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Technical Note

Use of AASHTO classification to evaluate soils for road construction in Jamaica, West Indies

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Abstract

The engineering properties of selected soil samples from Upper St Andrew, Jamaica and their suitability as sub-grades and sub-bases for road construction are presented. A few soil samples are potentially good for sub-bases (17 out of 42), namely the highly granular, non-plastic to low plasticity soils developed over highly fractured, slightly weathered igneous lithologies, coarse clastics or limestones. Clay-rich soils are unsuitable as sources of sub-grades. These were either bauxitic clays or clays within Alluvial Terrace and Alluvial Deposits, developed over mudrocks or highly altered igneous lithologies. Coarse granular soils with low plastic fines, developed over moderately weathered igneous lithologies or interbedded mudrocks and coarse clastics rated fair to poor as sub-grades but may be suitable if adequately drained and compacted and additional thicknesses of base courses added.

Introduction

The study area is located on the southwestern flank of the Blue Mountains in southeastern Jamaica (Fig. 1). Several roads transect this area, all following tortuous paths across the hillslopes. These roads generally have low to moderate traffic volumes and provide access to residents, re-forestation and watershed management projects, agricultural sites, and other multiple uses where access is required.

The sub-bases and sub-grades used as foundation materials in all of these roads were in situ soils. These frequently fail and all roads (except those over limestones) show widespread foundation failures. The severity of this problem is such that along some roads

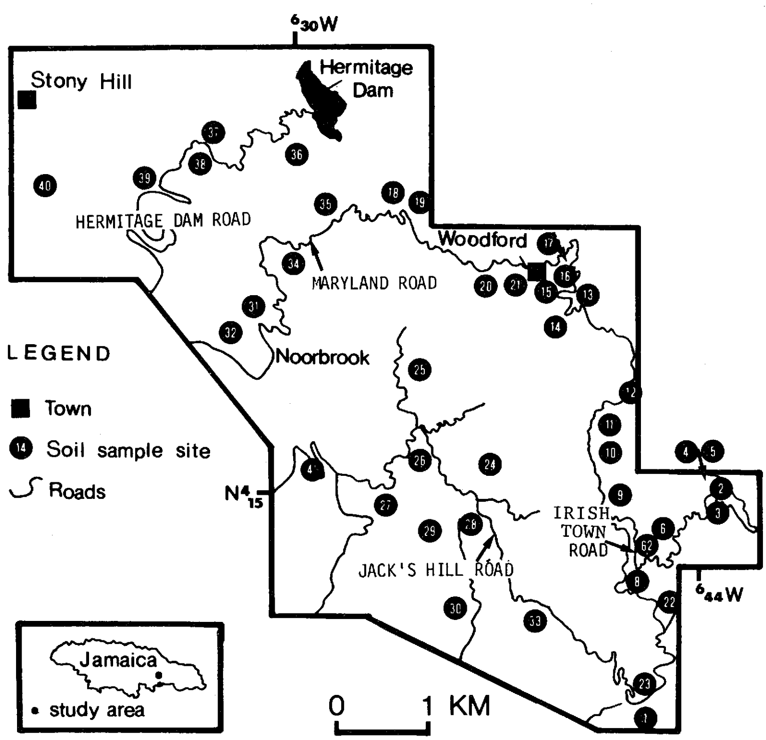

FIG. 1. Location map of the study area and soil sample sites.

there have been forty failures per unit length, ranging from a few metres to tens of metres long.

This technical note presents the results of investigations on the engineering evaluation of selected soils in the area as potential sources of road sub-grades and sub-bases. It is envisaged that this data will give some insight into the suitability of these soils as road foundation materials and be used as a guide to road design and construction in this upland watershed.

Methodology

Forty-two soils were sampled from a variety of lithologies and geotechnical units using a hand auger. Figure 1 shows the location and numbers of these samples.

Laboratory testing, geotechnical descriptions and evaluation of the soils as sub-bases and sub-grades conformed to the American Society for Testing Materials (ASTM 1982) Standard D3282-73, recommended by the American Association State Highway and Transport officials (AASHTO 1961) Standard No. M-145 as the 'Standard Recommended Practice for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes'. The description of weathering grades of soil and bedrock, fracturing and lithologic descriptions of bedrock follows those recommended by the International Association of Engineering Geology Commission on Engineering Geological Mapping (1981).

Brief geotechnical framework

The geological character of the area is dominated by highly deformed lithologies of the Wagwater Group (conglomerates, breccias, sandstones, mudstones and limestones of the Wagwater and Richmond Formations and volcanics of Newcastle Volcanic Formation; Geological Survey Division 1974). White limestones, granodiorites, minor igneous intrusions and altered andesites also outcrop in the area, with several Old Landslide Deposits and Recent Alluvium and Terrace deposits (Geological Survey Divison 1974; Fig. 2). Numerous sections have been faulted, producing steep slopes generally 20° to 30°. Elevations range from less than 150 m in the southwest to more than 600 m in the northeast of the study area.

The bedrocks are generally moderately to highly

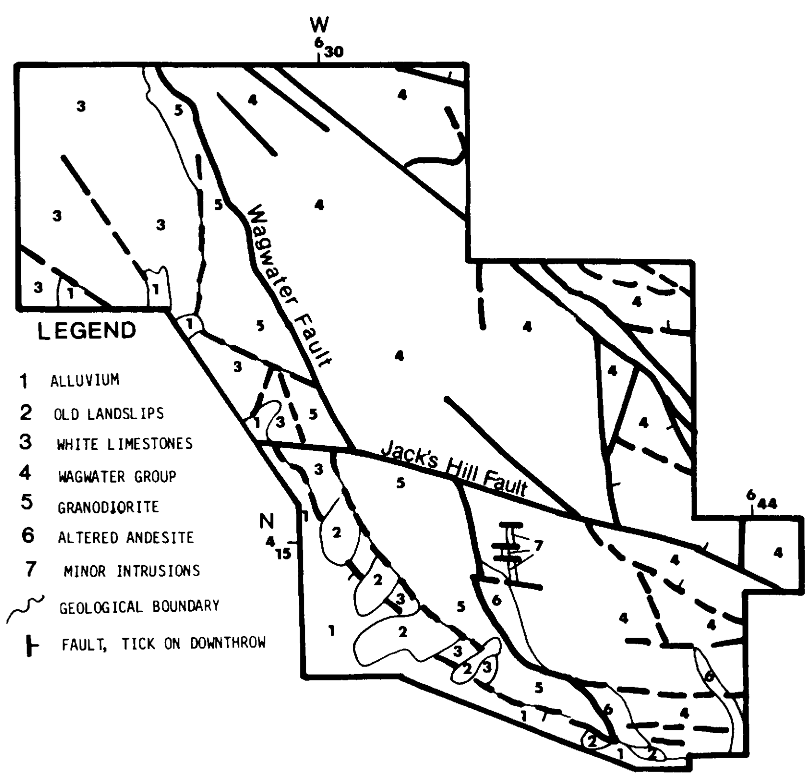

FIG. 2. Simplified geological map of the study area.

TABLE 1. *Results of geotechnical analyses and AASHTO (1961) and ASTM (1982) classification as sub-grades and sub-bases for each sample*

Soil sample numbers	Percent passing no. 200 sieve (75 µm) F	Liquid limit (w_L)	Plasticity index (PI)	Partial Group Index for w_L	Partial group Index for PI	Group Index (GI)	AASHTO soil class	$w_L > 40$	PI > 10	GI > 10	Usual types of significant constituents	Rating as sub-grade, sub-base
RM 1 T	95	83	59	26	40.52	66	A-7-6	*	*	*	Clayey soils	V, poor
RM 2 R	25	46	16	−1.85	0.70	1	A-2-7	*	*		Clayey-silty soils	Poor
RM 3 R	10	20	2	−2.20	0.16	0	A-2-4				Silty-clayey sand	Good
RM 4 W	24	28	13	−1.50	0.27	0.27	A-2-6		*		Silty-clayey sand	Poor–fair
RM 5 R	16	39	20	−2.34	0.80	1	A-2-6		*		Silty-clayey sand	Good–fair
RM 6 R	22	50	22	−1.97	1.45	2	A-2-7	*	*		Silty-clayey sand	Poor
RM 6,2 R	40	47	16	2.91	1.94	5	A-7-5	*	*		Clayey soils	Poor
RM 7 R	26	35	14	−0.75	0.62	1	A-2-6		*		Silty-clayey sand	Poor–fair
RM 8 W	23	28	16	−0.44	1.01	1	A-2-6		*		Silty-clayey sand	Poor–fair
RM 9 W	24	25	10	−0.58	0.00	0	A-2-4				Silty-clayey sand/gravel	Good–fair
RM 10 W	22	34	13	−1.27	0.37	0.37	A-2-6		*		Silty-clayey sand	Poor–fair
RM 11 R	23	NA	NA	NA	NA	0	A-2				Silty-clayey sands/gravels	Good
RM 12 R	13	36	24	−3.40	0.13	0.13	A-2-6		*		Silty sands	Poor–fair
RM 13 R	9	41	16	−4.93	−0.20	0	A-2-7	*	*		Silty sands	Poor–fair
RM 14 N	12	NA	NA	NA	NA	0	A-2				Silty-clayey sands/gravel	Good
RM 15 N	13	NA	NA	NA	NA	0	A-3 or A-1				Silty sands/gravels	Good
RM 16 N	12	NA	NA	NA	NA	0	A-2		*		Silty-sands gravels	Good
RM 17 N	51	34	10	3.38	0.00	4	A-4				Silty-clayey soils	Poor
RM 18 W	15	25	5	−2.01	−0.18	0	A-2-4				Silty-sands/gravels	Good–fair
RM 19 W	16	22	1	−1.56	−0.52	0	A-2-4				Silty-clayey sands	Good–fair
RM 20 R	60	49	14	9.20	2.30	11	A-7-6	*	*	*	Clayey soils	V. poor
RM 21 R	83	61	38	14.90	19.30	34	A-7-6	*	*	*	Clayey soils	V. poor
RM 22 W	15	NA	NA	NA	NA	0	A-2				Silty-clayey sands/gravels	Good
RM 23 I	9	30	10	−3.82	0.00	0	A-2-4				Silty-clayey sands/gravels	Good
RM 24 W	58	55	49	8.76	20.22	29	A-7-6	*	*	*	Clayey soils	V. poor
RM 25 W	17	37	13	−2.66	0.31	0.32	A-2-6		*		Silty-clayey soils	Poor–fair
RM 26 G	68	63	43	11.93	19.10	30	A-7-6	*	*	*	Clayey soils	V. poor
RM 27 G	25	35	12	1.26	0.25	0.25	A-2-6		*		Silty-clayey sands	Poor–fair
RM 28 A	49	55	31	6.30	9.01	15	A-7-5	*	*	*	Clayey soils	V. poor
RM 29 LS	18	40	19	−2.52	0.66	1	A-2-6		*		Silty-clayey sands	Poor–fair
RM 30 G	14	NA	NA	NA	NA	0	A-1 or A-2				Silty sand	Good
RM 31 G	24	27	11	−0.47	0.16	0.16	A-2-6		*		Silty-clayey sands	Poor–fair
RM 32 L	90	76	45	23.58	28.70	52	A-7-6	*	*	*	Clayey soils	V. poor
RM 33 A	48	50	30	3.25	6.60	7	A-7-6	*	*		Clayey soils	V. poor
RM 34 G	15	20	8	−2.00	0.00	0	A-2-4				Silty-clayey gravel/sand	Good
RM 35 W	15	23	6	−2.30	0.00	0	A-2-4				Silty-clayey gravel/sand	Good
RM 36 W	15	25	6	−2.50	0.00	0	A-2-4				Silty-clayey gravel/sand	Good
RM 37 G	22	19	7	−1.34	−0.21	0	A-2-4				Silty-clayey gravel/sand	Good
RM 38 L	9	NA	NA	NA	NA	0	A-1				Stone fragment, gravel	V. good
RM 39 L	88	77	47	20.41	27.01	47	A-7-6	*	*	*	Clayey soils	V. poor
RM 40 L	90	80	50	22.00	30.00	52	A-7-6	*	*	*	Clayey soils	V. poor
RM 41 L	3	NA	NA	NA	NA	0	A-1				Stone fragment/gravels	V. good

Letters in column one represent underlying geological units: T, Terrace Deposits; R, Richmond Formation; W, Wagwater Formation; N, Newcastle Volcanics; I, Intrusives; G, Granodiorite; A, Altered Andesite; Ls, Landslide Deposits; L, Limestones; NA, no assessment possible.

TABLE 2. *Average range of geotechnical properties, sub-base and sub-grade conditions for soils from each geological unit*

Variables	Wagwater Formation	Richmond Formation	Granodiorite	Newcastle volcanics	Altered andesite	White limestone	Minor acid intrusions	Alluvium and Terrace	Old Land-slide deposits
PGI, w_L	0–19	0–14	0–11	0–4	0–3	0–24	3.82	26	6
PGI, PI	0–20	0–19	0–19	0	1–7	0–30	0.00	40	9
GI	0–29	0–34	0–4	0–4	0–10	0–52	0.00	66	15
AASHTO soil group	A-2-4 to A-7-6	A-2-4 to A-7-6	A-2-6 to A-7-6	A-3 to A-4	A-2-6 to A-7-6	A-1 to A-7-6	A-2-4	A-7-6	A-7-5
Usual constituents	Sands to clay	Sands to clay	Sands to clay	Gravel sands to silts	Sands to clays	Gravels to clays	Sands to gravel	Clays	Clays
AASHTO rating	Good to very poor	Good to very poor	Fair to very poor	Good to poor	Fair to very poor	Good to very poor	Good	Very poor	Very poor

weathered. Highly weathered lithologies are usually mudrocks and altered igneous rocks frequently faulted, metamorphosed or metasomatized. The bedrocks are also highly fractured, especially the competent clastics, limestones and intrusive igneous lithologies.

Results

Table 1 gives the results of particle size analyses, Atterberg limits, partial group indices (PGI) and group indices (GI) and rating as a sub-grade and sub-base for each sample. Table 2 gives the range of these conditions for soils sampled from each geological unit.

AASHTO soil classes

Table 1 indicates the AASHTO soil classes for each soil sample analysed. Of the 42 samples tested, there were 11 silty–clayey sands, 13 silty–clayey sands with gravel, 11 clays, three silty sands and four gravels with stone fragments.

Soils overlying Wagwater Formation are generally coarse and granular, with less than 25% fines (11 samples); there was only one clayey sample. Eight of the soils overlying Richmond Formation are also coarse and granular with fines, although silty–clayey soils are more common than in Wagwater Formation (three samples). Soils over granodiorites, altered andesites, minor intrusions and Newcastle Volcanics are generally sandy with a higher percentage of fine soils in the more weathered and altered lithologies. Old Landslide Deposits generally produce sandy soils with fines. Soils developed within Terrace Deposits are clayey.

Plasticity

Total plasticity ranges from 0 to a liquid limit of 83 (Table 1). Fourteen samples have liquid limits greater than 40, while 24 samples have a plasticity index of greater than 10. Samples with liquid limits greater than 40 also have a plasticity index greater than 10. However, as can be seen in Fig. 3, ten samples have a plasticity index greater than 10 but liquid limit less than 40.

The soils with the highest plasticity are clays developed within Terrace Deposits (sample 1), over mudrocks (samples 6.2, 20, 21), over highly weathered igneous lithologies (samples 26 and 33); or the bauxitic clays developed over limestones (samples 14, 15, 16, 21, 31, 34, 37 and 38). The coarse sedimentary lithologies (samples 18, 19 and 22) are generally more granular and less plastic (Table 1).

Partial group index (PGI) and group index (GI)

Table 1 shows the PGI and GI values for each soil sample. Values for liquid limit range from −4.93 (reported as 0) to 26, while values for plasticity index range from −0.52 (reported as 0) to 41. Group index ranges from zero to 66, the higher values being noted

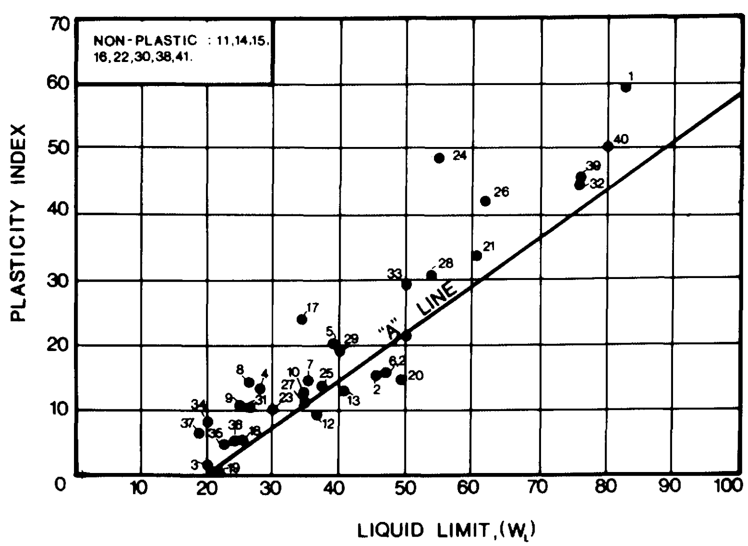

FIG. 3. Casagrande plot of total plastic soil samples with AASHTO (1961) soil groups.

in fine, clay-rich soils of high plasticity, e.g. samples 20, 21, 24, 26, 32 and 41. Nine samples had a GI greater than 10 and six samples had a GI greater than 20. Table 2 shows the range of PGI and GI values for soils over each geological unit.

Sub-grade and sub-base evaluation

The sub-base and sub-grade evaluation of each soil sample is also shown in Table 1. Soils range from very poor to excellent as potential sources of sub-grades and sub-bases. Seventeen out of the 42 samples rate good to very good, those remaining being poor or unsuitable. Very poor soils were clay rich, with liquid limits greater than 40, plasticity indices greater than ten, group indices greater than ten and a percentage of soils finer than 75 µm in excess of 48%. These soils had been developed over highly weathered mudrocks, highly altered and weathered igneous lithologies, bauxitic clays or clays developed within Terrace Deposits e.g. samples 20, 21, 24 and 26. Very good sub-bases were non-plastic soils, with less than 15% finer than 75 µm and with gravel or stone fragments, e.g. samples 40 and 41. Plastic soils fraction with between 15 and 48% finer than 75 µm are fair sub-grade and sub-base materials. These soils have GI values between 0 and 10. Table 2 gives the range of sub-grade conditions for soils over each geological unit.

General discussion

Geotechnical analyses and engineering classification using ASTM (1982) and AASHTO (1961) standards reveal that soils in the Upper St Andrew area show a high degree of variability. Correspondingly, sub-grade ratings are variable, ranging from poor to excellent (Tables 1 & 2).

ASTM (1982) indicates that soils with a liquid limit greater than 10, plasticity indices greater than 10 and greater than 35% finer than 75 µm, may be troublesome. In addition, clayey soils (A-7 group) may be elastic and expansive and thus also cause problems.

Highly weathered soils, developed on mudrocks, altered igneous lithologies or within Alluvium and Terrace Deposits and the bauxitic clays are highly plastic, have high PGI and GI values and subsequently rate very poor to poor as potential sources of sub-bases and sub-grades (samples 1, 6.2, 20, 21, 24, 26, 28, 32, 29 and 40; Table 1).

Slightly to moderately weathered soils, developed on highly fractured bedrock and/or predominantly coarse sedimentary units are coarse, granular and either sandy or gravelly. These soils generally are of low plasticity or non-plastic, have low PGI and GI values and prove satisfactory as sources of sub-grades and sub-bases (samples 11, 14, 15, 16, 18, 19, 22, 30, 34, 36, 38 and 41; Table 1). Further, these soils can be potentially better sources of sub-grades if properly drained, compacted under moderate thicknesses of pavement and if natural or artificial binders are added to particularly gravelly samples in order to increase their effective cohesion and strength.

The generally sandy, moderately weathered soils developed on any type of bedrock, with moderate fracturing and containing less than 15% fine soil, are either of low or intermediate plasticity, have intermediate PGI and GI values and rate as poor to fair sub-bases and sub-grades. These soils are A-2-6 and A-2-7 and are thus potential sources of sub-bases, if properly drained and with adequate road design (samples 7, 10, 12, 13 and 23). However, for optimum field performance, these soils will require a greater thickness of base course than other soil types in order to provide adequate support for traffic load.

According to AASHTO (1961) it may be possible to use soils which rate as unsuitable but only with extreme caution. Adequate drainage and additional sub-base and base layers will be required. Those soils which rate good are potentially better sources of sub-grade, but will still require good roadway drainage, natural or artificial binders and adequate compaction. Soils between these extremes can also be used, with additional sub-layer compaction and proper drainage, particularly if plasticity starts to increase.

It is significant to note that the geological nature of bedrock materials affects the physical properties of the soils developed on them and therefore their potential suitability as sources of road sub-grades and sub-bases. The composition, texture, degree of weathering, alteration and fracturing of lithologies are all important. Increased weathering and alteration results in an increase in the percentage of fine, plastic soils. Similarly mudrocks generally produce fine, plastic and expansive soils, expecially if highly weathered. At the other extreme, coarse igneous and sedimentary lithologies, e.g. sandstones and granodiorites, may produce sandy, non-plastic to low plastic soils, especially if moderately to slightly weathered, whereas highly fractured lithologies may have a high gravel and stone content.

The selection of soils as potential sources of sub-grades and sub-bases is critical as it will affect the performance of foundation materials. Even though soils may rate good to very good as potential sources of sub-grade, adequate road design should not be compromised and maintenance structures should be emplaced. It is significant to note that the performance of the road foundation is only as good as the design, while the design is only good as the data gathered from adequate evaluation and consideration of the geotechnical conditions existing on the site.

Conclusions

Of 42 soil samples analysed, only the highly granular, slightly to moderately weathered soils, developed over highly fractured igneous and coarse sedimentary lithologies and limestones proved satisfactory potential sources of sub-grades and sub-bases (samples 11, 14, 15, 16, 18, 19, 22, 30, 34, 35, 36, 38 and 41).

Highly weathered soils developed over mudstones, altered igneous lithologies, bauxitic clays or clays within Alluvium and Terrace Deposits, contain more than 40% fines and are unsuitable as sources of bases (samples 1, 6.2, 17, 20, 21, 24, 26, 28, 32, 29 and 41). Coarse granular soils with fines are fair to poor sub-base and sub-grade material and may be used with adequate engineering modifications (e.g. samples 7, 10, 12 and 13).

Although a more detailed engineering analysis will be required for actual road design, e.g. compaction and California bearing ratio, the basic soil engineering parameters have a predictable behaviour. These parameters will determine compaction, strength and bearing ratio characteristics, hence basic soils engineering properties are good indicators of their suitability as sub-bases and potential sources sub-grades for road construction (ASTM 1982).

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