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SUSTAINABLE STONE EXTRACTION FOR USING AS CONSTRUCTION MATERIAL AND SUITABILITY PROPERTIES: CASE STUDY OF KOTRE QUARRY OF NEPAL

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ABSTRACT

All Level of government is yet to formulate legal practice of sustainable extraction and uses of stone resources in only a few parts of the Nepal, and there are few or no guidelines for the extraction and uses of natural resources to follow. Nevertheless, the Stone industry can independently utilize sustainable management techniques to achieve the goals of meeting their needs for reserves without compromising the ability of future generations to meet their needs. This study includes the existing data and literature with laboratory testing for the suitability of stone and stone byproducts for different infrastructure projects. The different quarry site of Nepal has been identified by Department of Mines and Geology and Road Construction and Maintenance Materials Study (RCMMS), Department of Road. For this, Kotre quarry site is selected which is located at the boundary of Kaski and Tanahun district. As per the estimated area of Kotre quarry is 921887.119 square meter. It is found that the quarry is recharged due to the transportation of aggregate from Himalayan zone by flood in the monsoon season. The properties of aggregate are tested for the quality of the aggregate and required properties is fulfilling by this quarry.

KEYWORDS: Stone and Stone byproduct, Quarry, Extraction, Properties.

1. INTRODUCTION

Construction Materials obtained from natural aggregates, sand, gravel, and crushed stone are granular materials composed of rock fragments that are extracted or mined or quarried and used in the infrastructures except for such operations as crushing, washing, and sizing. Natural aggregate obtained from mine is an essential commodity in modern construction projects. Apartments, National and international roads, Tunnels, Bridges, railroads, airports, dams, Canal and energy generation facilities are all heavily dependent Natural stone and stone products. Every stage of life of human and animal or plant, nearly every individual in society uses products made with Stone and stone product. The suitability of the quarry material and the proper utilization of quarry should be guided by legal policy and values. The technical properties are vital for the proper management of quarries. There are many potential and existing quarry sites for the extraction of such stone materials in the country. These sites differ in size, type, and quality of extracted stone material. Department of Road and Ministry of Geology and Mines conducted a study related to the quarry site identification of stone aggregates. It has identified potential quarry sites and the respective quality of stone aggregates for the application in the construction and maintenance of engineering structure. The study "Road Construction and Maintenance Materials Study" conducted in 1990 A.D. by Department of Road was mainly focused in the identification of technical properties of aggregates. The sustainability issues are another vital question for the quarry management. In addition to this, many quarries is used for the purpose other than road construction. Demand on stone aggregates is one of the major components of infrastructure development is tremendously increasing. Local authorities mainly are dealing with the permission and revenue collection from the private entrepreneurs from the quarry. Most of the quarry sites are very affecting the stability of the river bank and bed. They are creating very critical environmental and geological hazards to the surrounding community. It needs the special attention and classification of quarries as per technical as well as environmental context. These quarries should be regulated on the basis of scientific reasons.

1.1 Background

The availability of natural resources in the different parts of the country is the foundation for overall economic development of the nation. Earth's crust, the rock is the base for the physical infrastructure development. Historically, the construction is the major indicators of human civilization. Furthermore, balanced mass of the rock is major indicator for the localized stability of the hill slopes as well as depressed part of the topography. The demand on such resource is ever increasing; hence the extraction rate is rapidly increasing. The utilization of the natural resources for economic benefit is matter of sustainability.

It is believed that after thousands of years, rocky materials finally turn into sand or clay. The sand that eroded from sandstone rocks, deposited as a beach, dune or desert. After millions of years, sandstone rocks turned into sandstone cliffs and eventually eroded for the second time (Koirala &Joshi, 2017).

The Kotre, one of the main quarry sites for stone aggregate has been taken as the case study for this research. The Pokhara valley is located in the Midland Region lying between Great Himalayas in the north and Mahabharat Range in the south. The valley has unique basin landscape, and it is surrounded by hills made up of Midland Meta sediment Group. The Midland Meta sediment Group is composed of meta-sandstone, quartzite and phyllites. The Seti River starts from Annapurna Range and the Machhapuchhre Himal, which are composed of the Himalayan Gneiss and Tibetan Tethys. The Tibetan Tethys consists of Paleozoic and Mesozoic sedimentary rocks containing fossiliferous limestone. The transported fossiliferous limestone is collected at the Kotre quarry site. Therefore, selection of aggregates depends on these properties and specification set by national and international norms. Works on aggregates and their properties have been made earlier in different areas by several authors (Tamrakar et al. 1999; Maharjan and Tamrakar 2003; Thapaliya 2005; Dhakal et al. 2006; Maharjan and Tamrakar 2007; Tamrakar et al. 2007). Tamrakar et al. (1999) suggested that the mechanical properties of sandstones and limestone depended on the rock types and content of calcium carbonate, and were independent on deposition age of rocks. Maharjan and Tamrakar (2003) evaluated quality of silt stone samples from the Tistung formation for concrete aggregate and found that the aggregates were appropriate for concrete aggregates. Thapaliya (2005) studied lime stones of the Chandragiri formation, southern Kathmandu, and showed that the rocks were medium to high strength, durable and suitable for both monumental and construction purposes. Maharjan and Tamrakar (2007) evaluated quality of the river gravels for aggregates and concluded that the majority of gravels had diverse chemical groups, high durability and good workability for road and concrete aggregates. Tamrakar et al. (2007) analyzed sand stones from the Siwalik group and concluded that the strength of the sand stones depends primarily on proportion of void space in sand stones. The research on evaluation of quality of quarried materials was conducted only for the quarries operated in the peripheral part of the Kotre. Kotre quarry site is the largest aggregate extraction site situated in Tanahun district of Nepal. The natural and crushed rock aggregates from Kotre area are being supplied to the market without following any technical specification. Therefore, this study aims in exploring and evaluating the suitability crushed rock aggregates for different infrastructure projects.

1.2 Problem Statement and hypothesis

There are serious debates on the utilization of natural resources in the country. Moreover, there are many other illegal quarry sites working for supplying materials locally. The engineering part of these quarry location, methods of extraction, environmental impact and many other aspects being challenges.

The main hypothesis in this topic of the research is:

a. The community concerns on the sustainability issues of the stone quarry sites are truthful.
b. The technical methods of the extraction are not proper.
c. The suitability of the stone materials for the particular purpose has not been studied.

1.3 Objectives of the research project

The broad objective of the proposed research is to study the suitability and sustainability of stone quarry sites in Nepal.

Further the specific objectives of the research project are:

a. Study of the issues regarding quarry sites and their policy matters;
b. Identify the sustainability indicators for the proper quarry management;
c. To study the prevailing methods of the extraction, types of quarry, application of extracted materials.

2. LITERATURE REVIEW

2.1. Sustainability of stone and aggregate

If aggregate is to be produced from new sources, certain conditions must be met.

Sand, gravel, or rock must exist in sufficient quantity and quality to make mining worthwhile, and it must be accessible to transportation systems and to markets. The property must be of sufficient size to locate a pit or quarry and processing equipment, and be owned by a person or people willing to sell or lease it at a reasonable price. The deposit must physically be able to be mined without causing unacceptable impacts to the environment. The extraction and processing site must qualify for all necessary permits. The approving officials and the public must be convinced that the operation can take place without adversely affecting the environment or their lifestyle. In other words, the operator must be able to obtain a 'social license' to mine. The operation must be profitable considering all costs including: exploration, acquisition, permitting, operation, environmental controls, compliance with regulations, transport to market, and reclamation. The production of aggregate involves extraction and processing of the raw material into a useable product, transport of that commodity to the point of use, and the reclamation of mined-out pits or quarries. The following is a general description of the production of natural aggregate. Global Issue the Environment Protection……The infrastructure, housing, and real estate projects degrade the environment if it is allowed run without planning. In order to implement even a one project, it is essential to import the construction materials, construction equipment, human resources and new technology from inside and outside the country. During construction period, lots of chemicals are used. By-product generated from the projects affects the environment. The byproduct and chemicals need to be disposed properly in the appropriate places (Koirala, 2017).

2.1.1 Extraction

Sand and gravel deposits commonly are excavated from pits utilizing conventional earth-moving equipment. Mining crushed stone generally requires drilling and blasting of solid bedrock (also referred to as ledge or ledge-rock), which breaks the rock into rubble of a size suitable for crushing. Crushed stone, sand and gravel commonly are obtained from dry pits or quarries, but in some settings may be mined from water-filled excavations using dredges mounted on barges, or with draglines. Sand and gravel or rock rubble at the mine face is transported by truck or conveyor to a processing plant. Sand and gravel may or may not be crushed, depending on the size of the largest gravel particles and the desired product. Depending on the specifications of the final product, the processed material may be washed to remove dust. Sand may be screened from the mixture and processed separately. After screening, sorting, and washing (if necessary), the sand and different size gravel/rock particles are moved by a conveyors to separate stockpiles where they are stored until sold and shipped. But there is no separate washing unit available in the Kotre Quarry site. There is no blasting process adopted for the mining quarry sites. Besides that, there is no dust control system installed for the protection of natural environment.

Fig 1: Crusher Plant, Kotre.

2.1.2 Transportation: Most aggregate is sold in bulk. Upon sale, aggregate is loaded on trucks, railcars, barges, or freighters for transport to a destination. Aggregate is a high-bulk, low value commodity, and transportation can add substantially to the cost at the point of use. The cost of transportation of aggregates in the European Union is about 13% of the total cost of the aggregate (Bleischwitz and Bahn-Walkowiak, 2006). Trucks are by far the most flexible and most common means of transporting aggregate. They can be loaded and unloaded at many locations using a variety of techniques and can accommodate most delivery schedules. Rail and barge are much less flexible because they utilize fixed route systems following strict schedules and require considerable investment capital in terms of loading facilities, off-loading facilities, and distribution yards. Trains and barges achieve economy by moving large volumes of aggregate long distances on regular schedules (Hayes, 1991).

2.1.3 Reclamation: Reclamation may be implemented following four reclamation strategies: progressive, segmental, interim, or post-mining (Norman and Lingley, 1992). Progressive reclamation immediately follows the removal of aggregate, but may be impractical for operations that must blend mined material from different parts of the pit or quarry. Segmental reclamation follows the removal of minerals in designated sections of the mine, is cost efficient, establishes final slopes as part of the mining operation, and works best in homogeneous deposits. Interim reclamation temporarily stabilizes disturbed areas with fast-growing grasses or legumes, and at a later time implements the final reclamation plan. Post-mining reclamation does not begin until the entire mine has been exhausted, which may lead to deterioration of stockpiled soils, a longer re-vegetation time frame, and high bonding liability (Norman and Lingley, 1992). Reclamation can produce economic benefits by reusing pits or quarries as residential property, industrial and commercial properties, office parks, landfills, golf courses, recreational areas, and botanical gardens.

2.1.4 Potential environmental impacts and their mitigation

The overall contribution of aggregate extraction to resource depletion, competing land-uses, global warming, and energy use is rather low (Bleischwitz and Bahn-Walkowiak, 2006). Nevertheless, aggregate extraction and processing cause environmental impacts including changes to the landscape, noise, dust, vibrations from blasting, and degradation of groundwater and surface water.

i. Changes to the landscape: The most obvious environmental impact of aggregate extraction is a change to the landscape, generally from undeveloped or agricultural lands to a pit or quarry. After closure, the pit or quarry may be reclaimed to function as the original habitat. Progressive, segmental, or interim reclamation can speed habitat recovery. The area of extraction may have contained important archaeological, paleontological, or geological features that can be identified during pre-quarry inventories. Ironically, such features may be recognized only after aggregate operations begin because aggregate extraction uncovers a relatively large area at a relatively slow pace, sometimes leading to serendipitous discoveries.

ii. Noise and dust: The primary source of noise and dust from aggregate extraction is from vehicle movements, processing equipment, and blasting. Aggregate producers are responsible for ensuring that the noise and dust emitted from the pit or quarry do not exceed regulated levels. Low-noise equipment and dust suppression or collection systems can significantly reduce impacts.

iii. Vibrations from blasting: Most of the energy of a quarry blast is expended on breaking the rock. Extensive research by the former US Bureau of Mines resulted in ground vibration and air blast standards that are recognized worldwide and have become industry standards for safe blasting (Siskind et al., 1980a, 1980b). Impacts from blasting can be mitigated by maintaining blast vibrations below well-documented limits on ground motion and air concussion (Langer et al., 2004).

iv. Impacts on groundwater: The environmental impacts of aggregate operations on groundwater are highly dependent on the local geology, hydrology, and climate. In dry climates, evaporation of water from pits or quarries may lower the water table. In humid climates, precipitation may flow into a quarry and recharge groundwater. Groundwater flow in springs, gaining streams, and wells may be impacted by nearby aggregate operations that pump groundwater from the pit or quarry. Extracting rock from Karst areas can have a severe impact on the groundwater, but the impact can commonly be controlled with well-designed and implemented environmental management procedures (Langer, 2001b). In highly permeable deposits, slurry walls or grouting may be necessary to isolate the operation from the water table.

v. Impacts from transportation: Aggregate is commonly delivered from the pit or quarry to the construction site by truck, which can create problems of noise and exhaust as the trucks pass nearby dwellings. Truck traffic ultimately intermingles with automobile traffic creating potential hazards such as those caused by trucks that transport other consumer products. The environmental impacts and hazards of trucks can be minimized when the trucks are well maintained and operated, and when automobile drivers allow reasonable space for truck drivers to maneuver and stop safely. Trucks can be equipped with mud flaps and load covers to prevent loose material from being thrown from wheels and loads. Limiting the number of quarry entrances and exits, and constructing acceleration and deceleration lanes at pit or quarry entrances can allow trucks to enter and exit traffic smoothly. Delivery routes can be designed to minimize interference with neighborhood traffic.

vi. Energy consumption: Producing aggregate requires the use of energy which in turn causes the release of greenhouse gases to the atmosphere. The energy consumption required to bring aggregate to a useful state is referred to as ‘embodied energy’. The energy consuming activities of aggregate extraction and processing include: Removing vegetation and soil, building the processing facilities, and otherwise preparing the site for operation; drilling, blasting (for crushed stone), and excavating the material and transporting material from the excavation site to the processing facility by truck or conveyor;

vii. Managing impacts through best management: Limiting environmental impacts from aggregate mining commonly requires following best management practices, which should be available as handbooks and guidelines. Industry practices have become so advanced in many industrialized countries that aggregate extraction adhering to best management practices can be considered a temporary, rather than permanent, land use (Wellmer and Becker-Platen, 2002). Increasingly, aggregate companies are receiving certification from the International

Organization for Standardization (ISO) by a voluntary international standard for environmental management. This standard is primarily concerned with the activities an organization takes to minimize harmful effects on the environment and to continually improve its environmental performance.

2.2 Properties of Stone Aggregate

It denotes all the required properties like grading need to be satisfactory, specific gravity, flakiness, elongation, water absorption, crushing strength including physical and chemical test must verify the requirement for the stone and stone byproducts.

i. Gradation Analysis: Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. This is done by sieving the aggregates as per IS: 2386 (Part I) – 1963. In this we use different sieves as standardized by the IS code and then pass aggregates through them and thus collect different sized particles left over different sieves. For this the sieve of sizes – 80mm, 63mm, 50mm, 40mm, 31.5mm, 25mm, 20mm, 16mm, 12.5mm, 10mm, 6.3mm,4.75mm, 3.35mm, 2.36mm, 1.18mm, 600µm, 300µm, 150µm and 75µm are used. After weighing the sample retained in each sieve the results of the sieve analysis may be recorded graphically on a semi-log graph with particle size as abscissa (log scale) and the percentage smaller than the specified diameter as ordinate.

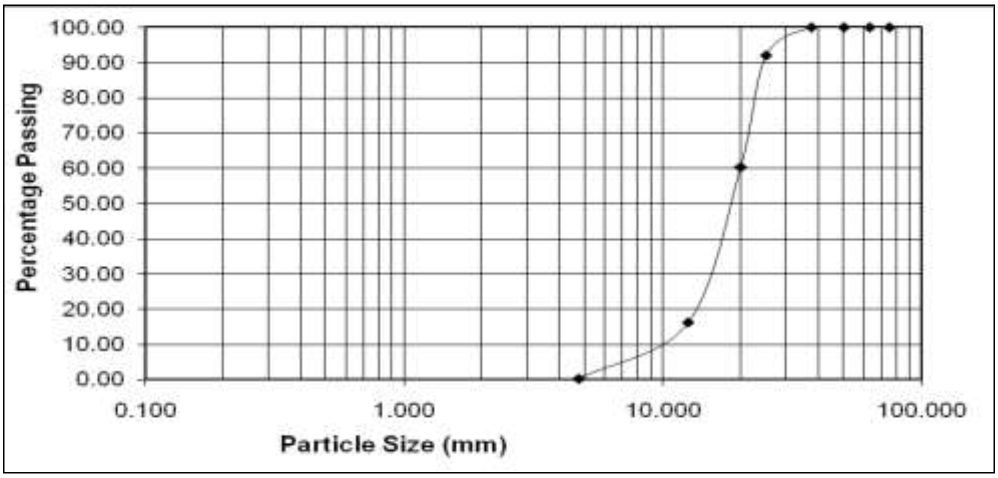


Fig. 2: Gradation analysis curve.

With reference to the plotted graph the value of D_{10}, D_{30} and D_{60} are estimated and hence coefficient of Uniformity and Curvature should be calculated as:

$C_C= (D_{30}* D_{30}) / (D_{10}*D_{60})$

$C_u= (D_{60}/D_{10})$

If the Value of C_c=1-3 and C_u> 4 for gravel and > 6 for sand is satisfied the aggregate is referred as well graded otherwise poorly graded. If some sized particle of aggregate are not present in the mix then the aggregate is call gap graded.

ii. Specific Gravity of Coarse and fine aggregate: The specific gravity of the aggregate is considered to be a measure of strength and quality of material. The specific gravity of aggregate ranges from 2.5-3.0.

iii. Flakiness and elongation index: Flakiness and elongation indices were determined using the methods of determining particle shape by BS 812 (BS I 1989). During FI test, aggregate sample was sieved through different sieve sizes; at least 200 pieces of each fraction were taken, weighed and allowed to pass through the selected slot-size which had width equal to 0.6 times the mean dimension. The fraction of samples passing through the thickness gauge was weighed and FI was calculated as below:

Flakiness index (FI) = (W_T/W)*100 (%): Where, W_T is the weight of the aggregate passing through the slot and W is the total weight of the test sample. During elongation index test, aggregate was allowed to pass through the length gauge whose longest dimension was greater than 1.8 times their mean dimension. **Elongation index (EI) = (W_L/W)*100 (%)**: Where, W_L is weight of aggregate retained in the length gauge and W is the total weight of test sample. Low percentage of FI shows that aggregate contains only a few flat grains and high percentage of EI indicates the presence of only small number of elongated grains. According to DOR 2001 the FI for base course should be less than 25% and for sub base should be less than 30%.

iv. Water Absorption Test: Aggregates having more water absorption are more porous in nature and are generally considered unsuitable unless they are found to be acceptable based on strength, impact and hardness test. Absorption values are used to calculate the change in the weight of an aggregate due to water absorbed in the pore spaces within the constituent particles, compared to the condition, when it is deemed that the aggregate has been in contact with water long enough to satisfy most of the absorption potential. The water absorption of aggregate ranges from 0.1-2%.

v. Aggregate Crushing and Impact Value Test: Aggregate used in construction should be enough to resist crushing under load. If aggregate are weak, the stability of the structure is likely to be adversely affected. The strength of coarse aggregate is determined by crushing strength test. This test helps to determine the aggregate crushing value of coarse aggregates as per IS: 2386 (Part IV) – 1963. Aggregate crushing value (ACV) and Aggregate impact value (AIV) were determined using a compression testing machine and hammer respectively following ASTM (1979). 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:

$$ACV = (W_2/W_1)\ 100\ (\%),$$
$$AIV = (W_3/W_1)\ 100\ (\%)$$

Where, W_1 is the total weight of the dry sample (grams), W_2 is the weight of the aggregate passing 4.75 mm sieve, and W_3 is the weight of an aggregate passing on 2.36 mm. The ACV < 10% indicates exceptionally strong, 10–20% Strong, 20–30% satisfactory for road surfacing & > 35% Weak for road surfacing. The aggregate crushing value for cement concrete pavement shall not be exceeding to 30%. Similarly, the Aggregate impact value should be under the standard value of ASTM, 10-20%, BS < 20% and NRS < 30%.

vi. Abrasion Resistance: Hardness and toughness of aggregates associated together are often carried out in the Los Angeles Abrasion test (LAA). The principle of the test is to find the percentage wear due to the relative rubbing action between the aggregate and the steel balls used as abrasive charge. This test has been standardized by the ASTM C: 535 (ASTM 1981). LAA was calculated using the following equation:

$$LAA = (W_1 – W_2/W_1)*100\ (\%)$$

Where, W_1 is weight of original sample and W_2 is weight of aggregate retained on 1.70 mm IS sieve after test. The percentage is a measure of the degradation or loss of material as a result of impact and abrasive actions.

vii. Sodium Sulphate Soundness Test: Soundness test is a good measure of how resistant an aggregate is to chemical weathering. Soundness test determines the resistance to disintegration of aggregates due to alternate cycles of dry and wet condition. Sample of size 10–14 mm and mass 455 gm for the test was washed with distilled water and oven dried at 105–110°C. A saturated solution of sodium sulphate was produced with the density of 1.32

g/cm^3. The test specimen was then subjected to five 48 hours immersion and drying cycles. The sodium sulphate soundness value was calculated as:

$$SSV = (W1ssv - W2ssv/W1ssv)*100\ (\%)$$

Where, W1ssv is the initial weight of the sample and W2ssv is the weight retained on 10 mm after the test. SSV less than 12% means the aggregates samples are sound and resistant against chemical weathering and frost susceptibility.

3. METHODOLOGY

Quantitative approach with post positivist worldview, experimental strategy of inquiry adopted. It has conducted pretest and hence a post-test measurement was ensured. Post-positivists hold a deterministic philosophy in which causes probably determine effects or outcomes. Thus, the problems studied by post-positivist reflect the need to identify and access the causes that influence outcomes, such as found in experiments (Creswell, 2011).

3.1 Primary Data Collection: Primary data has been collected from various literature like book, National and international Journal, and various publications.

3.2 Secondary Data Collection: Secondary data has been collected from the stone extraction site by field test or laboratory test adopted.

3.3 Research Area: Kotre Quarry site.

Fig 3. Google Earth Photograph of Kotre Quarry site.

3.1.1 Identification of Stone Quarry Site of Nepal

Rocks are the main construction materials since the Stone Age. Some of the rocks like marble, basalt, granite and red sandstones are used in decoration; Phyllite, Slates, flaggy quartzite and schist are used for roofing; limestone, dolomite, quartzite, sandstone are used for aggregate in various construction works, road paving and flooring. Vast amount of river boulders, cobbles, pebbles and sands are mined as construction materials. Department of mines and Geology (DMG) (1988) has evaluated such materials (Boulders = 347,006,000m^3, Cobbles = 214,261,000m^3 and Pebbles = 229,205,000m^3) in the Major Rivers of Terai region. District Development Committees (DDCs) are the local authorities, who provide licenses to the highest bidders to operate quarries on the riverbeds in annual basis. Vast amount of such construction materials are available in almost all the districts of Nepal.

Limestone: More than 1.298 billion metric tons of cement grade limestone deposits are already known from the Lesser Himalayan region only. Exploration of limestone by DMG, in the past was able to identify a number of large to small size limestone deposits. Some of the main limestone deposits are given below.

Table 1: Quarry Sites of Nepal.

Location of Limestone deposit/ District	Deposit (MT.)	Present Status & Remarks
Sindhali Limestone, Udayapur	72	Mines and factory in operation
Bhanise & Okhare, Limestone Makwanpur	20	Mines and factory in operation
Chobhar Limestone, Kathmandu	14.5	Factory is closed
Jogimara Limestone, Dhading	3.6	Mine in operation by Hetaunda Cement Ind.
Beldanda Limestone, Dhading	1.72	Mines and factory in operation.
Kakaru Khola, Sindhuli	1	Mines and factory in operation.
Narpani Limestone, Arghakhanchi	17	Production started
Nigale Limestone, Dhankuta	6.3	Cement Plant under construction
Badichaur Limestone, Makwanpur	NA	Cement Plant under construction
Dang Limestone	NA	Cement Plant under construction
Rolpa Limestone, Rolpa	NA	Cement Plant under construction
Chaukune Limestone, Surkhet	31	Process to establish a cement industry
Kajeri Limestone, Salyan	29	Process to establish a cement plant.
Sarada limestone, Dang	525	Proposed for a large cement factory
Hapure Limestone, Dang	26.5	Process to establish a cement plant
Gandhari Limestone, Dang	17.6	Process to establish a cement plant
Halesi Limestone, Khotang	8.0	Mining not possible
Lakharpata Limestone, Surkhet	30.0	Evaluation warranted
Supa Khola Limestone, Arghakhanchi	8.20	High overburden ratio
Diyarigad, Chauraha, and Bhimeshor	>250.00	Promoted for detail exploration and mining

Limestone, Baitadi		for a cement Ind.
Chuladhunga – Ghyampathumka Limestone, Udayapur	40.00	Planned to promote a cement industry
Galtar Limestone, Udayapur	21.54	Planned to establish a cement factory
Bhattedanda Limestone Lalitpur	5.68	Detail evaluation warranted
Lele Limestone, Lalitpur	3.98	Recently established a cement factory
Nandu Limestone, Kavre	4.67	Detail evaluation warranted
Pandrang Limestone, Makwanpur	2.56	Planned for cement industry
Badichaur Limestone, Makwanpur	2.80	In process to establish cement factory
Darshan Danda Limestone, Gorkha	NA	Planned for cement industry
Kanchan Limestone Quarry, Palpa	1.60	Quarry is in operation since long time
Shakti Khor, Chitwan	3.20	Industry established
Others	>150.00	Possible deposits
Total deposit	**>1,297.59**	**Proved + Probable + Possible**

Source: Department of Mines and Geology (DMG, FY 2066/67) and "Road Construction and Maintenance Materials Study (RCMMS)".

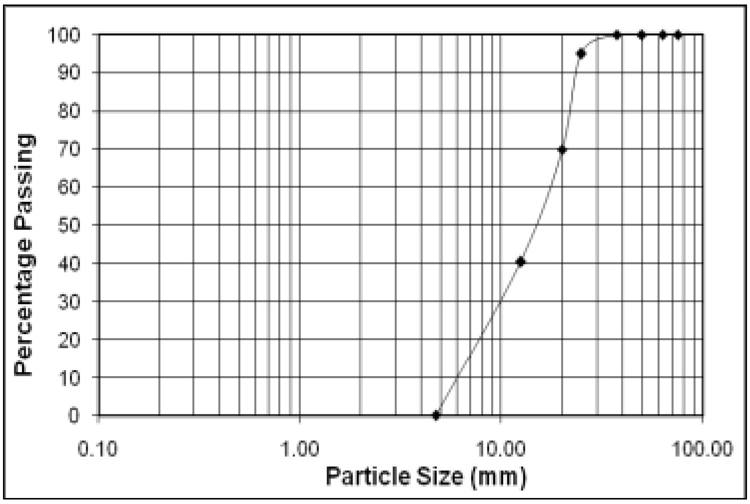
The methodology is explained as follows. In the first step, a thorough literature review was performed to identify the key elements that can explore the stone quarry as per required hypothesis and objective of research. Next pre-test was conducted in research area and finally post test was performed to get the required data. Based on the survey result and analysis, relevant conclusions and recommendations were drawn.

4. DATA AND ANALYSIS

Testing of Aggregate: All tasting mentioned below are conducted either in field or on laboratory.

4.1 Gradation Analysis: The number of sieve analysis of the coarse aggregate and fine aggregate is conducted and the sample graph with result is presented as following: The value of C_u is found between 2.04 to 3.70 of coarse aggregate and 3.08 to 6.67 for of aggregate and the value of C_c is 1.00 to 1.64 of coarse aggregate and that of fine aggregate is 1.00 to 2.25. The value of Cu should be greater than 4 for sand and greater than 6 for gravel and value of Cc should be in between 1 to 3 to be the well graded aggregate. This is not satisfied for whole sample of coarse aggregate. Some value indicates that the fine aggregate is well graded and almost of the test sample of fine aggregate is found as poorly graded.

For Coarse Aggregate: Sample testing



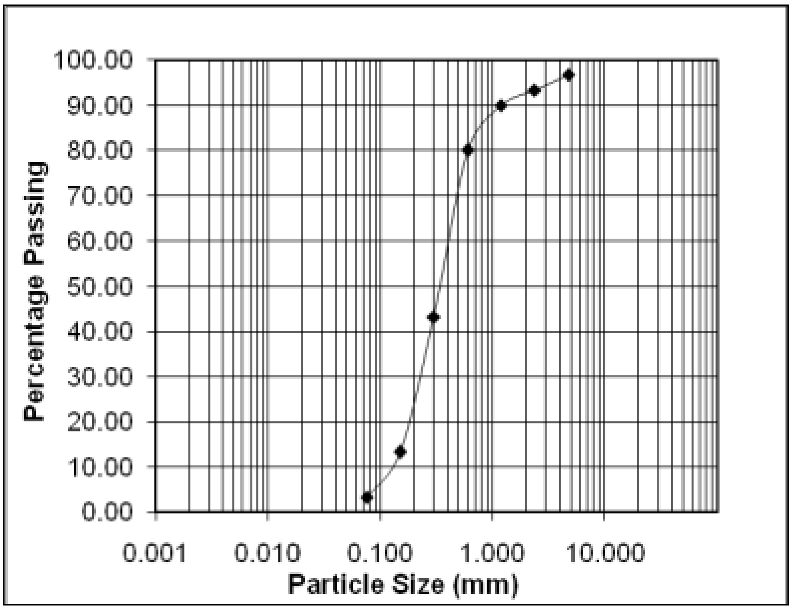
D_{10} =	5.00	Mm
D_{30}=	10.00	Mm
D_{60} =	18.50	Mm
C_u=	**3.70**	
C_c=	**1.08**	

Fig 4. Sample gradation curve.

Table 2: Gradation Parameters.

Sample	1	2	3	4	5	6	7	8	9	10	11
C_u	2.04	3.70	2.23	2.18	2.38	2.85	2.73	2.76	2.77	2.66	2.65
C_c	1.31	1.08	1.64	1.63	1.60	1.02	1.12	1.21	1.13	1.02	1.00

For Fine Aggregate



D_{10} =	0.13	Mm
D_{30}=	0.23	Mm
D_{60} =	0.40	Mm
C_u=	**3.08**	
C_c=	**1.02**	

Fig 4.1: Sample Gradation curve.

Table 3: Gradation Parameters.

Sample	1	2	3	4	5	6	7	8	9	10
C_u	4.00	3.08	4.17	4.50	4.00	4.00	6.67	6.15	6.31	5.57
C_c	1.00	1.02	1.04	1.08	1.27	1.67	2.07	2.12	2.25	1.62

4.2 Specific Gravity of aggregate

The specific gravity of the aggregate is found to be 2.46- 2.84 means dry density of 2040-2630 g/cm3. According to ASTM this value should be 2-3.1 and NRS 2.662 which almost satisfied to use for road base and sub base course.

Table 4: Specific Gravity of aggregate.

Sample	1	2	3	4	5	6	7	8	9	10
Sp. Gra.	2.69	2.61	2.58	2.84	2.63	2.59	2.58	2.60	2.46	2.51

4.3. Flakiness and Elongation Index

The FI and EI of coarse aggregate are found to be 16.04% to 23.00% and 79.00% to 88.09% respectively. According to DOR 2001 the FI for base course should be less than 25% and for sub base should be less than 30% and EI should be greater than 70 %.

Table 5: Flakiness and Elongation index of aggregate.

Sample	1	2	3	4	5	6	7	8	9
FI	16.60	13.20	16.04	19.90	19.08	23.00	21.02	20.06	21.44
EI	86.03	84.09	79.00	81.20	83.00	88.09	81.50	80.20	83.80

4.4. Water Absorption Test

The water absorption of coarse aggregate is found to be 1.00% to 1.90% and that of fine aggregate is 1.00% to 2.15%. According to BS this value should be less than 1%, ASTM should be less than 3% and NRS should be less than 4% which satisfied the ASTM and NRS Standard ranges.

Table 6: Water absorption of aggregate.

Sample	1	2	3	4	5	6	7	8	9	10
Fine	1.00	2.00	2.15	1.57	1.89	2.00	1.79	1.52	1.38	1.10
Coarse	1.20	1.90	1.00	1.57	1.04	0.79	0.99	1.38	1.24	1.19

4.5 Aggregate Crushing and Impact Value Test

The aggregate crushing value for cement concrete pavement is found to be 25.00% to 28.54% which is less than 45 % requirement to use in road base coarse. Similarly, the aggregate impact value is found to be 21.03% to 24.12% which is under the standard value of ASTM, 10-20%, BS < 20% and NRS (NRS) < 30%.

Table 7: Crushing and Impact Value of Aggregate.

Sample	1	2	3	4	5	6	7	8
ACV	27.00	28.54	28.04	26.09	25.74	27.29	26.32	25.00
AIV	21.03	22.01	22.84	23.93	22.00	24.12	24.60	23.70

4.6 Abrasion Resistance

The value of LAA is found to be 27% to 40%. This test has been standardized by the ASTM C: 535 (ASTM 1981) and the value of LAA for base course is limited to 30-35% and that of Sub base course is 45%.

Table 8: Abrasion Value of Aggregate.

Sample	1	2	3	4	5	6	7	8
LAA	29.30	32.19	34.60	28.00	32.65	30.50	33.00	34.86

4.7 Sodium Sulphate Soundness Test

The SSV value of aggregate is lies between 1.40% to as 5.40%. The less than 12% means the aggregates samples are sound and resistant against chemical weathering and frost susceptibility. This indicates that the aggregate is chemically sound to use in road base and sub base course.

Table 9: Soundness value of Aggregate.

Sample	1	2	3	4	5	6	7	8	9	10
Soundness	2.30	2.70	1.40	1.59	2.23	4.20	5.40	3.90	4.28	4.80

CONCLUSIONS AND RECOMMENDATION

5.1 Conclusion

Nepal is beautiful country having enough Natural resources. Among them stone and stone byproduct is important construction material. The proper policy has not yet initiated by providence and local level regarding the stone extraction. This study includes the study of existing data and literature review with laboratory testing for the suitability and sustainability of stone aggregate for different infrastructure projects. The different quarry site of Nepal has been identified by Department of Mines and Geology (DMG, FY 2066/67) and "Road Construction and Maintenance Materials Study (RCMMS)", Department of Road. For this, Kotre quarry site is selected which is located at the boundary of Kaski and Tanahun district of Nepal. The Total area of Kotre quarry site is estimated using the GPS data is 921887.119 sqm. The different properties of aggregate are tested for the sustainability regarding quality of the aggregate. For this the physical, mechanical and chemical properties of Kotre stone aggregate is tested. The gradation of aggregate is tested and found that it is hard to maintain the well graded aggregate requirement for different construction. The specific gravity of aggregate is found to be 2.46-2.84 which lies between 2-3.1of ASTM standard and 2.662 of NRS. The flakiness index is observed as 16.04% to 23.00% and Elongation index is 79.00%

to 88.09%. The water absorption of coarse aggregate is found to be 1.00% to 1.90% and that of fine aggregate is 1.00% to 2.15% which satisfied the specification set by NRS 2001. The aggregate crushing value for cement concrete pavement is found to be 25.00% to 28.54% which is less than 45 % requirement to use in road base coarse. Similarly, the aggregate impact value is found to be 21.03% to 24.12% which is under the standard value of ASTM, 10-20%, BS < 20% and NRS (NRS) < 30%. The value of LAA is found to be 27% to 40%.

This test has been standardized by the ASTM C: 535 (ASTM 1981) and the value of LAA for base course is limited to 30-35% and that of Sub base course is 45%. The SSV value of aggregate is lies between 1.40% to as 5.40%. The less than 12% means the aggregates samples are sound and resistant against chemical weathering.

5.2 Recommendations

The demand of Stone and aggregate in Nepal is increasing tremendously. Recently, there are many concerns on the export of stone aggregates to India. Moreover, there are many illegal quarry sites working for supplying materials locally. The engineering part of these quarry location, methods of extraction, environmental impact and many other aspects should be regularized. Concerning to the Kotre Quarry site, almost of the demand of stone aggregate is fulfilled. The sustainability of quarry site should be the major concern. Not unlike any development (commercial, residential, government, etc.), quarry operations can greatly modify landscape and topography, can impact wildlife populations, and require supplemental quantities of water and energy. Additionally, potential occupational health and safety risks may exist for quarry employees, and local residents may experience noise and vibrations. The dust can be controlled by adequate dust catchment or air filtration systems in saws and drilling machines. The establishment of roadway misting should highly recommend controlling the duct effect on nearby highway. The native vegetation throughout the quarry's operation should be established to stabilize and to control erosion. The cleaning water is collected from the nearby river without any treatment. It recommended to establishment of filtration of water for the cleaning of aggregate. The Care should be taken to minimize the operational footprint at the quarry site. It is advised that each quarry establish a maintenance and conservation plan to sustain site integrity. The strategy may include the goals described site clearance and organization, minimizing erosion and runoff, respecting and conserving ecosystems and quarry closure practices. At last, it is recommend to do further research regarding the bitumen-aggregate and cement aggregate binding properties.

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