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Mineralogical Composition and Physical – Mechanical Properties of Dasht - E - Taatrang Zar Sand Deposits (Afghanistan)

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Abstract: Sand is a common construction material used for various purposes, e.g. concrete, mortar, render, screed, and asphalt. The usage depends on its fineness, and its fineness is controlled by its mineralogical composition and physical – mechanical properties. This research aims to determine the chemical and mineralogical composition, and the physical – mechanical properties of the Dasht – e – Taatrang Zar sand deposits within the Qarabagh and Bagram districts of Kabul and Parwan provinces in Afghanistan. To achieve the objectives of this research, a review of the existing literature has been combined with new extensive field works for macroscopic studies and samples collection, and laboratory anayses. In total 23 samples during two phases of field works were collected and subjected to lab works for XRF, Schlich, and XRD analysis to determine the chemical and mineralogical composition, moreover, sieve and Atterberg analysis, specific gravity, soundness, and alkali-silica reaction tests were performed for characterization of the physical – mechanical properties of the studied samples. The results of the tests show that the Taatrang Zar sand deposits are considered as a suitable construction material and due to its simple accessibility, the deposits have high potential as a construction material supplier for the Kabul new city project (Dehsabz) in Kabul and adjacent Parwan and Kapisa provinces.

Keywords: sand, physical, mechanical, mineralogical, composition, determine.

1. Introduction

Sand is a crucial component of the construction industry, while the pure type (quartz sand) is used to make glasses and crystal dishes, it is the alluvial (or eolian) type that is most sought after for its use in concrete and cement or for example in pipe and underground pipeline coating. The Dasht – e - Taatrang Zar sand deposits are located 40 km North-East of Kabul city, the deposits extend from the end of the Dehsabz desert (Hotkai hill) up to Niazi and Aroki villages of Bagram district of Parwan province and to the right bank of Panjsher river.

The sands of Taatrang Zar are generally fine grained, and the sizes of grains vary from about 0.063 to 1 mm diameter. These deposits have formed over a long time in the hillside of the Zin Ghar Mountains, which is situated with an azimuth of 60 degrees in the area and provides a good obstacle for the accumulation of sands. The Dasht -e- Taatrang Zar sands have been exploited for use in construction and industrial affairs since 2004.

In 2006, Amir Mohammad Mosazai and Abdul Salam Kewla carried out joint research on these deposits regarding their mechanical characteristics, in which their results have been published in the Science and Technology Journal of Kabul Polytechnic University in 2008. In 2016, one of the master students of geological engineering and exploration of mines department of KPU (Mohammad Azim Ahmadi) did his master thesis on these deposits. Furthermore, Sadaf Jalal also one of the master students of the aforementioned department in 2018 completed his thesis on the comparison of Dasht -e- Laili sands with Dasht -e- Taatrang Zar Sands which had a suitable and interesting finding.

Several methods are applied to determine the mineralogical composition of the sand deposit; e.g. X-ray fluorescence, X – ray diffraction, polarized microscopic analysis, and spectrometric analysis [1–4]. The physical-mechanical properties of sands are considered as the most important parameters to be studied. Several physical-mechanical properties; e.g. density, hardness, shape, and size of grains, specific gravity, void ratio, and moisture contents are determined using different techniques to characterize the sands used for construction purposes [5–8].

Considering the reviewed literature, this study aims to determine the mineralogical composition and physical-mechanical properties of sand deposits of Dasht – e – Taatrang Zar within Kabul and Parwan provinces in Afghanistan. The findings of this study can significantly contribute to the related construction sectors and can be an effective reference for further detailed studies in academic institutions.

2. Study area

The Dasht -e- Taatrang Zar sand deposits are situated 40 - 45 km to the northeast of Kabul city within the hillsides of Zin Ghar Mountains, forming an irregular lens shape that is about 7 - 8 km long and 3 - 3.5 km wide. The thickness of the sand layers increases significantly towards the mountains. The initial thickness of the deposits is just several centimeters at the beginning adjacent to QIII clay which covers the surface of the study area and reaches about 35 - 40 m within the hillsides of Zin Ghar Mountains. Based on the administrative divisions, our study area (Dasht - Taatrang Zar) is placed in the borders of three districts (Qarabagh, Bagram, and Kuhe Safi Districts) between the geographic coordinates of 69°19'3.69"E - 34°54'50.22"N, 69°20'57.42"E-34°53'32.77"N and 69°16'20.01"E -34°51'32.98"N, 69°18'8.37"E - 34°50'29.86"N with the elevation ranges 1480 to 1600 m (Fig 1).

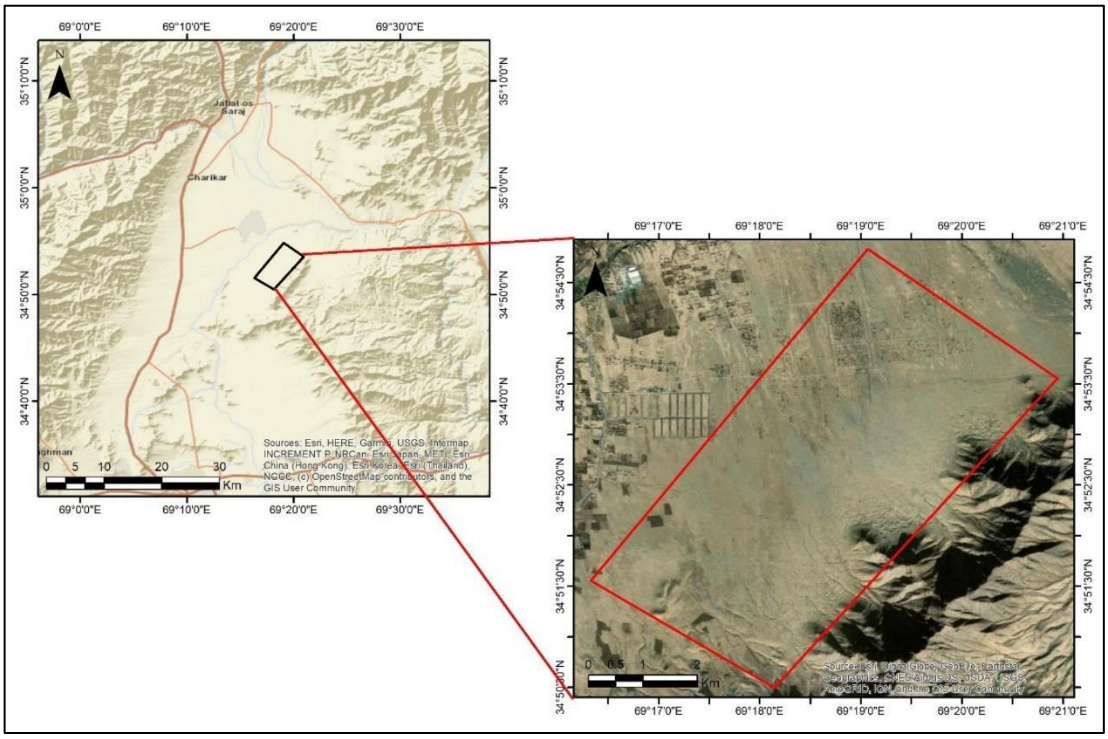

Figure 1. Location of the study area

3. Geological Setting

The Dasht - e - Taatrang Zar sand deposits are situated within the Kabul Block, specifically within the northern part. Although forming a coherent massif, the Kabul Block is highly deformed and consists of at least two distinctly different ancient geologic environments; a Permian to Jurassic marine platform carbonate section and the widespread belt of schistose mélange [9,10]. The Kabul massif is completely fault bounded. Its western edge is at the Chaman- Paghman fault system, and eastern edge is at the Sarobi and Gardiz faults [10,11] (Fig. 2).

The Paghman terrane, west of the Kabul massif, consists of Proterozoic gneiss and granite, Carboniferous to Cisuralian (Early Permian) sandstone and siltstone, Lopingion (Late Permian) to Triassic limestone and dolomite, Rhaetian and Norian shale and sandstone (possibly like that in Nuristan), and Early Cretaceous gabbro and monzonite. The oldest rocks occur within the northern part of the Kabul Block are Precambrian age metamorphics; e.g. amphibolites, quartzite, marble, and intrusive bodies such as granodiorites [12]. Based on [13], Paleozoic rocks of Ordovician, Silurian, Carboniferous, Permian formations are found around our study area. The rocks are marked as marble, schist, and quartzite (Fig. 2). Mesozoic rocks have been identified within the Paghman terrane and the northwestern corner of the northern Kabul block as Triassic formations, including metamorphosed sedimentary rocks, limestone, and dolomite [13,14]. Small outcrops of conglomerates and surficial deposits with Paleogene and Quaternary age are exposed within the various parts of northern Kabul block (Fig. 2).

In terms of magmatism, two expanses of plutonic rocks (granodiorite and mafic – ultramafics) are reported with Mesoproterozoic age over and around the Kabul Block. However, these ages are poorly constrained. Ultramafic bodies were also mapped within the Koh – i – Safi area, and assigned a Cretaceous age, similar to granitic plutons within the Kabul Block and the adjacent regions by [14] (Fig. 2).

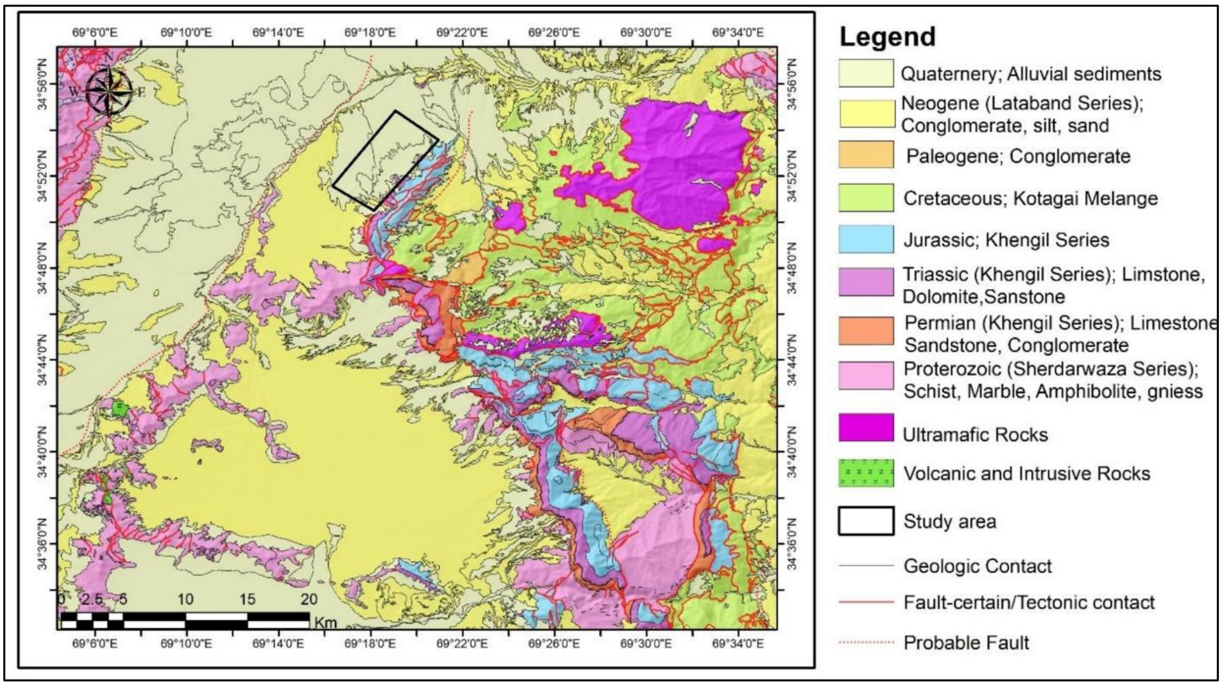

Figure 2. Simplified geologic map of northern Kabul Block modified from [13,15]

4. Methodology

This study was carried using the three following methods:

1. ***Library Method:*** This method formed the initial part of the study. A comprehensive review of the related literature using research and review articles, thesis, textbooks, authorized websites was carried out. This method was aimed at finding out the unrevealed and weakness points of previous studies carried out on the Taatrang Zar sand deposits, and also to select the proper analyses to be used for the mineralogical, physical- mechanical properties of sands. The general information including the geologic and tectonic setting of the study area was also provided by this method.

2. ***Field Observation Method:*** Fieldwork and sampling constitute a critical part of such studies. Therefore, field works in this study were carried out through several geologic transverses to study the macroscopic properties and to collect the samples from selected points. The sample collection for lab analysis was conducted within two phases of field works in the study area. The samples were collected randomly and based on the physical, morphological, and structural changes of sands. 23 samples were collected including 13 samples during the first phase and 10 samples through the second phase as shown in (Table 1) with their associated coordinates (Fig. 3).

3. ***Laboratory Method:*** The purpose of this method was the mineralogical, chemical, physical-mechanical analysis of the collected samples to reveal the selected properties of sands. For reliable results, the samples were sent to the Mineralogical Laboratory of Satbayev Institute of Geological Sciences, Kazakhstan, Diamond Geo Engineering Services, and Afghan Geological Survey in Kabul, Afghanistan. For chemical and mineralogical composition, the samples were subjected to X-ray fluorescence, X-ray diffraction (XRD), and Schlich analysis. Several tests e.g. Sieve analysis, Atterberg test, Specific gravity test, Soundness test, and Alkali-silica reaction test was carried out for the determination of the physical-mechanical properties of the Taatrang Zar sand deposits.

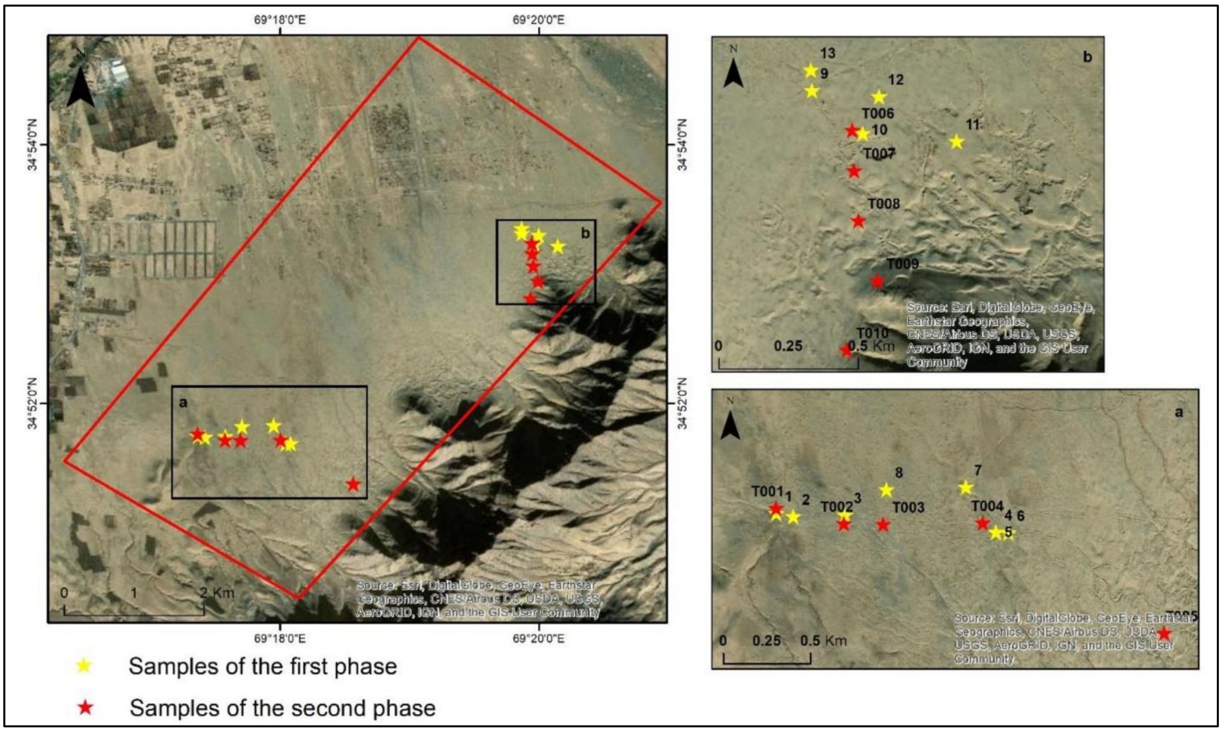

Figure 3. The plan of collected samples during the first and the second phases

Table 1. Associated coordinates and altitudes of the collected samples

Phase - I				Phase - II			
No	**Latitude**	**Longitude**	**Altitude**	**No**	**Latitude**	**Longitude**	**Altitude**
1	34^0 51' 44.8''	69^0 17' 21.9''	1586	T001	34^0 51' 45.7''	69^0 17' 21.9''	1674
2	34^0 51' 44.2''	69^0 17' 25.1''	1585	T002	34^0 51' 42.9''	69^0 17' 34.5''	1574
3	34^0 51' 44.5''	69^0 17' 34.7''	1584	T003	34^0 51' 42.8''	69^0 17' 41.8''	1580
4	34^0 51' 41.3''	69^0 18' 2.7''	1603	T004	34^0 51' 43.0''	69^0 18' 0.3''	1603
5	34^0 51' 41.3''	69^0 18' 2.7''	1603	T005	34^0 51' 22.6''	69^0 18' 34.0''	1664
6	34^0 51' 41.2''	69^0 18' 5''	1608	T006	34^0 53' 14.1''	69^0 19' 56.9''	1540
7	34^0 51' 49.7''	69^0 17' 57.1''	1591	T007	34^0 53' 9.4''	69^0 19' 57.1''	1549
8	34^0 51' 49.2''	69^0 17' 42.4''	1584	T008	34^0 53' 3.6''	69^0 19' 57.6''	1540
9	34^0 53' 18.7''	69^0 19' 52.2''	1544	T009	34^0 52' 56.6''	69^0 19' 59.8''	1586
10	34^0 53' 13.7''	69^0 19' 58.1''	1553	T010	34^0 52' 48.6''	69^0 19' 56.3''	1604
11	34^0 53' 12.8''	69^0 20' 09''	1555				
12	34^0 53' 18''	69^0 20' 00''	1552				
13	34^0 53' 21.1''	69^0 19' 52.1''	1545				

4.1. Chemical and mineralogical analysis

4.1.1. X-ray Fluorescence (XRF)

X-ray fluorescence is used to determine the bulk chemical composition of rocks, minerals, and sediments. The elements from fluorine to uranium in the periodic table can be detected by XRF [16,17]. 13 samples from various locations were analyzed using X-ray fluorescence targetting the elements Mg, Al, Si, P, K, Ca, Ti, Fe, S, Cl, Mn, Sr, Ba, and Zr. The concentrations of these elements in the composition of sand samples are highly variable ranging from high percentage to PPM contents. The associated results and percentage of each element is shown in the original report in (Table 2).

Table 2. Results of XRF analysis of the sand samples collected through the first phase

Sample No	Elements														
	%									PPM					
	Bal	**Mg**	**Al**	**Si**	**P**	**K**	**Ca**	**Ti**	**Fe**	**S**	**Mn**	**Cl**	**Ba**	**Sr**	**Zr**
1	53.58	1.99	6.44	26.81	0.14	2.59	2.45	0.72	5.02	834	559	666	380	239	-
2	54.83	1.41	6.5	29.95	-	1.66	2.52	0.36	2.61	688	306	240	349	308	-
3	54.62	1.25	5.79	29.15	-	1.46	3.85	0.41	3.13	735	561	261	352	299	153
4	51.18	0.87	6.74	31.32	0.15	1.18	3.22	0.53	3.288	776	693	230	381	242	334
5	53.65	1.13	6.62	29.55	0.11	1.48	3.59	0.44	3.19	818	514	367	323	105	169
6	52.96	1.23	6.3	30.62	0.14	1.39	3.12	0.29	2.71	729	388	315	296	365	-
7	52.96	1.23	6.3	30.62	-	1.39	3.12	0.29	2.73	-	388	315	365	296	-
8	54.62	1.22	5.82	29.65	-	1.46	3.35	0.4	3.14	740	556	266	352	294	158
9	54.1	1.31	6.21	29.58	-	1.62	4.36	0.47	3.61	973	637	572	386	226	237
10	64.8	0.95	4.98	22.3	-	1.15	2.31	0.12	1.55	625	169	367	136	360	-
11	54.62	1.25	5.79	29.15	-	1.46	3.85	0.41	3.13	735	561	261	352	299	-
12	56.95	-	6.73	29.67	0.15	1.04	3.21	0.14	1.47	866	232	469	349	350	-
13	53.26	1.31	6.21	28.74	-	1.74	4.36	0.47	3.48	971	632	577	482	233	232

4.1.2. Schlich Analysis

The schlich analysis is one of the mineralogical approaches that is used for the identification of mineral concentrations without complicated chemical analysis. This method is mostly used in placer deposits by consideration of physical characteristics of minerals; e.g. density, color, hardness...etc. The sample is divided into different fractions under the mineralogical microscope, then the existing minerals within the fractions are determined based on their physical characteristics. In this study, 13 collected samples were subjected to Schlich analysis to determine the mineralogical composition; the results are shown in (Table 3).

Table 3. Results obtained from schlich analysis for the collected samples through the first phase

Minerals/fragments		Samples												
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Quartzite fragments	Wt in %	40	60	45	52	31	60	61	47	55	66	60	62	60
Biotite and Muscovite		46	10	35	27	31	10	10	33	10	13	10	10	23
Calcite		10	15	15	21	15	10	15	13	20	4	13	9	17
Amphibolite fragments		-	5	5	-	7	10	5	7	5	9	5	10	-
Magnetite		4	5	-	-	3	5	6	-	5	3	7	4	-
Pyrite		-	-	-	-	3	5	-	-	-	5	-	-	-
Schist fragments		-	5	-	-	10	-	3	-	5	-	5	5	-

4.1.3. X – ray Diffraction (XRD)

X-ray diffraction (XRD) is the primary instruments used for the identification and quantification of mineralogy of crystalline compounds in rocks and sediments. Furthermore, this tool is essential for characterizing the nature of clay minerals that cannot be determined by any other methods [3,16]. The 10 collected samples during the second phase were sent to the Mineralogical Laboratory of Satbayev Institute of Geological Sciences, Kazakhstan for XRD analysis in which the results are shown in (Table 4).

Table 4. X-ray diffraction results for the collected sand samples through the second phase

Minerals		Samples									
		T001	T002	T003	T004	T005	T006	T007	T008	T009	T010
Quartz	Wt in %	53.2	45.0	41.6	41.5	45.9	34.4	51.1	42.9	31.0	44.0
Amphibole (tremolite)		16.8	19.0	23.7	28.2	24.7	33.6	17.6	24.2	25.4	32.9
Albite		15.7	20.0	20.0	18.4	14.9	18.5	22.4	23.3	24.9	17.4
Mica		4.3	4.9	5.3	4.9	2.6	7.0	3.3	3.7	3.5	1.4
Feldspar		3.4	3.9	3.3	4.1	10.6	3.0	3.3	3.6	12.7	3.3
Calcite		2.7	3.0	2.6	-	-	-	-	-	-	-
Chlorite		2.0	2.2	3.4	2.8	1.3	3.5	2.3	2.4	2.5	1.1
Hematite		1.7	2.0	-	-	-	-	-	-	-	-

4.2. Physical – Mechanical Analysis

4.2.1. *Sieve Analysis and Atterberg Limits*

Sieve analysis, also called the gradation test, is used to assess and define the particle size distribution of granular materials. The procedure is carried out by passing the materials through a series of sieves with different meshes. The Atterberg limits test is the measurement of the critical water contents of fine-grained soils and depending on the water contents, four types; solid, semi-solid, plastic, and liquid are determined [18].

In this study, 10 samples collected during the second phase were sent for sieve analysis, Atterberg limits, and soil classification following the ASTM D-422, ASTM D-4318, ASTM D-2487 standards (Table 1). The results show that all the samples are considered non plastic. From the total number of samples, 8 of them are classified as silty sand (SM) due high contents of sand and silt & clay contents (more than 10%). Two samples (T009 and T010) were classified as poorly graded sand with silt (SP – SM) and poorly graded sand (SP) respectively. These two samples were collected from the north east of study area close to the mountain hillside and rock bodies.

4.2.2. *Specific Gravity*

material to the weight of an equal volume of water (at 20°C). The specific gravity of soil and sands are depending on the density of the minerals existing within the soil particles. A substance with the specific gravity varying between 2.60 and 2.80 contains inorganic materials, while a substance with the gravity of 2.75 and 3.0 are lateritic soil. Sand particles, due to the presence of quartz minerals have gravity ranging from 2.65 to 2.67 [19,20]. In this study, 10 samples were tested for specific gravity which has been collected from different locations of the study area. The analysis was carried out under the ASTM – 854 standards as (T001=2.69, T002=2.70, T003=2.74, T004=2.71, T005=2.69, T006=2.71, T007=2.71, T008=2.70, T009=2.69, T010=2.69).

4.2.3. Soundness Test

Soundness is the loss percentage of materials from an aggregate blend during the sodium or magnesium sulfate soundness test. The test is carried out in ASTM – C8, estimates the resistance of aggregate to weathering. It can be done on both coarse- and fine-grained aggregates. The maximum loss percentage range from 10% to 20% [21,22]. 5 sand samples randomly were selected for this test within the study areas in which the results are shown in (Table 5).

Table 5. Soundness test results for the selected samples collected during the second phase

Sieve Size		Samples									
		T001		T002		T004		T006		T009	
Passing	Retained	Loss after test %	Weighted Loss %	Loss after test %	Weighted Loss %	Loss after test %	Weighted Loss %	Loss after test %	Weighted Loss %	Loss after test %	Weighted Loss %
#50 (.3mm)	#100 (0.15mm)	26.4	12.8	13.2	6.4	15.0	7.3	3.8	1.8	50.6	24.6
#30 (.6mm)	#50(3mm)			3.3	0.8	15.7	4.0	4.9	1.2	27.4	6.9
#16(1.18mm)	#30(6mm)					11.9	4.0	5.9	2.0		
Total Soundness		**12.8**		**7.2**		**15.3**		**5.1**		**31.4**	

4.2.4. Alkali Silica Reaction Test

This test is carried out to detect the potential of an aggregate used in concrete for undergoing alkali-silica reaction resulting in potentially deleterious internal expansion. Based on the X1 section ASTM C1260, the expansions of less than 0.10% at 16 days after casting are indicative of innocuous behavior in most cases, while the expansions between 0.10 and 0.20% at 16 days, the aggregates are known to be innocuous and deleterious, meanwhile, the deleterious aggregates are characterized by the expansions of more than 0.20% at 16 days after casting [23,24]. The same 5 samples (T001, T002, T004, T006, and T009) tested for soundness were also selected for the alkali-silica reaction test in this study. The results show that the expansion of all aggregate samples is less than 0.1% after 16 days, therefore these aggregates indicate innocuous behavior and have no alkali reaction potential.

5. Results and Discussions

The Taatrang Zar sand deposits have been used for the last several years for various construction purposes, however, no detailed testing was done to characterize the aggregate grading, mineralogical and chemical composition, and their resistance against weathering and other factors. In such cases, the use of sand may cause distinct problems from a construction and building perspective in the future. Considering the chemical and mineralogical composition results, the sand deposits of Dasht – e – Taatrang Zar contain various chemical elements and minerals. The most abundant elements being found is (Si) which can be a significant indicator of the mineral silicon dioxide (SiO_2) in the form of quartz or quartzite fragments. After the (Si) element, aluminum (Al) has a high distribution ranging from 4.98 to 6.72%. The iron content also has regular distribution as it is increasing from hillside to mountains according to the samples collected.

Based on the findings of X-ray diffraction (XRD) and Schlich analysis, quartz and quartzite fragments have the highest distribution with different ranges. The range is increasing from east to west within the study area. The Schlich analysis shows the highest distribution of carbonates that affect the quality and resistance of sands, however, the results from this analysis due to a classical method are not as reliable as XRD, and therefore the actual distribution of carbonates contents is confined within the study area. The limited samples show the existence of carbonate distribution.

Concrete strength is lowered with increasing silt contents present in fine aggregate used for the concrete production as the compressive strength of concrete decreases from 5 MPa to 3 MPa when the silt content of the fine aggregate increases from 7% to 9% [25]. The results from almost all of the samples show the silty sand type with higher than 10% content of silt and clay. The soundness test of the collected samples indicates that the deposits located within the central part having less loss (high soundness <10%) and are resistant against the weathering processes, while the deposits close to the hillside and road crossing are characterized by moderate or high loss (moderate to less soundness >10%). Considering the alkali-silica reaction test, Taatrang Zar sand deposits are characterized by non-reactive and can be used for different construction purposes.

6. Conclusions

Following the objectives of the research, which is the determination of chemical, mineralogical composition, and physical-mechanical properties of Taatrang Zar sand deposits within the Qarabagh, and Bagram districts in Afghanistan, comprehensive field works, and sample collection was carried out. Three separate analyses (Schlich, XRD, and XRF) were conducted for the chemical and mineralogical composition of the collected samples and show that the Taatrang Zar sand deposits are mostly composed of quartz and amphibole (tremolite) minerals. Existing quartz fragments within the sand are considered a significant mixture from a hardness and resistance perspective. Sieve analysis, specific gravity, soundness, alkali-silica reaction tests were performed for the characterization of the physical-mechanical properties of these deposits. The results of sieve analysis shows that these sands are classified as silty sand and of a non-plastic type. The amount of silt and clay is more than 10% and may consider as a caution for the direct usage of sand as a construction material. Therefore, it is highly recommended to take the required steps before using in construction purposes. Sands from the central parts are considered more resistant than other parts close to the hills. Furthermore, the findings show that Taatrang Zar sand deposits are characterized as non-reactive sands which can be an effective indicator to be used in different construction purposes. The sand deposits area has a simple geologic and geographic setting which may decrease the exploitation costs and somehow will affect the overall cost of construction projects. Meanwhile, the deposits can be a high potential of sand supplier for the Kabul new city (Dehsabz) project in Kabul, and to other adjacent provinces e.g. Parwan and Kapisa.

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