A Study on suitability of aggregates of Kavre and Sindhuli district quarries for different layers of Flexible Pavement

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***Abstract*—This paper focuses on the measurement of quality and usability of road construction materials near the quarries of Kathmandu Valley (Kavre and Sindhuli Districts. We have conducted the standard test procedure for the analysis of materials of different Quarries. And the results shows the materials for base and sub-base from all of the three Quarries (Challal Ganesh- Kavre; Aapghari- Ghampyakhola; Bhyakur khola) meets the standard.**

***Index Terms*—Aggregate– Quarry–Flexible Pavement–Aggregate Test**

I. Introduction

A. Background

Transportation contributes to the economic, industrial and cultural development of a country. It is considered as the backbone for the development of the nation. So every commodity needs transport facilities for both at the production stage as well as distribution stage. The nature of transport demand depends upon the stage of economic and social development, geographic, topographical and demographic conditions of the country. [1]

Since our country Nepal is a landlocked underdeveloping country, water transport is almost impossible and air transport is very costly. Thus road transport is the major means of transportation. Road Network in Nepal consists of the Strategic Road Network (SRN) and the Local Road Network (LRN). SRN lies under the Ministry of Physical Infrastructure and Transport (MoPIT) and its Department of Roads (DoR) and LRN lies under the Ministry of Federal Affairs and General Administration and its department of Local Infrastructure Development and Agricultural Roads (DoLIDAR) while the responsibility for the daily management lies with the local bodies (DCCs, Rural Municipalities and Municipalities). There is altogether 6823.43 km bituminous road, 2044.22 km gravel road, 4030.55 km earthen roads (SRN) according to 2015/16 report of DoR. Likewise there is altogether 2004 km bituminous road, 12823 km gravel road & 42805 km earthen roads (LRN) according to 2016 report of DoLIDAR.

Basically in Nepal, flexible road pavements are constructed. The basic components of flexible pavement are Sub grade, Sub-base course, Base course and Wearing course. Sub-grades are prepared either by cutting, filling, leveling and compacting the existing soil surface to 95 % Maximum Dry Density (MDD) or depositing soils from the approved borrow pits to the existing surface up to the designed formation level and compaction. In case of sub-base course, specified graded granular river bed materials or granular materials of quarry sites or borrow pits are generally used. In base course, specified graded crushed stone materials with crushing ratio greater than 80% are used. For surface course, Surface dressing, Bituminous macadam, Dense bituminous macadam, Asphalt concrete are generally used in our country. In Bituminous macadam, Dense bituminous macadam, Asphalt concrete(for surface course) specified graded crushed stone aggregates are used as per standard specification for road and bridge work.

The use of inferior construction materials and poor construction process deteriorates the pavement very fast. So, the use of good quality of materials is very essential for effective functioning of pavement throughout its life. The use of locally available good quality construction materials as per specification is very economic to the road construction project. Therefore, it necessary to assess the properties of locally available pavement construction materials to ensure quality of materials that comply the Standard Specifications for Road and Bridge Works,2073.

B. Construction Materials

A pavement may be defined as relatively stable layer or crust constructed over the natural soil. The main function of pavement is to support and distribute the heavy wheel loads of vehicles over a wide area of the underlying sub-grade soil and permitting the deformations within elastic or allowable range and to provide an adequate surface. [1] The effective and durable pavement surface is acquired through selection of suitable road construction materials.

1) Materials used for road construction may be classified into three broad groups:

Mineral materials

Mineral materials such as sub-grade soil, sand/stone dust (fine aggregate), stone chips, gravel/crushed aggregates (coarse aggregates), pit-run sand or river sand, screened materials, blast furnace slag, brick pebbles. These are either naturally occurring, semi processed or fully processed. Stone aggregates are used in pavement construction and road side construction.

Binding materials

Binding materials includes stone dust or cohesive soil; cement, lime and other inorganic binding materials and; bitumen, tar and other organic binding materials.

Other materials

Other common road construction materials such as reinforcement, timber, stones, bricks, boulders, cobbles, gabion wires, geo-textiles, geo-grids, chemical additives, HDP pipes, Hume pipes, precast units etc.

Mineral aggregates make up 90 to 95% of a HMA mix by weight or approximately 75 to 85% by volume. Their physical characteristics are responsible for providing a strong aggregate structure to resist deformation due to repeated load applications. Aggregate mineralogical and chemical makeup are important in evaluating characteristics such as hardness (toughness), soundness (durability), shape, and stripping potential. [2] In ASTM D8 aggregate is defined as a granular material of mineral composition such as sand, gravel, shell, slag, or crushed stone, used with cementing medium to form mortars or concrete or alone as in base courses, railroad ballasts, etc.

C. Desirable properties of Aggregates and their Tests

Aggregates must be strong, hard, tough, and durable and should have in proper shape and sizes, good adhesion and cementation characteristics. The parameters like strength, hardness, toughness, durable, proper shape, proper gradation and good adhesion or cementation are used to determine whether the selected road aggregates possess desirable properties or not. [3]

1) Tests on aggregates may be arbitrarily divided into different groups .: [3]

Crushing test

This test is done to determine the crushing strength of aggregates.

Abrasion test

Abrasion test is carried out to test the hardness property of aggregates and to decide whether they are suitable for different pavement construction works. Los-Angeles abrasion test is a preferred one for carrying out the hardness property.

Impact test

The aggregate impact test is carried out to evaluate the resistance to impact of aggregates.

Soundness test

Soundness test is intended to study the resistance of aggregates to weathering action, by conducting accelerated weathering test cycles

Shape test

The particle shape of the aggregate mass is determined by the percentage of flaky and elongated particles in it. Aggregates which are flaky or elongated are detrimental to higher work-ability and stability of mixes.

Specific gravity and water absorption test

The specific gravity and water absorption of aggregates are important properties that are required for the design of concrete and bituminous mixes. The specific gravity of a solid is the ratio of its mass to that of an equal volume of distilled water at a specified temperature.

Bitumen adhesion test

Bitumen adheres well to all normal types of road aggregates provided they are dry and free from dust. This is done by Stripping value of aggregate.

D. Importance of road aggregates in the context of Nepal

Since Nepal has large geological variation, the materials found inside the country will be beneficial for the construction of road. This will finally results the utilization of locally produced materials and enhances the constructions works. Generally flexible pavements are in practice in our country but nowadays rigid pavements are also in practice. In this thesis work, we have done study about the properties of materials used in different layers of the flexible pavements including different bituminous pavement surfaces.

E. Flexible Pavement

Flexible pavements are constructed of bituminous and granular materials. Flexible pavement are those, which on the whole have low or negligible flexural strength and rather flexible in their structural action under the loads. The flexible pavement layers reflect the deformation of the lower layers on-to the surface of the layer. Thus if the lower layer of the pavement or soil sub-grade is undulated, the flexible pavement surface also gets undulated. The flexible pavement layers transmit the vertical or compressive stresses to the lower layers by grain to grain transfer through the points of contact in the granular structure. A well compacted granular structure consisting of strong graded aggregates (interlocked aggregates structure with or

without binder materials) can transfer the compressive stresses through a wider area and thus forms a good flexible pavement layer. [4]

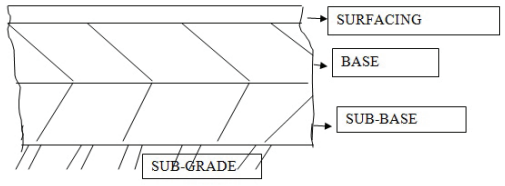

Fig. 1. Structure of Flexible Pavement

Structure of flexible pavement

Figure **??** represents the structure of figure of the structure.

The Sub-grade:

The entire load of the pavement including the load of traffic transmitted though the pavement is ultimately taken up by the sub-grade. It is also worth mentioning here that by the time the impact of the surface load reaches the sub-grade, the load has spread over a considerably large area and hence the strength requirement of the strata in bearing are much less than that of the upper strata i.e. sub-base, base and wearing courses. A slight improvement in the bearing capacity of soil brought about by proper compaction, stabilization and drainage or combination thereof could be very effective in reducing the thickness of the pavement thereby reducing the initial cost of construction of the road as well as the cost of maintenance. [5]

Sub-base course:

The sub-base also called as road-base is the main structural layer whose main function is to withstand the applied wheel stresses and strains incident on it and distribute them in such a manner that the materials beneath it do not become overloaded. [6]

Surfacing:

The surfacing combines good riding quality with adequate skidding resistance, while also minimizing the probability of water infiltrating the pavement with consequent surface cracks. Texture and durability are vital requirements of a good pavement surface as are surface regularity and flexibility. For flexible pavements, the surfacing is normally applied in two layers: **base-course and wearing course**; with the base-course and extension of the road-base layer but providing a regulating course on which the final layer is applied. [6]

F. Problem identification

Kathmandu Valley is center for construction activities. Ample amount of construction material is required for different construction purposes .Undergoing construction activities in road around and in Kathmandu Valley demands higher amount of road aggregates with varying standard properties. Thus proper source identification for the road construction is proposed by the study which will reduce the cost of transportation and aid for the good construction materials nearby the site.

G. Site selection

In this study different quarries near **Sindhuli and Kavre** district are chosen. Most of the aggregates for the construction purpose in the valley and around the valleys are brought from these sites as well. The quarries proposed for the study are:

1. Chalal Ganesh, Panauti Quarry
2. Kalo Dhunga, Bhyakur Khola
3. Nepalthok (Aapghari), Ghyampe Khola

Research objective

The general objective of this research is to study the suitability of the various nearby local resources for the use in different layers of road construction in the valley or nearby. This will finally promote the utilization of local resources enhancing the promotion of the business and thus reducing the transportation cost.

The specific objective of this research is listed as below:

i. To compare the various aggregate sources of Kavre and Sindhuli district for road construction based on different standard tests as per Standard Specification for Road and Bridge Works,2073.

ii. To recommend the best site for the construction materials.

iii. To define suitability of different aggregate sources based on tests.

Assumption:

The assumptions for the study are given below:

i. The sample aggregate chosen will define the source.

ii. The limited tests performed for the aggregate sources would represent the quality of the quarry.

Limitation:

i. The study is limited to only the quarries of Kavre and Sindhuli district and its nearby areas.

ii. Properties of materials like CBR, LL, PL, polished stone value and deleterious material & organic impurities are not considered in this research.

II. LITERATURE REVIEW

A. Properties of the road construction materials and its importance

The performance of a pavement reflects the proper functioning of the consecutive component layers of a given pavement. The design period, life of the pavement, durability and maintenance cost can be

explained by the selection of materials and their characteristics. [7]

The HMA stripping resistance was found to be significantly affected by the type of aggregate used in preparing the mix. HMA prepared using aggregate gradation followed upper limits of ASTM specification for dense graded showed the highest resistance to stripping, followed by HMA prepared using aggregate gradation followed mid-limits of ASTM specification for dense gradation. The work shows the importance of gradation in defining aggregate properties. [8]

Considering the other parameter such as voids ratio, percentage voids and maximum dry densities into account, it is identified that a dosage of 20-30% crusher dust make the gradation mixes dense and offer more shear strength due to mobilization of friction resistance under compression. [7]

The aggregates age as a result of a physical and mineralogical weathering process. Degradation of coarse rocks and the production of detrimental clay minerals considered as indications of weather ability of materials. [9] .

It was found that by reducing the air voids percentage and voids in mineral aggregate up to the certain amount, resilient modulus of the mixture will be increased and therefore deformation and non-recoverable strained will reduced. [10]

B. Codal Provision for Aggregate Tests and Their Suitability

Standard Specification for Road and Bridge Works, 2073 is a specification of different civil works required for road and bridge construction activities which was published by Department of Road, Ministry of Physical Infrastructure and Transport (MoPIT), Government of Nepal. The code has also provided standard tests involved in representation of the quality of aggregates for use in different layers of pavement. The table shown below is referred from SSRBW, 2073 which is also the basis for the further study of suitability of quarries. [11]

C. Desirable properties of materials and tests for different layers of flexible pavement.

Sub-grade Soil having the following properties is suitable for preparation of sub-grade.

Liquid limit (LL)less than 75% and

Plasticity Index (PI) less than 40%

Sub-base course

Granular sub-base should have following physical properties as per SSRBW, 2073, table 12.2

Base course

The general physical properties of crusher run aggregates for base course as per SSRBW, 2073 table 12.9 is shown as follows

Bituminous Macadam / Dense Bituminous Macadam/ Asphalt Concrete

The general physical properties of Bituminous Macadam (BM), Dense Bituminous Macadam (DBM) and Asphalt Concrete (AC) as per SSRBW, 2075 table 13.24, 13.26 and 13.32 is shown as follows.

TABLE I
PHYSICAL PROPERTIES OF SUB-BASE MATERIALS

Physical properties	Test method	Requirement for Class I & II	Requirement for Class III , IV and maintenance work
Aggregate Impact Value (AIV)	IS 2386-4 or IS 5640	Maximum 40	Maximum 45
Liquid Limit	IS 2720-5	maximum 25	maximum 25
Plasticity Index	IS 2720-5	Maximum 6	Maximum 6
CBR at 95 % dry density (at IS 2720-part8)	IS 2720-5	Minimum 30 unless specified in the Contract	Minimum 25 unless specified in the Contract

TABLE II
PHYSICAL PROPERTIES OF BASE MATERIAL

Test	Test method	Requirements
Loss Angeles Abrasion Value(LAA) or Aggregate Impact Value (AIV)	IS: 2386 -4	40 max 30 max
Combined Flakiness & Elongation Index	IS: 2386 -1	35 max
Water Absorption	IS: 1386 -3	2 % max
Liquid limit of material passing 425μ	IS: 2720- 5	25 max
Plasticity index of material passing 425μ	IS: 2720- 5	6 max

III. COLLECTION OF AGGREGATES FROM QUARRIES FOR DIFFERENT LAYER AND THEIR TESTS

A. Collection of aggregates from quarries for different layer

All quarries produce different quality material as per the road site construction activity needs. Different standards have set different limits for different layers in terms of its physical properties. Thus, collection of materials would be performed for

i. Sub-base layers (SB)

ii. Base layers (B)

iii.Bituminous Macadam (BM)

iv. Dense Bituminous Macadam (DBM)

v. Asphalt Concrete (AC)

The above mentioned layers are selected based on its dominant use in the construction field herein Nepal. So, materials from three quarries namely Challal Ganesh , Aapghari (Ghyampe Khola) and Bhyakure Khola of Kavre and Sindhuli District are collected to check the suitability of these aggregates for different layers of flexible pavement.

TABLE III
PHYSICAL PROPERTIES OF BM, DBM AND AC MATERIALS

Property	Test	Specification	Method of Test
Cleanliness (dust)	Grain size analysis	Max 5% passing 0.075 mm sieve	IS:2386 Part I
Particle shape	Combined Flakiness and Elongation Indices	Max 35%	IS:2386 Part I
Strength	Los Angeles Abrasion Value or Aggregate Impact Value	Max 30% (for BM 40% & for DBM 35%) Max 24% (for BM 30% & for DBM 27%)	IS:2386 Part IV
Durability	Soundness either: Sodium Sulphate or Magnesium Sulphate	Max 12% Max 18%	IS:2386 Part V
Polishing	Polished Stone Value	Min 55 only for AC	BS:812-114
Water Absorption	Water Absorption	Max 2%	IS:2386.Part Ill
Stripping	Coating and Stripping of Bitumen Aggregate Mix	Minimum retained coating 95%	IS: 6241
Water Sensitivity	Retained Tensile Strength*	Min 80%	AASHTO 283

Fig. 2. Aggregate samples from different quarries

B. Tests on Aggregate

After the collection, different experiment sets, as from recommendation of SSRBW, 2073, were performed. The test result of study are tabulated below:

Test results of Sub- Base Course

The result of sub base is in usable range for both the quarries Challal Ganesh and Aapghari. But we did not get the material for sub-base from Bhyakure Khola quary.

Test results of Base Course

Gradation of Bhyakure Khola quarry meets the specification for base as per SSRBW 2073, gap grading was found in case of base material of Aapghari quarry. The material of Aapghari quary can be used as a base material by adding the aggregate of required size. Besides gradation requirement, other properties such as LAA, AIV, MDD etc. meets the requirement as per specification. The material from Bhyakura Khola can be used as base material without any treatment. There seems to be addition of certain gap graded aggregate in the base material of Aapghari quary. We did not get the material for base from Challal Ganesh quary.

Test results of Bituminous Macadam Gradation analysis shows that none of the three quarries meets the specification (passing through 0.075mm sieve is greater than 5%). Except gradation other properties required for construction of Bituminous Macadam such as LAA, AIV, Water absorption etc. as shown in table meets the requirement as per specification. So the materials from these quarries can be used for Bituminous Macadam by adding certain percentage of coarser aggregate.

Test results of Dense Bituminous Macadam

Gradation analysis shows that none of the three quarries meets the specification (passing through 0.075mm sieve is greater than 5%). Except gradation other properties required for construction of Dense Bituminous Macadam such as LAA, AIV, Water absorption etc. as shown in table meets the requirement as per specification. So the materials from these quarries can be used for Dense Bituminous Macadam by adding certain percentage of coarser aggregate.

Test results of Asphalt Concrete

Gradation analysis shows that none of the three quarries meets the specification (passing through 0.075mm sieve is greater than 5%). Except gradation other properties required for construction of Asphalt Concrete such as LAA, AIV, Water absorption etc. as shown in table meets the requirement as per specification for two quarries Challal Ganesh and Aapghari. AIV of Bhyakure Khola quarry is found as 27% which is greater than standard (24%), the material from this quarry is not suitable for Asphalt Concrete. So the materials from these quarries can be used for Asphalt Concrete by adding certain percentage of coarser aggregate.

AIV: Aggregate Impact Value Test

LL: Liquid Limit

TABLE IV
TEST RESULT ON SUB-BASE COURSE

Pavement Component	Test Name	Test Result			
		Challal Ganesh.		Aapghari (Ghampe Khola)	
Sub Base Course	Sieve Analysis/ Gradation	Sieve size, mm	% Passing by wt.	% Passing by wt.	% Passing by wt.
		63	100	63	100
		40	98%	40	87.9%
		20	89%	20	71.4%
		10	65%	10	60.1%
		4.75	41%	4.75	44.4%
		2.36	17%	2.36	40.00%
		1.18	11.21%	1.18	29.11%
		0.075	8.74%	0.075	6.57%
	MDD	2.249		2.312	
	OMC	6.20%		6.27%	
	PI	Nonplastic		Nonplastic	

TABLE V
TEST RESULT OF BASE COURSE

Pavement Component	Test Name	Test Result			
			Aapghari (Ghampe Khola)		Bhyakure Khola
Base Course	Analysis/ Gradation	Sieve size, mm	% Passing by wt. 40mm(1)	% Passing by wt. 40mm(2)	% passing by weight
		40	100.00%	100.00%	99.14%
		20	5.33%	1.58%	69.68%
		10	0.08%	0.09%	54.45%
		4.75	0.02%	0.02%	35.98%
		2.36	0.00%	0.00%	31.79%
		0.6	0.00%	0.00%	21.22%
		0.075	0.00%	0.00%	11.24%
	LAA		30.40%	30.40%	37.00%
	AIV		19.69%	19.69%	27.48%
	FI		12%	7%	20.08%
	EI		9%	17%	11.85%
	MDD		2.312	2.312	2.215
	OMC		6.27%	6.27%	6.45%
	PI		Nonplastic	Nonplastic	Nonplastic

Fig. 3. Sample for LAA test

Fig. 4. Sample for OMC, MDD test

PI: Plasticity Index
CBR: California Bearing Ratio

TABLE VI
TEST RESULTS OF BITUMINOUS MACADAM

Pavement Component	Test Name	Test Result Challal Ganesh.	Aapghari (Ghampe Khola)	Bhyakure Khola
Bituminous Macadam	Gradation	8.74% passing 0.075mm	6.57% passing 0.075mm	11.24% passing 0.075mm
	LAA	26.04% 20 mm; 38.68% 40mm	28.48% 20mm ; 30.40% 40mm	37.00% 40 mm
	AIV	18.65%	19.69%	27.48%
	FI	20	18	24%
	EI	28	28	21%
	Water Absorption	0.49%	0.74%	0.75%
	Stripping	Greater than 95%	Greater than 95%	Greater than 95%
	PI	Non plastic	Non plastic	Non plastic

TABLE VII
TEST RESULTS OF DENSE BITUMINOUS MACADAM

Pavement Component	Test Name	Test Result Challal Ganesh.	Aapghari (Ghampe Khola)	Bhyakure Khola
Dense Bituminous Macadam	Gradation	8.74% passing 0.075mm	6.57% passing 0.075mm	11.24% passing 0.075mm
	LAA	26.04% 20 mm; 38.68% 40mm	28.48% 20mm ; 30.40% 40mm	37.00% 40 mm
	AIV	18.65%	19.69%	27.48%
	FI	20	18	24%
	EI	28	28	21%
	Water Absorption	0.49%	0.74%	0.75%
	Stripping	Greater than 95%	Greater than 95%	Greater than 95%
	PI	Non plastic	Non plastic	Non plastic

TABLE VIII
TEST RESULTS OF ASPHALT CONCRETE

Pavement Component	Test Name	Test Result Challal Ganesh.	Aapghari (Ghampe Khola)	Bhyakure Khola
Asphalt Concrete	Gradation	8.74% passing 0.075mm	6.57% passing 0.075mm	11.24% passing 0.075mm
	LAA	26.04%	28.48%	
	AIV	18.65%	19.69%	27.48%
	SSS	3.75%		
	FI	20	18	24%
	EI	28	28	21%
	Water Absorption	0.49%	0.74%	0.75%
	Stripping	Greater than 95%	Greater than 95%	Greater than 95%
	PI	Non plastic	Non plastic	Non plastic

MC: Moisture Content
MDD: Maximum Dry Density
OMC: Optimum Moisture Content
FI/EI: Flakiness Index/ Elongation Index
LAA: Loss Angeles Abrasion Value
SSS: Sodium Sulphate Soundness

IV. Analysis of Result

In this paper, we conducted different experiment as per SSRBW-2073. The data for experiments are collected in a standard sheet and we found that the materials from different Quarries satisfies the standard for base and sub-base layers of flexible pavement. Materials from Quarries of Challal Ganesh and Aapghari satisfies the standard for bituminous macadam, dense bituminous macadam and asphalt concrete of surface course of flexible pavement. Our experiment shows that the material of Bhyakure Khola Quarry fails the standard for asphalt concrete, yet it can be used for bituminous macadam, dense bituminous macadam.

V. Recommendation

- Based on the comparative analysis, Challal Ganesh quarry of Kavre Disrtict is the best and suitable quarry for different layers of flexible pavement.

- The study can also identify the importance of experiments such as LAA, AIV, Specific gravity, Water contain, OMC,MDD,Gradation in representing the quality of aggregate from quarries of the selected areas.

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