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Source of cement raw material for the construction of Bhasha Dam in Gilgit Diamir District, Pakistan

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Abstract

Appreciable amount of limestone deposits ranging from Jurassic to Eocene occurs near the construction site of the Bhasha Dam, District Abbottabad. The current investigation utilizes techniques like, petrography, geochemistry and geotechnical tests on the Samana Suk Formation, Kawagarh Formation, Lockhart Limestone and Margalla Hill Limestone of Abbottabad area to check their feasibility as construction material for Bhasha Dam. Mineralogically, the studied limestones have high calcite content with minor quartz. Microstylolites with insoluble residue are present in some samples while sparry calcite-filled hairline fractures are common. Generally, the CaO content of the limestone is high in most of the studied limestone except some samples from Lockhart Limestone and Margalla Hill Limestone. Most of the studied limestone samples have permissible amounts of SiO_2 for its use for various purposes and though some of the samples have higher values of silica, but they cannot be regarded as argillaceous limestones. Al_2O_3 and Fe_2O_3 are also within the permissible limits for use in various industries. Na_2O and K_2O are found only in traces as per the pure stone chemistry. The MgO contents are predominantly low except in certain samples of the Samana Suk Limestone where certain horizons are more dolomitized with high MgO. These studied limestone vary from minor to considerable degree of secondary dolomitization, however, no other deleterious constituents are present. The studied limestone samples from different Formations of district Abbottabad fulfill the specifications for their use in cement industry and in aggregate. The Samana Suk and Kawagarh formations are the nearest source for the cement manufacturing plant to cater for Bhasha Dam construction.

Keywords: Limestone; Cement; Abbottabad; Bhasha dam.

1. Introduction

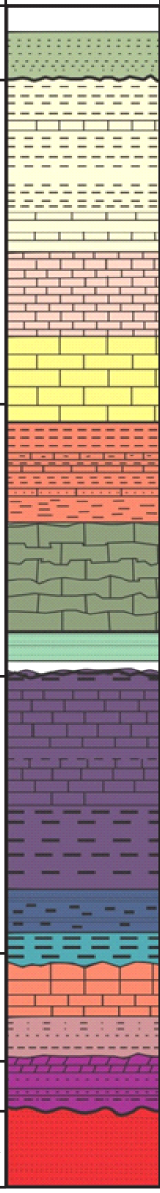
Pakistan is currently facing severe energy production problems and construction of dams is the one way out to overcome the prevailing energy crisis. One large dam, the Bhasha Dam, is being constructed in Diamir District in which many tens of tons of cement are needed for its construction. However, the nearest cement plant is in Hattar industrial estate which is about 250 km away from the dam site so the sole purpose of the present study is to locate a nearest limestone source suitable for cement production for the construction of the said power generation dam.

Huge reserves of limestone in the vicinity of Abbottabad provide immense natural resource at a reasonable distance for their economic exploitation. Sporadic work has been carried out on the limestones of this area (Bilqees et al., 2012) for use in various industries but detailed and systematic work for the evaluation of limestone for cement manufacturing is still lacking. The sampling has been done from Samana Suk Formation (Jurassic), Kawagarh Formation (Cretaceous), Lockhart Limestone (Paleocene) and Margalla Hill Limestone (Eocene). The present study provides the evaluation of these limestones for use in cement and construction industries. The specifications of limestone used in cement industry and its use as an aggregate are given in Harrison (1993) and Oates (1998).

2. Stratigraphy and geological settings

The study area is located in the vicinity of Abbottabad (latitude 34° 9'to 34°16' N and longitude 73°15' to 73°18') along the Karakorum Highway and lies in southeast Hazara, which is part of the Attock-Hazara Fold and Thrust Belt (Yeats and Lawrence, 1984). It lies southwest of Hazara Kashmir Syntaxis, west of Panjal Thrust, south of Nathiagali Fault and south east of the Main Boundary Thrust (Gansser, 1964). The area is tectonically very complex and has experienced several episodes of deformation. Rocks usually dip towards northwest and southeast (Coward and Butler, 1985). The summary of the stratigraphic sequence in the study area has been shown in Table 1.

Table 1. Composite sratigraphic column of Hazara area, Khyber Pakhtunkhwa, Pakistan (after Latif, 1970 and Shah, 1977).

AGE	LITHOLOGY	FORMATIONS AND DESCRIPTION
Plio-Miocene		**Muree Formation** (sandstone, siltstone, claystone)
Eocene		**Kuldana Formation** (shale and gypsum with interbeds of limestone)
		Chorgali Formation (limestone with interlayers of shale/marl)
		Margalla Hill Limestone (limestone with shale/marl interbeds)
Paleocene		**Patala Shale** (marly shale with few thin limestone beds)
		Lockhart Limestone (limestone with occasional marl/shale layers)
		Hangu Formation (silt, sandstone, shale, bituminous shale)
Cretaceous		**Kawagarh Formation** (limestone with shale in the lower part)
		Lumshiwal Formation (sand, siltstone with shale interlayers)
		Chichali Shale (shale beds)
Jurassic		**Samana Suk Formation** (limestone with intraformational conglomerate)
		Datta Formation (calcareous sandstone with fire clay and shale)
Cambrian		**Abboattabad Formation** (dolomite with sandstone, shale and conglomerate)
Pre-Cambrian		**Hazara Formation** (slate, phyllite, shale with minor limestone and graphite)

3. Material and methods

A detailed field survey was conducted in the study area and a total of 18 samples were collected from different exposures of Samana Suk, Kawagarh, Lockhart, and Margalla Hill limestones. Big sized (15-20 Kg) samples were collected from each location for obtaining cores for Engineering tests.

Chemical analyses were carried out using Atomic Absorption Spectrometer (Analyst 700, Perkin Elmer). Petrographic study was carried out to know about the mineralogy and the textural features. Different engineering tests were performed for the determination of strength and durability, impermeability, resistance to abrasion and soundness.

Specific gravity and water absorption of the aggregates were determined in accordance to the ASTM method C 127-7. With the help of mass values and the formulas used in this method, specific gravity and water absorption values were calculated. The rocks having specific gravity greater than 2.55 are considered suitable for heavy construction work (Blyth and de Freitas, 1974; Harrison, 1993). For water absorption ASTM C121-06 was used and soundness was determined according to AASHTO T 104 method in which

Compressive strength was determined using ASTM C 39/ C 39 M method. The Los Angeles Abrasion Value (L.A.A.V.) was determined by ASTM C 131-89. Aggregates which do not have adequate toughness and abrasion resistance may cause problems in buildings. For the determination of Los Angeles abrasion value (LAAV) of limestone, class B grading of aggregates was used and the results were then compared with that of ASTM specified limits. The value obtained by this test (Table 4) is the percent weight loss by the aggregate. Therefore, the lower the value the better is the competence of the rock. All the above mentioned engineering tests were then compared with ASTM (Table 4) for evaluating the samples of this study.

4. Results

4.1. Petrography

Samples were selected from the total number of samples on the basis of results from other laboratory tests, i.e. chemical analysis and physical tests. Samples having higher amounts of MgO and SiO_2 and lower compressive strength values were selected for petrographic study to compare these with results of various tests. Dunham (1962) classification scheme was used for classification of various limestones. A brief account of the petrographic features observed in each of the studied limestones is given in Table 2 and Plate 1(a-f).

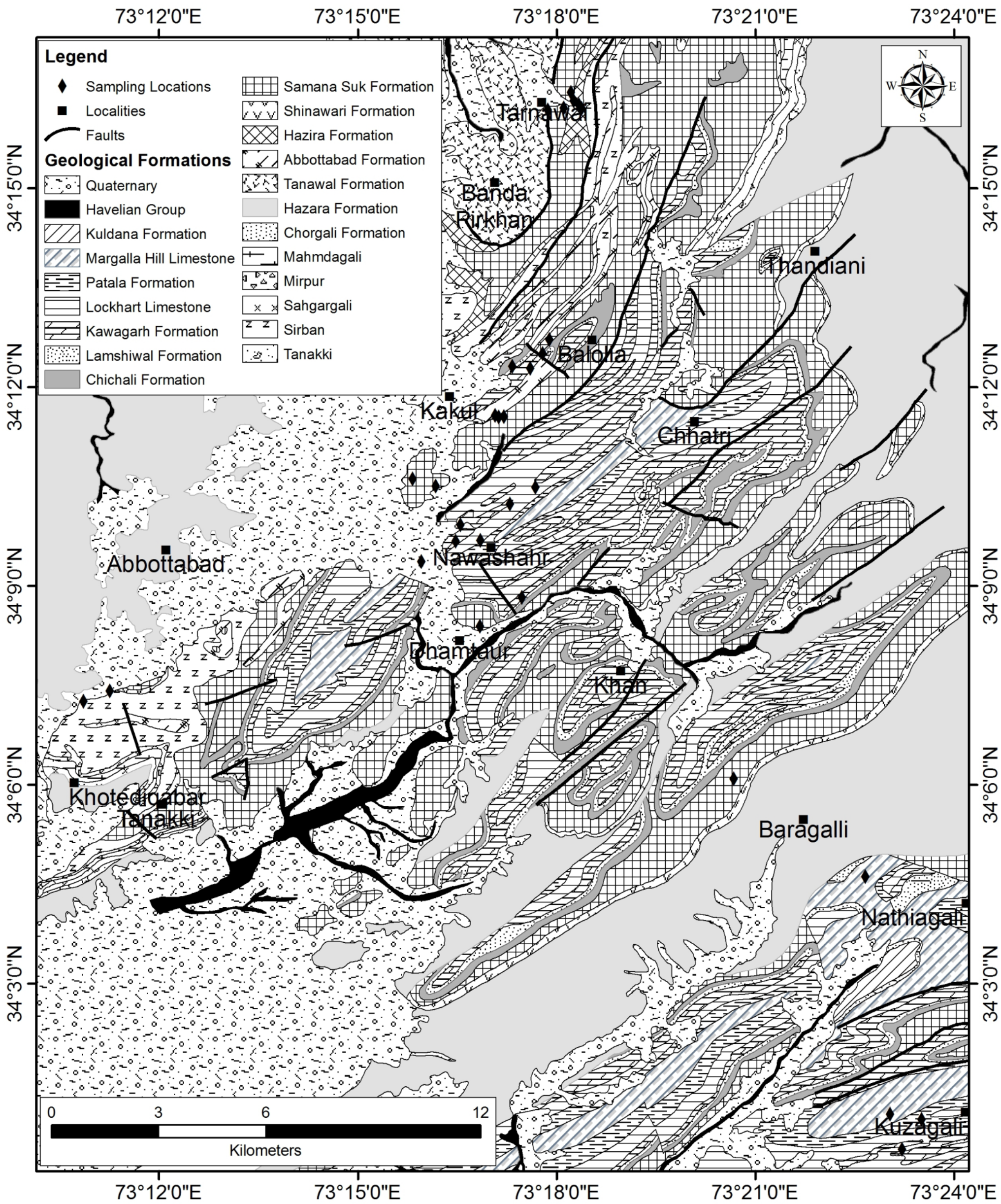


Fig. 1. Geological map of area around Abbottabad showing the study area and sample locations (after Latif, 1970).

Table 2. Mineralogy and petrographic features of limestone deposits of district Abbottabad.

Sample No.	Formation	Locality	Mineralogical Composition (%)			Stylolites (%)	Classification
			Calcite	Dolomite	Quartz		
S1	Samana Suk	Nawashehr	95	2	Trace	3	Mudstone
S2		Balolia	90	5	-	5	
S3		Balolia	97	Absent	-	3	
S4		Tarnawai	99	1	-	traces	
S5		Nawashehr	97	Absent	-	3	
S6		Nawashehr	98	Absent	1	2	
S7		Tarnawai	96	1	2	1	
K1	Kawagarh	Ghumanwa Query	98	Absent	-	0-2	Wackestone
K2		Balolia	100	Absent	-	10	
K3		Balolia	70	15	15	5	
K4		Nawashehr	98	Absent	Trace	0-2	
L1	Lockhart	Kuzagalli	95	Absent	Trace	5	Bioclastic wackestone
L2		Nathiagalli	85	Absent	3	15	
L3		Nawashehr	95	Absent	Trace	0-3	
L4		Nawashehr	95	Absent	Trace	0-3	
M1	Margalla Hill	Ayubia Intersection	95	Absent	Trace	4	Bioclastic wackestone
M2		Kuzagalli	90	Absent	Trace	10	
M3		Near Tarnawai	80	10	5	5	

Abbreviations: Sample numbers with prefix S are from Samana Suk Formation; K from Kawagarh Formation, L from Lockhart Formation and those with M are from Margalla Hill Limestone.
Sample Locations: S-1: Thai, S-2: Along road between Giya and Baragali, S-3, S-5 and S-6: Balolia, S-4: Nawashehar, S-7: Tarnawai, K-1: Ghumanwa Querry, K-2: Balolia, K-3: Balolia, K-4: Nawashehar.

4.2. Chemical properties

Majority of limestones, in general, are pure, containing less than 5% impurities. The impurities may be homogeneous or/and heterogeneous (Oats, 1998). According to him, the homogeneous impurities are the inclusions of non-carbonate matter into the sediment at the time of deposition, while the heterogeneous are the ones that had occurred during the terrigenous sedimentation) or they may be concentrated along fractures.

The major element chemistry of different limestones from district Abbottabad is given in the Table 3. In limestones, the increase of MgO content increases the dolomite component and may

Plate 1

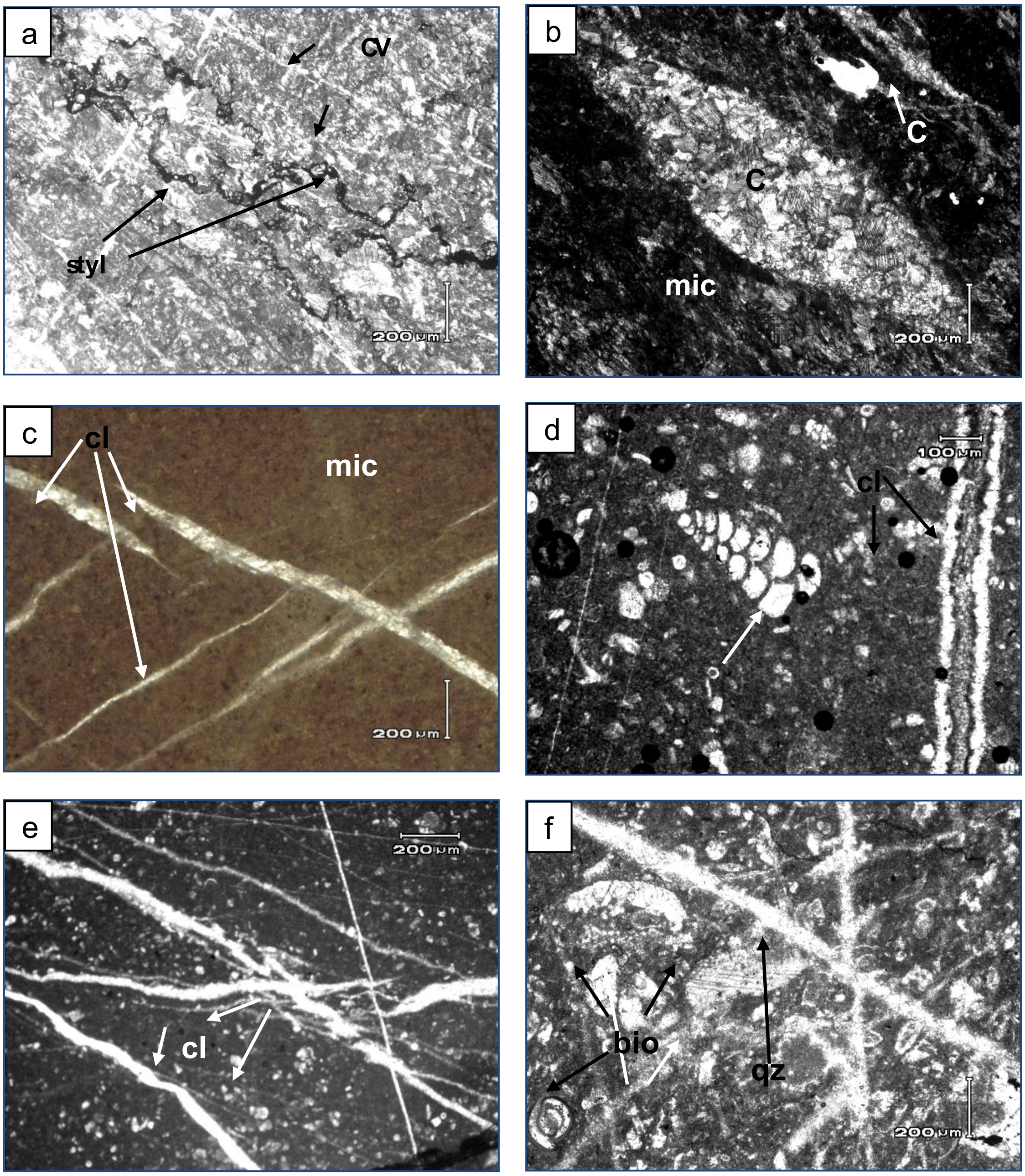


Plate. 1. Photomicrographs of limestones from different stratigraphic units of the study area: a) Calcite veins (CV) and stylolites (styl) in micritic background in Samana Suk Formation; b) Enechelon vein filled with calcite (C) while micritic groundmass (mic) in Samana Suk Formation; c) Calcite-filled fractures (cl) in Micrite groundmass (mic) in limestone of Samana Suk Formation; d) Biserial foraminifer (BF) and calcite veins (cl) in Kawagrah Formation; e) Multiple calcite-filled fractures (cl) and quartz silt (qz) in mud-supported limestone of the Kawagarh Limestone; f) Diagenetic alteration within Lockhart Limestone Formation marked by leached and spar-replaced bioclasts (bio) and calcite-filled fractures (cl).

aggravate the alkali carbonate reactions in favorable conditions. Limestone with less than 4% $MgCO_3$ are termed as Low Mg-Calcite (LMC) while limestone with $MgCO_3$ content more than 4% are referred to as High Mg- calcite (HMC). For applications like concrete, roadstone, cement and dimension stone, less than 5% MgO by volume is required. Silica (SiO_2) and alumina (Al_2O_3) in the form of clay, silt and sand are commonly found as heterogeneous impurities in features such as faults and bedding planes but these also occur as homogeneous impurities (Oates, 1998).

Table 3. Chemical composition of Limestone deposits of district Abbottabad. Sample numbers and locations are same as of Table 1.

Sample No./Formation		CaO	MgO	SiO_2	Fe_2O_3	Al_2O_3	Na_2O	K_2O	MnO	L.O.I.	Total	$CaCO_3$
S-1	Samana Suk Formation	50.75	1.957	0.73	0.392	0.18	0.315	0.135	0.01	43.6	98.25	90.62
S-2		52.2	2.235	0.83	0.470	0.19	0.330	0.159	0.01	43.2	99.62	92.91
S-3		51.85	0.115	0.53	0.438	0.33	0.663	0.268	0.01	43.25	97.46	92.29
S-4		52.81	0.65	0.84	0.33	0.23	0.14	0.01	0.00	41.2	96.21	94.30
S-5		52.77	0.56	1.44	0.03	0.68	0.23	0.03	0.00	42.5	98.24	93.93
S-6		54.74	0.80	2.11	0.17	0.43	0.14	0.05	0.00	42.5	100.94	97.75
S-7		51.86	1.37	2.85	1.18	0.82	0.23	0.15	0.00	42.5	100.96	92.57
K-1	Kawagarh Formation	51.38	0.342	2.133	0.145	1.73	0.209	0.088	0.00	42	98.03	91.75
K-2		51.38	0.426	2.23	0.116	1.51	0.482	0.099	0.00	42.2	98.45	91.75
K-3		40.48	18.46	4.22	0.35	2.23	0.33	0.98	0.00	37	104.05	72.28
K-4		53.63	0.15	1.27	0.00	0.36	0.16	0.04	0.00	42	97.61	95.72
L-1	Lockhart Limestone	47.40	2.215	4.53	1.016	2.44	0.561	0.361	0.02	41.5	100.04	84.64
L-2		46.66	1.89	6.66	0.88	0.81	0.432	0.393	0.02	42	99.74	83.05
L-3		54.99	0.83	3.91	0.05	0.86	0.24	0.11	0.00	42	102.99	97.88
L-4		51.69	1.56	6.47	0.06	1.10	0.17	0.10	0.00	41.5	102.65	92.00
M-1	Margalla Hill Limestone	45.55	1.855	5.11	0.403	1.58	0.27	0.11	0.07	43	97.95	81.08
M-2		46.39	0.775	3.10	0.43	1.41	0.23	0.10	0.06	44	96.49	82.57
M-3		37.13	8.92	17.00	0.312	0.10	0.140	0.064	0.06	39.5	103.23	66.27

4.3. Alkali-silica reactivity of aggregates (Chemical method) ASTM C 289-07

Alkali silica reaction (ASR) is a concrete durability problem which is caused by the dissolution of silica rich aggregates in highly alkaline solutions (Hobbs, 1988; St. Johns et al., 1998). As a result of this reaction, an alkali silica gel is produced that expands in the presence of moisture and results in the deleterious cracking of concrete. The alkali silica reactivity of the present limestone was determined by the chemical method in accordance with the ASTM method C 289-07.

The graphical representation between dissolved silica and reduction in alkalinity for limestone aggregates from district Abbottabad (Fig. 2) illustrates that the studied limestone are generally innocuous for concrete with minor exceptions (sample K3 is showing the deleterious category). The results of this test, however, cannot be used as a sole basis for the acceptance or rejection of specimens, especially those of carbonate rocks with high ferrous and magnesium concentration due to reduction in their ions (Derucher and Heins, 1981).

4.4. Engineering properties

Various engineering properties of these limestone samples were studied following the experimental methodology of ASTM standards (Table 4). Specific gravity was determined because the rocks having specific gravity greater than 2.55 are considered suitable for heavy construction work (Blyth and de Freitas, 1974; Harrison, 1993). Moreover, the aggregates that do not have adequate toughness and abrasion resistance may cause problems in construction.

5. Discussion

Limestone is widely extracted for aggregate material and for cement manufacturing, while the other industrial uses depend on their chemical properties (Harrison, 1994). Magnesium carbonate is the main undesirable impurity generally present in naturally occurring calcareous materials. In the process of cement manufacturing, the level of MgO in the clinker should not exceed 5% (Oates, 1998). The dolomitic limestone is also unsuitable for use as concrete and other potential purposes, because the dolomitic content can trigger Alkali-Carbonate reaction under favorable conditions. This reaction generally occurs between the alkalis of the cement and the aggregates of the dolomitic limestone causing extensive expansion and swelling which has a deteriorating effect on buildings (Gohar, 1999).

Petrographic study indicates that there is no or very little reactive silica and pore spaces in most of the studied samples, so these are suitable for use as aggregate except two samples of Balolia area from Samana Suk and Kawagarh Formations and one from Tarnawai area belonging to Margala Hill Formation showing the presence of reactive silica in the form of quartz. High degree of stylolitization and microfractures are also noticed in these samples making these unsuitable for use in aggregates.

The various physical parameters such as Los Angeles Abrasion (ranging from 18.4-2.3), Soundness (3-4), Water absorption (0.5-1.03 %) and Specific gravity (2.57-2.72) determined for samples from various Formations are mostly found to be within the specified limits of BGS's technical report of Harrison (1993) for use in concrete and ASTM C-33. Table 5 shows the ASTM specifications. The physical properties of the aggregates are relevant to the behavior of aggregate in concrete and to the properties of concrete made with the given aggregates (Neville Brooks, 1987). In limestone sample of the Abbottabad area, low values of compressive strength are observed at some places due to large amounts of microfractures and stylolization.

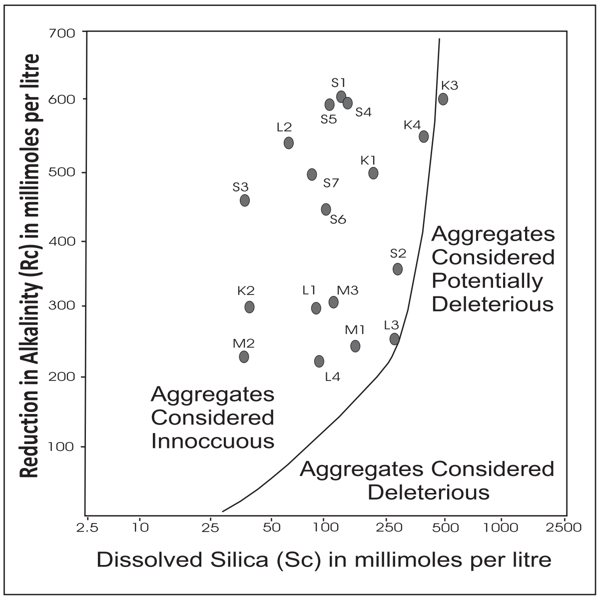


Fig. 2. Graphical representation between dissolved silica (Sc) and reduction in alkalinity (Rc) for limestone aggregates from district Abbottabad (ASTM C-289-07)

Table 4. Physical properties of selected limestones of district Abbottabad. Samples numbers and locations are same as those of Table 1.

Sample No.	L.A.A.V.	Soundness (% loss in weight)	Sp. Gravity	Water absorption (%)	Compressive Strength(N/m^2) (at 28 days)
S1	20.1	3	2.67	1.03	42.46
S2	19.5	3	2.66	0.97	41.46
S3	22	3	2.72	0.88	29.97
K1	21.6	4	2.71	0.67	39.98
K2	23	4	2.63	0.73	23.97
L1	18.8	3	2.68	0.91	35.98
L2	19	3	2.57	0.53	17.98
L3	18.4	3	2.60	0.90	32.50
M1	22.8	4	2.66	0.87	42.96
M2	21	4	2.61	0.79	47.45

Table 5. ASTM specification requirements for aggregates and dimension stones.

	Density (min)	Water absorption (max) %	Compressive strength (min)	LAAV (min)
High density limestone	2.56	3	55	10
Low density limestone	2.16	12	12	10

6. Conclusions

The main factors involved for the selection of a suitable location for cement industry include an easy access to a limestone resource having less concentration of impurities, like magnesium and silica, and availability of a nearby argillaceous deposit. Considering all these factors and the results of the present research, the high purity of limestone deposits of Nawashehr, Balolia, Ghumanwa and Tarnawai belonging to Samana Suk and Kawagarh Formations are recommended for cement industry that may cater for a high demand of cement in the area for the ongoing mega-constructional projects like Bhasha Dam. Hence, keeping in view the quality and huge amount of the reserves, and proximity to the dam location, the afore mentioned resources can provide a continuous supply of raw material for the production of good quality cement. Besides, many tens of local people can get employment with the installation of this cement industry which is a big step for the economic uplift of the area also.

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