Bulletin of the Department of Geology

Central Department of Geology
Kirtipur

Bulletin of the Department of Geology, Tribhuvan University, Kathmandu, Nepal, vol. 18, 2015, pp. 49–58

Qualitative and quantitative assessment of gravel deposits between Aaptar and Malekhu, Central Nepal for aggregates

*Sunu Dawadi

Central Department of Geology, Tribhuvan University, Kathmandu, Nepal

ABSTRACT

The Malekhu Khola is rich in sediments which are widely exposed along its banks. In recent years, river mining sites have been established and mining has been carried on to produce aggregates to meet a small portion of the market demand. Because the riverbank deposits are of heterogeneous composition, quality of the aggregate from such deposits is of main issue. This study therefore, aims to evaluate quality of river sediment to know its suitability for aggregate as raw material for various uses, and the volume of the deposit. Field observation and intensive laboratory works were carried out to evaluate aggregates. The samples of aggregates were analyzed for texture, composition, durability and physical and mechanical properties. Majority of the aggregate particles were found metamorphic rocks of the Lesser Himalaya like quartzite, schist, marble, metasandstone, amphibolites, gneiss and granite, etc. Most of the deposits were matrix-supported and the matrix was basically sandy. The majority of clasts showed bladed to disc, and were generally rounded to sub rounded. The sediment size ranged from granule to upto boulder but the modal size was of cobble grade. While tested for gradation, the coarse aggregates ranged from uniform to gap graded categories. In terms of shape, workability of aggregate was found satisfactory. Aggregate samples possessed low Water Absorption Value (0.53–1.08%) and thus low effective porosity. Aggregate Impact Value (13.40–15.70%) and Aggregate Crushing Value (17.50–19.67%) showed good soundness. Los Angeles Abrasion Value (37.00–48.40%) showed the consistent hardness of each of the samples. The low range of Sodium Sulphate Soundness Value (1.37–2.16%) indicated good resistance of aggregates against chemical weathering and frosting. The aggregates were also resistant to slaking as indicated by very high range of Slake Durability Strength Index (98.67–99.72%). Comparing with the existing Nepal Standard (NS), British Standard (BS) and American Standard of Testing Material (ASTM), the studied samples were suitable for concrete structures and unbound pavements. Six different localities were considered in the study area to estimate for resource of aggregates. The total volume of the deposits was estimated to be 392273 cubic meter.

Key words: Aggregates, Los Angeles Abrasion Value, Aggregate Crushing Value, Aggregate Impact Value

Received: 20 June, 2015 **Accepted:** 14 Aug, 2015

INTRODUCTION

A gravel deposit is one of the accessible resources of construction materials. Construction material plays a vital role in development of infrastructure in the nation. The huge volume of gravelly construction material can be observed in the active bars as well as inactive bars and floodplain along the Malekhu Khola due to accumulation of sediments basically during the debris flow events. From few years, sediments of the Malekhu Khola of Malekhu-Aaptar area are being used as construction aggregates, which have markets in locally as well as in the cities. The locally constructed infrastructure such as roads, bridges, building foundations, etc. are also in search of huge amount of construction aggregates. The potential volume available for extraction and the quality of aggregates which are used in construction structures is of great concerns. Smith and Collis (1993) identified main factors influencing aggregate behavior in various operational and environmental conditions, and concluded that the performance of aggregates depends upon their intrinsic

*Corresponding author:

E-mail address: sunudwd@gmail.com

properties i.e. particle shape, grading, composition and its physical and chemical properties. Shrestha and Tamrakar (2013) have studied the geotechnical properties of construction aggregate from the Trishuli Ganga River, Galchi area, Central Nepal and showed that aggregate of the area is resistant to weathering and abrasion. Tamrakar et al. (2002) studied Siwalik sandstones from the Central Nepal and concluded that dry density and porosity were correlated well with uniaxial compressive strength, point load index and modulus ratio. Maharjan and Tamrakar (2003) evaluated quality of siltstone samples of the Tistung Formation for concrete aggregate. Bista (2014) has studied the durability of rocks for aggregates from Thopal-Malekhu Khola area and concluded that aggregate of the area can be used as road stone aggregate, concrete aggregate and filter aggregate. Maharjan and Tamrakar (2007) evaluated quality of the river gravel from the Rapti and the Narayani Rivers, and concluded that the majority of gravels of both rivers were of high roundness and high sphericity, and of diverse chemical groups, and were compositionally sound with good workability for road and concrete aggregates. Therefore, study of properties of aggregates is important to evaluate their usefulness in various uses as aggregates. The main aims of the present study are to analyse physical and mechanical properties of the material to evaluate their potential uses as construction aggregates as well as the volume of the deposit available along the Malekhu Khola between Aaptar and Malekhu Bazar. The study area is characterized by the rocks belonging to the Upper Nawakot Group of the Nawakot Complex and the Bhimphedi Group of the Kathmandu Complex (Stöcklin and Bhattarai, 1977).

MATERIAL AND METHODS

During the field study columnar sections were prepared from the exposures of river bars and banks. The composition of the aggregate, nature of the clast and matrix, grading, sorting, proportion of matrix to clast, particle mode, maximum, ranges and their roundness were observed and recorded. Length, breadth and height of the deposits were measured for the

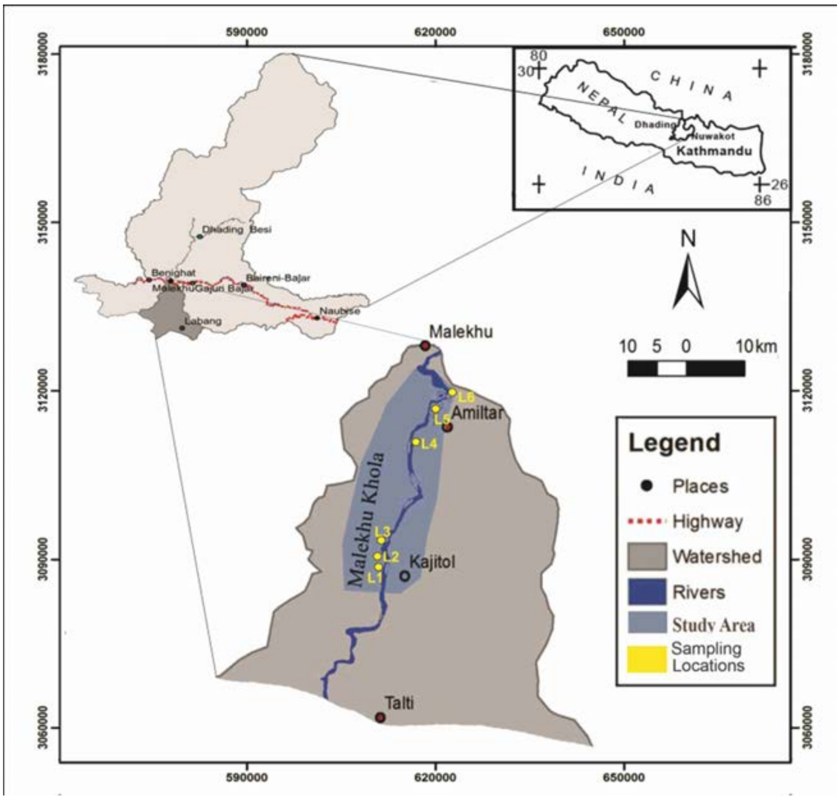

Fig. 1 Location map of the study area

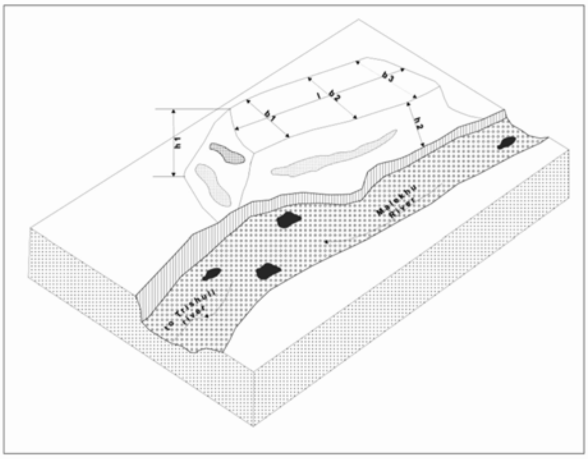

Fig. 2 Schematic block diagram showing the method for the reserve calculation in the field

resource estimation. Calculations of potential resource volumes involve a multiplication of the areal extent of the deposit by the thickness of the deposit. The areal extent of the deposit was derived from the manual area calculation. Deposit thickness was estimated from the face height of the deposit exposed at the river bank of aggregate in a deposit. Aggregate samples for the laboratory study were obtained from 6 different locations from floodplain deposits and point bar deposits along the Malekhu Khola between Aaptar village and Malekhu Bazar. Some crushers are also found operating along the banks which have been utilizing the river gravel. About 30 kg samples from each location were brought for the laboratory analysis of composition, shape, physical and mechanical properties.

Though the aggregate samples contained both fine and coarse material, analysis were made for the coarse aggregates only. Sieve analysis (ASTM C 136, 2001) was carried out on both fine and coarse aggregate and different grading curve was obtained. To determine the composition of coarse aggregates, firstly the coarse aggregates were sieved in specified sieves, then each of the fraction of coarse aggregate were separated according to their compositional characteristics. Further, the representative aggregate (pebbles) samples were selected from different locations and six thin sections were prepared and examined under the petrographic microscope for the study of general mineralogical composition and texture.

Shape indices such as an elongation index and a flakiness index were determined. The Elongation Index (EI) was calculated by using the equation after BS 812 105.2 (1990):

$$\text{Elongation Index} = m/M \times 100 \qquad (1)$$

Where, m= weight of materials retained on specified gauges, and M= total weight of the aggregate passing and retained on the specified sieves

Similarly, Flakiness Index (FI) was calculated by using the equation after BS 812 105.1 (1989):

$$\text{Flakiness Index} = w/W \times 100 \qquad (2)$$

Where, w = weights of the material passing the various thickness gauges and W= total weight of the aggregate passing and retained on the specified sieves.

The physical properties such as water absorption (WA) and dry density, and specific gravity were determined after AASTHO M-132 (1987). Samples were immersed in water for 24 hours, surface dried, weighed and percent absorption relative to dry weight were calculated as:

$$WA = \{(W2-W1)/W1\} \times 100\% \qquad (3)$$

Where, W1 = Weight of oven dried sample, and W2 =Weight of the surface dry saturated sample.

Specific gravity (SG), which is a mass of a given substance divided by unit mass of an equal volume of water, was determined. Apparent specific gravity (ASG), the ratio of density of the particles to the density of the water, was also determined after ASTM C127-01 (2001).

The point load strength index was determined for lump sample following ASTM D 5731-02 (2008). Los Angles Abrasion test were made following ASTM C131-01 (2001) to obtain mechanical soundness or hardness against abrasion of aggregate. To obtain soundness of aggregates against frosting and chemical weathering, sulphate soundness test was made based on ASTM C88–05 (ASTM, 2001). The sodium sulphate soundness value (SSV) in percentage was obtained as the relative loss of the fine (<10 mm) after five cycles of test.

Aggregate crushing value (ACV) and Aggregate impact value (AIV) were determined using a compression testing machine and 14kg weight hammer respectively following (BS 812:1990). ACV provides the relative measure of resistance to crushing under the gradually applied compressive load while AIV is the resistance of the stones to fracture under repeated impact. ACV and AIV were calculated using the equations:

$$ACV = M2/M1 \times 100 \quad (4)$$

$$AIV = W2/W1 \times 100 \quad (5)$$

Where, M1 is initial weight of the aggregate sample, in gram, M2 is the weight of sample passing on 2.36 mm sieve in gram, W1 is the total weight of the aggregate samples, and W2 is the weight of aggregated fraction passing through 2.36 mm sieve.

The slake durability index was determined following ASTM D 4644-87 (1992).

RESULTS

The description of aggregates of the various sampling sites has been given in Table 1. The samples L1 and L5 are respectively from an active point bar and an inactive point bar. Samples L2 and L3 are from overbank flood plains. Sample L4 is from older terrace. Sample L6 is from mid-channel bar.

Gradation

Grading curve of the fine aggregate from location L1, L2 and L4 fall within the recommended range. But L6, L5 and L3 fall outside the gradation limits and significant portion (finest portion) of the curve is below the upper limit requirement. Similarly, the grading curve for coarse aggregated from L3 and L2 fall outside the recommended range and they are lower than the lower limit and grading curve from L1, L4, L5 and L6 show reasonable fallout from the gradation limit and a significant portion (coarsest portion) of the curve is

Table 1: Field description of aggregate deposit

Locations	L1	L2	L3	L4	L5	L6
Outcrop condition	Point bar deposit,	Overbank flood plain deposit	Overbank flood plain deposit	Older river terrace deposit	Inactive point bar deposit,	Mid channel bar
Composition	granite, marble, schist quartzite	granite, marble, schist gneiss, quartzite	granite, marble, schist, quartzite	granite, marble, schist, , quartzite	granite, marble, schist, quartzite	granite, marble, schist, quartzite
Clast %	80	75	60	70	80	35
Matrix%	20	25	40	30	20	65
Mode	cobble	Cobble	cobble	cobble	cobble	Cobble
Maximum	0.50 m	0.45 m	0.45 m	0.45 cm	0.40 m	0.45m to > 1m
Range	fine granule to upto 1m boulder	fine granule to upto 1m boulder	fine granule to upto 1m boulder	fine granule to upto 80 cm boulder	fine granule to upto 70 cm boulder	sandy matrix to mega boulder, highly varied.
Structure	massive, scattered	Massive, randomly oriented pebbles and cobbles,	laminated, stratified	Massive, randomly oriented pebbles and cobbles,	Massive, randomly oriented pebbles and cobbles,	Massive, randomly oriented pebbles cobbles, poorly sorted.
Avg. thickness	1.4m	1.5m	1.5m	4.5m	2.59m	2m
Overburden thickness	0.30 m	0.20 m	0.20 m	about 1 m	Variable. Avg. 0.50 m	0.30 m

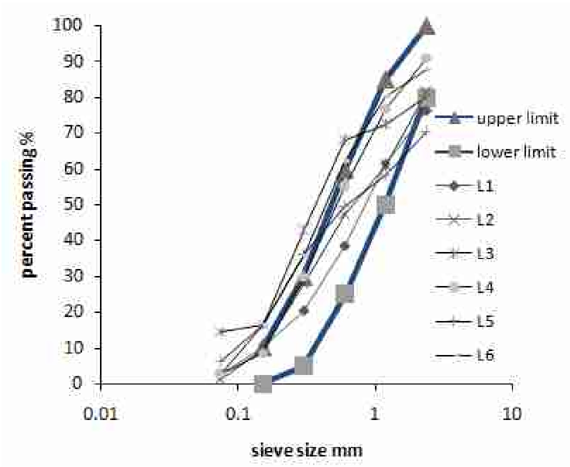

Fig. 3 Grainsize distribution curve of the fine aggregate samples from the Malekhu Khola compared with the gradation curves of ASTM C33-02 (2002)

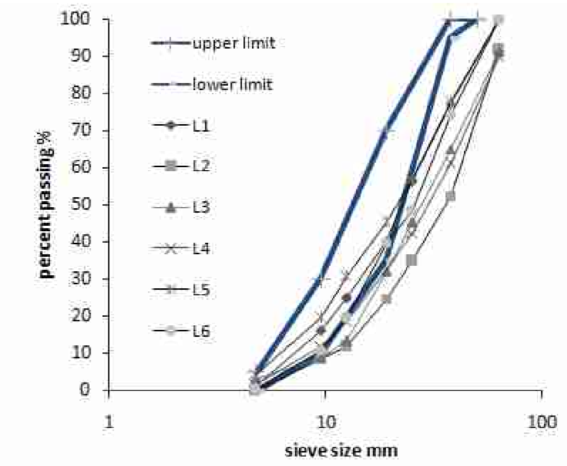

Fig. 4 Grain size distribution curve of the samples from the Malekhu Khola compared with the gradation curves of nominal size 25mm of 40 mm ASTM C33-02 (2002)

below the lower limit requirement. This may affect the workability of the concrete, unless mixture proportioning adjustment is carried out.

Composition

The aggregates from the Malekhu Khola area contain various particles. Pebbles from different locations were collected and thin sections were prepared and investigated under petrographic microscope and composition and the rock types were identified. The results are listed in Table 2. The coarse aggregates contain maximum percentage of marble, quartzite, metasandstone, schist and few granite and gneiss.

Shape Indices

The flakiness index ranges from 16.77%-28.81%, and the elongation index ranges from 25.79% to 46.71% (Table 3). According to BS 812 .105.1 (BS, 1989), maximum permitted flakiness index is less than 25%. Aggregates which are flaky or elongated are detrimental to higher workability and stability of mixes.

Physical and Mechanical Properties

Results of laboratory analysis of aggregate properties have been listed in Table 4.

AIV of the aggregate sample ranges from 13.40% to 15.70%. ACV of the sample ranges from 17.50% to 19.67%. Less than 40% is desirable for wearing surface and less than 45% is for normal concrete (NS 297-1994). Since all the values fall within the recommended range (BS 882: 1983), it can be used for heavy-duty concrete floor finishes, for concrete pavement wearing surfaces and in other concrete.

Table 2: Modal composition of the selected pebbles from different locations

Samples	Mineral %								
	Quartz	Feldspar	Biotite	Muscovite	Calcite	Clay Mineral	Range (mm)	Modal Size (mm)	Rock Type
SL1	65	5	10	12		8	0.03-0.18	0.09	Metasandstone
SL2	90		5	5			0.09-1.37	0.18	Quartzite
SL3					95	5	0.18-1.5	0.75	Marble
SL4	75		7	8		10	0.04-0.18	0.9	Metasandstone
SL5	70	15	5	10			0.9-1.00	0.37	Granite
SL6	65	15	10	10			0.03-0.18	0.9	Schist

Table 3: Result of the elongation index and flakiness index

Location	Elongation Index, %	Flakiness Index, %
L1	34.72	21.01
L2	25.79	16.77
L3	46.71	28.23
L4	33.47	20.28
L5	40.53	28.81
L6	30.25	18.94

Table 4: Result of Physical and Mechanical test of aggregate samples

S.N.	Test Type	L1	L2	L3	L4	L5	L6
1	AIV (%)	14.1	13.4	14.4	13.4	15.6	15.7
2	ACV (%)	19.7	17.5	18.4	18.1	18.2	19.2
3	Point Load Strength Index (Mpa)	2.98	0.84	5.1	6.1	5.62	4.99
4	Specific Gravity	2.47	2.52	2.58	2.61	2.5	2.87
5	Water Absorption Value (%)	1.07	0.54	1.07	0.53	0.53	1.08
6	Los Angeles Abrasion Value (%)	38.0	34.5	42.1	45.7	37.0	48.4
7	Sodium Sulphate Soundness Value (%)	2.16	1.04	1.37	1.41	1.59	2.23
8	Slake Durability Index {Id (2) %}	99.71	99.37	99.13	99.7	99.19	98.66

Point load strength index varies from 0.84 MPa of metasandstone pebble from L2 and 6.10MPa of quartzite pebble from L4.

The values of the specific gravities of the aggregates are from 2.47 to 2.88. Except for the aggregate sample from L6, these values are within the ranges for the specific gravity of aggregates (BS: Specific gravity generally less than 2.65 for roadstone and less than 2.50 for filter aggregates). The water absorption value (WAV) ranges from 0.53% to 1.08%. According to the specification of BS 812-2 (1995), WAV should be <3% for overall uses of aggregates. AASHTO M-132 (1987) specifies WAV<5% for the general use. But ASTM C 127 (2001) has specified that this should be <2.0 for coarse aggregates. Because the recorded WAVs for six tested samples of aggregate are below 2% showing low effective porosity, there are wide possibilities of applicability of these aggregates in construction.

The Los Angeles abrasion value ranges from 37.00% to 48.40%. Los Angeles value below 30% can be used for bituminous mix, below 50% for base course and less than 16% for PCC (ASTM C 131). Therefore, the aggregate is suitable for base course only.

AASHTO T 104 (1999) specifies the SSV value with 10% loss at 5 cycles is required for PCC and asphalt, 12% loss at 5 cycles required for surfacing and foundation courses, and less than 5% loss is required for armour coat. The SSV of the tested samples varies from 1.37% to 2.16%. The samples fall within specified range and are resistant against chemical weathering and frosting.

Slake durability index shows small loss in total mass due to abrasion and wear during two successive cycles of test. Slake durability index ranges from 98.66% to 99.71%. Therefore, comparing the average values found with the Gamble's table of classification, the aggregate samples are found to be very high durable in nature.

Results obtained from the various laboratory tests are compared with the specified standards and based on the specification their possible end uses are tabulated in the Table 5.

Resources (Fig. 5) for aggregate assigned in six different locations and their reserves are tabulated in Table 6. The total estimated reserve comes to be 392273 cubic meter.

CONCLUSIONS

From the study of the sediments from the MalekhuKhola (between the Aaptar Village and Malekhu Bazar) it is found that the major composition of the sediments are metamorphosed rocks of the Lesser Himalayan rocks like marble, quartzite, metasandstone, schist, granite, gneiss, etc. They are mostly sub-rounded to sub-angular with rough to smooth surface texture; therefore workability of aggregate is good considering the textural attributes.

The results of shape indices measurements show that the coarse aggregate of the samples from L2 is more suitable since it has less EI and FI. The flakiness indices of L3 and L5 exceed the specified limit of 25% after BS 812. 105.1 (BS, 1989), and the elongation indices of all the samples exceed the limit (<25%) of BS812. 105.2 (1990).

Although grading of the coarse aggregate deviated from the standard gradation limits (ASTM C33-02,

Table 5: Suitability of sample in terms of end -uses

Sample no			L1	L2	L3	L4	L5
FI, %	Obtained value		21.01	16.77	28.23	20.28	28.81
	Specified value [BS 812. 105.1 (1989)],		<25%				
EI%	Obtained value		34.72	25.79	46.71	33.47	40.53
	Specified value [BS 812. 105.2 (1990)]		<25%				
WAV %	Obtained value		1.08	0.55	1.08	0.53	0.53
	Specification [BS 812-2]		Generally, <3%, 2% for roadstone aggregate. Not usually limited, but a recommended max. value of 2.5% is sometimes specified for concrete aggregate and less than 3% for filter aggregates.				
SG	Obtained value		2.47	2.52	2.58	2.61	2.51
	Specification [BS 812-2]		Specific gravity generally less than 2.65 for roadstone and less than 2.5 for filter aggregates.				
ACV %	Obtained value		19.67	17.5	18.37	18.1	18.17
	Specification [BS 882: 1983]		<25% for heavy-duty concrete floor finishes, <30% for concrete pavement wearing surfaces and <45% in other concrete				
LAAV %	Obtained value		38	34.5	42.1	45.7	37
	Specification [ASTM C 131]		<30% for Bituminous mix, <50% for base course				
SSSV %	Obtained Value		2.16	1.04	1.37	1.41	1.59
	Specification [AASHTO T 104]		10% loss at 5 cycle (PCC, Asphalt), 12% loss at 5 cycle (surfacing and foundation courses), Armour coat <5%				
$I_{s\,(50)}$ (mpa)	Obtained Value		2.45	4.22	5.1	1.37	5.62
	Specification [Bieniawski, 1989]		Medium strength	High strength	High strength	Low strength	High strength
End Uses		Suitability based on					
Pavement	Wearing surface	LAAV, AIV, ACV, FI, SSV	*Y	Y	Y	Y	Y
	Base course	LAAV,	Y	Y	Y	Y	Y
	Sub-base course	LAAV,	Y	Y	Y	Y	Y
	Heavy-duty cocerete floor	ACV, AIV,WAV, SG, SSSV	Y	Y	Y	Y	Y
Concrete aggregate		ACV, AIV, WAV, SG, SSSV	Y	Y	Y	Y	Y
Filter aggregate		SG	Y	**N	N	N	N

*Y: yes; **N: no

2002) the sample tested are well graded. AIV and ACV vary between 10 and 20% of BSI (1992) and lies below 30% of NS (1994). Therefore, aggregate from the MalekhuKhola can be used as aggregate for heavy duty concrete floor finishes, pavement wearing surfaces, sub-base, road-base and for other concrete.

They have normal density of medium weight aggregates. Water absorption value is also low and is less than the standard, 3% (0.53 to1.08%). SSSV falls below 10% suggesting that aggregate samples are competent against frosting and chemical decomposition. The Los Angles Abrasion Value (LAAV) of sample lies between 34.50% and 48.40% According to NS 297, (NS, 1994), it can be used for concrete surface and wearing road. ASTM C131 specified LAAV of <30% for bituminous mixture, and

Table 6.Reserve estimation

Location	Resource site	Length (m)	Avg. breadth (m)	Area (m^2)	Avg. thickness (m)	Reserve in Volume (m^3)
L1	Left bank of the Malekhu Khola about 500 m upstream from the confluence of the Malekhu Khola and the Aap Khola	490	52.45	25701	1.41	36238
L2	Left bank of the Malekhu Khola at the confluence of the Malekhu Khola and a stream from the Aptar.	464	44.82	20796	1.13	23500
L3	Leftt bank of the Malekhu Khola about 500 m downstream from the confluence of the Malekhu Khola and the stream from the Aptar.	510	65.14	33221	1.60	53154
L4	Right bank of the Malekhu Khola about 500 m upstream from the crusher near the Amiltar village.	600	49.28	29568	4.31	127438
L5	Right bank of the Malekhu Khola about 200 m upstream from the confluence of the Malekhu Khola and the Dhobi Khola.	800	71.56	57248	2.59	148272
L6	About 1 km upstream from the Malekhu Bridge of the Prithvi highway, at the right bank of the Malekhu Khola.	200	15.83	3166	1.16	3673

between 30 and 50% for Portland cement concrete. Though the LAAV obtained for the present samples is slightly excess for bituminous mixture, it is suitable for rest of the end uses. The results from different tests fall within the specified values of standards, suggesting that the MalekhuKhola aggregate materials are appropriate for concrete and road aggregates.

Estimation of reserve from six different locations is found to be 392273 cubic meter.

ACKNOWLEDGEMENTS

The article is related to the M. Sc. dissertation of the author. Author is grateful to Dr. N. K. Tamrakar for supervision. Author is thankful to Central Department of Geology for providing necessary laboratory facility.

REFERENCES

AASHTO M-132, 1987. Standard specification for terms relating to density and specific gravity of solids, liquids and gases, The American Association of State Highway and Transport Officials, pp. 1–4.

AASHTO T-104, 1999. Method of test for Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate.

ASTM C33-02, 2002. Standard Specification for Concrete Aggregates, ASTM International, West Conshohocken, PA, pp. 1–11.

ASTM C88-05, 2001. Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate, ASTM International, West Conshohocken, PA, pp. 1–5.

ASTM C131-01, 2001. Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine, ASTM International, West Conshohocken, PA, pp. 1–4.

ASTM C127-01, 2001. Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate ASTM International, West Conshohocken, PA, pp. 1–6.

ASTM C136-01, 2001. Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates, ASTM International, West Conshohocken, PA, pp.1–5.

ASTM D4644-87, 1992. Standard Test Method for Slake Durability of Shales and Similar Weak Rocks: Annual Book of ASTM Standards, West Conshohocken, and PA, pp.1–3.

ASTM D5731-02, 2008. Standard test method for

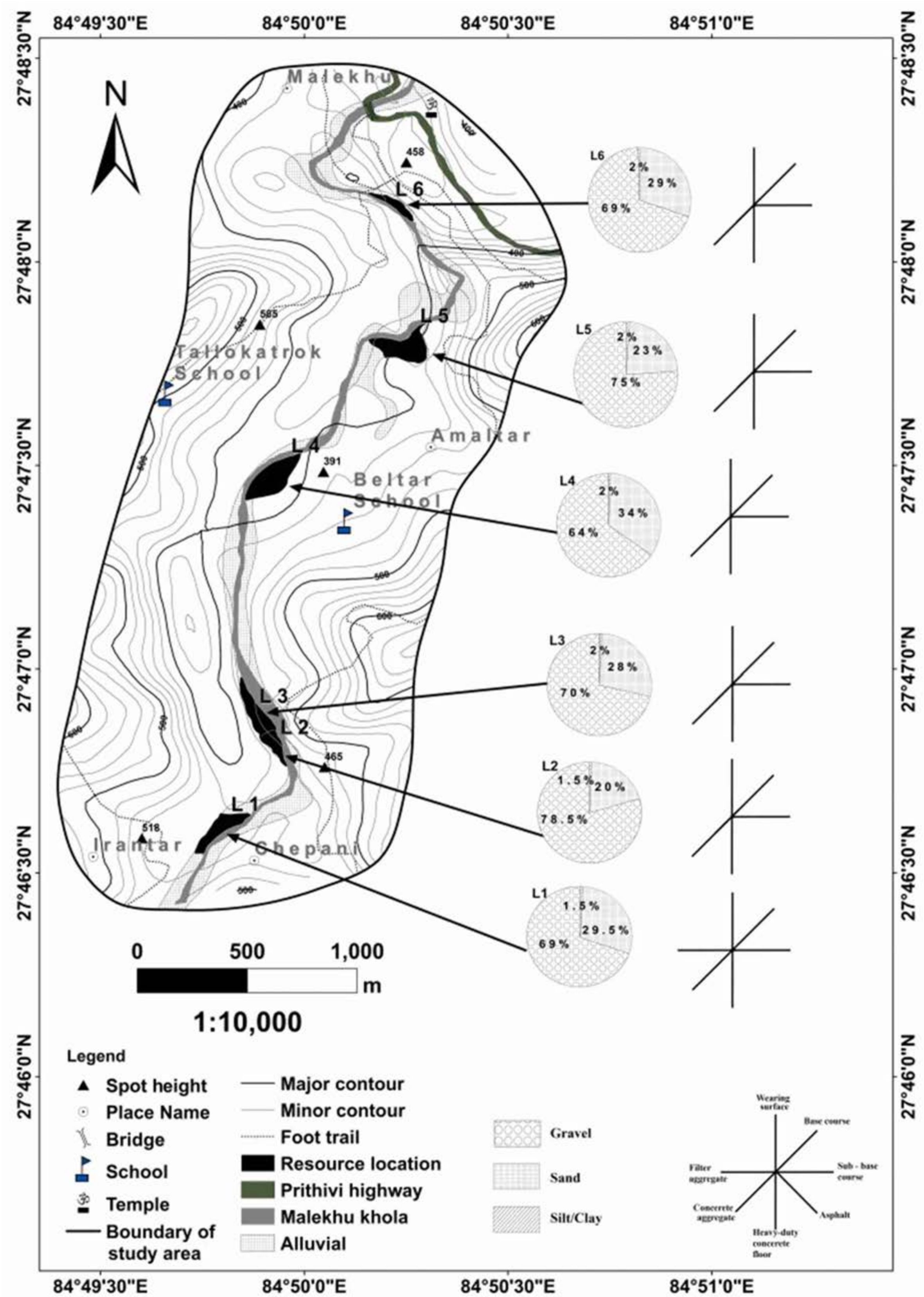

Fig. 7 Resource Map of the MalekhuKhola area between Aaptar Village and Malekhu Bazar

determination of point load strength index of rock, ASTM International, West Conshohocken, PA, pp. 1–9.

Bista, K.K., 2014. Study of durability of rocks for aggregates from Thopal- Malekhu River area, central Nepal, Lesser Himalaya, dissertation submitted to the Tribhuvan University, central department of Geology, Kritipur, Kathmandu, 67 p.

BS 812 105.1, 1989. Testing aggregates. Methods for determination of particle shape. Flakiness index. BSI London, pp. 1–8.

BS 812 105.2, 1990. Testing aggregates. Methods for determination of particle shape. Elongation index. BSI London, pp. 1–12.

Gamble, J.C., 1971. Durability-Plasticity Classification of Shales and other Argillaceous Rocks, Ph. D. Thesis, Univerity of Illinois, USA, 159p.

Khanal, S. and Tamrakar, N.K., 2009. Evaluation and quality of crushed- limestone and siltsone for road aggregates, Bulletin of Department of Geology, T.U., Kathmandu, Nepal. v. 12, pp. 29–42. DOI: http://dx.doi.org/10.3126/bdg.v12i0.2248

Maharjan, S. and Tamrakar, N.K., 2007. Evaluation of gravel for concrete and road aggregates, Rapti River, Central Nepal Sub-Himalaya. Bull. Dept. Geol., Tribhuvan University, Nepal, v. 10, pp. 99–106. DOI: http://dx.doi.org/10.3126/bdg.v10i0.1425

Nepal Standard and Measurement Bureau, 1994. Specification for aggregates (NS-297-2050) U.D.C N620, 113 p.

Shrestha, S. and Tamrakar, N.K., 2013.Geotechnical properties of construction aggregates from the Trishuli Ganga River, Galchi area, Central Nepal. Bull. Dept. Geol., Tribhuvan University, Nepal, v. 16, pp. 43–52.

Smith, M. R & L. Colliis, 1993. Aggregates: sand, gravel and crushed rock aggregate for construction purposes. London Geological Society 339 p.

Stöcklin J. and Bhattarai, K.D., 1977. Geology of the Kathmandu area and Central Mahabharat Range, Nepal Himalaya. Report of Dept. Mines and Geology/ UNDP unpublished, 86 p.

Tamrakar, N.K., Yokota, S. and Nakamura, M., 1999. Some Mechanical Properties of Siwalik Sandstones and their relation to Petrographic Properties, Geoscience Report of Shimane University, v. 18 pp. 41–54.