REPUBLIC OF THE PHILIPPINES
DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
OFFICE OF THE SECRETARY
MANILA

099.13 DPWH (R)
2-7-94

05 July 1993

DEPARTMENT ORDER)
NO. 329
SERIES OF 1993

2-7-94

SUBJECT: **GUIDELINES ON SOIL SURVEY AND SAMPLING FOR HIGHWAY DESIGN AND SUBSURFACE EXPLORATION FOR DESIGN AND CONSTRUCTION OF FOUNDATION OF BRIDGES**

In order to ensure a rational, safe and economical design and construction of highways and bridges, soil survey and subsurface exploration of any proposed sites for highways and bridges, respectively, should be undertaken before the plans and design are finalized, as part of the preliminary or detailed engineering of the proposed projects.

For the guidance of all concerned, attached are the new Guidelines on Soil Survey and Sampling for Highway Design and Subsurface Exploration for Design and Construction of Foundation of Bridges. The procedures set forth in these guidelines should be followed as closely as possible.

All expenses to be incurred in connection with soil survey and subsurface exploration works are chargeable against funds allocated for preliminary engineering.

This supersedes all circulars and other issuances issued contrary hereto.

This Order shall take effect immediately.

GREGORIO R. VIGILAR
Secretary

Attachment: As stated.

GUIDELINES ON SOIL SURVEY AND SAMPLING FOR HIGHWAY DESIGN AND SUBSURFACE EXPLORATION FOR DESIGN AND CONSTRUCTION OF FOUNDATION OF BRIDGES

OBJECTIVES:

1. The objective of soil survey which is made in connection with the preliminary or detailed engineering study of a proposed highway is to obtain information relative to the distribution and properties of soils, ground water and surface drainage conditions and other pertinent data necessary for a rational and economic design of the highway.

2. The objective of a sub-surface exploration is to determine the arrangement of the soil strata and engineering properties of the underlying soils, particularly strength and deformation characteristics, as well as the soil bearing capacities, in order that a safe and economical foundation may be designed.

I. FOR SOIL SURVEY AND SAMPLING FOR HIGHWAY DESIGN

EQUIPMENT:

A. *Along New Route:*

1. Two (2) post-hole augers, 4-inch diameter
2. Six (6) 3 feet post-hole auger extensions with couplings
3. Two (2) screw type soil augers, 1-1/2" diameter
4. Ten (10) 3 feet soil auger extensions with couplings
5. Two (2) pipe wrenches, 8-inch
6. Two (2) crow bars
7. Four (4) spades
8. Two (2) picks
9. One (1) 50-meter metallic tape
10. One (1) 1.8 meter carpenter's folding rule
11. One (1) roll, 20-inch cross-section paper
12. Supply of sample bags (50 kg. cap.) and sample tags
13. Supply of plastic bags (20 kg. cap.)
14. Supply of marking crayons
15. Roll of twine
16. Record books and pencils
17. Heavy truck

B. *Along Existing Road:*

In addition to the equipment listed under new route, the following shall be included:

1. One (1) sand density cone and bottle
2. One (1) guide plate, 6-inch diameter hole
3. One (1) solution balance, 20 kg. x 1 g.
4. One (1) beam balance, 2 kg. x 1 g.
5. One (1) dozen, moisture content cans
6. One (1) set, portable stove with oven
7. Supply of calibrated sand (10 kg.)

EXPLORATION TEAM:

One (1) - Materials Engineer
Two (2) - Laboratory Technicians
One (1) - Driver
Three (3) - Aides

The above number of personnel may be increased depending upon the nature of the exploration work, length of proposed route, and time allocated for the exploration work.

PROCEDURE:

1. Before starting, obtain information that may be useful in planning and organizing the field work from among the following sources:

   a. Topographic maps
   b. Aerial photographs
   c. Geological maps
   d. Soil maps
   e. Previous laboratory test data
   f. Available engineering or construction data of similar completed structures in the vicinity of the site.
   g. Satellite immageries (land use maps)

2. Conduct reconnaissance investigation along the proposed route to obtain additional information on the probable soil conditions, rock outcrops, nature of terrain, kind of vegetation, and other land features which will influence the planning and organizing the field work, as well as the size of the exploration crew and the equipment to be used.

3. Conduct field exploration by means of auger borings and examination of the soil from test pits or road cuttings. Geophysical methods may also be employed, if warranted.

A. *Along New Route:*

   a. Location of Borings

Borings shall be taken along the proposed centerline. Borings may also be taken along the sides, if necessary.

b. Spacing of Borings

On existing earth roads, auger borings and test pits shall be made along the centerline of the road at an average interval of 250 metres where traffic is greater than 300 vehicles per day or every 500 metres where traffic is less. In widening of existing pavements, borings and test pits shall be located in the area of widening usually below the shoulder. On new roads, auger borings shall be made on the proposed alignment at an average interval of 500 metres for homogeneous strata, and 250 metres for loose or heterogeneous strata and lesser for soft, marshy portions.

c. Depth of Borings

For areas of light cut and fill where there are no special problems, the exploration shall extend to a maximum depth of 1.5 metres below the proposed subgrade. Where deep cuts are to be made, such as large embankment across the marshland or subsurface information indicate presence of weak layers, the depth shall depend on the totpography and nature of the subsoil. On existing earth roads, auger borings and test pits, 1.5 metres deep shall be made along the centerline while on new roads, a boring depth of 2.0 metres on the road alignment shall be made.

B. *Along Existing Road:*

Same as in New Route, but shall include the following:

a. Condition of surfacing, shoulder, back slopes and ditches shall be noted.

b. In areas where there are pavement failures, supplemental borings shall be taken to a depth of at least one (1) meter below the subgrade.

c. Moisture content and density determination shall be performed on the base, subbase, and subgrade.

d. When borings cannot be made along the centerline as in concrete pavements, these may be made along the shoulders. Additional information on the soil profile may also be obtained by visual examination of the backslope.

4. Prepare the log of borings, which shall include the following:

a. Location of each test pit or auger boring

b. Depth of water table

c. Thickness of each soil layer

d. Description of each layer soil according to texture, structure, organic content, relative moisture, and degree of cementation.

e. Location and identification of each sample taken for laboratory test.

f. Location of seepage zones.

5. Explore and sample probable sources of borrow and aggregates along the route and determine the approximate quantity of available materials. Note down also the hauling differences and accessibility.

6. Prepare a sketch of the soil profile similar to the attached sheet.

BORING SAMPLES:

Sufficient sample shall be taken to enable the performance of all the necessary test. The kind and quantity of samples shall be as follows:

a. Disturbed samples

a. 5-10 kg. for classification test
b. 15 kg. for compaction test
c. 50 kg. for CBR test
d. 50 kg. for materials source

b. Undisturbed samples

1 - Shelby Tube sample, full length, for strength or consolidation test.

COMMON LABORATORY TESTS:

1. Mechanical analysis and Atterberg Limits
2. Natural moisture content, field density and compaction test
3. CBR, unconfined compression, and other tests that may be required

APPROXIMATE TOTAL COST PER KILOMETER (Inclusive of salaries, wages, travelling expenses, truck rental, supplies, shipment of samples, and cost of testing)

A. *Along New Route:* (Add 20% if terrain is rugged)

1. Preliminary survey - - - - - - - - - - - - P 13,000.00
2. Detailed survey - - - - - - - - - - - - - P 21,000.00

B. *Along Existing Roadway:*

1. Preliminary survey - - - - - - - - - - - - P 19,000.00
2. Detailed survey - - - - - - - - - - - - - P 26,000.00

Breakdown of the Total Cost per Kilometer

For New Route

Preliminary

Cost of Testing:

Moisture Content Determination	=	P 24.20
Grading	=	54.45
Liquid Limit	=	54.45
Plastic Limit	=	54.45
CBR	=	665.50
Compaction	=	302.50
		P 1,155.55

For four (4) holes per kilometer = P 4,622.20

Salaries and Wages:

1 Materials Engineer	=P	217.50/day
2 Laboratory Technician	=	254.54/day
1 Driver	=	98.00/day
3 Aides	=	375.00/day
1 Core Driller/Machine Operator	=	112.27/day
		P 1,057.31/day

For two (2) days = 1057.31 x 2 days = P 2,114.62

Per Diem = rate x no. of personnel x no. of days
= P 135.00/day x 8 x 2
= P 2,160.00

Equipment Rental/Day:

Rental of equipment, per day or fraction thereof
= Rate/day x no. of days
= 692.12 x 2
= P 1,384.24

Travelling Expenses, Shipment of Samples:
Approx. Cost for Two (2) days
= no. of liters/day x price/liter x no. of days
= 8 x P 10.00 x 2
= P 160.00

Total Estimated Cost:
= 4,622.20 + 2,144.62 + 2,160.00 + 1,384.24 + 160.00
= P 10,441.06

Plus Contingency = 20% of the total estimated cost
= 10,441.06 x 1.2
= P 12,529.27 say P 13,000.00

Detailed

Cost of Testing:

Moisture Content Determination	= P 24.20
Grading	= 54.45
Liquid Limit	= 54.45
Plastic Limit	= 54.45
CBR	= 665.50
Compaction	= 302.50
	P 1,155.55

For seven (7) holes per kilometer = P 8,088.85

Salaries and Wages:

1 Materials Engineer	=P 217.50/day
2 Laboratory Technician	= 254.54/day
1 Driver	= 98.00/day
3 Aides	= 375.00/day
1 Core Driller/Machine Operator	= 112.27/day
	P 1,057.31/day

For three (3) days = 1057.31 x 3 days = P 3,171.93

Per Diem = rate x no. of personnel x no. of days
= P 135.00/day x 8 x 3
= P 3,240.00

Equipment Rental/Day:

Rental of equipment, per day or fraction thereof
= Rate/day x no. of days
= 692.12 x 3
= P 2,076.36

Travelling Expenses, Shipment of Samples:

Approx. Cost for Three (3) days
= no. of liters/day x price/liter x no. of days
= 8 x P 10.00 x 3
= P 240.00

Total Estimated Cost:
= 8,088.85 + 3,171.93 + 3,240.00 + 2,076.36 + 240.00
= P 16,817.14

Plus Contingency = 20% of the total estimated cost
= 16,817.14 x 1.2
= P 20,180.57 say P 21,000.00

For Existing Route

Preliminary

Cost of Testing:

Grading	= 54.45
Liquid Limit	= 54.45
Plastic Limit	= 54.45
CBR	= 665.50
Compaction	= 302.50
	P 1,131.35

Additional Tests:

Field Density (Base, Subbase, Subgrade)
= 181.50 x 3 = P 544.50

Moisture Content (Base,Subbase, Subgrade)
= 24.20 x 3 = P 72.60

For four (4) holes per kilometer = P 6,993.80

Salaries and Wages:

1 Materials Engineer	=P 217.50/day
2 Laboratory Technician	= 254.54/day
1 Driver	= 98.00/day
3 Aides	= 375.00/day
1 Core Driller/Machine Operator	= 112.27/day
	P 1,057.31/day

For three (3) days = 1057.31 x 3 days = P 3,171.93

Per Diem = rate x no. of personnel x no. of days
= P 135..00/day x 8 x 3
= P 3,240.00

Equipment Rental/Day:

Rental of equipment, per day or fraction thereof
= Rate/day x no. of days
= 692.12 x 3
= P 2,076.36

Travelling Expenses, Shipment of Samples:

Approx. Cost for Three (3) days
= no. of liters/day x price/liter x no. of days
= 8 x P 10.00 x 3
= P 240.00

Total Estimated Cost:
= 6,993.80 + 3,171.93 + 3,240.00 + 2,076.36 + 240.00
= P 15,722.09

Plus Contingency = 20% of the total estimated cost
= 15,722.09 x 1.2
= P 18,866.51 say P 19,000.00

Detailed

Cost of Testing:

Moisture Content Determination	= P 24.20
Grading	= 54.45
Liquid Limit	= 54.45
Plastic Limit	= 54.45
CBR	= 665.50
Compaction	= 302.50
	P 1,155.55

Additional Tests:

Field Density (Base, Subbase, Subgrade)
= 181.50 x 3 = P 544.50

Moisture Content (Subbase, Subgrade)
= 24.20 x 2 = P 48.40

For seven (7) holes per kilometer = P 12,239.15

Salaries and Wages:

1	Materials Engineer	=P 217.50/day
2	Laboratory Technician	= 254.54/day
1	Driver	= 98.00/day
3	Aides	= 375.00/day
1	Core Driller/Machine Operator	= 112.27/day
		P 1,057.31/day

For three (3) days = 1057.31 x 3 days = P 3,171.93

Per Diem = rate x no. of personnel x no. of days
= P 135.00/day x 8 x 3
= P 3,240.00

Equipment Rental/Day:

Rental of equipment, per day or fraction thereof
= Rate/day x no. of days
= 692.12 x 3
= P 2,076.36

Travelling Expenses, Shipment of Samples:

Approx. Cost for Three (3) days
= no. of liters/day x price/liter x no. of days
= 8 x P 10.00 x 3
= P 240.00

Total Estimated Cost:
= 12,239.15 + 3,171.93 + 3,240.00 + 2,076.36 + 240.00
= P 20,967.44

Plus Contingency = 20% of the total estimated cost
= 20,967.44 x 1.2
= P 25,160.93 say P 26,000.00

II. FOR SUBSURFACE EXPLORATION FOR DESIGN AND CONSTRUCTION OF FOUNDATION OF BRIDGES

METHODS OF EXPLORATION:

The most widely used method is by boring and/or drilling holes into the ground from which samples are obtained, either, for visual inspection or laboratory testing. Several procedures are used to drill the holes and to obtain the soil samples.

For light structures, test pits of sufficient size wherein the various soils above water table could be examined and sampled may suffice.

In-situ tests may also be performed directly on the foundation soil. Some of the most common are:

a. Vane Shear tests - to determine in-situ shear strength of soft to medium clays by pushing a small, four bladed vane attached to the end of a rod into the undisturbed clay and measuring the maximum torque necessary for rotation.

b. Plate Bearing tests - to determine soil bearing capacity by loading a steel plate, usually 30 inches in diameter, at different increments to values in excess of the design load, and measuring corresponding settlements.

c. Pile Load tests - to determine pile bearing capacity by loading one or more piles and measuring settlement under load to values in excess of the design load.

In major structures, the borings and in-situ tests may be supplemented by geological studies and geophysical methods of exploration, such as electrical resistivity and seismic.

PLANNING OF EXPLORATION:

A plan or program of work is prepared prior to actual performance of exploration. The program should include depth and location of boring, procedures to be used, and establishment of methods of soil sampling and tests to be done.

The cost of exploration is estimated from the program of work.

DEPTH OF EXPLORATION:

Borings shall be carried to a minimum depth of 20 metres below the river bed in ordinary soil and 3 metres in bedrocks.

SPACING AND NUMBER OF BORINGS:

A minimum of two (2) deep borings shall be made at each abutment and an additional boring at each pier for multi-span bridges. Penetration tests shall be made at a maximum interval of 1.5 metres and at every change of soil stratum.

BORING EQUIPMENT AND SUPPLIES:

1. Drilling outfit, complete with drilling machine, water pump, tripod, drill rods, casing pipes, core barrels, drill bits, tools and accessories.

2. Standard split-spoon sampler and 140-lb. drop hammer with guide.

3. Shelby tube sampler and Shelby tubes.

4. Hand auger with extensions.

5. Plastic bags, sealing wax, identification tags, marking crayons, 20-inch cross-section paper, boring log and report forms.

BORING CREW:

One (1) - Materials Engineer
One (1) - Sr. Mechanic
One (1) - Sr. Core Driller
One (1) - Core Driller
Three (3) - Core Drill Aide

BORING PROCEDURE:

1. Start drilling test hole using the high-speed revolving bit and circulating water to remove cuttings. (The hand auger may be used at the start to open the test hole from the ground surface down to a practical depth above the water).

2. As drilling progresses, especially through soft clays and sands below the water table, keep the test hole open by inserting or driving pipe casings into the hole as required to prevent caving.

3. Note any change in soil strata by examining the cuttings carried by the drilling water as drilling operation goes on.

4. Obtain representative samples (disturbed) from hand auger borings, core barrel and split-spoon sampler whenever a change in soil layer is noted and/or at every 1.5 meters interval. The samples obtained shall be examined visually, roughly classified, identified and placed in plastic bags for shipment to the laboratory.

5. Measure the relative density or relative consistency of the soil strata at every 1.5 meter depth interval by means of the Standard Penetration Test as follows:

   a. Clean out the bore hole to test elevation with the circulating drill water. Casing shall not be driven below test elevation.

   b. Remove core barrel and attach the standard split spoon sampler to the drill rod, and lower it to the bottom of the hole.

   c. First, drive the spoon 6 inches into the soil with the 140-lb. hammer dropping freely 30 inches to ensure that the cutting edge is seated in virgin material. Record the number of blows to seat the spoon.

   d. Then, proceed driving the sampler an additional 12 inches or 60 to 70 blows of the hammer have been applied. Record the number of hammer blows for every 6 inches penetration. The total number of hammer blows required to drive the sampler 12 inches is the penetration resistance, N, of the soil.

PRECAUTION: If the sampler does not penetrate at all after 10 blows, stop the penetration test to avoid damaging the sampler. Continue core drilling before making another penetration test.

If the sampler is driven less than 18 inches total, the N-value shall be the number of blows for the last 12 inches of penetration. If less than 12 inches is penetrated, state the number of hammer blows and the measured depth of penetration. Refusal shall be considered to have been reached when the rate of advance of the sampler is less than one (1) inch for 50 blows. Refusal may indicate a highly compacted soil, a boulder or rock.

e. Raise samples to the surface and detach from the drill rod. Remove the soil from the sampler, examine, classify roughly and place in a plastic bag properly identified and tagged for shipment to the laboratory.

6. Whenever layers of cohesive, fine-grained soils are encountered during the boring operation, obtain undisturbed samples of the material at every change in soil strata and at interval of not more than 1.5 meter if the soil deposit is thick. The procedure for obtaining undisturbed sample is as follows:

a. Clean out the hole to sampling elevation with the circulating drill water. Casing pipes shall not be driven below sampling elevation.

b. Remove core barrel and attached the thin-wall tube sampler (Shelby Tube) to the drill rod, and lower it to the bottom of the hole.

c. Push the tube sampler into the undisturbed soil gradually and continuously without impact or twisting. In no case shall the tube sampler be pushed further than the length provided for the soil sampler.

When pushing will not penetrate the tube sampler sufficiently for recovery, a heavy weight may be used to drive tube sampler. The weight, height and number of blows shall be recorded.

d. Before withdrawing the tube sampler, twist the rod at least two revolutions to shear the sample off at the bottom.

e. Raise the rod out of the hole to the ground surface and detach the tube sampler from the rod.

f. Remove the disturbed material at both ends of the tube and immediately seal both ends with sufficient thickness of wax before shipping to the laboratory.

g. Care should be taken to prevent the tube samples from dropping sharply. The samples should be encased in cushioning material during transport.

7. Whenever hard of rock strata is encountered, obtain core samples by core drilling, and record the percentage of recovery. The percentage of recovery is equivalent to the length of core sample recovered divided by te advance in depth of the drill rod during the taking of the core sample.

8. Keep records of ground water table for each test hole. For the location of the water table, the depth from the ground surface in sands may be measured 30 minutes after pulling up the casing pipes. For less previous soils, the depth shall be measured 24 hours after the removal of the casing pipes.

PRESENTATION OF EXPLORATION DATA:

The data obtained from the surface from the subsurface exploration work shall be reported by the Materials Engineer in the Subsurface Exploration Field Record, see attached form. In addition, a sketch of the boring layout in plan view indicating the number and location of each hole, as referred to the stationing in the plans, shall be accomplished.

As unusual conditions noted, such as, loss of drilling water, upward boiling of bottom of boring, obstructions and difficulties encountered, shall be reported.

QUANTITY OF SIZE OF BORING/DRILLING SAMPLES:

The weight of disturbed samples from hand-auger, core barrel or split-spoon or drilling shall be at least one (1) kg. Undisturbed samples from Shelby tube or other shall be at least eighteen (18) inches long.

LABORATORY TESTING:

Laboratory test on soils may be grouped into two general classes:

1. Classification and soil bearing capacity tests, which may be run on either disturbed or undisturbed samples.

2. Quantitative tests, for shear strength and compressibility, which must be made on undisturbed samples.

The most commonly used test in the two groups are:

1. **Classification Tests**

   a. Mechanical analysis - to determine particle size distribution.

   b. Atterberg Limits - to determine plasticity of cohesive soils.

c. Particle specific gravity.

d. Organic Content.

2. **Quantitative Tests**

a. Unconfined and Triaxial Compression - to determine soil strength parameters.

b. Consolidation - to determine time-settlement characteristics.

c. In-place unit weight.

d. Natural water content.

COST OF BORING:

The cost of boring of subsurface exploration for a bridge site can only be approximated, as it depends on several factors, such as accessibility and location, number of test holes, type and thickness of materials encountered, depth of boring, and extent of sampling and laboratory testing.

Generally, under normal conditions, it will cost approximately P 21,000.00 per test hole for a boring of about 30 meters depth. This is inclusive of salaries, wages, travelling expenses, shipment of equipment, supplies and shipment of samples.

Breakdown of the Total Cost Per Test Hole (30 m. depth)

Mobilization = P 3,000.00

Demobilization = P 3,000.00

Drilling through ordinary soil per linear meter = P 500.00

Total Cost per Test Hole Per 30 m. Depth

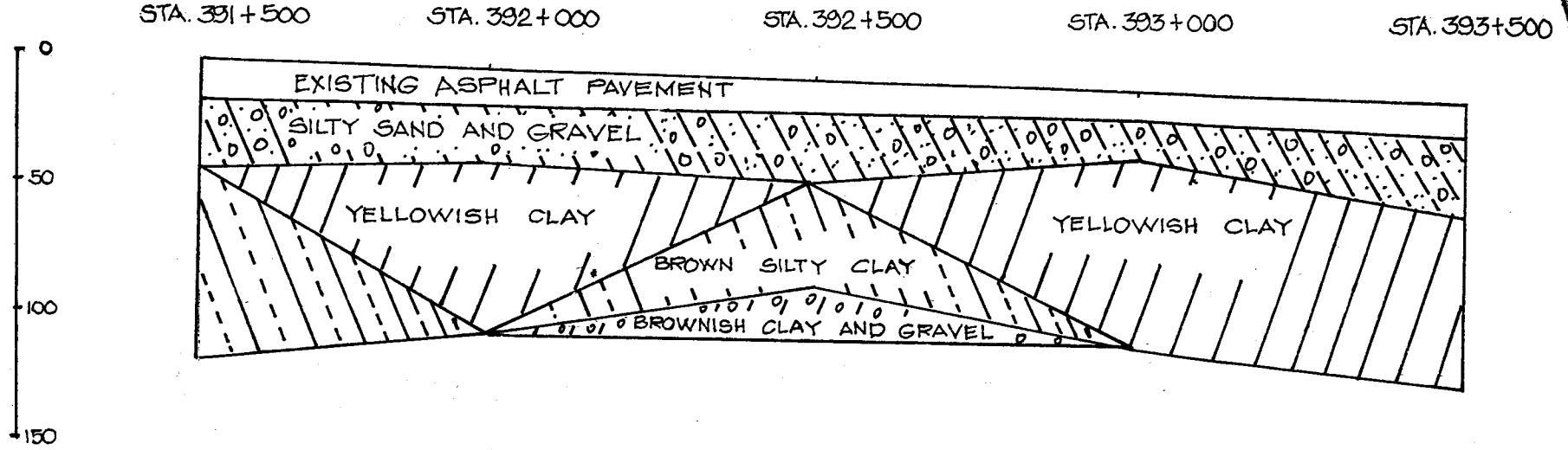
= Depth x Drilling through ordinary soil per 1.m. + Mobilization + Demobilization

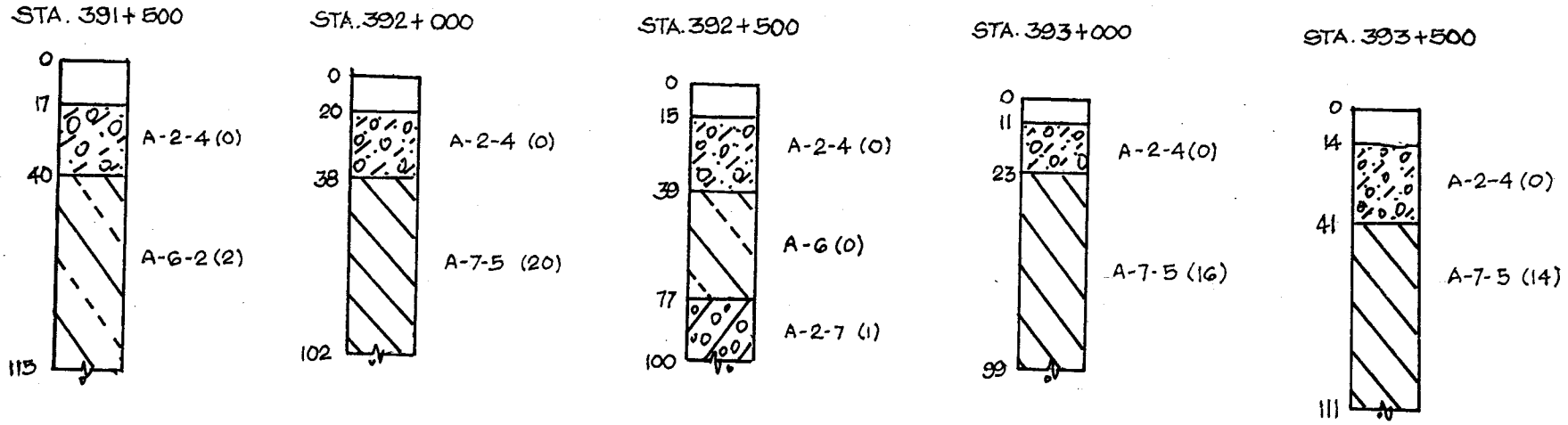
= 30 m. x 500.00 + 3,000.00 + 3,000.00

= P 21,000.00

Note:

Add P 1,000.00 for hole to hole transfer, per hole.





SOIL PROFILE

SUBSURFACE EXPLORATION FIELD RECORD
(SPLIT SPOON AND UNDISTURBED SAMPLING)

PROJECT _____ (NAME) (Km, STATION AND ROUTE) PROVINCE

BORING NO. AND LOCATION _____

SURFACE ELEVATION _____ WATER-TABLE AFTER 24 HOURS _____

TIME AND DATE STARTED _____ TIME AND DATE COMPLETED _____

LEGEND FOR SYMBOLIC CHART

SAMPLE NO.+	DEPTH FROM SURFACE IN METERS	SYMBOLIC CHART	VISUAL IDENTIFICATION OF SOIL AND REMARKS INDICATE COLOR AND TEXTURE OF SOIL AND OBSERVATION OF DRILLINGS	PENETRATION RESISTANCE NO. OF BLOWS 1st 6" 152.4mm	2nd 6" 152.4mm	3rd 6" 152.4mm	% RECOVERY (ROCK)
	1						
	2						
	3						
	4						
	5						
	6						
	7						
	8						
	9						
	10						
	11						
	12						
	13						
	14						
	15						
	16						
	17						
	18						
	19						
	20						
	21						
	22						
	23						
	24						
	25						
	26						

NOTE: + FOR UNDISTURBED SAMPLES PLACE (U) AFTER THE SAMPLE NO. AS 1 (U)

CALYX DRILL NO: _____

SR. CORE DRILLER: _____ SUBMITTED BY: _____
SOIL ENGINEER

SR. MECHANIC: _____

DATE SUBMITTED: _____

SUBSURFACE EXPLORATION FIELD RECORD
(SF : SPOON AND UNDISTURBED SAMPLING)

PROJECT _____ (NAME) (Km, STATION AND ROUTE) PROVINCE

BORING NO. AND LOCATION _____

SURFACE ELEVATION _____ WATER TABLE AFTER 24 HOURS _____

TIME AND DATE STARTED _____ TIME AND DATE COMPLETED _____

LEGEND FOR SYMBOLIC CHART

SAMPLE NO.+	DEPTH FROM SURFACE in METERS	SYMBOLIC CHART	VISUAL IDENTIFICATION OF SOIL AND REMARKS INDICATE COLOR AND TEXTURE OF SOIL AND OBSERVATION OF DRILLINGS	PENETRATION RESISTANCE NO. OF BLOWS 1st 6" 152.4mm	2nd 6" 152.4mm	3rd 6" 152.4mm	% RECOVERY (ROCK)
	1						
	2						
	3						
	4						
	5						
	6						
	7						
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NOTE: + FOR UNDISTURBED SAMPLES PLACE (U) AFTER THE SAMPLE NO. AS 1 (U)

CALYX DRILL NO: _____

SR. CORE DRILLER: _____ SUBMITTED BY: _____
SOIL ENGINEER

SR. MECHANIC: _____

DATE SUBMITTED: _____