SindhUniv. Res. Jour. (Sci. Ser.) Vol. 52 (02) 221-228 (2020)

http://doi.org/10.26692/sujo/2020.06.33

SINDHUNIVERSITYRESEARCHJOURNAL(SCIENCE SERIES)

Geotechnical Properties of Cambrian Dolomite, Abbottabad Formation, Hazara-Kashmir Syntaxis and Azad Kashmir, Pakistan

M. ALAM, J. A. QURESHI*. G. KHAN[++]*, N. ABBAS**, Y. BANO***, I. BANO ****

Government Degree College Gilgit,15100 Pakistan.

Received 16th January 2020 and Revised 04th May 2020

Abstract: The Geotechnical and mineralogical characteristics of Abbottabad Dolomite have been investigated to evaluate the rock as concrete aggregate. The study extent at longitudes 73° 26′-73° 30′ and latitudes 34° 12′ -34° 24′ with a total covered area of 140 sq.km from district Muzaffarabad (Azad Kashmir, Pakistan) and Abbottabad district (Khyber Pakhtunkhwa, Pakistan). From Lohargali to ChattarKalas along Neelum and Jhelum rivers was mapped at the scale of 1:12,500. The main objective of the study to explore and interpret all the physical and geotechnical properties of dolomite as aggregate, which is exposed in the area and presently being used for buildings construction, road, airports and bridges etc. The study concentrates on the various mechanical and mineralogical properties of the Dolomites as a construction material to evaluate the environmental impact, as well as the ground properties. As well as, mineralogical composition of dolomite was also investigated to know the weathering effects in acidic and alkaline environments. To explore and extract specific portion of the study area survey of Pakistan Toposheet # 47-F/7 with scale of 1: 12500 were used. During the field work, number of traverses were made to explore the relevant area and samples were collected according to color, texture, structure, joints and thickness of the rock bed. Total number of 4 samples about 40 kg mass were collected according to British standards. Standards (B.S) from different sampling locations of the study area, such as MakriNalah, ShiwaiNalahandYadgar. Dip, strikes, joints, and cracks were plotted on site for the preparation of geological map. From results, all the tests (such as Crushing Value, Impact Value, Los Angele’s test, Specific Gravity, shape of particles and water absorption) are not comparable with B.S (British Standard).At places rocks are highly crushed and deleterious material in the rock aggregate are high. The alkali-silica reactions in dolomite involves disordered form of silica, particularly Chert and Iron. The presence of Cherty minerals and silica in dolomite is not desirable elements and create serious complications during the reactions between alkalies and silica. The result of elements reaction gives rises magnesium-silicate gel, which swells and cause cracks in the concrete/actual shape. The tensile strength is also reduced and gel material appears as white exhalation on the surface of the concrete. The alkali-silica reaction occurs in specific areas of MakriNalah, ShiwaiNalah and Yadgar area. Reserves of the Abbottabad Dolomite as geo-material at different localities were also estimated for the mine purposes.

Keywords: Geological Mapping, Engineering Characteristics, Abbottabad Dolomite, Geo-Material

Construction material used in buildings, roads and construction of walls in Azad Kashmir needs geological engineering evaluation. The aggregates available in the area are different, but our main focus is Abbotabad Dolomite. The potential area for Abbotabad dolomite is Muzaffarabad and adjoining areas of Azad Kashmir where Abbotabad dolomite is well exposed in the areas like Yadgar, MakriNalah and ShiwaiNalah. About threequarries are working and supplying aggregate material to Muzaffarabad for different construction purposes. Therefore, scientific based pits are not developed in the area due to lack of scientific knowledge, and commercial reasons. The present investigations reveal that Abbotabad dolomite has varieties which differ in colour, texture, mineralogy and hardness.

Most of the quarries are open quarries and are present at the roadside. The scientific approach is needed for further exploitation of these reserves, but at present, these rocks are being used as retaining wall stones, road construction and the building constructions as well.

++Corresponding author: **garee.khan@kiu.edu.pk** E-mail: alam.geo@gmail.com

*Department of Earth Sciences, Karakoram International University, Gilgit, 15100, Pakistan.: Javed.akhter@kiu.edu.pk

** Department of Mining engineering, Karakoram International University, Gilgit, 15100, Pakistan. naeem.abbas@kiu.edu.pk

*** Woman Degree College, Gilgit, 15100 Pakistan.

**** Department of Earth Sciences, Karakoram International University, Gilgit, 15100 Pakistan. E-mail:iram.bano@kiu.edu.pk

1.1 REGIONAL GEOLOGY

The study area is lying within the Middle and Lesser Himalayan zone. Kashmir Hazara Syntaxis is the central part of the study area. In Muzaffarabad and the adjoining areas, rocks range from Pre-Cambrian to Miocene age. The Precambrian rock formation is Hazara slates, which were introduced by (Wadia, 1931).

1.2 GEOLOGY OF THE STUDY AREA

The lithostratigraphic units exposed in the study area are representing age of Pre-Cambrian (Hazara Formation) to Recent (Alluvium), and cover sedimentary and metamorphic rocks. Hazara Formation (Precambrian) is the oldest formation, and the Murree Formation (Miocene) is the youngest.

The sedimentary rocks in southern Muzaffarabad consist of argillaceous sandstone, claystone, siltstone, mudstone and stand by clays of Murree Formation (Miocene), Hazara slates, Gypsum (Kotli, PattanKhurd) of Hazara Formation of Pre-Cambrian age (Wiecz, 1984; Middlemiss, 1986; Wadia, 1928, Ali, 1954, and Wynne, 1879). The area was uplifted during Miocene-Pliocene time. (Greco, 1984, 1991). Erosion of rocks reshaped the surface into steep hills and valleys. During Pleistocene, Southern part was repeatedly filled with 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.

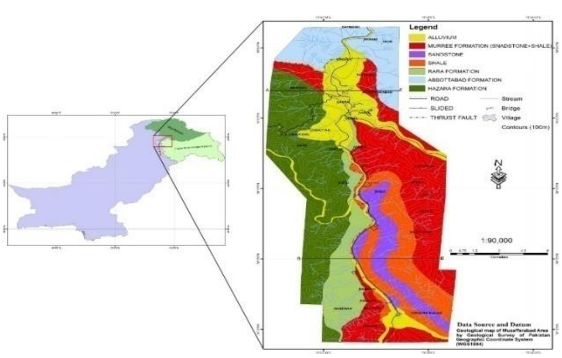

Fig. 1. Geological map of Muzaffarabad area, Azad Kashmir, Pakistan

The exposed rock surface includes Hazara Formation (Precambrian), Abbotabad Formation (Cambrian), Rara Limestone (Jurassic) and the Murree Formation (Miocene). The contact between Hazara Formation (Pre-Cambrian) and Murree Formation (Miocene) is faulted. There is faulted contact between Abbotabad Formation and Murree formation.

The older 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 common in the area.

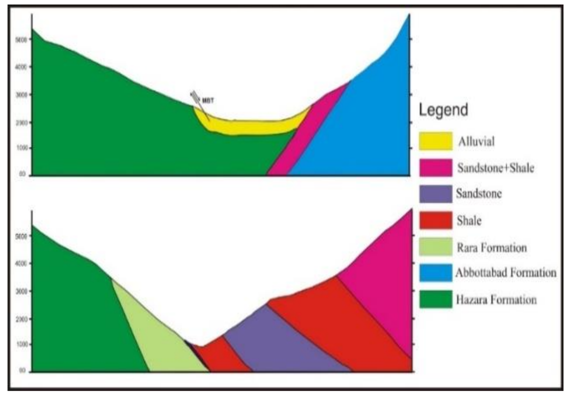

Fig. 2. Cross sectional map of the field area in Muzaffarabad.

1.3 STRUCTURE

The structure of the investigated area can be divided into three different regions. Wadia (1931) studied the eastern part of the Hazara Kashmir Syntaxes and presented a structural map. Tahirkheli, (1980) concluded that Precambrian units are present along the western part of the Murree formation (Miocene) adjacent to Murree, which is the main part of the thrust. In the eastern slope of the formation, the rocks are deformed into broad folds. The hills made up of sandstone, limestone, slates and clays which are well exposed on the hill slopes and along with the road cuttings. A north-south trending thrust fault separates these. West of this fault Muzaffarabad anticline is present. The overall structure of the area form anticlines and synclines. The main structure in the Muzaffarabad area is symmetrical anticline in the east of Muzaffarabad proper.

Greco, (1941), and Bossart (1984) mentioned that the trend of axis falls approximately N.W-N.E. The symmetrical anticline thrust over the older slates of the west and south-west. The thrust junction is near Ambor, Jehlum valley, Muzaffarabad.

Structural features like folding and faulting in the investigated area have affected the rocks of the area. Jehlum fault has been traced continuously from the Kunhar river to 4 Km west of Muzaffarabad city and then to south along the Jhelum river.

Fig. 3. The contact between Murree Formation (Miocene) and Abbotabad Formation (Cambrian) near Chellabandini Muzaffarabad, Azad Kasmir Pakistan.

2. METHODS

140 sq. Km of Muzaffarabad (Azad Kashmir) and Hazara, Abbotabad district of KPK (Khyber Pukhtunkhaw) at Longitudes 73° 26′-73° 30′ and Latitudes 34° 12′ -34° 24′ was mapped at a scale of 1: 50000.It extends from Muzaffarabad (Azad Kashmir) and District Abbotabad (KPK) from Lohargali to Chattarclass along Neelum and Jehlum rivers covered with vegetation and alluvium. The objective of the study is to explore and interpret all the physical and geotechnical properties of dolomite as 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 Dolomites as a construction material to evaluate the environmental as well as the ground effects on the aggregates and 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. These tests indicate the hardness and the resistance against the load applied on the aggregates to know exact values to be applied in heavy traffic roads and airports etc.

The top sheets no 47-F/7 survey of Pakistan used for the enlargement of the relevant portion and the base map prepared at a scale of 1: 12500.During the field-work number of traverses were made to explore the relevant area and samples were collected according to colour, texture — structure, joints and thickness of the rock bed. Four samples of 40kg were collected according to B.S Standards from different areas for mechanical tests. The mineralogical composition of dolomite was also investigated to know the weathering effects in acidic and alkaline environments. The samples collected from the areas are MakriNalah, ShiwaiNalah and Yadgar area. Collected samples name is given on the basis of their locality, rock type and sample number collected from field in a sequence (e.g. MAD, SAD and YAD etc). Where M stands for MakriNalah, S stands for ShiwaiNalah, and Y stands for Yadgar, Astands for Abbotabad Formation, and D stands for rock type dolomite. Dip, strikes, joints, and cracks were plotted on site for the preparation of engineering geological map.

3. RESULTS

3.1 MECHANICAL PROPERTIES OF ROCK AGGREGATE (RA)

Abbottabad Dolomite (Cambrian) in the investigated area is mostly used as a construction material. The objective of the study is to explore and interpret all the physical and geotechnical properties of Abbottabad dolomite to evaluate the rational use of this rock as concrete aggregate for different civil engineering purposes. The dolomite is highly crushed, jointed and fractured because of various faults (Muzaffarabad fault and Jehlum fault) and main boundary thrust (MBT) passing near quarries. These fractures are filled with clays and calcareous material which facilitates the excavation of blocks of the blocks which can be used in basements of the buildings, retaining walls and in abutments of the bridges.

Various geotechnical tests were conducted in the laboratory to know the strength of Hazara Slates. The tests which were performed in the laboratory are Los Angle, s Abrasion Value (Av), Crushing Value (Cv), Impact Value (Iv), Specific Gravity (Sg), Water Absorption Test (Wa), Shape Test i.e. Flakiness Index (Fi), Elongation Index (Ei), Porosity Values (Pv), Sieve Analysis and California Bearing Ratio Test (CBR).

3.1.1 LOS ANGELES ABRASION VALUE (LAA)

This test was conducted to know the effects of the flow of low and high traffic through the roads. To evaluate the effects of fast-moving traffic with pneumatic wheels move on the roads when road surface and the wheel abrade each other. Hence, in order to test the suitability of road aggregates, this test was conducted on dolomite aggregates size about ¾ pass ½ retain and ½ pass 3/8 retain and it was found during the experiment that the maximum abrasion value in Abbottabad dolomite range from 17.6% to 20.8% which is comparable to B.S. standards 16.5%. This suggests that the Abbottabad dolomite does not qualify for road construction where heavy traffic is flowing.

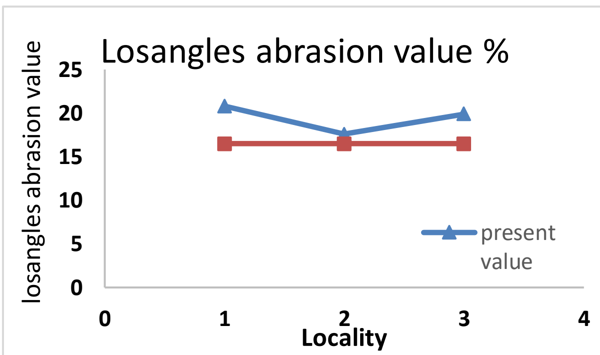

Fig. 4. Los Angeles Abrasion value Cambrian dolomite of Abbotabad Formation

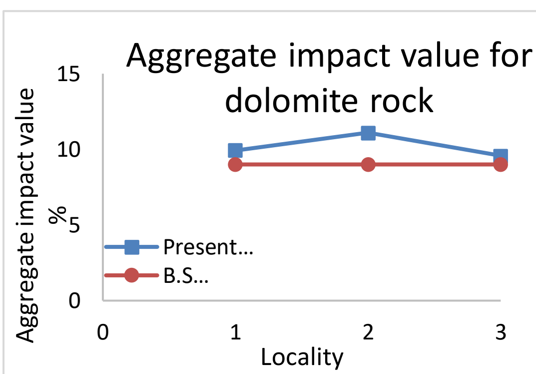

Fig. 5. Aggregate abrasion value Cambrian dolomite of Abbottabad Formation.

3.1.2 AGGREGATE IMPACT VALUE (AI)

Aggregate impact value determines the toughness of the aggregate. The possibility of breaking the aggregates due to heavy traffic into smaller pieces. The repeated input test was conducted. Applying this test on road aggregate, the sudden shocks of the heavy traffic on the road were investigated. The test reveals that the maximum impact on Abbottabad dolomite aggregate is 11.1% and 9.58% compared to the B.S. standards 9%. This test reveals that these slates are not suitable to be used as road aggregates.

3.1.3 AGGREGATE CRUSHING VALUE (AC)

Aggregate crushing value is conducted on the aggregates in the regions where heavy and low traffic is flowing. Abbottabad dolomite is highly crushed, fractured and cracked due to the thrust faults running near this formation. During the test conducted, it was found that the crushing values of Abbottabad dolomite vary from 10.82% to 10.85%comparable to B.S standards 24%. This test reveals that dolomite is a bit harder but cannot be used as a concrete aggregate due to the presence of silica (chalcedony, chert) in aggregates as secondary vein concentration and is one of the causes of defects.

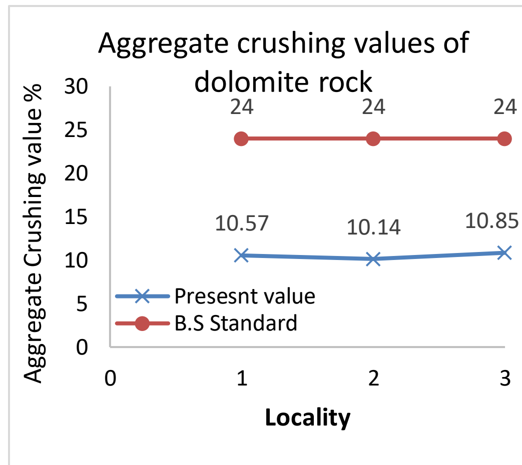

Fig. 6. Aggregate crushing value of Cambrian dolomite of Abbottabad Formation.

3.1.4 SPECIFIC GRAVITY AND WATER ABSORPTION (SG & WA)

The specific gravity and water absorption test were taken to calculate the strength and quality of the rock aggregate. This was conducted on 2kg of rock sample in the lab on room temperature (22° c to 32°c) for 24 hours sowing in water. After that the sample was dried by a cloth and put in an oven for 24 hours for dry. After drying it was weighted again and calculated the specific gravity and water absorption values with a given equation.

3.1.5 SPECIFIC GRAVITY (SG)

Specific gravity is necessary to evaluate the quality of the aggregate. The specific gravity in Abbottabad dolomite increase from ShiwaiNalah to Yadgar due to the presence of iron concentration in the samples. It was found that the specific gravity ranges from 2.84 to 2.88 as compared to B.S standards 2.66.

3.1.6 3.1.6 WATER ABSORPTION TEST (WA)

Water absorption decreases the strength of aggregates. Aggregates having more water absorption are not suitable to use as aggregates. It was found that water absorption in Abbottabad dolomite range from 0.23% to 0.31% comparable to B.S. Standards 0.6%. The suitability of a sample of road aggregate depends upon the mechanical properties, but any one of the mechanical properties favour the rock not means that the rock is suitable. So, all the properties have been combined for the conclusion.

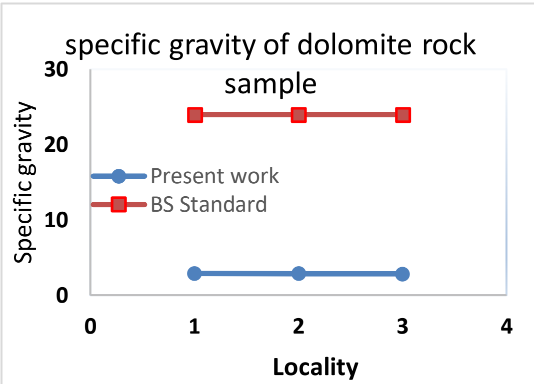

Fig. 7.The specific gravity of Cambrian Dolomite of Abbotabad Formation.

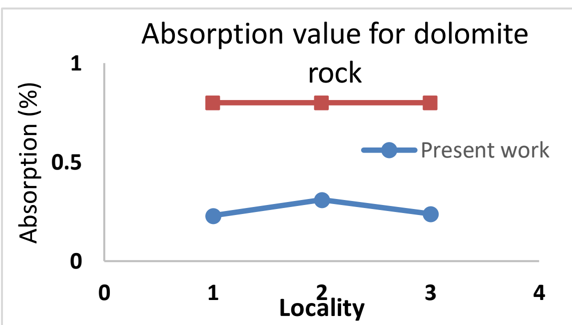

Fig. 8. Water absorption value of Cambrian dolomite of Abbottabad Formation.

3.1.7 Flakiness Index and Elongation Index (FI & EI)

The shape of particle aggregate was measured by their percentage of flaky and elongated particles contained by the samples. The existing particle (flaky and elongated) in the sample or rock may cause immediately weakness of the rock, which will possible breakdown rock under occurring heavy loads. The evaluation of the shape is quite necessary for the aggregate which is going to be used for determination of rock. The material was passed through the specified thickness gauge and length gauge. The flakiness index of Abbottabad dolomite has a maximum value of 37.69%. The elongation index of dolomite taken from ShiwaiNalah has 45.63% compared to recommended B.S standards 15%.

3.1.8 Porosity Values (PV)

Porosity values vary in the investigated aggregates. The porosity of rocks is an essential factor for aggregates. Less porous aggregates contain less volume of water and limit the weathering effects. Highly porous aggregates contain a high volume of water, and high weathering affect the porosity values of Abbottabad dolomite vary from 1.97% to 1.932%.

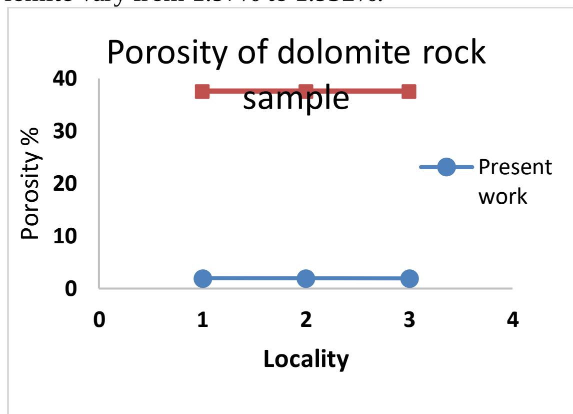

Fig. 9. Porosity value of Cambrian dolomite of Abbottabad Formation.

3.1.9 California Bearing Ratio (CBR %)

Considering the limitations of the CBR test, it is strictly adhered the test procedure. CBR test was conducted on the prepared specimen in the laboratory for the field correlation. The test valueof CBR varies from 22.78% to 25% for Abbottabad dolomite.

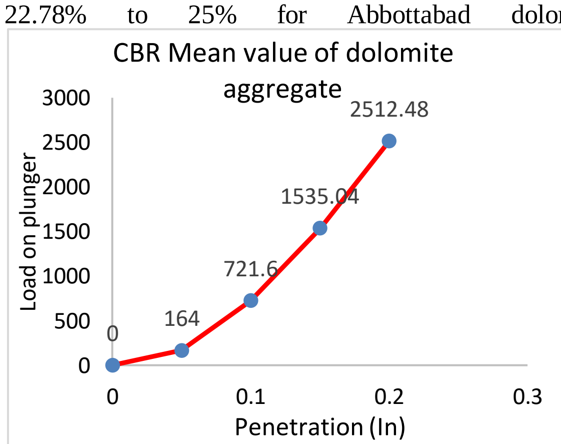

Fig. 10. CBR value of Cambrian dolomite of Abbottabad Formation.

3.1.10 Petrographic Characters of Abbottabad Dolomite

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. The petrographic examination was applied to solid rock thin section. Abbottabad dolomite is fine to medium grained. The fresh surface is light grey, and while on the weathered surface, it is grey. Calcite veins and stromatolites are also present. It is highly fractured and crushed.

3.1.11 MINERALOGY

The mineral composition of Abbottabad dolomite is fine to medium grained, chert showing salt and pepper texture. Dolomite range from 61% to 68%. Interference colour is pearl grey. Colourless to grey in thin section. Subhedral with perfect cleavage and resembles with calcite. Calcite is colourless to cloudy in thin section. Maximum interference colour is pearl grey. Cleavage is present, and relief is absent — calcite range from 24% to 25%. The chert is colourless to pale brown having salt and pepper texture. Relief is low. Quartz is colourless in the thin section having low relief. Weak birefringence having no cleavage, it occurs in prismatic crystals and having first order interference colour. The quartz ranges from 3% to 8%. Iron is opaque to translucent remain grey; black occur in euhedral crystals — the iron content range 0 to 1%.

4. DISCUSSION

4.1 DELETERIOUS SUBSTANCES IN AGGREGATES

The samples of concrete (alkali-aggregate of dolomites) of Yadgar to Makri are analysed which qualify physical expectance tests. From the results it is indicated that the samples composition was based on clay, fine calcite about 25% and other insoluble residents enclosed in the mixture. The attack upon expansive rocks and mineralsthe concrete pore solution of NaOH and KOH is responsible.

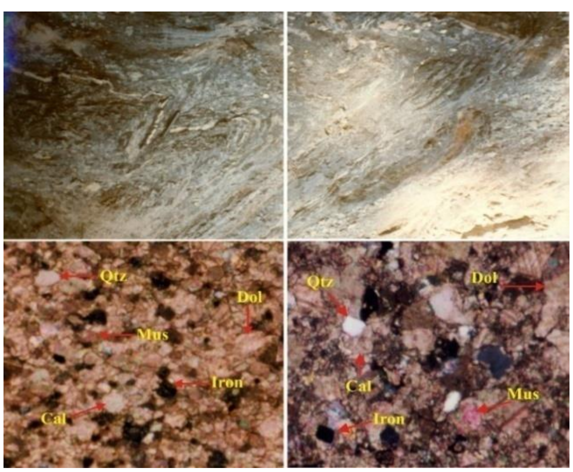

Fig. 11. Thin sections of Abbotabad Dolomite, showing different mineral compositions.

Note: Cal: Calcite, Qtz: Quartz, Iron: Iron ore, Dol: Dolomite, Mus: Muscovite

During the process of alkali carbonate reactions, the $Mg (OH)_2$ and $CaCo_3$ as solid products were formatted due to resultant of dolomite attacked of alkalies, which decrease the solid volume, and increase the permeability of aggregates. The solution of moisture designed during the reaction gain excess to the clay and expand the clay minerals. During the process, clay earnings water and increase volume and the resultant extensive force was produced.

The alkali-aggregate reactions were recorded in many buildings, and the understudy concrete were also observed cracking characteristics which reference in mapping as cracking. Similarly, the study extended for measuring the increase in the dimensions of concrete blocks etc.The gel product formed due to alkali-silica reaction, which was seems as white sums on the external sides of the under-study blocks, as well as already constructed buildings, internal sides, fillings in cracks, and negated spaces.The petrographic examination provides conformity indications, which makes possible for identification of known reactive minerals. However, it was recorded that, due to the alkali-aggregate reaction the many of these structures are found in concrete which isrepresenting durability failure. A chemical method was used to measure the dimensional changes of the concrete blocks. The 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. As remedies a suitable pozzolan is suggested for the reduction of available moisture from alkali.

4.2 RELATIONSHIP BETWEEN PETROGRAPHIC CHARACTERISTICS AND ENGINEERING PROPERTIES

Petrographic properties and the engineering properties of the Abbotabad dolomite were correlated. The present investigation of Abbotabad dolomite indicates that these aggregates do not qualify the Engineering Properties to B.S Standards. Mineralogically the presence of deleterious material in dolomite as cementing material, iron content and cherty material (5%) is not qualifying the chemical tests. So, dolomite cannot be used as concrete aggregate for the construction purpose.

5. CONCLUSION

After the study of geotechnical, mineralogical and chemical characteristics of Abbotabad Dolomite currently in use as aggregates in Muzaffarabad and surroundings, the following conclusions derived are great importance for the exploitation. The Dolomites are of two broad categories concerning texture and harmful material.

a). Aggregate coatings which prevent good bonding between the grains of aggregates.

b). Unsound particles in the aggregates which change volume and lead to deterioration of concrete. The unsound particles are limited in quantity but are too soft and expand on wetting, freezing and temperature changes.

Different mechanical properties tests (such as like, AC, AI, LAA, SG, WA, Fl, EI, PV, CBR and SA) were studied for Abbottabad dolomite. is variable from place to place in mechanical as well as in mineralogical composition.

Los Angles Abrasion value of dolomite range from 17.60% to 20.80% as compared to B.S. standards 16.50%. This is probably due to the high percentage of calcite in dolomite samples.

The impact value of dolomite aggregate ranges from 9.50% to 11.10% as compared to B.S. standards 9%. It seems that toughness of aggregate under applied load is lower in the presence of deleterious constituent. Probably the chert content degrades the rock aggregate.

The crushing value in dolomite range from 10.14% to 10.85% as compared to B.S. standards 24%. Probably the depositional environment is similar and does not affect the crushing value. However, the ferruginous material absorbs more water and decrease strength characteristics. The shape of particles seems to cause weakness with possibilities of breaking down under heavy load.

The specific gravity of dolomite ranges from 2.84% to 2.88%. The increase and decrease in specific gravity indicate the concentration of quartz and chert during the depositional environment of dolomite. The presence of iron content activates the swelling potential and decrease the strength of concrete.

The presence of flaky and elongated particles in dolomite is undesirable. They may cause weakness and possibilities of breaking down under heavy load.

The California Bearing Ratio (CBR) indicates the strength of the dolomite aggregate and deformation during shearing. It seems that the presence of water in aggregate increase the swelling potential and degrade the performance of dolomite. The dolomite aggregate and the active silica gel create complex reactions with alkalies present in the cement, especially in humid conditions, which is common in Muzaffarabad. The constituents produced absorb water and expand, causing disruptions in the concrete. The fine-grained dolomite is dedolomitize and may involve clay minerals which cause alkali-carbonate reactions that ultimately give rise to expansions. Reactive silica (chert) is present in the aggregate as secondary vein concentration and is one of the causes of defects.

The selection of dolomite as construction raw material (aggregate) is unscientific, irrational and if used, will lead to serious deterioration of buildings and other civil engineering projects in future. The preferable and rational use of Abbotabad Dolomite should be as a source of magnesium and refractory material in the steel industry and other metallurgical works instead of using as aggregates.

REFERENCES:

Akhter, M., (1981-1986). Geology and mapping of Muzaffarabad area from Chela Bandi to Chatter Klass with special emphasis on landslides along roads, M.Sc. Unpublished thesis, Institute of Geology, Azad Jammu and Kashmir University. 24-50.

Ahmed, Z., (1981). Geological sketch and mineral deposits of Azad Kashmir. Records of Geological survey of Pakistan. No57. 1-27.

Bossart. Dictrich, D., Greco. A., Ottiger. Ramsay, J.G. (1984). A new structural interpretation of the Hazara Kashmir Syntaxes, Southern Himalayas, Pakistan, Kash. Jour. Geol. Vol. 2, pp. 19-35.

Greco, A., (1991). Stratigraphy, Metamorphism and Tectonics of the Hazara-Kashmir Syntaxes. Kash- jour. Of Geol., vol. 8, 9, 39-65.

Hale, B.C., (1979). The development and application of a standard compaction degradation test for shales. Unpublished M.Sc. Thesis and joint highway research project report No. 79, Department of Civil Engineering Purdue University, West Lafayette, in, 1-129.

Khanna, S. K., C.E.G. Justo. (1983). Tests on natural aggregates.3rd.ed. New Chand and brothers.IN. Utar pardesh.pp.48-86.

Knight, B. H., R. G. Knight, (1960). Road Aggregates, their uses and testing Revised ed., Edward Arnold co. INC. London. 1-86.

Khan M. A., M. S. Khan, E.A. Khan (1992). Use of Cambrian dolomites as concrete aggregate from Yadgar, Azad Kashmir. Karachi University, J.Sc. 20(1&2). 113-122.

Latif M. A., (1974). A Cambrian age for Abbotabad group of Hazara, Pakistan Geol. Bull. Punjab Univ. Vol 10. 1-20.

Mohy-ud-din, S., (1993). Geological mapping of Nauseri- Muzaffarabad, Garhi-Habib-ul-lah area and evaluation of landslide hazards on western limb of Hazara Kashmir Syntaxes. Kash. Univ. Msc. unpublished thesis 1-13.

Marks, P., (1962). The Abbotabad Formation: a new name for MiddlemissIntera - Trias, Ibid. No. 2, 56Pp.

Middlemiss, C.S., (1896). The geology of Hazara and Black mountains. Geol. Survey of India. Memoir, Vol. 26, 302Pp.

Neville, A.M., (1976). Properties of Concrete, 3rd. ed., ELBS INC. Canada. 18-198.

Otigger., R., (1986). EinigeAspekete der geologic der Hazara Kashmir Syntaxes (Pakistan). Diss., ETH Nr. 8083, Zurich.

Robert. F., L., (1962). Geology and Engineering. Mc-Graw-Hill Company, London. 111-113.

Shakoor, A., (1975) the geology of Muzaffarabad Nauseri area, Azad Kashmir, with comments on the engineering behavior of rocks exposed. Geol. Bull. Punjab University. Vol. 12, 79-90.

Wadia, D. N., (1931). The Syntaxes of North- West Himalaya. Its rocks, Tectonics and Orogeny. Rec. Geol. Surv. India, Vol.65/2 .198-220.