Int. J. Econ. Environ. Geol. Vol. 10 (2) 129-133, 2019

Journal home page: www.econ-environ-geol.org

Open Access

ISSN: 2223-957X

The Evaluation of Geotechnical Properties of Precambrian Hazara Slates, Hazara-Kashmir Syntaxis, Azad Kashmir, Pakistan

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***Received:** 18 February, 2019* ***Accepted:** 12 July, 2019*

Abstract: The fold and thrust belt of the eastern Hazara division characterised the sedimentary rocks of Precambrian to Paleocene age. The sequence and formation of Precambrian signify the oldest rock unit as Hazara Slate. Geological map of the study area was prepared at the scale of 1:75,000 for about 140 square kilometre area located in Muzaffarabad (Azad Kashmir) district and Lohargali of Abbottabad (Khyber Pakhtunkhwa) district. The lab analysis shows that it is not rational to use Hazara slates as aggregate material due to its mineral accumulation and composition. Los Angele's Abrasion Value, Impact Value, Crushing Value, Specific Gravity, Water Absorption, Flakiness Index, Elongation Index, Porosity Value, California Bearing Ratio test and Grain Size Analysis were done and co-related with B.S standards and the parameters were deduced. It was observed that the mineral composition of Hazara Slates ranges for illite, kaolinite, quartz and carbonate. Kaolinite and illite are clay minerals which haveswelling potential to cause construction material damage the material. The presence of Carbonate and Quartz gives strength to the material, but its percentage is low. Reserves calculation of different localities was also done for the quarry development.

Keywords: Geological mapping, engineering characteristics, Hazara slate, geo-material.

Introduction

The use of Hazara slates as a construction material in Azad Kashmir is a common practice but the study of its geotechnical properties requires to the nature of composition of the rock. The potential area for Hazara Slates is Kashmir Hazara Syntaxis. Presently there is a number of quarry mines, which provide the slates as aggregate material for different construction purposes but unaware about geotechnical properties of Hazara Slates. Present study of geotechnical properties of slates will reveal the varieties of slates (Figure 2) based on their different color, texture, hardness and mineralogy which affect its quality.

Most of the mines are located at the roadsides, from which the slates are extracted for different purposes such as road construction, as rock tiles for pavements, and also used as stones for local houses construction.

Regional Geology

The study area is mainly located within Middle and Lesser Himalayan zone, in which Kashmir Hazara Syntaxis is the central part. The rocks age of Muzaffarabad and the connecting areas in the range from Pre-Cambrian to Miocene age. Age of Hazara formation (slates) is Precambrian (Tahir Khali 1980), and its distribution along western part of the Murree Formation (Miocene) adjacent to Murree which is the main part of Murree Thrust. The formation of eastern slope rocks is deformed into broad folds. Hills of the formation made of limestone, sandstone, clays and slates. These all type of stones exposed along the hill slopes of the study area especially very clear along road cuttings. These are parted by north-south trending thrust fault and in the west of the fault exist Muzaffarabad anticline. The overall structure of the area forms the synclines and anticlines. The Muzaffarabad (main structure) area is symmetrical anticline towards in the eastern side of proper Muzaffarabad. According to Bossart (1984) the trend of the axis falls approximately N.W-N.E. The symmetrical anticline thrust separated along south-west to west along and over the older slates and trusted junction presented near Ambor in Jehlum Valley (Muzaffarabad). The folding and faulting structural features affected the rocks of study area. Jehlum fault separated along Kunhar river and in the south along Jehlum river, about 4 km from western side of Muzaffarabad city. The cross bedding and ripple marks were observed on sandstone. Weathering solution on limestone is commonly presented with micro folding and slickenside in the Hazara slate areas.

Geological Description of the Study Area

The lithostratigraphic units exposed in the study area ranging in age from Pre-Cambrian (Hazara Formation) to Recent (Alluvium) and consist mainly of sedimentary and metamorphic rocks. Hazara

Formation (Precambrian) is the oldest formation and the Murree Formation (Miocene) is the youngest.

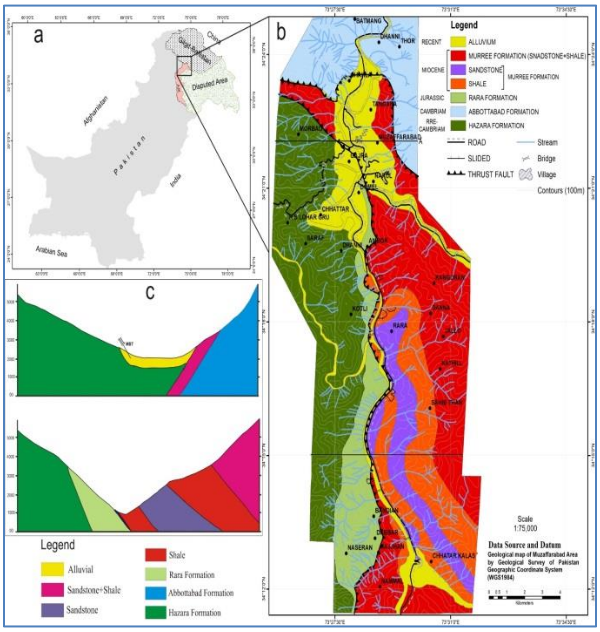

Fig. 1 The maps show (a) Study area location, (b.) Geological map of Muzaffarabad Area and (c) Cross-sectional map.

The sedimentary rocks in southern Muzaffarabad consist of argillaceous sandstone, claystone, siltstone, mudstone and standby clays of Murree Formation (Miocene), Hazara slates, Gypsum (Kotli, Pattan Khurd) of Hazara Formation of Pre-Cambrian age (Middlemiss, 1986; Wadia, 1928, and Wynne, 1874). The area was uplifted during Miocene to Pliocene time (Greco, 1984, 1991). Erosion of rocks reshaped the surface into steep hills and valleys. During Pleistocene, the southern part was repeatedly filled by river deposits. As river deposits retreated, bedrock valleys were filled with different thickness and heterogeneous river sediments that currently mark much of the bedrock surface. The exposed rocks in the study area belong to Hazara Formation (Precambrian), Abbottabad Formation (Cambrian), Rara Limestone (Jurassic) and the Murree Formation (Miocene). The contact between Hazara Formation (Pre-Cambrian) and Murree Formation (Miocene) is faulted and also faulted contact between Abbottabad Formation and Murree Formation.

The old sequence of rocks from Pre-Cambrian to Miocene (Hazara Formation and Murree Formation) is thrust along the western foothills of Hazara Formation (Pre- Cambrian). The trend of rock is generally in an east-west direction with moderate to high dips toward the east. However, folding and faulting is a common phenomenon in the area.

Materials and Methods

The total covered area of 140 square Kilometer (km^2) of Muzaffarabad (Azad Kashmir) and Hazara, Abbottabad district (Khyber Pakhtunkhwa) at latitudes 34° 12″ -34° 24″ N and longitudes 73° 26″-73° 30″ E was mapped at a scale of 1: 75000 (Figure 1). For the extraction of topographic layers and base map development of the study area used acquired toposheet (Survey of Pakistan) no 47 F/7 at scale of 1:125,500. It extends from Muzaffarabad and District Abbottabad from Lohargali to Chattarclass along Neelum and Jehlum rivers covered with vegetation and alluvium fans. During the field study number of cross-sections were made to explore the relevant area. The samples were taken according to colour, texture, structure, joints and thickness of the bed rock. Eight samples about 40kg were collected from different sites of the study area according to B.S Standards from different sites for mechanical tests. All the samples were collected from Chattar Kalas, Gullian, Dulai, Nandal,

Table 1. Classification of Hazara Slates by mechanical tests.

S. No	Name of Test	Locality	Sample No	Max. Value	Min. Value	Mean Value	B.S standard
1	Los Angles Abrasion Test	Skrat	SHS	29.8%	28.52%	29.16%	18.7%
		Lohar Gali 1	LHS-1				
2	Aggregate Impact Value	Lohar Gali 2	LHS-2	22.2%	19.09%	20.65%	13%
		Lohar Gali 1	LHS-1				
3	Aggregate Crushing Value	Lohar Gali 2	LHS-2	22%	21.7%	21.85%	20%
		Lohar Gali 1	LHS-2				
4	Specific Gravity	Lohar Gali 1	LHS-1	2.92%	2.81%	2.86%	2.76
		Skrat	SHS				
5	Absorption Test	Skrat	SHS	0.72%	0.36%	0.54%	0.6%
		Lohar Gali 1	LHS-1				
6	Flakiness Index	Lohar Gali 1	LHS-1	35.70%	-	35.70%	
7	Elongation Index	Lohar Gali 1	LHS-1	58.80%	-	58.80%	15%
8	Porosity	Lohar Gali 1	LHS-1	2%	1.92%	1.96%	
		Skrit	SHS				
9	California Bearing Ration Test	Lohar Gali 1	LHS-1	33.33%	32.78%	33.05%	

Makri Nalah, Majuhan, Masina Kalan, Pattan Khurd, Geri Rara, Sarar, and Lohargali with properly labeled of rock type. Locality and the number indicate the position of the sample collected from the field. Such as LHS-1, L stands for Lohargali, H stands for Hazara formation and S for rock type Slate.

The study explores and interpret all the physical and geotechnical properties of slate as an aggregate which is exposed in the area and presently being used for road construction, buildings, airports and the bridges etc. This study concentrates on the various mechanical and mineralogical properties of the slates as construction material. To evaluate the environmental as well as the ground effects on the aggregates, proper utilization and the rational exploitation of concrete of this material. Aggregate Crushing Values, Aggregate Impact Values, Los Angles Abrasion Values, Specific Gravity, Water Absorption Test, Shape Tests like Flakiness Index and Elongation Index, Porosity Values, Sieve Analysis and California Bearing Ratio Test were determined in the Frontier Works Organization (FWO) laboratory Chaklala airbase, Rawalpindi. These tests describe the hardness and the resistance against the load applied on the aggregates to find exact values to be applied in heavy traffic roads and airports etc.

The mineralogical composition of rocks was also investigated to know the weathering effects in acidic and alkaline environments. Dip, strikes, joints and cracks were plotted on the base map for the development of the geological map.

Results and Discussion

Mechanical Properties of Rock Aggregate

Hazara Slates from the investigated area are mostly qurried for construction material purposes. The purpose of the study is to know whether these slates are suitable for construction material in future. In the field area these rocks are highly fractured, jointed and cracked, whereas these are filled by clays and calcareous material. These jointed blocks from the rock were used in basements of the buildings, retaining walls, abutments and bridges.

From the results with British standards shows in the figure 2. the maximum value of Los Angles Abrasion in slates range from 28.7% to 29.81% which is comparable to British standards (B.S) 18.7%.

Similarly, maximum Aggregate Impact Value on slate is 22.22% and 19.92% compared to the B.S standards 13%. This test reveals that these slates are not suitable to be used as road aggregates. The aggregate crushing values of Hazara Slates vary from 21.7 to 22% compared to B.S standards 20%. This test reveals that slates are not suitable to use as aggregates. As well as the specific gravity ranges from 2.29 to 2.82 as compared to B.S standards 2.76. The result of **w**ater absorption test in Hazara Slates range from 0.72% to 0.36% compared to B.S Standards 0.6%. The suitability of the sample of road aggregate depends on mechanical properties if one of the mechanical properties is suitable not mean that the rock is suitable for use it. Therefore, all the properties are more important for the decision of the suitability of the rock.

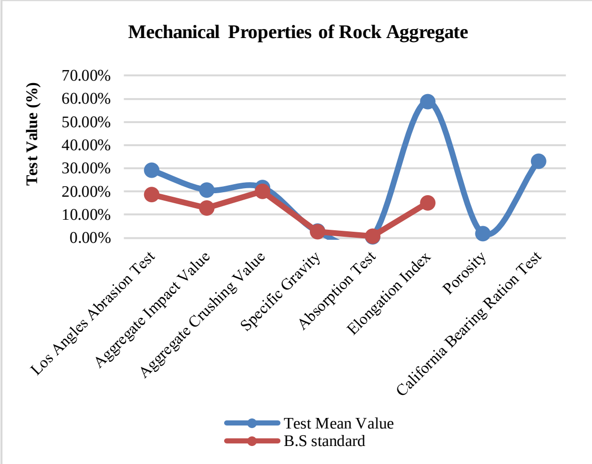

Fig. 2 Mechanical Properties of Rock Aggregate values with B.S standard.

Flakiness Index and Elongation Index: The particle shape of the aggregate is determined by the percentage of flaky and elongated particles contained in it. The presence of flaky and elongated particles closely contained and may cause inherent weakness with possibilities of breaking down under heavy loads. During the experiment, it was concluded that those aggregate particles which are angular improved the interlocking and therefore decreased the workability of concrete. The above approach was conducted on 200 fragments coarser than 6.5mm using standard gauge.

The flakiness index of aggregates is the percentage by weight of particles whose least dimension (thickness) is less than three fifths (0.6) of their mean dimension. The test does not apply to sizes smaller than 6.3mm. The flakiness index of the slate aggregate depends upon the texture and effect on the abrasion and crushing. The flakiness index of the slate aggregate sample has maximum value 35.70. Similarly, the elongation index of the slate sample taken from Lohargali has 58.80% comparable to B.S Standards 15%, and the porosity values of Hazara Slates vary from 1.89% to 2%. The CBR test values of Hazara Slates range from 32.78% to 33.33%, which was conducted on the moulded specimen for the field correlation.

Petrographic Characters of Hazara Slates

Petrographic studies are required to describe and classify the constituents of the sample to determine the physical and chemical characters of each constituent to determine the proportion of the constituent. A petrographic examination was taken to solid rock thin section. Hazara Slates are fine-grained (figure 3). The fresh surface is brownish, grey to dark grey while weathered surface is brown. Calcite veins along the cleavage planes. Pyrite crystals and closely spaced joints are also present.

Mineral composition of Hazara Slates includes Illite, Kaolinite, Quartz and Carbonate. Illite is colourless in thin section. It is a clay mineral present in irregular flakes. Birefringence is strong and relief is low. The kaolinite is also a clay mineral. Colourless and pale yellow in thin section. Interference colour range from second order to third order. It has perfect cleavage, but relief is absent. Quartz is colourless in thin section. Relief is low. It occurs in euhedal prismatic crystals. It has no cleavage and has weak birefringence.

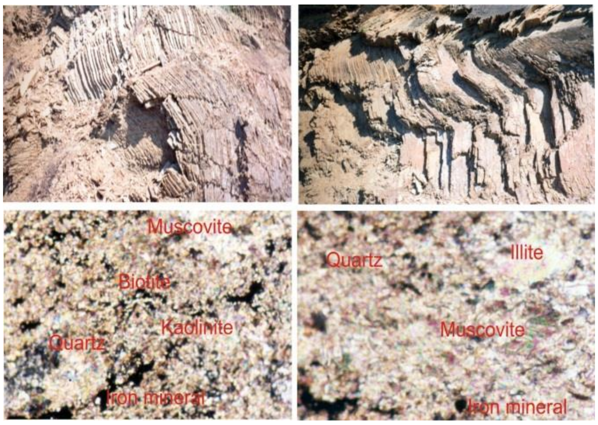

Fig. 3 Petrography of Hazara Slate showing a fine matrix of Illite and Kaolinite with a minor amount of quartz in Muzaffarabad area.

Deleterious substances in aggregates

The study results reveal that the harmful substances present in Hazara Slates include Clay, Quartz and Carbonates and finer material is clay. The principle reaction component in the aggregate are silica minerals. The analogous osmosis is the system of expansion, but it is probably necessary a semi-permeable membrane. The system of water formed the alkali-silica gel because in the resultant of sinking of the particle-free energy. The extensive pressure generates uptake by water while the material is as yet strong and in the end, broke in light of the fact that the elasticity was surpass. Uptake of extra water was attended by a decrease in thickness and the alkali-silica gel was transformed to a sol which exudes into void spaces and cracks appear on the existing external surface.

The alkali-aggregate reactions were recognised in many buildings and under study concrete by observing the cracking type of characteristics refers to as map cracking. It was also studied by measuring the increase in the dimensions of concrete blocks etc. The gel product formed due to alkali-silica reaction seems as white deposits on the outside surfaces of the under-study blocks and already constructed buildings, inner surfaces, fillings in void spaces and cracks. The petrographic examination provides conformity sign and also make possible identification of known reactive minerals. It was noted, that many of these features are found in concrete showing durability failure due to alkali-aggregate reaction. A chemical method was used to measure the dimensional changes of the concrete blocks. Potential durability problems may also be reduced by using the non-expensive aggregates. If this is not possible then design to reduce the excess of moisture to the concrete. Reduction of the available alkali is incorporation in the moisture of a suitable pozzolan is frequently suggested remedies.

The relationship between Petrographic Characteristics and Engineering Properties

Petrographic properties and the engineering properties of the Hazara Slates were correlated. The present investigation of Hazara Slates indicates that these aggregates do not qualify the Engineering properties to British Standards. Mineralogically the presence of different material which does not support to use slates as aggregate also do not qualify to be used as aggregates, and the presence of clay material which is up to 65% cannot be exploited as concrete aggregate.

Conclusion

The physical, mechanical, mineralogical and textural properties were examined to know the grade of Hazara Slates. Hazara Slates is variable from place to place in mechanical as well as in mineralogical composition. The present investigation reveals that all the values do not qualify the recommended British Standards (B.S) except the water Absorption which range from 0.72% to 0.36% comparable to B.S Standards 0.6%. Hazara Slates have reserves at different localities such as Skrat where the reserves are 20 million tons, Masina Kalan 10 million tons and Pattan Kalan 10 million tons. These reserves are mostly used for the construction of roads, walls and pavements. The investigated slates in the area mainly composed of clay minerals. The presence of clay and the finer material in the concrete aggregate increase the potential swellability of the aggregates. The presence of water decreases the strength. The flakiness and elongation values decrease the toughness of the aggregate under heavy loads and it may cause failure, so the use of slates as a concrete aggregate is dangerous. It is concluded that the use of Slates as a concrete aggregate is not rational. It suggests that the Hazara slates do not qualify for road construction where heavy traffic is flowing.

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