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Construction material assessment from quarry sites at Chaktan-Ghasa-Kaligandaki River area, western Nepal

*Ujwal Raghubanshi[1] and Naresh Kazi Tamrakar[2]

[1]*East Management and Engineering Services,Pvt. Ltd., Lalitpur, Nepal*
[2]*Central Department of Geology, Tribhuvan University, Kathmandu, Nepal*

ABSTRACT

Construction material assessment is the crucial part of the hydroelectric power projects. The quality and quantity of the construction material is the major concern when exploring construction material. Four quarry sites (Q1, Q2, Q3 and Q4) were identified and assessed for both quantity and quality. Distribution of rock quarry sites was taken for quantitative assessment of reserves. The rock samples were obtained from the sites and were analysed for physical, mechanical and petrographic features. Rock types in quarry sites were schistose marble (in Q1), augen gneiss (in Q2), and banded gneisses (in Q3 and Q4). The analytical results showed that water absorption values were < 1% in all the samples, but was the highest in Q2 (0.92%). Contrarily, Q2 possessed the least specific gravity among the samples. Sodium sulphate soundness values ranged from 0.21 to 0.77, which was the highest in Q2. Samples Q1, Q3 and Q4 yielded Los Angeles Abrasion value below 45%, whereas Q2 gave 57.5%. Similarly, Q2 also yielded the least value (1.82 MPa) of point-load strength index tested along the foliation. Augen gneiss (Q2) showed the low abrasion resistance and soundness to freeze and thaw because of weak bonding between platy and other constituents of the rock , whereas schistose marble and banded gneisses yielded better resistance to abrasion and freeze and thaw, and possessed better strength perhaps due to well bonding among the mineralogical constituents due to the presence of appreciable amount of carbonate minerals.

INTRODUCTION

Surveying and exploring potential resources of construction materials around the project area is a component of the main investigation works undertaken contemporaneously with the survey of the project area, the Kaligandaki Koban Hydroelectric Project. A substantial quantity of suitable construction material needs to be identified near by the project area for infrastructure development and other civil constructions to establish a hydropower project. Therefore, the survey work was conducted by identifying potential resources of construction material form the bedrock quarries at different locations around the project.

In fact, there is an abundant quantity of aggregate and hard rock material available nearby the project area. The identified materials are required to be explored and tested to determine their engineering and mineralogical properties to justify the properties usable for construction purpose. The quarry sites are situated at the Chhaktan Khola, Dhampu headworks area, Lower Lete (near to confluence of the Kaligandaki River and the Lete Khola) and Ghasa power house area, and named them as Q1, Q2, Q3 and Q4, respectively.

*Corresponding author:
E-mail address: ujwol80@hotmail.com

LOCATION AND DESCRIPTION OF SITE

The proposed project, i.e., Kaligandaki Koban Hydroelectric Project is located in Mustang District of the Western Development Region of the country (Fig. 1). The proposed headworks and powerhouse sites are located near to Dhampu village and Ghasa village, respectively, which lie at about 325 km from Kathmandu. The proposed power house area is located in the Ghasa village, which is about 8 km ahead from Titar towards Jomsom, headquarter of Mustang District. Similarly, headwork area is located around the Dhampu village, about 8 km (half an hour by local bus) from Ghasa along the Jomsom motorable road.

Out of the four hard rock quarry sites, three are located along a tunnel alignment of the project area, and are situated at the Dhampu headworks area, Lower Lete (near to confluence of the Kaligandaki River

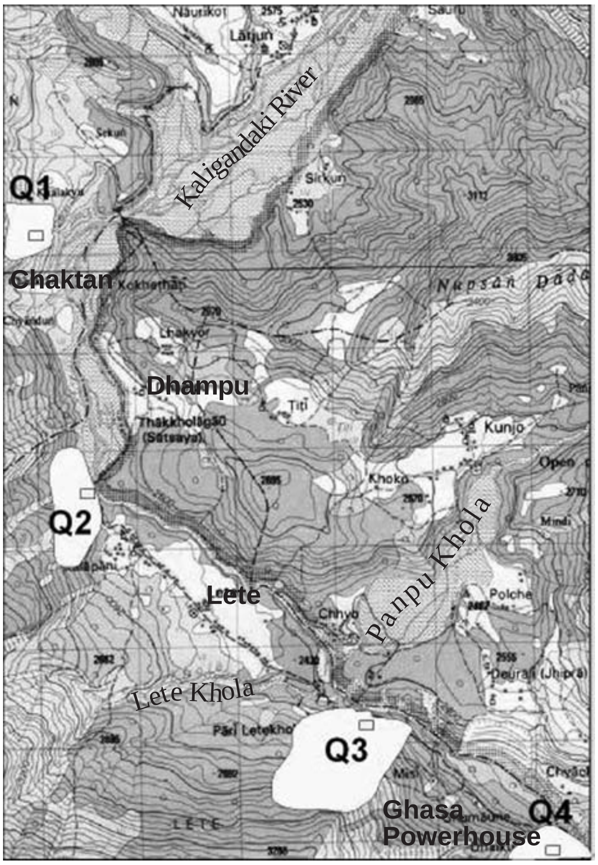

Fig. 1 Location of bedrock exposure; probable quarry sites

and the Lete Khola) and the Ghasa power house area and the fourth quarry site lies at the Chhaktan Khola upstream of the headworks site of the project (Fig. 1).

The quarry sites are distributed in three geological formations based on Le Forte (1975), of which two belong to the higher Himalayan Crystalline and one to the Tibetan Tethys Sediments (Fig. 2). The Quarry site Q1 is located at the Larjung Formation of the Tibetan Tethys Sediments comprising of metamorphosed argillo-arenaceous limestone probably of the lowest part of the the Tibetan Tethys sediments. The Larjung Formation is separated from the underlying augen gneisses of the Higher Himalayan crystalline, formation III, by a gradational transition of the South Tibetan Detachment System (STDS). In this formation, the quarry site Q2 is located (Figs. 1 and 2). Similarly, the quarry sites Q3 and Q4 are located at the formation II of the Higher Himalayan Crystalline comprising of calcareous banded gneisses.

The main objective of the construction material survey and investigation is to carry out the assessment of suitable construction material within the vicinity of the project area from where the material is feasible to mine and haulage to the corresponding construction sites. Therefore, the purpose is to identify the quarry sites, quantify the material, and characterise the physical and petrographic properties of the material.

METHODOLOGY

The 1:10,000 scale topographic survey map was used as a base map to prepare a geological map (Fig.2) showing potential resources of the construction material suitable for the project. The Geological map was prepared by walk over survey using Brunton compass, tape and GPS. The area for hard rock quarry was selected and delineated the location considering its accessibility, cover with minimum vegetation and stable slope. Geological parameters like dip, strike were plotted on the base map. Geological profiles and cross sections are drawn to determine the nature and probable reserves of different types of construction material required for the project.

Survey of hard rock material was explored by walk over survey using tape and compass. The out crops of the hard rock materials were identified and measured for their strikes, dips and other geological parameters. Block samples were collected from major outcrops for laboratory testing using geological hammer and chisel. The strike extension, the width and the thickness of the deposits were considered to determine the probable reserve of the quarry material.

The specific gravity and water absorption were determined in accordance to AASHTO T85-81 (AASHTO, 1982a). The sulphate soundness test was carried out on the construction material to determine the durability of aggregates against physical weathering. The test was done as per the standard procedures of determining the sulphate soundness of aggregates as recommended by AASHTO T104-77 (AASHTO, 1982b). The Los Angeles Abrasion test was carried out according to the standard procedures outlined by AASHTO T96-77 (AASHTO, 1982c).

Table 1. Summary of Quarry Sites For Hard Rock

S.n	Quarry	Site Name	Easting(N)	Northing(N)
1	Q1	Chhaktan Khola	459959	3171757
2	Q2	Dhampu, Weir axis	460440	3169562
3	Q3	Lower Lete, Road side	463775	3166928
4	Q4	Ghasa, Powerhouse site	464935	3164492

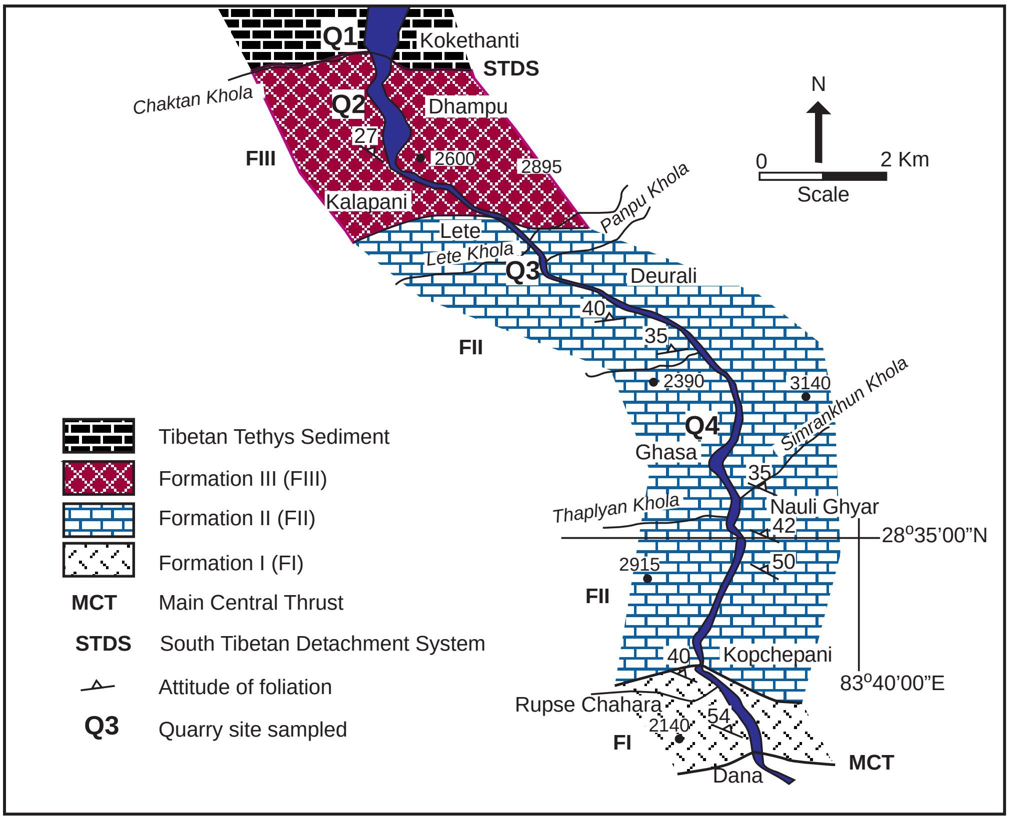

Fig. 2 A geological map of the study site (After Upreti and Yoshida, 2003) showing the location of quarry site sampling location.

The percentage of abrasion was calculated on the basis of the tests.

SITE INVESTIGATION OF CONSTRUCTION MATERIAL

In all four quarry sites were explored for evaluation of construction material in the form of hard rock. These areas were surveyed by walk over GPS and compass measurement so as to estimate thickness, strike extension and width of the deposits. While selecting the rock quarry site the slope stability and environmental conditions were also taken into consideration. Some block samples were collected from different locations of the deposit for testing in the laboratory. Geological parameters of different outcrops were measured and plotted in a base map. Detail of quarry sites are summarized and presented in Table 1.

Quarry Site Q1: schistose marble

The quarry site (Q1) is located near to confluence of the Kaligandaki River and the Chhaktan Khola at about 2 km upstream from the Headworks site. The area lies at the close vicinity of (South Tibetan Detachment System) STDS. The attitude of discontinuity of rock mass is given in Table 2. The outcrop comprises of light brownish grey to bluish grey, strong to moderately strong, slightly weathered to fresh schistose marble. Under thin-section, a banded texture is developed due to preferred arrangement of biotite and muscovite over calicte and dolomite (Fig. 3). The sample comprises chiefly carbonate minerals and subordinately quartz and biotite. (Table 3). Along with micas, siliceous bands with a granular equant quartz (50–120 microns) in association with calcite, dolomite and mica roughly alternate with calcite rich bands. The extractable volume of rock of the quarry Q1 is 133948575 m^3 (Table 4).

Quarry Site Q2: augen gneiss

The quarry site (Q2) is located at the right bank of the Kaligandaki River across the weir axis of headworks site. The outcrop comprises of milky white and black, strong to moderately strong, slightly weathered to fresh augen gneiss. Garnet is also found

Table 2: Attitude of discontinuities of bedrocks, and hill slope

Quarry site	Foliation	Joints		Hill slope
Q1	22°/66°	J1: 78°/293°	J2: 70°/215°	67° /144°
Q2	31°/47°	J1: 67°/270°°	J2: 62°/95°	38° /46°
Q3	36°/40°	J1: 72°/210°	J2: 76°/102°	61° /45°
Q4	29°/347°	J1: 69°/220°	J2: 71°/132°	75° /133°

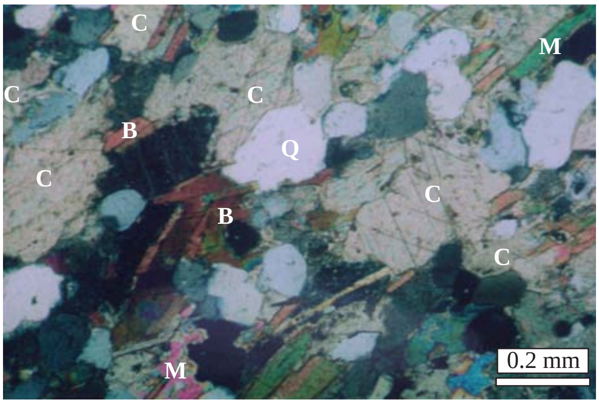

Fig. 3 Photomicrograph of schistose marble from quarry site Q1. C = calcite; B = biotite; M = muscovite; Q = quartz.

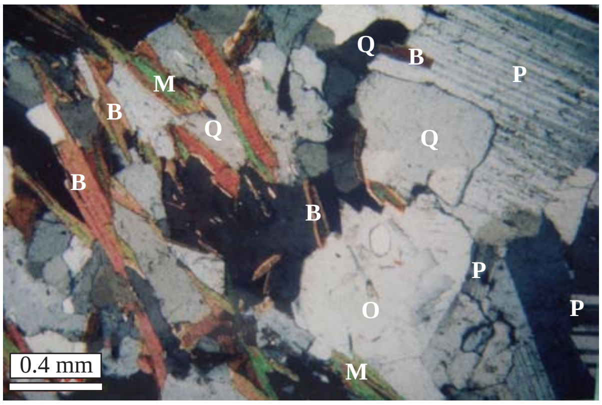

Fig. 4 Photomicrograph of Augen gneiss from quarry site Q2. B = biotite; M = muscovite; Q = quartz; P = plagioclase; O = orthoclase.

at some part of the rock. The dominant constituent of the rock is quartz and the subordinate constituents are plagioclase, microcline and muscovite (Table 3). Under the thin-section, a gneissose texture is developed including augens. Biotite distributes roughly along foliation (Fig. 4). Biotites are smaller and thiner compared to muscovites. Muscovites are commonly giant grains of tabular shape. Plagioclase (1.6 to 2 mm) (Fig. 4) and muscovite (2–3 mm long) produce very large crystals. They are poikiloblastic (Helicitic). Quartz crystals are generally 200–300 microns, or 1–1.5 mm. They are polygonal, equant and with sutured grain boundaries. The extractable volume of rock at the quarry is 67647800 m^3 (Table 4).

Table 3: Constituents of rock samples

Minerals	**Q1**	**Q2**	**Q3**	**Q4**
Quartz	20	55	40	50
Orthoclase	-	-	11	-
Microcline	-	10	5	-
Plagioclase	-	15	5	9
Biotite	10	7	23	25
Muscovite	6	10	7	10
Sericite	-	-	5	-
Calcite	40	-	3	5
Dolomite	23	-	-	-
Tourmaline	-	3	-	-
Opaque	1	-	1	1

Quarry Site Q3: banded gneiss

The quarry site (Q3) is located at the right bank of the Kaligandaki River a few meter downstream from the confluence of the Kaligandaki River and the Lete Khola at Tallo Lete. The outcrop comprises of light greenish grey, strong to very strong, slightly weathered to fresh banded gneiss. Under the thin-section, gneissose texture or well banding is observed (Fig. 5). Quartz is the dominant constituent which is followed by biotite, orthoclase, muscovite, and so on (Table 3). Chiefly biotite and minorly muscovite form dark bandings and are associated with microcline, plagioclase, orthoclase and quartz. Quartz and feldspar bands alternating with biotite bands also contain biotite and some muscovite. These bands contain equant to slightly elongate quartz interlocked with orthoclase, plagioclase and microcline. Feldspars show alteration to sericites and give dusty looking. Calcite occurs in isolated patches because muscovites and some feldspars are replaced by calcite. The extractable volume of rock at the quarry is 428761000 m^3.

Table 4: Estimation of bedrock material

Quarry No	Strike length m	X- section Area(A1) m^2	X- section Area(A2) m^2	X- section Area(A3) m^2	Mean Area m^2	Volume m^3	Type of material
Q1	450	359221	236106		297663.5	133948575	Schistose marble
Q2	1100	74647	61165	48682	61498.0	67647800	Augen gneiss
Q3	1000	486817	370705		428761.0	428761000	Banded gneiss
Q4	1100	169387	83466		126426.5	139069150	Banded gneiss
					Total estimated Volume of Quarry Material	769426525	

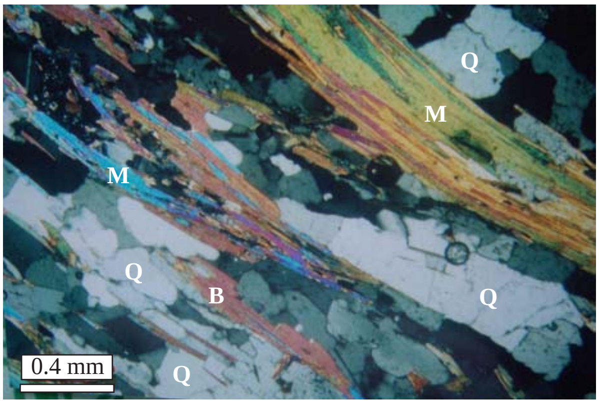

Fig. 5 Photomicrograph of a banded gneiss from quarry site Q3. B = biotite; M = muscovite; Q = quartz.

Quarry Site Q4: banded gneiss

The quarry site (Q4) is located at the right bank of the Kaligandaki River near to proposed powerhouse site at Ghasa. The outcrop comprises of light greenish grey, strong to very strong, slightly weathered to fresh banded gneiss. Quartz is the dominant constitutent and is followed by biotite, muscovite, plagioclase, and so on (Table 3). Gneissose texture with distinct dark bandings of dominantly biotite and some muscovite, and light bandings of quartz and plagioclase along with some muscovite and biotite is characteristic. Muscovite is often huge patches with inclusions of quartz and feldspars, thus forming poikiloblasts. Biotite are fish-like to patchy and short tabular. Some huge biotite also occur and include quartz, plagioclase, and muscovite. Quartz grains are commonly 100–200 microns and 500–800 microns in size. They are polygonal to elongate in shape. Plagioclase grains are commonly 400–800 microns. Calcite frequently replaces micas. The attitude of discontinuity of rock mass is shown in Table 2. The extractable volume of rock at the quarry is 139069150 m^3.

RESULTS OF PHYSICAL AND MECHANICAL PROPERTIES

Results of laboratory analysis of physical mechanical properties of rocks have been tabulated (Table 5).

The specific gravity was determined for the rock shows that all the samples have specific gravity of heavy weight aggregate (>2.6). Based on these results the rock samples are sound because the specific gravity of rocks have inverse relationship with the porosity and strongly correlate with strength of rocks (Tamrakar et al, 1999; Tamrakar et al, 2007).

The water absorption values are less than 1% indicating soundness of rock samples. Water absorption greater than 1% will be vulnerable to concrete structures as access of water to aggregate

Table 5: Results of physical, mechanical and chemical test of rock samples

S.N.	Test Type	Q1	Q2	Q3	Q4
1	Specific Gravity	2.69	2.61	2.70	2.70
2	Water Absorption (%)	0.27	0.92	0.46	0.49
3	Point Load Index perpendicular to foliation (MPa)	7.21	7.71	4.87	6.22
4	Point Load Index parallel to foliation (MPa)	6.05	1.82	7.98	7.12
5	Los Angeles Abrasion Value (%)	26.6	57.5	41.6	42.2
6	Sodium Sulphate Soundness Value (%)	0.43	0.77	0.21	0.32

increases possibility of reaction with deleterious constituents (clay or reactive silica) and induces swelling.

Point-load strength index perpendicular to foliation ranges from 4.87 to 7.71 Mpa and those parallel to foliation ranges from 1.82 to 7.98 MPa. The greatest heterogeneity (1.82–7.71 MPa) is recorded to augen gneisses of the quarry site Q2. Excluding this heterogeneous result, the other values yielded by the samples show rocks with good strengths.

The Los Angeles Abrasion test results of hard rock are less than the limiting value 45 % (IS 2386 Part IV (IS, 1975)) except the value of the hard rock sample Q2 quarry material. This indicates that the rock sample Q1 possesses good abrasion resistance. The samples Q3 and Q4 also showed abrasion resistance below the limiting range and the sample Q2 exceeds (57.5%) to this limit.

The sodium sulphate soundness tests were carried out on the samples collected from the quarries to determine the durability of aggregates against physical weathering. The test results of all the material are quite below the maximum limit, quoted by IS 2386 Part IV (IS, 1975), i.e., 10%.

CONCLUSIONS

The hard rock and aggregate material are available in enormous quantity within the project area, so the survey work is performed in comparatively most potential and accessible areas. Generally there are three types of rocks identified in the quarry sites namely schistose marble Q1, augen gneiss Q2 and banded gneiss Q3 and Q4. The results of different tests executed for all rock types are within the permissible limit, but the Los Angeles Abrasion value of augen gneiss Q2 is higher than the permissible limit, which could be due to splitting of grains from micaceous domain. Whereas, in other cases for Q1, Q3 and Q4, the carbonate mineral could have bonded strongly the other mineral constituents thus yielding lower values of Los Angeles Abrasion. But Q1, being a schistose marble has relatively lower Los Angeles abrasion value compared to those of Q3, and Q4, showing that percent of carbonate mineral in rock is negatively related to Los Angeles Abrasion value.

The point load value, which indicates the strength of the rocks are high to very high and the values are more or less similar in all rock types while tested perpendicular to foliation of the rock but the value decreases substantially in augen gneiss Q2 while tested parallel to the foliation of the rock. This indicates weak bonding of mineral grains perpendicular to the foliation. This condition also explains why Q2 results high Los Angeles Abrasion value.

ACKNOWLEDGEMENTS

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