abo-Teshet quarry, where samples were collected at five locations from trenches as shown in Figure 3.

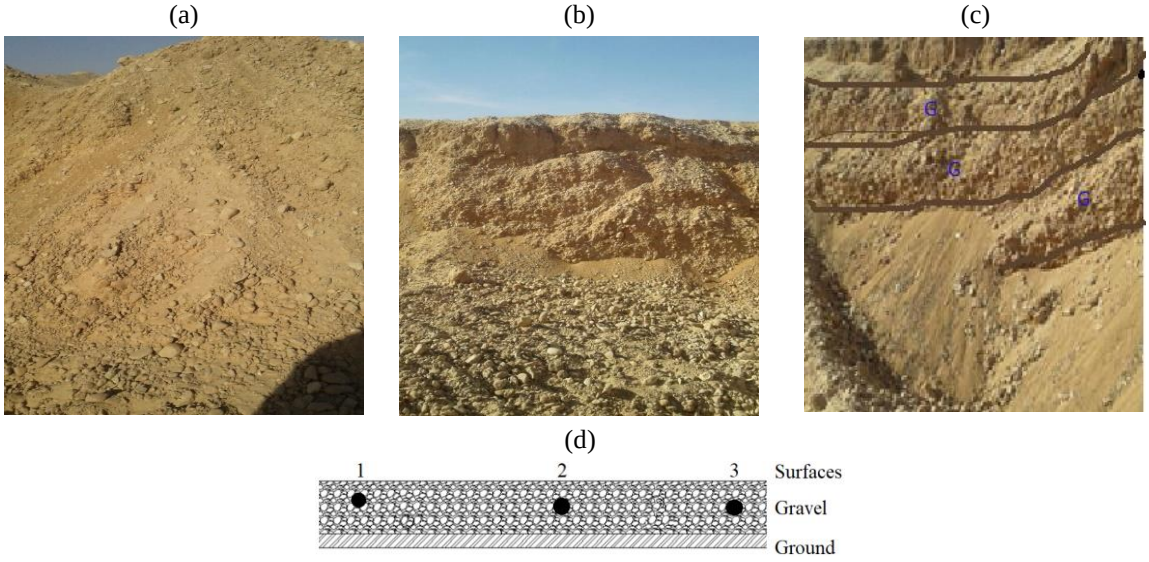


Figure 2. Working sides for Abo-Teshet 1 quarry and locations of sample procurement: (a) wall side section 1; (b) wall side section 2; (c) wall side section 3; (d) sample location with depth

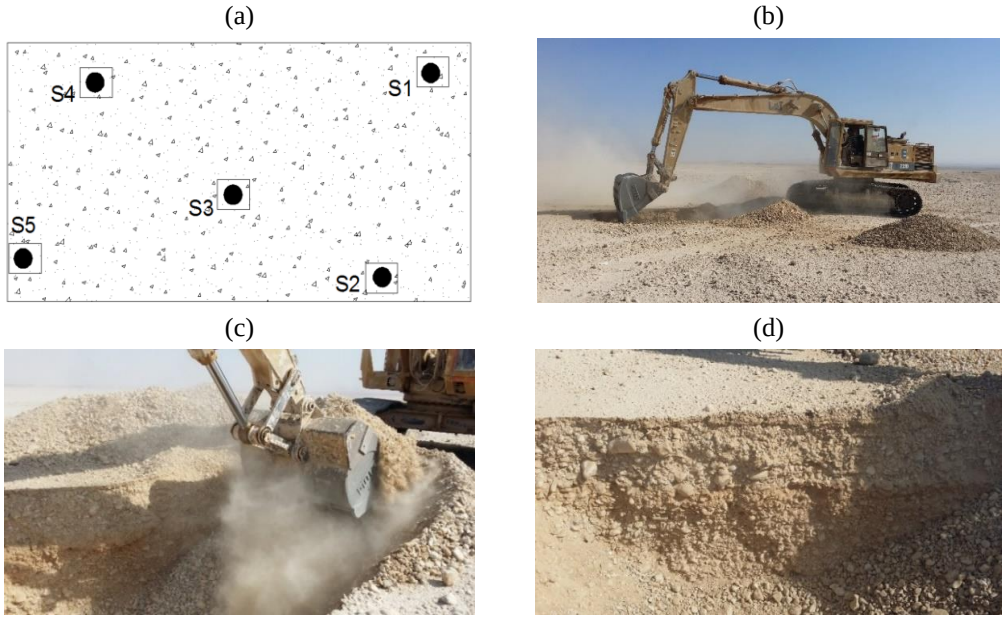


Figure 3. Trenches from which were procured for Abo-Teshet 2: (a) wall side section 1; (b) wall side section 2; (c) wall side section 3; (d) sample location with depth

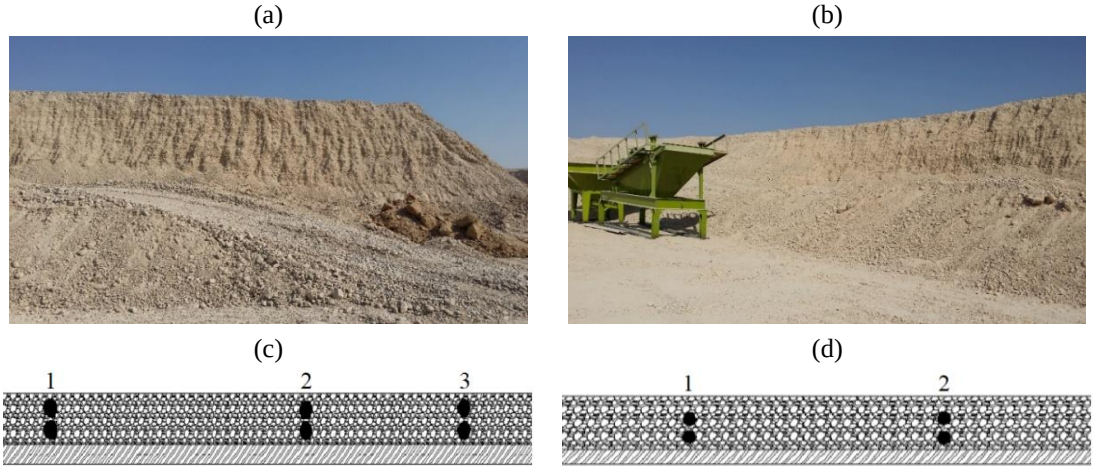


Figure 4. Location of sample procurement for Farshoot(a) wall side section 1 (b) wall side section 2; (c) sample location with depth 1; (d) wample location with depth 2

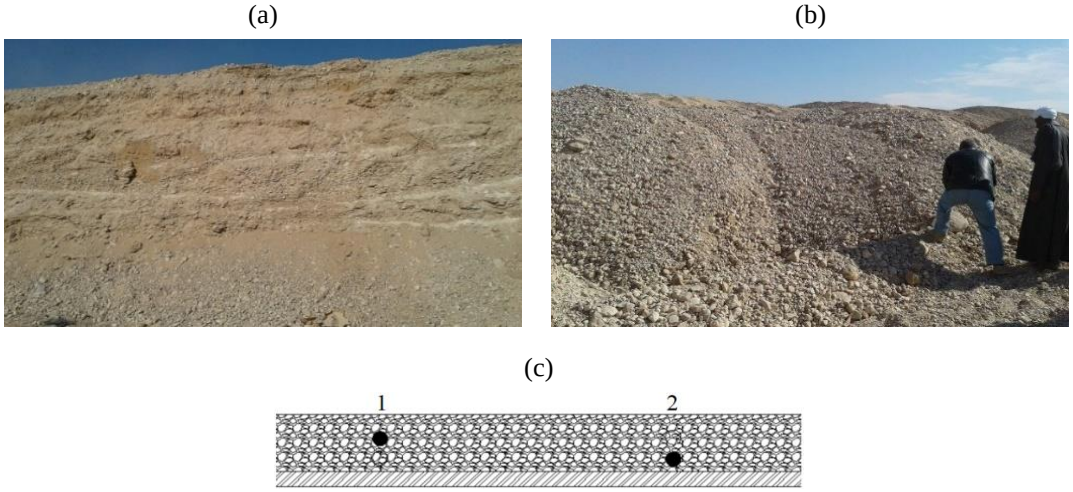


Figure 5. Location of sample procurment for Qus: (a) wall side section 1; (b) wall side section 2; (c) sample location with depth

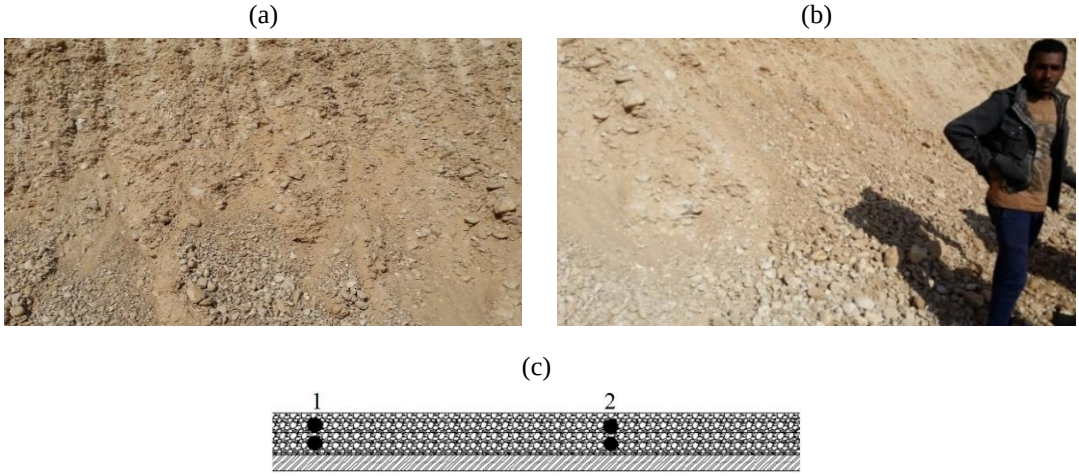


Figure 6. Loaction of sample procurement for Elgeash Road: (a) wall side section 1; (b) wall side section 2; (c) sample location with depth

3. Methodology

Evaluations of the aggregates in the gravel quarries of Qena depend on physical properties such as density, water absorption capacity, size fraction, shape, and chemical properties. as well as the mineral contents in the aggregates. Petrography examination of the gravel was carried out according to the ASTM standard 295 to identify the constitutes of the samples and identify the alkali-silica reactive ingredients such as opal, tridymite, chalcedony, crystobalite and alkali carbonate reactive rocks. Were also examined. Coatings prevent the development of strong bonds between the gravel and cement. Table 1 summarizes the chemical and physical properties for the samples obtained from different locations [14].

Table 1. Chemical and physical properties for gravel from quarry sites in Qena

Quarry	Properties				
	cL	Sulfate (%)	Adsorption (%)	pH	Density
Abo-Teshet 1	0.0021	0.00145	2.46	7.4	2.57
Abo-Teshet 2	0.0032	0.0013	2.32	7.5	2.62
Farshoot	0.0033	0.0015	2.21	7.3	2.61
Qus	0.0025	0.0012	2.42	7.45	2.58
Elgeash roads	0.0029	0.0011	2.47	7.5	2.55
Limits*	< 0.06	< 0.002	< 2.5	7.5	–

*These values are based on the Egyptian Code (2003) [15], [16]

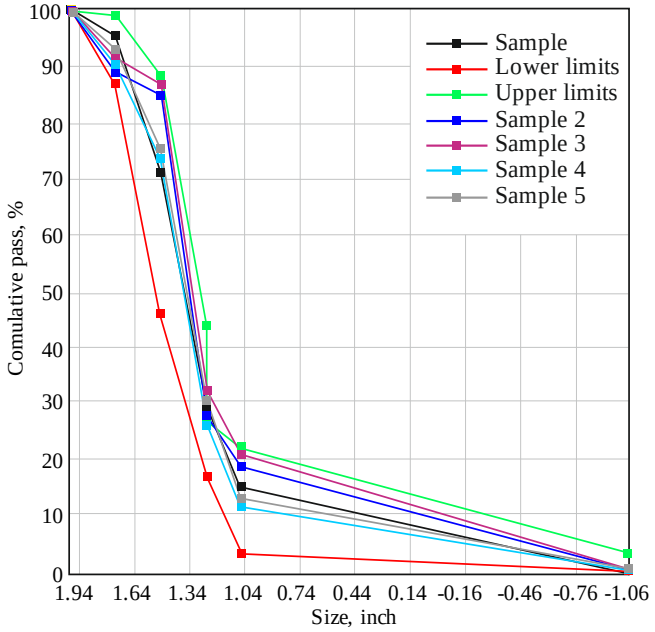
These minerals react with alkalis in the cement, leading to the expansion and cracking of concrete. Others constituent such as sulfides, sulfate, halite, iron oxide, clay minerals, and anhydrite, which might be present in the form of coatings impurities.

4. Results and discussions

The evaluations results indicate that, sulfate and chloride contents ranged from 0.0021 to 0.0033 for samples from all locations, as listed in Table 1. The sample from Abo-Teshet 1 contained 0.0021 and 0.00145 cL and sulfate respectively; its water absorption capacity was 2.46%, and its pH and density were 7.4 and 2.57, respectively. Therefore, this location was deemed suitable of many applications.

The sample from Abo-Teshet 2 contained 0.0032 and 0.0013 cL and sulfate, respectively, its water absorption capacity was 2.32% and its pH and density were 7.5 and 2.62, respectively. According to the Egyptian Code, this quarry is suitable for use in concrete and civil applications. The sample from Farshoot quarry was evaluated to possess a density of 2.61, a pH of 7.3, an adsorption capacity of 2.21%, and sulfate and cL contents of 0.0015 and 0.0033 respectively. Furthermore, samples from the Qus quarry contained cL and sulfate contents of 0.0025, and of 0.0012, respectively; their adsorption capacity pH, and density were 2.42%, 7.45 and 2.58, respectively.

The fifth quarry located on Elgeash Road yielded samples containing cL and sulfate contents of 0.0029 and 0.0011, respectively; these samples exhibited an adsorption capacity of 2.47, a pH of 7.5, and a density of 2.55. According to the Egyptian Code, gravel from all these locations was deemed to be satisfactory for use in concrete. All the samples were screened via grizzly, and the results indicated that the samples passed between the upper and lower limits stipulated in the Egyptian Code. The general classification of soils was discussed detail as shown in Figure 7 [17].



Abo Teshet 1>>1, Abo Teshet 2>>2, Farshoot>>3, Qus>>4, and Elgeash Road>>5

Figure 7. Particle size distribution for Quarries 1-5

Every material type was classified according to size (mm). Based on this from this, the Egyptian Code was implemented according to the general applications of gravel in civil tasks such as all concrete type and asphalt. (Egyptian Code ECP 203-2017). All the samples were evaluated to determine the corresponding losses, as illustrated in Tables 2-4.

Table 2. Particle size classification of soil [17], [18]

Types of material		Sizes, mm
Boulders		Over 200
Cobbles		60~200
Gravel	Coarse	20~60
	Medium	6~20
	Fine	2~6
Sand	Coarse	0.6~2
	Medium	0.2~0.6
	Fine	0.06~0.2
Silt	Coarse	0.02~0.06
	Medium	0.006~0.02
	Fine	0.002~0.006
Clay		Less than 0.002

Table 3. Standard code for concrete uses

No.	Size, inch	Size, mm	Uses	Remark
1	1.5-0.75	37.5-19	All concrete type	
2	2.5-2	50-63	Asphalt	
3	< 63		Not economic	Should be crushed

Table 4. Estimated losses of gravel in the samples

Locations	No. of samples	Losses for every sample, %	Average loss for every location, %
Abo-Teshet 1	5	41.80 51.69 40.17 44.64 42.01	44.06
Abo-Teshet 2	5	39.49 33.63 33.58 31.33 27.06	32.88
Farshoot	6	31.91 35.80 31.92 41.42 36.85 34.53	35.41
Qus	5	48.51 39.74 38.71 39.40 38.78	41.03
Elgeash roads	5	39.58 37.71 44.01 42.80 37.20	40.26

5. Conclusions

The results indicate that the gravels were dense and hard. Their water absorption capacities ranged from 0.47 to 2.21% (i.e., than 5%). These values suggested that the gravel from the studied quarries were suitable to be used foundation and sub-base layers, in accordance with the Egyptian Code for cement, asphalt, and road structure mixtures. The evaluation of the gravel from these sites depended on a visual study of gravel canyons demonstrating the elongation type. The chemical and mineralogical compositions of the analyzed gravel, including the petrographic analysis, revealed that they belonged to alluvial fans from the quaternary and stream sediments. The Abo-Tesheat 1-2 key spring rock, Farshoot, Qus, and Elgeash Road quarries. In the studied quarries, the loss of gravel deposits amounted to 32.88-44.06%. Abo-Teshet 1 exhibited the highest loss of gravel deposits with thicknesses ranging from 0.5 to 1.50 m, which was attributed to the fill layers. Lastly, the gravel deposits at the eastern bank of the Nile valley in the Qena region were widely distributed and of a high quality.

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Оцінка якості гравію та його втрат на прикладі гравійних кар'єрів у провінції Кена, Єгипет

М.А. Алі, М.М.А. Хассан, Ю.-Г. Кім, Ю.-Г. Кім

Мета. Оцінка якості гравію на основі дослідження його фізико-хімічних і фізико-механічних властивостей, а також визначення втрат на прикладі гравійних кар'єрів у провінції Кена, Єгипет.

Методика. Зразки були відібрані з п'яти місць кар'єрів у провінції Кена, Єгипет, на площі від 100×100 до 200×100 м^2 з двох робочих сторін кар'єрів. Зразки оброблені в лабораторії для визначення якості зразків залежно від їх місцезнаходження та оцінки їх властивостей відповідно до існуючих стандартів бетону й дорожнього покриття. Петрографічне дослідження гравію проводилося відповідно до стандарту ASTM 295.

Результати. Встановлено, що зразки гравію є щільними і твердими, а його водопоглинання змінюється від 0.47 до 2.21% (тобто більше 5%) і свідчать про те, що гравій підходить для використання в якості фундаменту і підстилаючого шару відповідно до єгипетських правил для цементних, асфальтових і дорожніх сумішей. Хімічний та мінералогічний склад гравію, в тому числі петрографічний аналіз, показав, що вони належали конусам виносу з четвертинних і річкових відкладень. Встановлено, що у вивчених кар'єрах втрата гравійних відкладень склала 32.88-44.06%. Визначено, що родовища гравію на східному березі долини Нілу в районі Кени були широко розповсюджені та мали високу якість.

Наукова новизна. Вперше проведена оцінка фізико-хімічних і фізико-механічних властивостей гравію кар'єрів провінції Кена, Єгипет, для встановлення можливості їх застосування в будівельній промисловості.

Практична значимість. Доведено, що гравій досліджуваних локацій підходить для будівництва доріг і використання в суміші асфальту та цементу, що дає можливість забезпечити місцеві регіони сировиною для будівельної промисловості.

Ключові слова: *характеристика гравію, будівельні матеріали, гравійний кар'єр, хімічні властивості гравію*

Оценка качества гравия и его потерь на примере гравийных карьеров в провинции Кена, Египет

М.А. Али, М.М.А. Хассан, Ю.-Г. Ким, Ю.-Г. Ким

Цель. Оценка качеств гравия на основе исследования его физико-химических и физико-механических свойств, а также определение потерь на примере гравийных карьеров в провинции Кена, Египет.

Методика. Образцы были отобраны из пяти мест карьеров в провинции Кена, Египет, на площади от 100×100 до 200×100 м^2 с двух рабочих сторон карьеров. Образцы обработаны в лаборатории для определения качества образцов в зависимости от их местонахождения и оценки их свойств в соответствии с существующими стандартами бетона и дорожного покрытия. Петрографическое исследование гравия проводилось в соответствии со стандартом ASTM 295.

Результаты. Установлено, что образцы гравия являются плотными и твердыми, а его водопоглощение изменяется от 0.47 до 2.21% (т.е. более 5%) и свидетельствуют о том, что гравий подходит для использования в качестве фундамента и подстилающего слоя в соответствии с египетскими правилами для цементных, асфальтовых и дорожных смесей. Химический и минералогический состав гравия, в том числе петрографический анализ, показал, что он принадлежал конусам выноса из четвертичных и ручьевых отложений. Установлено, что в изученных карьерах потеря гравийных отложений составила 32.88-44.06%. Определено, что месторождения гравия на восточном берегу долины Нила в районе Кены были широко распространены и имели высокое качество.

Научная новизна. Впервые проведена оценка физико-химических и физико-механических свойств гравия карьеров провинции Кена, Египет, для установления возможности их применения в строительной промышленности.

Практическая значимость. Доказано, что гравий исследуемых локаций подходит для строительства дорог и использования в смеси асфальта и цемента, что дает возможность обеспечить местные регионы сырьем для строительной промышленности.

Ключевые слова: *характеристика гравия, строительные материалы, гравийный карьер, химические свойства гравия*