



EVALUATING THE STABILITY OF GEOLOGICAL FORMATIONS FOR THE CONSTRUCTION OF WATERSHED MANAGEMENT STRUCTURES AND BUILDINGS

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Abstract

The stratigraphic and lithological properties of the formations in Babagir Watershed from old to new predominantly stem from various kinds of sedimentary and stone facies that have been subjected to the various tectonic events and geological processes spread with certain specifications all over the watershed. The general trend of the folds is prevalently east-westward subject to the structural properties of the region. The formations feature their own specific stabilities and instabilities based on the lithological and geotectonic characteristics influencing the peripheral environment. In a more precise and exclusive spot investigation of the detached formations, mechanical properties of the soil and the rock were measured and examined in a more detailed manner in various projects. These experiments are usually costly. However, the stability of these formations has been figured out without these experiments and only based on the field investigations as well as by examining the geological properties and physical and chemical traits of the rocks and the general characteristics of the region such as slope and structural elements. Moreover, the engineering behavior of the rock was controlled through the existent discontinuities, including stratifications, joints, faults, foliation, rock facies and others of the like and the classification of the stone formations into separate segments. The other factor influencing the rock behavior was the type and specifications of the engineered structures. A given rock with fixed properties might react differently in various applications which have been taken into account. According to the stratigraphic and lithological columns' characteristics, the comprehensive plan of the sedimentary rocks' are consisted of limestone, shales and marls and detached sediments of old and new alluvial terraces, gravel and the main rivers' bed alluvium which uses the massive formations as rock borrow pits and the alluvial and colluvial deposits as the sand and soil borrow pits.

Keywords: lithology of the geological formations, engineered structures, geotectonic properties, geodynamics, Ilam Province

Introduction

Borrow pits is an expression referring to the collection of stones and gravel masonry that are usable for the construction of a building (Berajam Dass, 1998). In between, certain borrow pits specific to every region are required for the construction of each structure. According to the fact that the watershed management structures are mostly constructed in the form of gabion, rock and mortar, soil, dry-laid bulkhead, embankment and other dykes, the feasibility of applying stone and gravel masonry in the vicinity of the watershed has been discussed and investigated in this part of the study (Safinejad and Dadras, 2000). On the other hand, the use of the gravel borrow pits has been also discussed and investigated and their spatial location has been specified in respect to the watershed management structures for such purposes as finding sand and rock borrow pits (coarse-grained stone borrow pits), clay borrow pits (fine-grained borrow pits) and combined stone-gravel borrow pits for the construction of earth dike (Davoudi and Nabipay Lashkariyan, 2001).

Geographical Position

The study region features independent and dependent basins. Babagir Watershed, as the

independent basin, is 6511.7 hectare in area and it is situated in the southeastern part of Babagir Watershed. This independent basin, is 1595.8 hectare in area and it is positioned within a 20-kilometer distance from northwest of Eywan County in Ilam Province in $46^{\circ} 2' 39''$ to $46^{\circ} 10' 52''$ longitude and in $33^{\circ} 52' 50''$ to $34^{\circ} 1' 52''$ northern latitude. It is bordered by Shaylan Mountain in the north; by Nesar Belaleh in the northeast; and, by Bayeh Mountain in the south. The residential areas near the watershed are Darvand, Sartang, Sartang Sofla, Tran Naderi, Shourabeh Tran, Babagir and Pir all of which are also within the study region. The basin is about 46.904 km in perimeter and the independent area's perimeter is 19.021 km. The highest elevation of the region is 1931 m and the lowest elevation is 995.6 m from the sea level (Sharifi, Rahman, 2005).

Materials and Methods

The required maps were prepared in 1:50000 scale based on the collected information and field surveys and by the use of field instruments (GPS, loop, pocket stereoscope and others). They assisted by geology maps, 1:250000 and 1:100000, of Ilam's four corners and topography maps, 1:250000 and 1:50000, prepared by the country's geography organization and the aerial

maps, 1:55000 and 1:20000. Based on these prepared maps, especially geology map (lithology), borrow pits were examined in the following classifications that also contain some parts of the obtained results (Sharifi, Rahman, 2006):

(A) Stone Borrow Pits

Rock is amongst the constructional materials applied in the construction of watershed management structures. These materials should be appropriate in terms of durability, non-decomposability, mechanical strength and the other physical and chemical properties so that the structure could have the required efficiency.

Based thereon, the recognition and use of the rocks' general properties are necessary in regard of the structure of the plan's analysis and implementation. From geological perspectives, rocks are divided into igneous, metamorphosed and sedimentary. The latter type has been observed in the study region. The aforementioned classification somewhat reflects the physical and mechanical properties of the rocks. However, a rock type might appear fresh and integrated

(intact) and/or decomposed and weathered and/or it might have become separated into pieces due to the development of cracks and cleavage (rock masses). According to the aforementioned cases, rock quality designation index is used for determining its extraction worthiness from borrow pits. This has been investigated as below:

(i) Classification of Stone Masonry Based on RQD:

Rock quality designation (RQD) index is applied for the identification of the quality of stones as borrow pits (Bowles, 2013). The index refers to the ratio of the total length of segments larger than 100mm in an integrated cylindrical sample to the total length of the core. But, according to the fact that performing core-drilling operation on rock units entails making large costs, RQD has been estimated in the entire course of the present study by measuring the distance and position of the rock discontinuities in various stratigraphic stations, calculating the number of joints and cracks per every cubic meter of rock (JV) and applying the following equation.

$$RQD=115-3.3JV$$

Table 1: The relationship between the rock quality designation (RQD) index and the rock type and status (Bowles, 2013)

Rock quality designation (RQD) index	Type and status of rock
<0.25	Very weak
0.25-0.50	Weak
0.5-0.75	Relatively good
0.75-0.9	Good
>0.9	Excellent

According to the investigation of RQD amounts in the rock units of the studied watershed, it can be stated that the limestone layers in Gachsaran Formation were intensively shattered in the vicinity of the drift in the southwest of the basin and had very low RQDs. This made them unable to produce proper stone blocks hence they were not appropriate as stone borrow pits. This is while the RQDs of the limestones in the other spots have been 74 and 69 in the other stratigraphic stations so they are classified as relatively good rock blocks. Therefore, it can be stated that the limestone layers of Gachsaran Formation can be used as stone borrow pits (rubble) in some spots (Majidifar, 2009). In between, it is necessary to mention that these rock layers can be used in the case that they are not intensively weathered. According to the investigations, Asmari Formation, in the southwest, south and northeast of the study region, featured extensive outcrops and, based on the field investigations in 34°

27' 29" and 45° 44' 12.5", the aforesaid rock unit featured a RQD index equal to 72 so it felt in the relatively good rock rank hence it was applicable as a stone borrow pit.

Based on what was mentioned above, only the limestone layers of Gachsaran Formation produced good rock blocks inside the studied watershed area hence it was applicable as stone borrow pits. However, it has to be pointed out that the aforesaid limestones also contained considerable amounts of clay in their texture and this caused the reduction of their strength against weathering. Therefore, the foresaid rock units had undergone considerable weathering in the studied area. This way, only the limestone layers existent in the southern, southwestern and northeastern parts (Asmari Limestone) featured the required conditions for being utilized as stone borrow pits for the construction of watershed management structures. Hence, the results of the experiments conducted on the aforementioned

limestone layers are offered in this part of the research, parallel to the investigation of the foresaid stone layers’

quality for using as stone masonry in the hydraulic structures corresponding to the existing standards.

Table 2: Maximum and minimum values of the measured parameters in Asmari limestone layers (Majidifar, 2009)

Formation name	Point load index (%)	Point load index (MPa)	Aggregate soundness (%)	Water absorption (%)	Dry density (gr/cm ³)	Uniaxial strength (MPa)	
						Dry	Saturation
Limestone layers of Asmari Formation	Minimum	2.9	2.4	3.2	2.26	392	311
	Maximum	4.2	3.21	5.2	2.4	460	412

(B) Gravel Borrow Pits

(i) Coarse-Grained Gravel Borrow Pits

In writings, sands and stones are used interchangeably for gravel borrow-pits. But, in the present study, a more general concept of gravel borrow pits has been used so that it can incorporate a vaster domain of these materials’ applications in engineering projects, including particles finer than sand and coarser than gravel. Quaternary alluvial sediments are easily exploitable for their vast outcropping and triviality of the bonds between their particles hence they are considered as the most important source of sand and gravel. These sediments differ in their sources and only certain groups of them can be considered as sand and stone borrow pits (Refahi, Hussein Gholi, 1996). In the studied area, the alluvial units of the young alluvial cones and the colluvium of the river beds were visible. The following part deals with the investigation of the feasibility of using them as gravel borrow pits (Zia’ei and Behniya, 2001).

(a) River Bed Alluvium

Following the separation of stone particles from the bedrock by weathering, they are carried by water towards the downstream (Faizniya, 2003). Then the coarse-grained particles, of the size of the sand and stone and gravel, are transferred in the form of leaping and rolling. These particles become polished in the stream due to abrasion and their sphericity depends on the distance to which they are carried away from the bedrock. The coarse-grain particles cannot be carried in places that the water energy is reduced and, resultantly, they are sequestrated on the river bed. This way, firstly the coarser particles and gradually the finer particles settle down. So, the aforementioned particles might feature different mating. The riverbed alluvium is substantially comprised of sand and stone particles coarser than that and, due to the high mechanical strength, their granularities are usually appropriate and

devoid of loose and harmful particles. Thus, these are most often the most important sources of sand and stone supplies (Faizniya, 1995).

(b) Young Alluvial Cones

This alluvial unit is composed of segments of the same size of gravel as well as the coarser particles in a background of sand, silt and clay. This borrow pit is applied for preparing and constructing the impermeable core of the earth dikes. Based on the field studies performed within the format of the current research paper, there is soil with heavy texture in the surface of marl layers in Gachsaran and Aghajari Formations. But, the field studies are also reflective of the idea that a substantial fraction of these soils contain particles of the size of silt and the marls. Because they are being formed following weathering, they mostly lack the required cohesion. On the other hand, due to the alternativeness of the Anhydrite and marl layers in Gachsaran Formation and gypsum and Marl in Aghajari Formation, evaporitic rock segments can be most often found in the texture of these soils (Ghadimi Arous Mahalleh, and Ebrahim, Amin Sobhani, 1998). On the other hand, the aforesaid soils mostly contain considerable amounts of salt. According to the aforesaid cases and considering the low thickness of the foresaid soil types, they cannot be used as clay borrow-pits for the construction of the core of the earth dam.

(c) Combined Gravel Borrow Pits

By combined gravel borrow pits in the present study, the suitable borrow pits are intended, including GC, SC, GM and SM that are used for the construction of the body of the earth dams. Based on the studies carried out in regard of the characteristics of the basin’s alluvial units, it can be concluded that the soils with the aforementioned characteristics should be sought inside the young and old alluvial cones. In the young alluvial cones, the segments of the size of sand and larger up to clay size can be seen. In this alluvial unit, the majority

of the segments are of the same size as sand and silt (Ebrahimi, Nader Gholi and Varvani, Javad, 2005). Thus sand and clay take the next ranks in terms of weight. According to the cases introduced in the section on the coarse-grain gravel borrow pits, it can be concluded that the coarse grain segments feature suitable mechanical strength for being pounded but segments of the same size as sand have been mostly consisted of weak marl particles that are prone to shattering when pounded. On the other hand, the amount of clay existent in this alluvial unit is very low. Accordingly, the aforesaid alluvial unit features low cohesion. According to the cases mentioned up to now, this alluvial unit is not a suitable borrow-pit for the construction of the body of the earth dikes (Toghrol, Nourollah, 2002).

Therefore, this alluvial unit, as well, is not favorable as gravel borrow pit for the construction of the earth dam. In other words, in case of designing such a structure, the suitable borrow pits should be supplied from outside the basin and transferred thereto.

Results and Discussion

In the studied watershed area, strong and weak rock units have been found lying at the side of one another. Likewise, the segments resulting from the slopes' erosion have found their way into the ancillary water channels and finally the main water channel. Based on the studies performed in this regard, the entire parts of the basin could be found with large spreading of runoffs due to the abrupt reduction of the water channels' bed slope. Accordingly, the particles with high and low mechanical strength were found deposited all of a sudden. In these areas, the alluvium of the riverbed was usually found composed of fine-grain stone segments of the lime-bearing sandstone and even marl and anhydrite and the sand parts were found to be composed of marl particles. This part of the alluvium on the riverbed was not considered as sand and stone borrow pit for its containing of soluble sulfide minerals (gypsum and anhydrite) for a large volume, inappropriate granularity, low relative density of the particles, weathered nature of the particles' margins (that prevent adhesion to cement) and the existence of segments with low mechanical strength. Considering the small transverse expansion of this alluvial unit, it was not possible to show it on the map of the borrow pits. In the meanwhile, it was envisaged sufficient for the construction of low-volume structures.

Comparing the amounts obtained from the experiments (table 2) with the standard values (table 1), it could be concluded that the amount of point load index of Asmari Formation's limestone layer was in a good limit with good aggregate soundness, intermediate water adsorption and intermediate dry density. In other words, the aforementioned stone layers had the capabilities of being applied in hydraulic structures for flood control in a relatively proper level. They could also be applied as stone borrow pits for the construction of stone and mortar and gabion dams as well as protective layers further up the stream in the form of earth (riprap) dams. The results of these series of experiments indicated that Asmari limestone layers were appropriate for the construction of controlling hydraulic structures. Considering the outcropping of Asmari limestone layers in the southwest, south and northeast of the studied area, these layers could be utilized for the construction of hydraulic structures for flood control.

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