Journal of Advanced Research in Geo Sciences & Remote Sensing
Volume 6, Issue 3&4 - 2019, Pg. No. 16-26
Peer Reviewed Journal

Research Article

Dry Densities Achieved in Relation to Variation of Fines Content

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DOI: https://doi.org/10.24321/2455.3190.201904

I N F O

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How to cite this article:
Aryal B, Mishra AK. Dry Densities Achieved in Relation to Variation of Fines Content. *J Adv Res Geo Sci Rem Sens* 2019; 6(3&4): 16-26.

Date of Submission: 2019-12-08
Date of Acceptance: 2019-12-27

A B S T R A C T

The objective of this research study is to find the relation between dry densities achieved with variation of fines content. The method of choice in the determination of themaximum dry density from different soils was the Standard Proctor Test following the procedure for the standard Proctor test as is explained in ASTM Test Designation D-698. Several laboratory tests on material obtained from TikaBhairab quarry and Bhim Phedi quarry have been conducted. The laboratory test includes sieve analysis of fines and aggregate mix, index properties of fine, compaction of aggregate mix and soaked CBR test. From the test results analysis were carried out to find the correlation between CBR with fine content using Statistical Package for Social Sciences (SPSS) V 20 software.

From this investigation, the maximum dry density of two types of aggregate was obtained, the aggregate mix were classified by using the Unified Soil Classification System. The influence on the maximum dry density of the type of aggregate, type of fines, amount of fines and distribution of the grain size was determined, followed by a sensitivity analysis that measured the influence of these parameters on the obtained maximum dry density. For sub-base material obtained from Tikabhairab, best compaction is achieved at 15% fine content.

This paper focuses on the samples retrieved from the selected quarries furthermore it is recommended to carry out this research with a large number of samples including geographical areas in Nepal which are not covered by this research.

Keywords: Unified Soil Classification, Dry Density, Aggregate Types, Fines

Introduction

The national Road Network of Nepal has reached 13060.25 Km including 6980.02 Km blacktopped, 2045.18 Km gravel and 4035.05 Km earth roads. Similarly 378.5 Km roads are under construction and GoN has proposed Strategic Roads Network of about 1965.20 Km in the coming decade (DoR, 2016).

A substantial proportion of the road network in the country consists of earth or gravel roads. Roads connectivity is one of the key components for national development, as it promotes access to economic and social services, generating increased agricultural income and productive employment.

A relatively stable layer constructed over the natural soil for the purpose of supporting and distributing the wheel load and providing adequate surface for the movement of the vehicles may be defined as road pavement. A flexible pavement is a multilayer system comprising of a surface layer, a road base layer and a sub-base layer installed on a compacted sub-grade. Each layer has particular functions and characteristics. Of these layers, the road sub-base layer which lies immediately below the base layer is one of the main structural components of the pavement. It plays a major role in spreading the load imposed at the surface evenly, so that the stresses transmitted to the subgrade do not exceed the strength of these layers. The layer therefore most possesses high stiffness and strength. Material used in road sub-base construction includes cemented and bituminous material and unbound granular material. An unbound granular road sub-base derives its high stability from particle interlock and inter-particle friction. Aggregate grading and properties are of particle importance in this type of construction. While building roads, the parameters that affect the sustainability are to be provisioned at minimum cost. The conventional methods and specifications tend to recommend technology and materials, which normally result in higher cost of construction. For achieving cost effectiveness in roads building it is necessary to study on compaction and strength behavior of locally available materials.

In the majority of grading specification, limits are placed on the percentage of fines, i.e. material passing the No.200 (75μm) sieve. In addition a maximum value is specified for Plasticity Index (PI). The amount of material finer than 75 μm can be expected to influence the dry density, strength and permeability of unbound granular sub-base; the plasticity of fines is likely to influence strength characteristic. The purpose of this research is to find the relation between dry densities achieved with variation of fines content.

Literature Review

Unbound Aggregate Sub Base Course

Aflexible pavement consists of layered system. It consists of sub-grade, sub-base, base and wearing course. Among them sub-base is main structural layer which transmit the traffic loads into lower layer safely. A road sub-base may be treated or not treated. The treated sub-base is known as stabilized base where as untreated sub-base are called unbound road sub-base.

Aggregate is the largest single material used in highway construction and its properties are important for the quality of the pavement. The design of the aggregate mixture to ensure high stability is an important aspect of pavement design. Mechanical properties of unbound road materials

The amount by which an unbound aggregate is deformed when loaded depends on its stiffness and stability. Stiffness or the ability to spread the load, is a measure of the resistance to resilient deformation. It is expressed in terms of a modulus of elasticity or resilience that is used in designing the pavement. Stability is a measure of the ability to resist permanent deformation. Another term is load bearing capacity, which could be defined as the load a layer of material can carry without being deformed more than the permissible amount. Determination of a bearing capacity thus requires a limiting deformation value. Fines are defined as materials with a particle size of up to 0.075mm. The particle size distribution is usually presented as a graph. In this graph, the maximum particle size, the fines content and the curve shape are important parameters. The curve shape can be characterized by a uniformity coefficient, C_u, which is the ratio of D_{60} to D_{10}. D_{60} means the mesh of the sieve through which 60% of the material passes. However, the c_u can be lacking in sensitivity as it does not indicate unstable curves with ‘sand bumps’. In that case, the curvature index, C_c, $(=D_{30}^2/ (D_{60}.D_{10}))$ is more usable. A well-known equation used to describe the curve shape is Fuller’s equation which could be written:

$$p=100\ (d/D)^n$$

Where,

p = percentage smaller than particle diameter (d)

D = largest particle diameter in the material

n = parameter describing the shape of the curve, here

n = 0.5 (Mier, 1996)

For natural aggregate materials, the size of the particles that form the material skeleton that transmits the load is most important for the stiffness. It is also well known that the less steep the particle size distribution curve, the more stable the material. To obtain the maximum number of contact points between particles, so called optimal compaction, the distribution curve should have n values of 0.35 to 0.45 in the above equation (Zheng, 1990).

Plasticity of Fines

Plasticity is the property of cohesive soils which possess the ability to undergo changes of shape without rupture. The most common use of the plasticity test results is in the classification of fine grained soils and the fine fraction of mixed soils. The range of water content between the Liquid Limit (LL) and Plastic Limits (PL), which is an important measure of plastic behavior, is called the plasticity index, PI.

PI = LL-PL

In soils having same values of liquid limit with different values of plasticity index; it is generally found that the rate of volume change and dry strength increases and permeability decreases with increase in plasticity index. In soils having same values of plasticity index but different values of liquid limit, it is seen that compressibility and permeability increase and dry strength decreases with increase in liquid limit. Both LL and PI can be used as a quality-measuring device for pavement materials, to exclude granular materials with too many fine-grained particles. For instance, when blending of two soils is needed to meet the soil-aggregate specification, a guide to the initial proportions to be blended to give a desired plasticity index for a mixture of two soils can be obtained from the following equations (O'Flaherty, 2002):

$a = 100S_B (P-P_B)/[S_B (P-P_B)-S_A (P-P_A)]$ and

$b = 100-a$, where,

a = amount of soil A in the blended mix (%),

b = amount of soil B in the blended mix (%),

P = desired PI of the blended mix,

P_A = PI of soil A,

P_B = PI of soil B,

S_A = amount of soil A passing the 0.425 mm sieve (%) and,

S_B = amount of soil B passing the 0.425 mm sieve (%)

Strength of Unbound Aggregate Sub Base Course

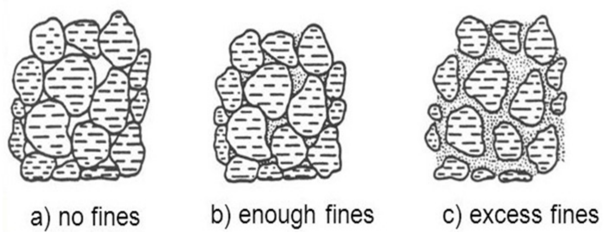

Figure 1.Physical state of soil- Aggregate Mixes (Yoder, 1975)

As shown in Figure 1 (c), material that contains a great amount of fines has no grain-to-grain contact and the aggregate merely 'float' in the soil. Its density is low; it is practically impervious and it is frost susceptible. In addition, the stability of this type of material is greatly affected by adverse water conditions. Paradoxically, the material at times is quite easy to handle during construction and compacts quite readily (Yoder, 1975).

The stability of soil-aggregate mix used in flexible pavement construction is normally determined by the CBR test. The test provides for compacting the soil in a cylindrical mold and soaking the sample for 4 days with an imposed load roughly equivalent to that which would be applied by a prototype pavement. The compaction simulates construction and the soaking simulates a water content adjustment roughly equivalent to that which would occur if the water table is 2ft. below the base formation.

Influence of Fines content on Plasticity

Plasticity index of soil aggregate mixtures were determined for various fines content. From the test, it was concluded that PI were high for high values of fines content.

Influence of Fines Content on Dry Density

When studying the influence of fines content on dry density of a compacted material there are several factors that it depends on, including the grain size and shape and the amount of fines, as well as external factors like the compaction method.

The method adopted when compacting a granular material has a significant effect on the resistance to permanent deformation and long term stability (Austin, 2009). The grain size also has an influence. Different results are obtained when tri-axial testing is completed on specimens that are fabricated using a vibration hammer when compared to the results obtained from Modified Proctor compaction.

Dry density with high fines content may be important for dry of optimum conditions. However, as the fines content continues to increase, the optimum water content increase overrides the effect of dry density of the samples.

Influence of Fines Content on CBR Value

The density values represent the peaks of the compaction curves; the California Bearing Ratios are for soaked samples. The maximum stability as measured by the CBR test resulted when about 6 to 8 percent of the material passed a No. 200 mesh sieve.

Compaction Curve

When samples of the same material are compacted with the same energybut with different water contents, they present different densification stages, as shown on Figure 2.

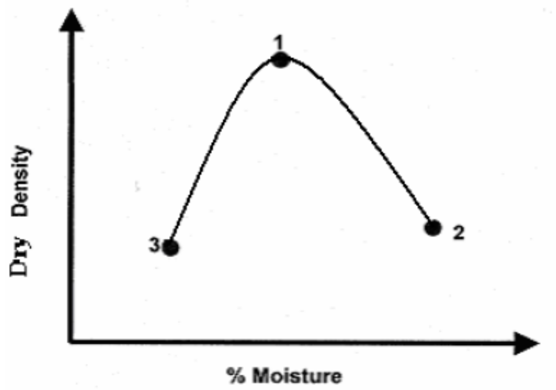

Figure 2.Moisture Density Curve

This densification stages are represented in the compaction curve, which has a particular shape. Many theories have tried to explain the shape of this curve. The principal theories are presented following:

At this stage the soil is at its maximum dry density (γ_{dmax}) and optimum water content *w* (%)optimumas represented

ISSN: 2455-3190
DOI: https://doi.org/10.24321/2455.3190.201904

in point 1 in Figure 3. For anyincrement in the water content after the "optimum water content", the volume of voids tends to increase and the soil will obtain a lower density and resistance (Proctor, 1933).

As shown in Figure 3, Hogentogler's moisture-density curve differs from Proctor's curve in the abscise axe. Hogentogler used for this axe the percentage of water content in the total volume of the sample. Hogentogler believed that by using that chart the compaction curve becomes four straight lines that represent his humectation stages.

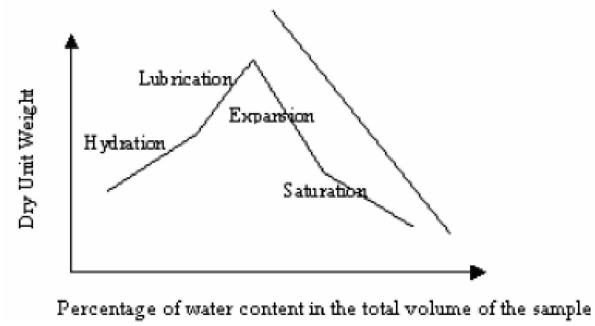

Figure 3.Compaction Curve

He believed that more water after the lubrication stage will create the "expansion" of the soil mass without affecting the volume of the air voids, so the additional water in this stage acts in the displacement of the soil particles. Addition of more water to the soil produces its "saturation", which is the stage where the air content is displaced (Hogentogler, 1936).

In his chart the zero air voids curve is shown as astraight line and so are the saturation lines, all originating at zero void ratio and zero moisture content. Points representing soil samples with equal air void ratios (volume of airto volume of solids) plot on lines parallel to the zero air voids or 100% saturation line (Hilf, 1956).

Lambeexplained the compaction curve based on theories that used the soils surface chemical characteristics. In lower water contents, the particles flocculation iscaused by the high electrolytic concentration. The flocculation causes lower compaction densities, but when the water content is increased the electrolytic concentration is reduced (Lambe, 1958).

Oslonconfirmed that the air permeability of a soil is dramatically reduced at orvery close to the optimum moisture content. At this point, high pore air pressures and porewater pressures minimize effective stress allowing adjustments of the relative position ofthe soil particles to produce a maximum density. At water contents below optimum, ol sonattributes resistance to repeated compaction forces to the high negative residual pore pressures, the relatively low shear-induced pore pressures and the high residual lateral totalstress. On the wet side of optimum, Olson explains the reduced densification effect bypointing out that the rammer or foot penetration during compaction is larger than in driersoil, which may cause temporary negative pore pressure known to be associated with largestrains in over-consolidated soil; in addition the soil resists compaction by increasingbearing capacity due to the depth effect (Oslon, 1963).

Barden and sides, made experimental researches on the compaction of clays thatwere partially saturated, reporting the obtained microscopic observations of themodifications in the clay structure. The conclusions obtained can be summarized asfollows:

- The theories based on the effective tensions used to determine the curve shape aremore reliable than the theories that used viscosity and lubrication.
- It is logical to suppose that soils with low humidity content remain conglomerateddue to the effective tension caused by the capillarity. The dryer these soils are thebigger the tensions are. In the compaction process the soil remains conglomerated. Byincreasing the water content these tensions are reduced and the compaction is moreeffective.
- The blockage of the air in the soil mass provides a reasonable explanation of theeffectiveness of used compaction energy.
- If by increasing the water content the blocked air is not expelled and the air pressureis increased, the soil will resist the compaction (Barden & Sides, 1970).

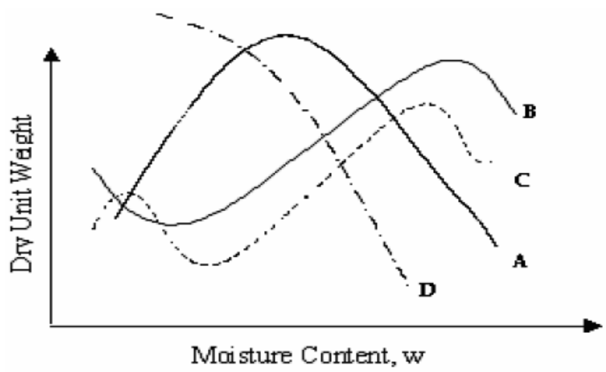

Figure 4.Types of Compaction Curves (Lee & Suedkamp, 1972)

Methodology

Primarily in order to have satisfactory data for utilizing the correlations, laboratory tests were conducted. Sampleswere collected from different quarries of Bagmati Zone so as to get records of test results of CBR values along with the associated soil indices particularly the grain size analysis, Atterberg limits, moisture-density relationships.Statistical regression analyses of test results were carried out using SPSS software and correlations were developed and also

ISSN: 2455-3190
DOI: https://doi.org/10.24321/2455.3190.201904

analyzed to fit the test results. Under the discussions of the obtained results the suitability of the developed correlations were examined. Finally, generalized conclusions and recommendations were made.

Phase 1:- Problem identification, formulation of objective and literature review

It is the first phase of the research, main problem was identified and objective and goal was set followed by the literature review.

Phase 2:- Study area Selection, secondary data collection, lab test, field test

This phase consists of selection of study area. The study area was the quarry located at TikaBhairav and BhimPhedi of Bagmati District.

Phase 3:- Data Collection, management and analysis

Various data required for the study of compaction behavior of sub-base materials was identified and analysis of data was done.

Phase 4:- Result and Discussion

This phase include the results analysis, conclusion and recommendations that present the main findings of research. This phase also discuss the research objective achieve during the study.

Research Approach

The research approach is based on the primary data of the sub-base material obtained from selected quarries which will be the criterion to fulfill the objective of the study. After critical review of the objective and the scope, the proven methodology is used to accomplish the study in the stipulated time frame including the full use of available journals, research papers, proceedings, guidelines and other related information of the study.

- **Pre-field work phase**

Literature review for topic selection and to support the proposed study, problem identification related to the selected topics of research, setting of the objectives and design of survey forms were developed in pre- field work phase.

- **Field work Phase**

Sub-base material is collected from the quarry to perform laboratory test which determines Atterberg's limit, MDD, OMC and CBR value.

- **Post Field work Phase**

In post field work phase, processing and analysis of data, generation of idea regarding the subject matter, drawing of conclusion and making necessary recommendation and final report preparation was done.

Study Population

In this study, the targeted population is the different type of sub-base material obtained from two quarries of Bagmati zone. The required data of selected sample was collected andanalyzedwith addition of varying percentage of fines at an increment of 5% and correlation is established with help of data.

Sample Selection

In order to have sufficient and reliable data for the target analysis, laboratory tests isconducted on soil samples obtained from selected quarries of Bagmati zone.

The sample are selected in accordance to the DoR Standard Specification for Road and Bridge Works, Clause 1200 (DoR, 2073) which suggests the frequency of the material to be tested is for new source and in every 400 cum or part of it or one set of each test for each 1000 sqm of each layer. Accordingly the number of samples used in this research are explained in Table 1.

Table 1.Sample Selection and Methods of Analysis

S. No.	Tests	Number of Samples	Methods	Output	Remarks
1.	Sieve Analysis	Fines=1 nos Quarry 1= 6 nos Quarry 2=6 nos	(ASTM D 422-63)	Soil type identification	Including fines and aggregate mix
2.	Atterberg's Limit Test (LL, PL, PI)	Fines= 1nos	(ASTM D 4318)	Determine LL, PL and PI value	For fines
3.	Standard Proctor Compaction Test (MDD, OMC)	Quarry 1= 5 nos Quarry 2=5 nos	(AASHTO T 180)	Determine MDD and OMC value	For both Quarries
4.	CBR Test	Quarry 1= 5 nos Quarry 2=5 nos	(AASHTO T 193)	CBR Value	For both Quarries

Data Collection

The data was collected from primary source. The primary data was collected by and laboratory test. The data collected from the laboratory test includes CBR, moisture content,

ISSN: 2455-3190
DOI: https://doi.org/10.24321/2455.3190.201904

dry density, liquid limit, plastic limit, plastic index, sieve analysis and Proctor test. Soil mixes were prepared at different contents of binder i.e. fines passing 75μm sieve and the contents of binder were varied from 5% to 25% at an increment of 5%.

Lab Tests

Based on the samples retrieved from the quarry, laboratory tests on the samples were conducted in the Central Material Testing Laboratory of Institute of Engineering. Laboratory test were performed on the data collected from primary source. Following test have been performed from the samples collected. Soaked CBR value from primary data was observed from laboratory test:

- Grain size Analysis Test (ASTM D 422-63)
- Liquid Limit Test (ASTM D 4318)
- Plastic Limit Test (ASTM D4318-III)
- Plastic Index (ASTM D4318-III)
- Modified Proctor Test (AASHTO T 180)
- CBR Test (AASHTO T 193)

The above mentioned tests were conducted on the aggregate samples with varying percentage of fines at an increment of 5% and a range of test results were achieved. Based on the obtained test results of plasticity and grain size distribution the soil classification was made.

A modified proctor test conducted as per AASHTO T 180 D, through which samples compacted at five layers each compacted by 56 uniform blows using 4.54 kg weight of hammer. From the modified proctor test, after plotting moisture-density curve, a range of maximum dry density along with the optimum moisture content were obtained. Similarly, the CBR test was carried out, on samples remolded with OMC using 10, 30 and 65 blows of modified proctor density and soaked for four days. Consequently, after the penetration test were carried out a CBR value ranging from 2.2 up to 10 is obtained at 95% MDD of modified ASHTO proctor density.

Result and Discussion

Characteristics of Fines

The fines used in the study are obtained from the Tikabhairab. The soil is classified as the fine grained as 91.99 % of the particles are smaller than 75μm. The fineness modulus of the fines is 0.20 signifying that the predominant particles are clay size. Table 2, presents a summary of engineering properties of fines used in the study.

Table 2.Summary of engineering properties of fines

S. No.	Properties	Description
1.	Color	Dark Grey
2.	Atterberg's Limit	LL= 26.7% PL= 21.5% PI= 5.2% (PI= 0.73* (LL-20), Below A-Line)
3.	Specific Gravity	2.58
4.	Soil Classification as per USCS	ML i.e. Low Plastic Silt

The natural color of the fine obtained is dark greyish. The test on fine shows the Atterberg's Limit value i.e. Liquid Limit and Plastic Limit of 26.7% and 21.5% respectively. The Plasticity Index is obtained by the A-Line equation given by the USCS soil classification system and the fine is classified as ML which represents that the fine is a Low Plastic Silt having specific gravity of 2.58. The sieve analysis of fines is shown in Figure 5.

The graph plotted between moisture content vs. number of blows shows the Liquid Limit at 25 numbers of blows corresponds to 26.7% moisture content as shown in Figure 6. The Plastic Limit of the fine obtained is 21.5%.

Methodological Summary

Objective	Data needs	Source	Method of data collection	Analytical tools
To find the effect of grain size distribution of sub base soil on properties of sub base layer.	• Hydrometer Analysis • Soil Index Properties • Moisture Content • Liquid Limit • Plastic Limit • Sieve Analysis	**Primary** • Fines	• Lab test	Ms. Excel (IS), Standard lab formulas
To find the relation between dry densities achieved with variation of fines content.	• MDD • CBR Value • Sieve Analysis	**Primary** • Finen aggregate Mix	• Lab test	SPSS, Ms. Excel

ISSN: 2455-3190
DOI: https://doi.org/10.24321/2455.3190.201904

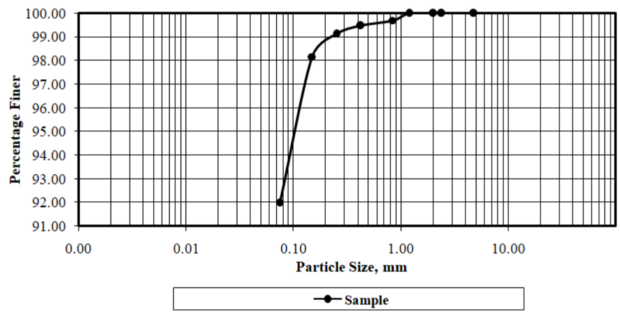

Figure 5.Sieve analysis of fines

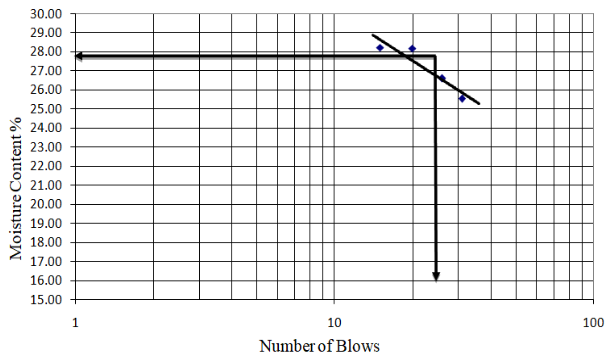

Figure 6.Moisture Content vs. Number of blows

Classification of Soil Aggregate Mix

Soil mixes were prepared at different contents of binder i.e. fines passing 75µm sieve and the contents of binder were varied from 5% to 25% at an increment of 5%. The gradations of mix investigated are shown in Figures 7-18.

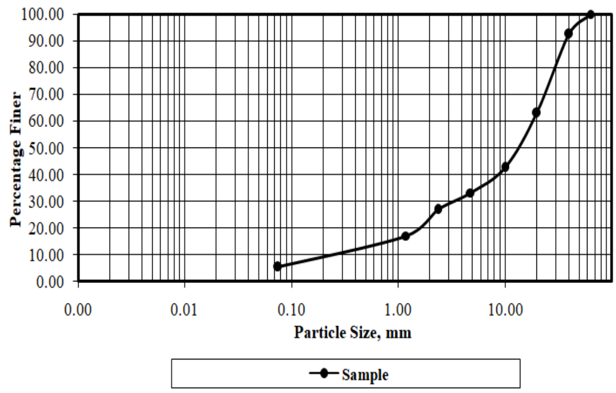

Figure 7.Gradation of mix for no fines (Quarry 1)

Figure 7, shows the gradation mix of quarry 1 for no fine content. The coefficient of uniformity (C_u) and coefficient of curvature (C_c) obtained are 81.81 and 3.09 respectively. The mix is classified as Poorly Graded gravel (GP) according to USCS soil classification system.

Figure 8, shows the gradation mix of quarry 1 for 5% fine content. The coefficient of uniformity (C_u) and coefficient of curvature (C_c) obtained are 92.36 and 2.06 respectively. The mix is classified as Poorly Graded gravel (GP) according to USCS soil classification system.

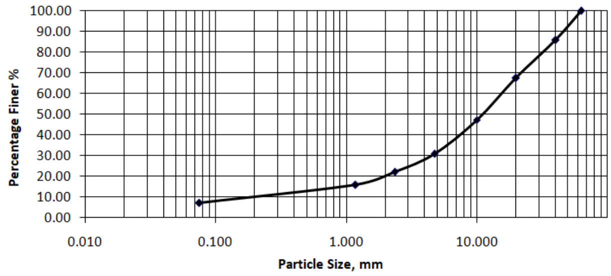

Figure 8.Gradation of mix for 5% fines (Quarry 1)

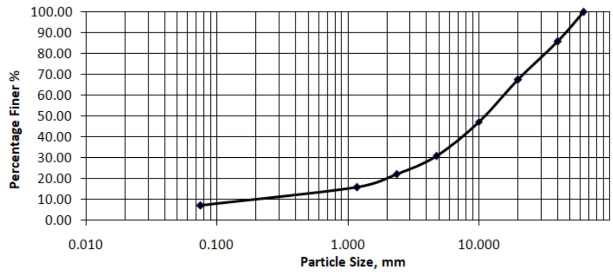

Figure 9.Gradation of mix for 10% fines (Quarry 1)

Figure 9, shows the gradation mix of quarry 1 for 10% fine content. The coefficient of uniformity (C_u) and coefficient of curvature (C_c) obtained are 113.33 and 1.27 respectively. The mix is classified as Well Graded gravel with Silt (GW-GM) according to USCS soil classification system.

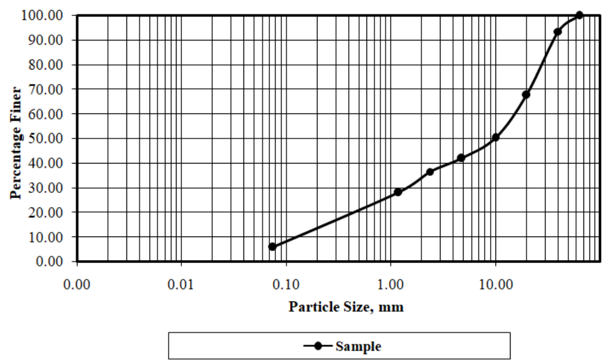

Figure 10.Gradation of mix at 15% fines (Quarry 1)

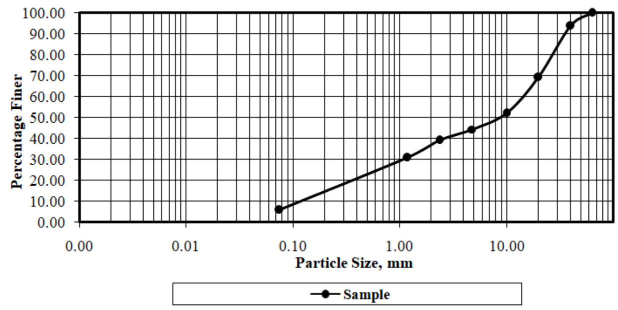

Figure 11.Gradation of mix at 20% fines (Quarry 1)

Figure 10, shows the gradation mix of quarry 1 for 15% fine content. The coefficient of uniformity (C_u) and coefficient of curvature (C_c) obtained are 123 and 1.23 respectively. The mix is classified as Silty Gravel (GM) according to USCS soil classification system.

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Figure 11, shows the gradation mix of quarry 1 for 20% fine content. The coefficient of uniformity (C_u) and coefficient of curvature (C_c) obtained are 125 and 0.75 respectively. The mix is classified as Silty Gravel (GM) according to USCS soil classification system.

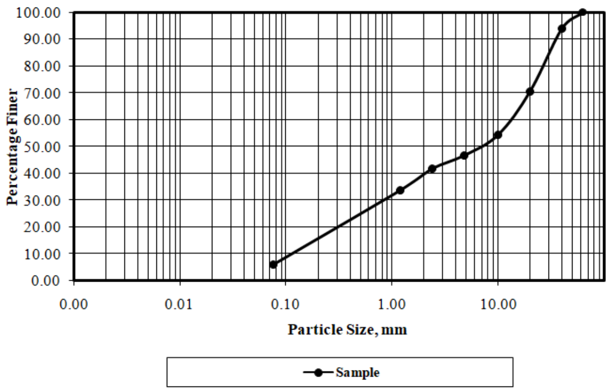

Figure 12.Gradation of mix at 25% fines (Quarry 1)

Figure 12, shows the gradation mix of quarry 1 for 25% fine content. The coefficient of uniformity (C_u) and coefficient of curvature (C_c) obtained are 127.27 and 0.42 respectively. The mix is classified as Silty Gravel (GM) according to USCS soil classification system.

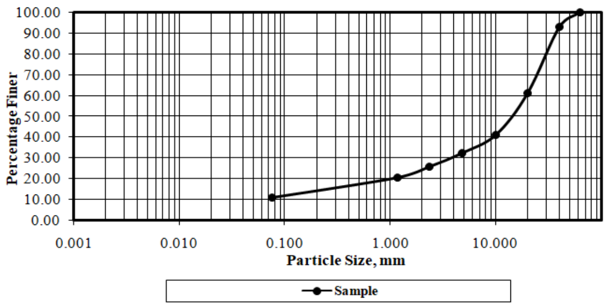

Figure 13.Gradation of mix at no fines (Quarry 2)

Figure 13, shows the gradation mix of quarry 2 for no fine condition. The coefficient of uniformity (C_u) and coefficient of curvature (C_c) obtained are 266.67 and 9.62 respectively. The mix is classified as Poorly Graded gravel (GP) according to USCS soil classification system.

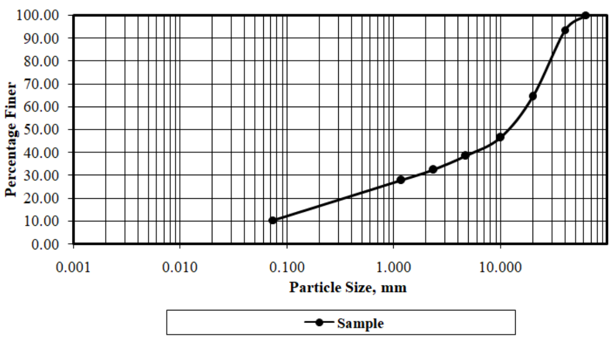

Figure 14.Gradation of mix at 5% fines content (Quarry 2)

Figure 14, shows the gradation mix of quarry 2 at 5% fine condition. The coefficient of uniformity (C_u) and coefficient of curvature (C_c) obtained are 256.34 and 2.42 respectively. The mix is classified as Poorly Graded gravel (GP) according to USCS soil classification system.

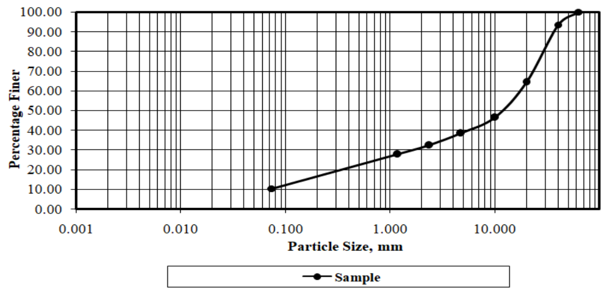

Figure 15.Gradation of mix at 10% fines content (Quarry 2)

Figure 15, shows the gradation mix of quarry 2 for 10% fine content. The coefficient of uniformity (C_u) and coefficient of curvature (C_c) obtained are 240 and 2.4 respectively. The mix is classified as Well Graded gravel with Silt (GW-GM) according to USCS soil classification system.

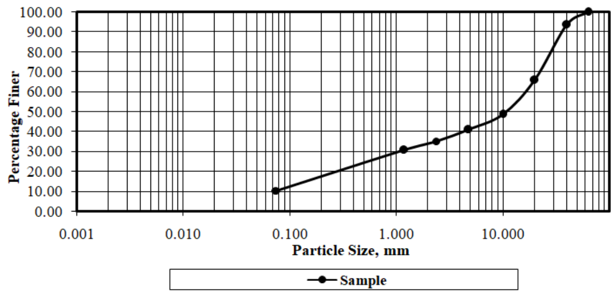

Figure 16.Gradation of mix at 15% fines (Quarry 2)

Figure 16, shows the gradation mix of quarry 2 for 15% fine content. The coefficient of uniformity (C_u) and coefficient of curvature (C_c) obtained are 240 and 1.06 respectively. The mix is classified as Silty Gravel with Silt (GM) according to USCS soil classification system.

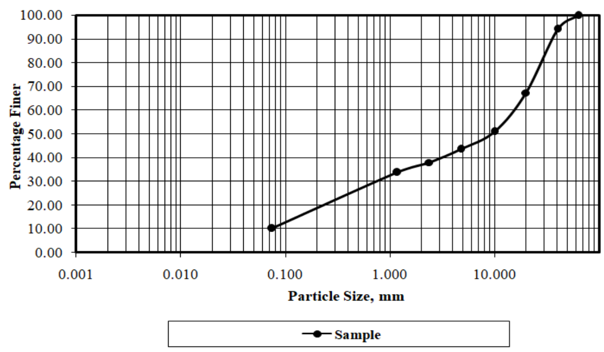

Figure 17.Gradation of mix at 20% fines (Quarry 2)

Figure 17, shows the gradation mix of quarry 2 for 20% fine content. The coefficient of uniformity (C_u) and coefficient of curvature (C_c) obtained are 229.6 and 0.56 respectively.

The mix is classified as Silty Gravel (GM) according to USCS soil classification system.

Figure 18, shows the gradation mix of quarry 2 for 25% fine content. The coefficient of uniformity (C_u) and coefficient of curvature (C_c) obtained are 214.28 and 0.34 respectively. The mix is classified as Silty Gravel (GM) according to USCS soil classification system. The summary of sieve analysis of soil aggregate mix of quarry 1 and quarry 2 is given in Tables 3 and 4, respectively:

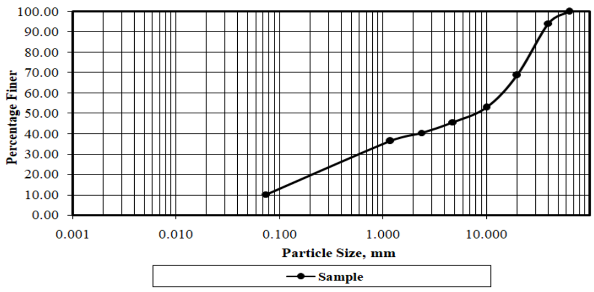

Figure 18.Gradation of mix at 25% fines (Quarry 2)

Table 3.Summary of sieve analysis of soil aggregate mix (Quarry 1)

Sieve size mm	Fines content in soil aggregate mix				
	5%	10%	15%	20%	25%
	Percentage Passing by Mass				
63.000	100.00	100.00	100.00	100.00	100.00
40.000	92.78	93.13	93.43	93.71	93.96
20.000	65.20	66.25	67.71	69.06	70.30
10.000	45.54	47.86	50.13	52.21	54.12
4.750	38.60	39.32	41.96	44.38	46.60
2.360	32.23	33.61	36.49	39.14	41.57
1.180	22.59	24.67	27.95	30.95	33.71
0.075	5.62	5.73	5.83	5.92	6.00

Table 4.Summary of sieve analysis of soil aggregate mix (Quarry 2)

Sieve size mm	Fines content in soil aggregate mix				
	5%	10%	15%	20%	25%
	Percentage Passing by Mass				
63.000	100.00	100.00	100.00	100.00	100.00
40.000	92.72	93.50	93.79	94.05	94.28
20.000	62.35	64.40	65.95	67.37	68.67
10.000	44.29	46.41	48.74	50.88	52.84
4.750	37.51	38.35	41.03	43.48	45.75
2.360	32.02	32.34	35.28	37.98	40.46
1.180	26.80	27.70	30.84	33.72	36.38
0.075	10.36	10.49	10.39	10.29	10.20

Table 5.Summary of gradation of aggregate mix

S. No.	Fine %	D_{60}	D_{30}	D_{10}	C_u	C_c	USCS Soil Classifi-cation
Quarry 1	No Fines	18	3.50	0.220	81.81	3.09	GP
	5	17.5	3.20	0.120	92.36	2.06	GP
	10	17	1.80	0.150	113.33	1.27	GW-GM
	15	16	1.60	0.130	123.00	1.23	GM
	20	15	1.16	0.120	125.00	0.75	GM
	25	14	0.80	0.110	127.27	0.42	GM
Quarry 2	No Fines	20	3.80	0.075	266.67	9.62	GP
	5	19	2.60	0.075	256.34	2.42	GP
	10	18	1.80	0.075	240.00	2.40	GW-GM
	15	18	1.20	0.075	240.00	1.06	GM
	20	16	0.79	0.070	228.60	0.56	GM
	25	15	0.60	0.070	214.28	0.34	GM
GP-Poorly Graded Gravel GW-Well Graded Gravel GM-Silty Gravel GW-GM-Well Graded Gravel with Silt							

The gradation of soil aggregate mix and soil mix classification according to USCS soil classification system is given in Table 5.

Conclusion

In this research, mixture of aggregate sub-base material with fines was investigated. Accordingly the required lab tests were conducted with the samples recovered from the two quarries located in the Bagmati District. The samples were prepared in the laboratory mixing fines at an increment of 5%. The conclusion reached in relation to compaction and soaked CBR with fine having LL= 26.7%, PL= 21.5%, PI= 5.2% and classified as ML i.e. Low Plastic Silt by USCS soil classification system is summarized as follows:

For Quarry 1 (Tika Bhairb)

- The gradation of aggregate mix at 15% fine content is obtained i.e. D_{60}, D_{30}, D_{10} are 17, 1.8, 0.15 respectively with Cu= 113.33 and Cc= 1.27.
- For quarry 1 at 15% fine content maximum value of dry density is achieved as 2.4 gm/cc at optimum moisture content of 8.05%.
- The result of CBR test also indicates maximum value

of CBR is 60% at 15% fine content where Dry density is also maximum i.e. 2.4 at an optimum moisture content of 8.05%.

For Quarry 2 (Bhimphedi)

- The gradation of aggregate mix at 10% fine content is obtained i.e. D_{60}, D_{30}, D_{10} are 18, 1.8, 0.075 respectively with Cu= 240 and Cc= 2.4.
- At 10% fine content maximum value of dry density is achieved as 2.39 gm/cc at optimum moisture content of 8.06%.
- The result of CBR test also indicates maximum value of CBR is 60% at 10% fine content where Dry density is also maximum i.e. 2.39 at an optimum moisture content of 8.06%.

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ISSN: 2455-3190
DOI: https://doi.org/10.24321/2455.3190.201904