RELATÓRIO GEOTÉCNICO

DADOS DE PESQUISA

PORTO DO RIO DE JANEIRO

BAÍA DA GUANABARA

Relatório Fugro Nº VOO-002-REP-001

EDIÇÃO 3-PT

Van Oord Serviços de Operações Marítimas Ltda.

RELATÓRIO GEOTÉCNICO
DADOS DE PESQUISA
PORTO DO RIO DE JANEIRO
BAÍA DA GUANABARA

Cliente	Van Oord Serviços de Operações Marítimas Ltda.
Endereço do Cliente	Rua da Assembleia, 11, 6º andar Centro, Rio de Janeiro 20.011-001 Rio de Janeiro
Relatório Fugro Nº	**VOO-002-REP-001(3-PT)**
Confidencialidade	A distribuição do relatório é restrita aos participantes do projeto aprovados pelo cliente

Resumo:

Este relatório apresenta resultados da prospecção geotécnica marinha e fornece classificação geotécnica do solo na área planejada para o alargamento, por meio de dragagens, do canal atual de acesso ao porto do Rio de Janeiro, na Baía da Guanabara, Rio de Janeiro. A profundidade da lâmina d'água nos locais dos furos varia aproximadamente entre 1,6 m e 13,0 m com respeito à DHN.

As informações geotécnicas apresentados neste relatório incluem:

– Boletins de sondagem de 17 furos com diferentes profundidades
– Descrição visual das amostras de todos os solos e rochas coletadas
– Resultados de ensaios de laboratório
– Relatórios de posicionamento.

A pesquisa geotécnica indicou que os solos nos locais pesquisados consistiram argila muito mole a argila arenosa na superfície, sobrepondo-se a argilas arenosas rijas a duras na maioria dos furos de sondagem. Em alguns locais, camadas de areia e cascalho foram encontradas dentro de argilas duras. Foi também encontrado solo residual de Gnaisse a Gnaisse muito alterado, muito incoerente e baixa resistência.

Edição relatório nº	Data	Status do relatório	Aprovado
1	19-Jun-2015	Relatório de Campo – Prospecção Geotécnica Marinha	PTM
2	10-Jul-2015	Relatório fatual – Prospecção Geotécnica Marinha	PTM
3	13-Jul-2015	Relatório Final	PTM

Van Oord Serviços de Operações Marítimas Ltda.
Rua da Assembléia, 11, 6º andar
Centro, Rio de Janeiro
20.011-001 Rio de Janeiro

A/C: Sr. Joop Rijkers

Nossa ref.: VOO-002-REP-001 (2)

Rio de Janeiro, 15 de julho de 2015.

RELATÓRIO GEOTÉCNICO – DADOS DE INVESTIGAÇÃO
PORTO DO RIO DE JANEIRO - BAÍA DA GUANABARA

Este relatório apresenta dados de uma campanha de prospecção geotécnica marinha na área da Baía da Guanabara, no município do Rio de Janeiro, RJ. O relatório foi preparado em conformidade com o contrato nº C1721 de 24 de abril de 2015.

O membro da equipe principal na preparação do relatório foi a Srta. M. Vieira (Geóloga do Projeto). A Sra. P. Tulha Moutinho (Engenheira Geotécnica Sênior) foi a revisora do projeto. Reconhecemos a valiosa ajuda do Sr. M. Van Oord que atuou como contato de campo do cliente para este projeto.

Esta é uma tradução do relatório original em inglês. Qualquer dúvida que possa surgir o original prevalece.

Agradecemos pela oportunidade em atendê-los. Não hesite em nos contatar se precisar de qualquer informação adicional.

Atenciosamente
FUGRO GEOTECNIA MARINHA

Marianna Vieira Marques Vargas

M. Vieira
Geóloga do Projeto

ÍNDICE: Página

CONTROLE DE EDIÇÃO DO RELATÓRIO

Seção	Página nº	Ilustração nº	Edição nº	Revisão
Texto principal	tudo		3-PT	Tradução para português do relatório original em inglês
Ilustrações após o texto principal:		tudo	3-PT	Tradução para português do relatório original em inglês
Seção A	tudo		3-PT	Tradução para português do relatório original em inglês
Ilustrações após Seção A		tudo	3-PT	Tradução para português do relatório original em inglês
Seção B	tudo		3-PT	Tradução para português do relatório original em inglês
Seção C	tudo		3-PT	Tradução para português do relatório original em inglês
Ilustrações após Seção C		C2-1 a C2-34 C2-48 a C2-64	3-PT	Tradução para português do relatório original em inglês

Notas:

1) O número de edição do relatório é o mesmo do mais alto número de edição de qualquer página individual.

2) As páginas deste relatório estão na edição 3-PT.

3) O número no canto inferior esquerdo de cada página mostra o número de relatório Fugro e o número de edição da página. O número entre parênteses indica o número de edição da página.

REGISTRO DE GERENCIAMENTO DA QUALIDADE

Seção do relatório	Preparado por	Revisado por
Texto Principal	MV	PTM
Ilustrações após o texto principal:	MV	PTM
A Boletins de Sondagem	MV	PTM
B Resultados dos Testes In-Situ	MV	PTM
C Resultados dos Ensaios Laboratoriais	MV	PTM
D Dados de Posicionamento e Profundidade da Lâmina d'Água	MV	PTM

Pessoa(s)
MV: Marianna Vieira
PTM: Paula Tulha Moutinho

1. INTRODUÇÃO

1.1 Finalidade do Relatório

A Van Oord Serviços de Operações Marítimas Ltda., doravante denominada Cliente, está planejando a ampliação do canal de acesso ao Porto do Rio de Janeiro na Baía da Guanabara, Rio de Janeiro por meio de dragagens. O local proposto está localizado dentro da Baía da Guanabara. Para tal, o Cliente necessita de informações geotécnicas sobre as condições dos solos no local proposto (ilustração 1-1).

A finalidade do presente relatório é apresentar dados de uma pesquisa geotécnica, realizada por meio de amostragem e de ensaios *in-situ* (SPT), para ajudar com a planejada operação de dragagem do canal.

1.2 Escopo do Relatório

O escopo principal da campanha de prospecção geotécnica inclui o seguinte:

- 14 furos de sondagem incluindo testes padrão de penetração (SPT) e amostras não deformadas de solo, coletadas nas profundidades indicadas pelo cliente no local.
- 1 furo de sondagem incluindo SPTs e amostras não deformadas de solo e rocha
- 1 furo de sondagem incluindo SPTs e amostras de rocha
- 1 furo de sondagem incluindo somente amostras de rocha.

Este relatório factual inclui todas as informações recolhidas durante o trabalho no local e os resultados dos ensaios de laboratório. Consequentemente, o escopo deste relatório inclui:

- Boletins de sondagem de 17 furos com diferentes profundidades
- Resultados SPT
- Resultados de ensaios de laboratório

1.3 Uso do relatório

Este relatório deve ser lido em conjunto com o "Guia para uso de relatório", Seção E.

A Fugro entende que este relatório será usado para a finalidade descrita nesta Seção de "Introdução". Essa finalidade foi um fator significativo na determinação do escopo e nível dos serviços. Os resultados não devem ser usados se a finalidade para o qual o relatório foi preparado ou o cliente propuser alterações no empreendimento ou nas atividades. Os resultados podem, possivelmente, ter usos alternativos. A adequação deve ser confirmada.

2. RESUMO DA CAMPANHA

2.1 Fontes de Informação

As informações fornecidas pelo Cliente incluíram o seguinte:

- detalhes da localização dos furos de sondagem (reproduzidos na Ilustração 1-1)

Este relatório usa e resume informações selecionadas.

2.2 Programa de Prospecção

2.2.1 Posicionamento e Medição da Lâmina d'Água

O sistema geodésico usado para projeção horizontal é o WGS84, projeção UTM, Zona 23 S. As coordenadas e lâminas d'água dos locais de teste estão apresentadas na Ilustração 2-1, nos boletins de furos de sondagem da Seção A e nos relatórios de posicionamento da Seção D.

O posicionamento foi realizado utilizando um sistema de GPS diferencial. O Starfix HP foi usado como o sistema de posicionamento primário. O sistema SkyFix-XP estava a bordo como sistema de posicionamento de reserva.

No furo POR-15, o relatório de posicionamento não foi impresso, assim sendo esse documento não será apresentado na Seção D. As coordenadas atuais são apresentadas na ilustração 2-1 e nos boletins de furos de sondagem da Seção A.

A profundidade da lâmina d'água foi medida usando uma trena com um peso no final. A medição da profundidade da água foi obtida pela diferença de duas medidas: a profundidade da plataforma até ao leito (DML) e a distância a partir do convés da plataforma até a superfície da água (DWL). As medições foram feitas dentro da coluna de perfuração a fim de minimizar o efeito das correntes locais e do vento. As profundidades medidas foram então corrigidas para DHN e esses valores são indicados na Ilustração 2-1 e nos boletins de furos de sondagem na Seção A, como cota da boca do furo de sondagem. A cota da boca do furo é o nível de referência vertical da medição da profundidade da água e dos testes geotécnicos.

O usuário das informações geodésicas apresentadas deve considerar a precisão das medições, especialmente quando o uso puder diferir das intenções originais. Por exemplo, as medições de profundidade da água servem para estabelecer as profundidades da amostragem e testes in-situ abaixo do leito.

2.2.2 Prospecção Geotécnica Marinha

Um projeto específico de prospecção geotécnica foi realizado a partir da plataforma autoelevatória Skate 3C, entre 5 e 12 de junho de 2015.

O Cliente planejou o programa da campanha de prospecção. Durante a campanha, o programa do Cliente foi ajustado para se adequar às condições e restrições operacionais encontradas. O escopo do relatório inclui os resultados das decisões finais.

O programa de amostragem consistiu, na maioria dos locais e, dependendo da profundidade alvo do furo de sondagem, de testes SPT, com coleta de amostras deformadas, amostras não deformadas coletadas com amostradores de 4" e 3" e testemunhos de rocha em formações mais competentes, como rochas fracas a solo residual.

O programa de testes *in-situ* consistiu de SPTs.

Consulte as Seções A e B, respectivamente intituladas "Boletins de Sondagem" e "Resultados dos Testes In-Situ" para obter mais informações sobre amostragem e resultados de testes. Consulte o documento intitulado "*Geotechnical Borehole*", apresentado no Apêndice 1 para obter detalhes sobre os procedimentos.

2.2.3 Manipulação das amostras

As etapas importantes na manipulação da amostra incluem:

- Medição da recuperação da amostra no tubo
- Descrição visual do solo e das rochas coletadas
- Embalagem das amostras para o seu transporte para o laboratório geotécnico em terra. As amostras SPT foram ensacadas e rotuladas e amostras não deformadas foram seladas com cera em ambas as extremidades, rotuladas e armazenados verticalmente, com o topo para cima. As amostras de rochas foram mantidas no interior do revestimento de plástico e colocadas em caixas de plástico adequadas para o seu transporte.

A Seção de relatório intitulada "Resultados de Ensaios de Laboratório" fornecerá mais detalhes sobre a manipulação da amostra.

2.2.4 Ensaios de laboratório

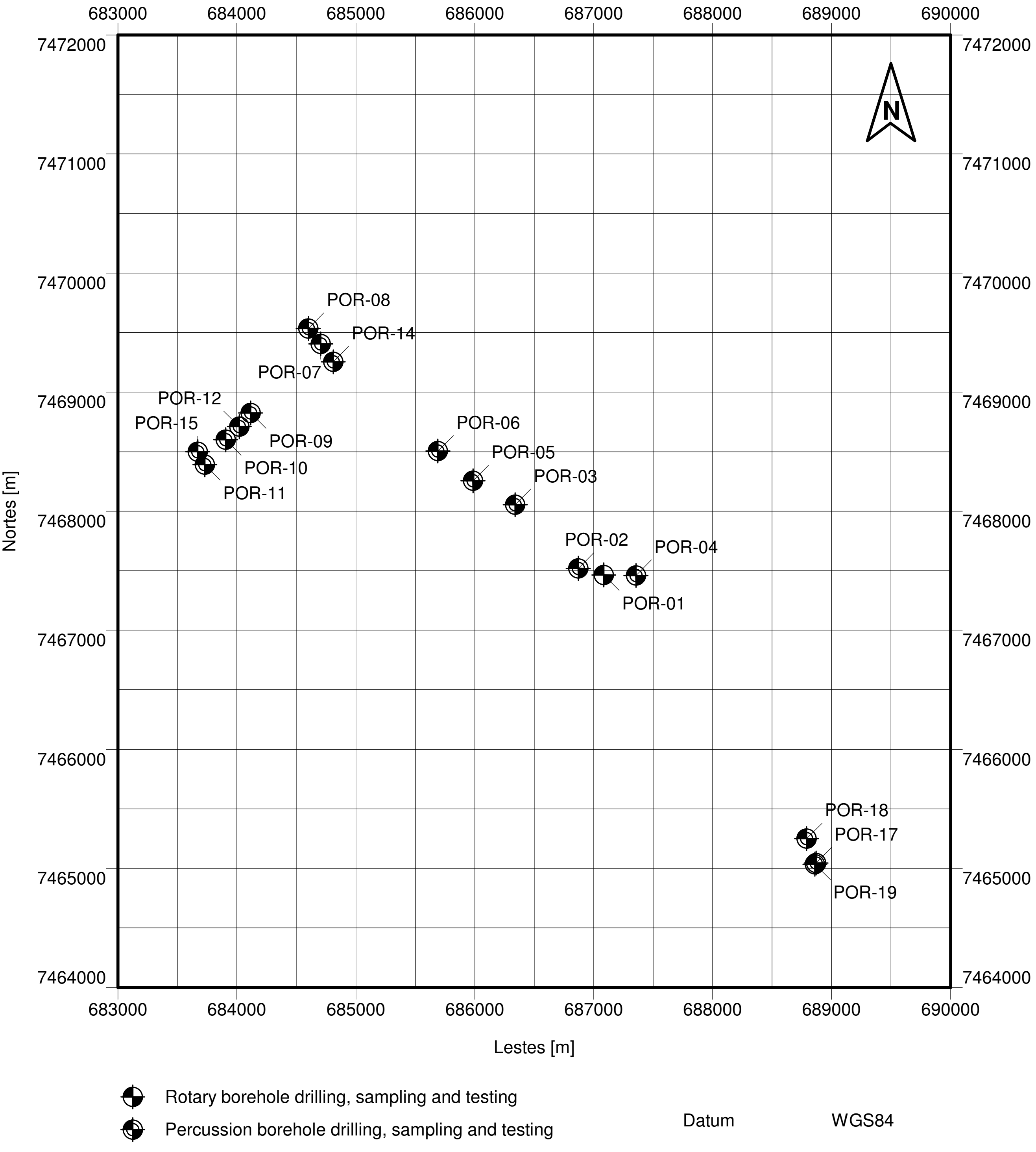
Apenas ensaios básicos para determinar o índice de resistência, como o penetrômetro de bolso (PP) e *torvane* (TV) foram realizados durante a campanha de campo. Todos os outros ensaios foram realizados no laboratório da Fugro em Curitiba e os resultados são apresentados na Seção C deste relatório.

2.3 Processamento de dados geotécnicos

O processamento de dados geotécnicos incluíu:

- Preparação dos boletins de furos de sondagem incluindo número de golpes do SPT e resistência ao cisalhamento não drenado a partir dos testes índice PP e TV e compressão uniaxial (UCS)
- Descrição de estratos integrando a descrição visual de amostras e resultados de testes laboratoriais e *in-situ*

MAPA DA ÁREA
PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA



GeODin-System 3.0 / Detailed location plan.GLO / 16/07/2015 / 17:17:34

LOCALIZAÇÃO DETALHADA DOS FUROS DE SONDAGEM

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Furo	Coordenadas Propostas		Coordenadas Finais		Lâmina d'Água (m)	Lâmina d'Água Corrigida (m)	Elevação (m)
	E	N	E	N			
POR-01	687083	7467467	687084	7467467	12.10	11.11	-11.11
POR-02	686873	7467522	686872	7467520	11.00	9.81	-9.81
POR-03	686339	7468053	686340	7468053	9.10	7.88	-7.88
POR-04	687354	7467461	687357	7467462	11.40	10.31	-10.31
POR-05	685987	7468255	685983	7468255	9.30	8.41	-8.41
POR-06	685689	7468505	685689	7468507	8.00	6.91	-6.91
POR-07	684705	7469406	684705	7469406	5.00	4.56	-4.56
POR-08	684599	7469536	684599	7469536	3.65	2.94	-2.94
POR-09	684116	7468828	684113	7468827	6.90	6.51	-6.51
POR-10	683903	7468599	683904	7468601	4.60	3.51	-3.51
POR-11	683732	7468388	683732	7468392	2.30	1.61	-1.61
POR-12	684017	7468713	684019	7468709	4.70	3.71	-3.71
POR-14	684816	7469259	684812	7469257	9.70	9.41	-9.41
POR-15	683674	7468503	683672	7468500	13.80	13.01	-13.01
POR-17	688870	7465044	688871	7465047	6.80	5.61	-5.61
POR-18	688791	7465249	688791	7465252	6.70	5.91	-5.91
POR-19	688859	7465034	688858	7465034	5.10	3.86	-3.86

* Datum: WGS 84

COORDENADAS E PROFUNDIDADE DA LÂMINA D'ÁGUA

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

SEÇÃO A: BOLETINS DE SONDAGEM

TEXTO - SEÇÃO A: Página

LISTA DE ILUSTRAÇÕES NA SEÇÃO A: Ilustração

A. BOLETINS DE SONDAGEM

A.1 DETALHES

Sempre que duas amostras consecutivas apresentarem o mesmo tipo de solo, correlacionamos e assumimos que o solo entre elas é do mesmo tipo. Quando elas mostram diferentes solos, supôs-se que a camada foi alterada na metade da distância entre as duas amostras. O solo coletado a partir do "*bailer*" durante o avanço do furo de sondagem foi utilizado para ajudar a caracterizar os estratos.

A cada vez que uma amostra pareceu adequada, foram realizados testes de índice de resistência (PP e/ou TV). mesmo em amostras SPT, apesar de consideradas como deformadas. Mesmo em amostras SPT, apesar de consideradas como deformadas.

Os primeiros 50 cm da RC1 e RC2 no furo de sondagem POR-01 são considerados como deformados devido aos SPTs realizados a 1,5 m e 3,0 m, respectivamente.

O furo de sondagem POR-19 não fazia parte do escopo inicial. Esse furo foi incluído para ajudar a caracterizar a área em torno do POR-17 pois foram encontrados fragmentos de rocha e seixos nesse local. Um afloramento de rocha foi observado a cerca de 50 m do local.

Nos furos POR-01 e POR-05 solo residual de Gnaisse foi amostrado. Dentro do solo residual foram encontradas finas camadas de Gnaisse alterado com baixa resistência. No furo POR-19 foi encontrado Gnaisse alterado e com baixa resistência intercalado com solo residual.

Em algumas das amostras coletadas PP e TV não foram realizados por três razões principais: solos muito moles, solos extremamente duros, e argilas muito arenosas ou com conchas.

A.2 COMENTÁRIOS DOS RESULTADOS

A descrição do solo nas amostras indeformadas coletadas é baseada no topo e base de cada amostra.
A amostra coletada na superfície do leito marinho nos furos POR-06, POR-08, POR-10, POR-12, POR-15 e POR-17 não teve recuperação. O solo foi coletado do "*bailer*" durante avanço do furo de sondagem e essas amostras foram consideradas amostras deformadas. As amostras podem ser utilizadas para caracterizar o solo.

A amostra a 7,0 m no furo POR-03 foi substituída por um SPT porque durante o avanço do furo areia grossa a cascalho fino foram observados.

A amostra a 1,0 m no furo POR-11 caiu do tubo amostrador quando a amostra estava no convés. O solo foi recolhido e ensacado.

Um SPT extra foi realizado a 13,5 m no furo POR-11, devido à recuperação curta (40 cm) da amostra a 13.0 m.

A primeira tentativa de tirar uma amostra a 5,5 m no furo POR-12 foi feita com um tubo shelby de 3" e veio sem recuperação. Uma segunda tentativa usando um tubo shelby de 4" coletou uma amostra de 70 cm. A amostra coletada foi considerada como deformada.

A amostra a 2,5 m, no furo POR-14 tinha apenas uma recuperação de 5 cm. A amostra foi ensacada e considerada deformada. Devido à pouca recuperação, outra amostra foi recolhida do "*bailer*", uma vez que era o mesmo tipo de solo.

A amostra a 1,0 m no furo POR-15 recuperou 30 cm de solo no meio do tubo amostrador. Os 25 cm da base caíram. Ao limpar o furo de sondagem, foram coletados dois seixos de quartzo; um com 8 cm e outro com 5 cm, aproximadamente.

A.3 PRÁTICA PARA BOLETIM DE SONDAGEM

Boletim de Sondagem

Finalidade:	Fornecer características geotécnicas das amostras e formações testadas para o alargamento do canal de acesso ao Porto do Rio de Janeiro
Processamento dos Dados e Interpretação:	– Escalas gráficas selecionadas para atender à apresentação geral de dados – Nenhuma exibição de dados fora dos limites do gráfico, i.e. alguns valores podem não ser apresentados – A descrição geotécnica é uma interpretação dos dados processados disponíveis no momento de preparação; por exemplo, as interfaces entre os estratos podem ser mais graduais do que um boletim indica – O nível de detalhe e precisão na descrição geotécnica e interpretação depende de fatores tais como dados de teste, tamanho da amostra, qualidade, cobertura, disponibilidade de informação complementar e exigências do projeto
Correspondência de Amostras e Dados de Teste In-Situ:	Os boletins de sondagem incluem os resultados SPT
Descrição do Solo:	De acordo com o documento intitulado "*Soil Description*" (ref. Fugro FEBV/CDE/APP/005) apresentado no Apêndice 1
Peso Específico Derivado do Teste In-Situ:	– Não aplicável
Densidade Relativa Derivada do Teste In-Situ:	– Consulte o documento intitulado "*Standard Penetration Tests*" (ref. Fugro FEBV/CDE/APP /036.), apresentado no Apêndice 1 – Aplica-se ao solo de granulometria grossa e sem coesão
Resistência Não Drenada Derivada de Teste In-Situ:	– Os resultados SPT dão uma indicação aproximada – Aplica-se a solos de granulometria fina e com comportamento coesivo
Coordenadas e profundidade da água:	Aplicáveis à localização de furo de sondagem
Referência de profundidade da água:	Conforme obtido a partir de medições no início dos testes/amostragem
Correção de referência de profundidade:	Nenhuma aplicada. Aa amostras e testes *in-situ* estão referenciadas à superfície do leito marinho

Referências

– Programa de computador GeODin®, gravação, apresentação e análise de dados geodésicos.
– NBR 6502:1995 – Rochas e solos- terminologia
– NBR 6484:2001 – Solo – Sondagem de Simples Reconhecimento com SPT – Método de Ensaio

A.4 PRÁTICA PARA FURO DE SONDAGEM GEOTÉCNICA

Controle de furo de sondagem

Procedimento Geral:	Consulte o documento intitulado " *Geotechnical Borehole* " (Ref. Fugro . FEBV/CDE/APP/002), apresentado no Apêndice 1
Estágio de Instalação:	Localização, conforme indicado pelo Cliente
Nível de Referência de Profundidade:	Avaliação da precisão de profundidade "*Downhole – Favorable*"; consulte o documento intitulado "*Positioning Survey and Depth Measurement*" (ref. Fugro FEBV/CDE/APP/029) apresentado no Apêndice 1
Perfuração:	Furo aberto por percussão e perfuração rotativa
Amostragem e Testes:	Consulte o Texto Principal e a Seção A para obter detalhes
Monitoramento do Nível de Água no Furo de Sondagem:	Não aplicável
Término do Furo de Sondagem:	O que ocorrer primeiro: – De acordo com as instruções do Cliente – Ao atingir a profundidade alvo dos furos de sondagem – Circunstâncias a critério do operador do equipamento, tais como risco de dano ao equipamento ou risco para a segurança do pessoal
Restauração do Furo:	– Sem preenchimento do furo de sondagem – Deformação do leito marinho – Possibilidade de depressão(ões) do fundo marinho e solo acumulado ao redor da boca do furo

Teste In-Situ – SPT	Consulte a seção de relatório intitulada "Resultados dos Testes In-Situ"

Coleta de Amostra

Equipamento de Inserção do Amostrador:	Unidade com capacidade máxima de empuxo de 60 kN a 80 kN, e taxa de penetração de cerca de 20 mm/s
Equipamento de Reação:	Peso próprio dos tubos de perfuração e mastro
Amostrador de Tubo Aberto	Tubo de amostra cilíndrico com paredes espessas de 3", 80 mm de diâmetro externo, 72 mm de diâmetro interno Tubo de amostra cilíndrico com paredes finas de 4", 102 mm de diâmetro externo, 100 mm de diâmetro interno
Aranha:	Aplicável em caso de problemas de recuperação de amostras
Término de Amostragem:	O que ocorrer primeiro: – Atingir a penetração máxima do tubo de amostrador – Atingir a capacidade máxima do equipamento de inserção – Atingir a capacidade máxima do equipamento de reação – Circunstâncias a critério do operador do equipamento, tais como risco de dano ao equipamento ou risco para a segurança do pessoal

Amostragem Rotativa

Sistema de Amostragem:	Amostragem a cabo – sistema “*wireline*”
Tipo de Amostrador:	Geobor-S
Equipamento de Inserção do Amostrador:	Unidade com capacidade máxima de empuxo de 60 kN a 80 kN, e taxa de penetração de cerca de 20 mm/s
Amostrador:	Tubo triplo, 100 mm de diâmetro e comprimento máximo de amostra de 1,5 m
Término da Amostragem:	O que ocorrer primeiro: – Atingir a penetração máxima permitida – Taxa de penetração <1 m/hora – Circunstâncias a critério do operador do equipamento, como o risco de danos ao equipamento ou risco para a segurança do pessoal

Manipulação da Amostra

Consulte a sub-seção "Práticas Para a Manipulação de Amostras e Testes de Laboratório" apresentada na seção intitulada "Resultados dos Ensaios de Laboratório"

Relatório Fugro Nº. VOO-002-REP-001(3PT)

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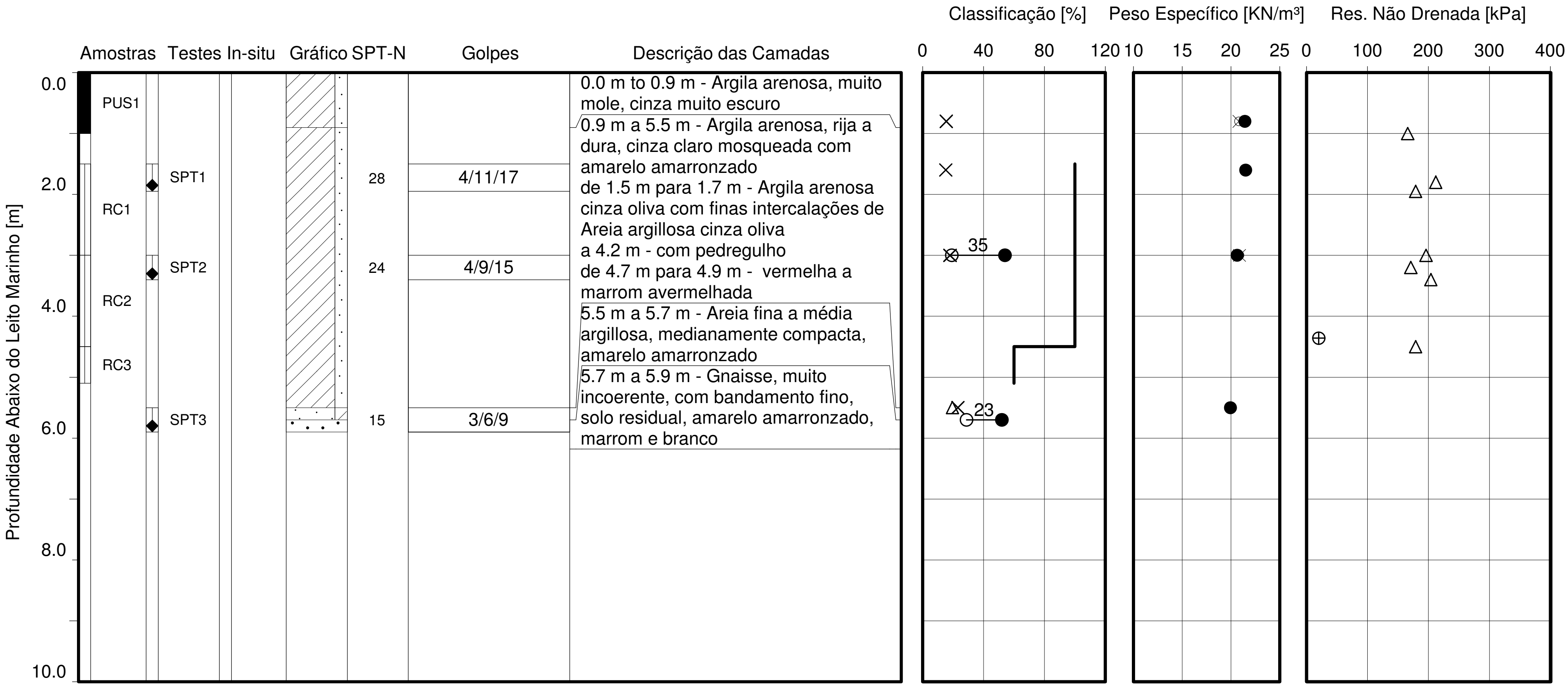


Data de início : 10-jun-2015
Método : Rotary borehole drilling, sampling and testing
Recuperação : to 5.9 m profundidade abaixo do leito marinho
Penetração : to 6.0 m profundidade abaixo do leito marinho
Elevação : -11.1 m
Co-ordenadas : 687084 m E 7467467 m N

- Recuperação total
- Recuperação sólida
- RQD
- Teor de água
- Limite plástico
- Limite líquido
- Índice de plasticidade
- Percentagem de finos
- Teor de carbonato
- Teor de matéria orgânica
- Densidade relativa derivada do CPT

- Peso específico derivado do teor de água
- Peso especifico derivado do cálculo de volume e massa

- Penetrometro de bolso
- Torvane
- Fallcone
- Mini-vane de laboratório
- UU-triaxial
- CU-triaxial
- DSS
- Point Load
- UCS
- CU de CPT
- Referente a testes remoldados

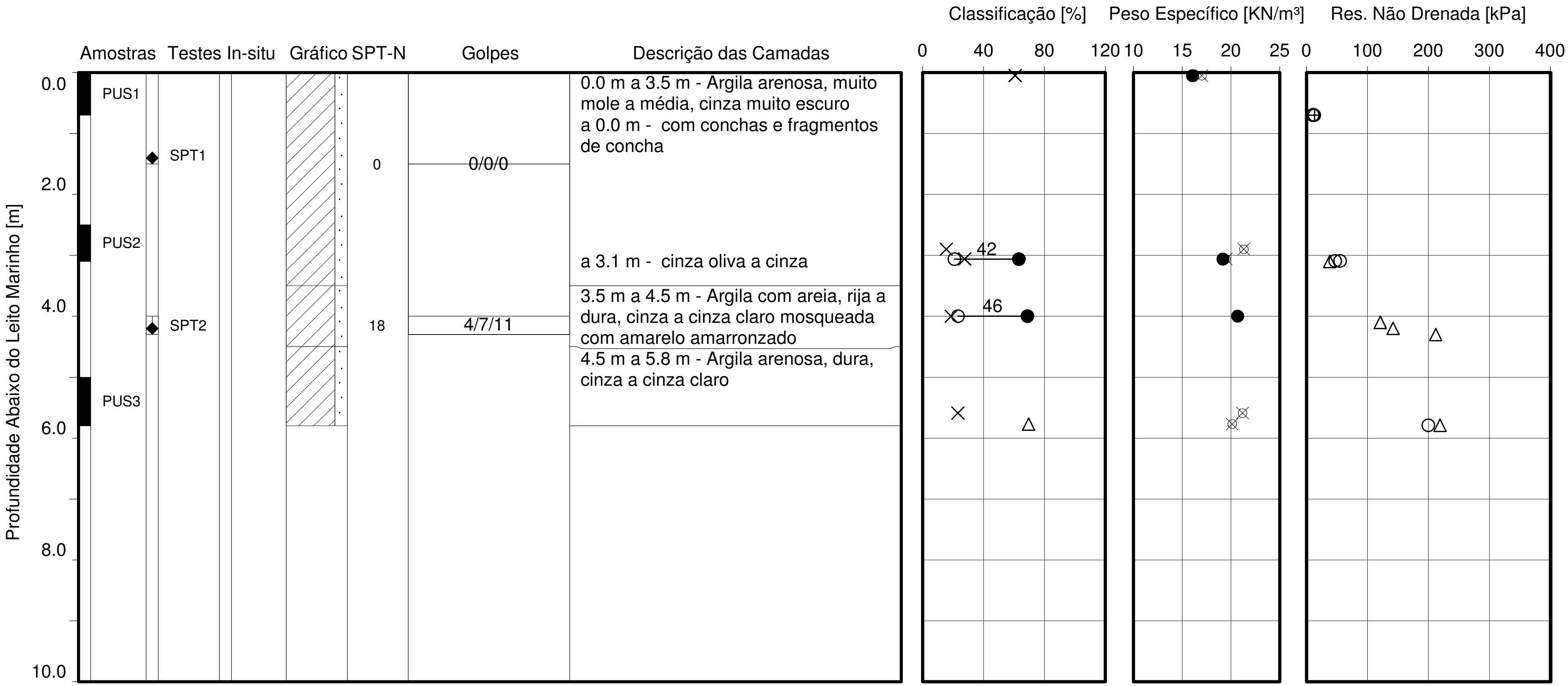
BOLETIM DE SONDAGEM

FURO POR-01

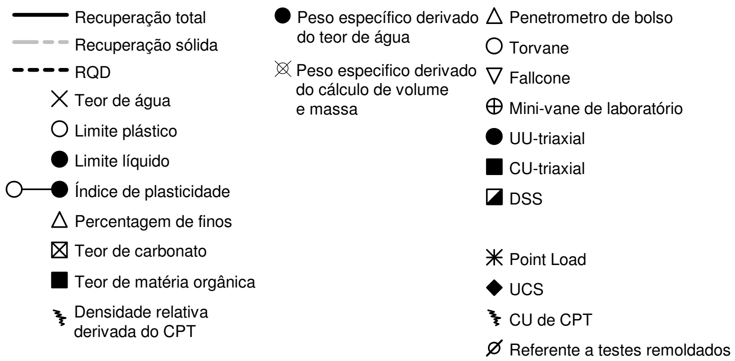
PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Ilustração A1

GeODin/VOO-02 LOG 10m.GLO/2015-07-16 16:37:32



Data de início : 11-jun-2015
Método : Percussion borehole drilling, sampling and testing
Recuperação : to 5.8 m profundidade abaixo do leito marinho
Penetração : to 6.0 m profundidade abaixo do leito marinho
Elevação : -9.8 m
Co-ordenadas : 686872 m E 7467520 m N



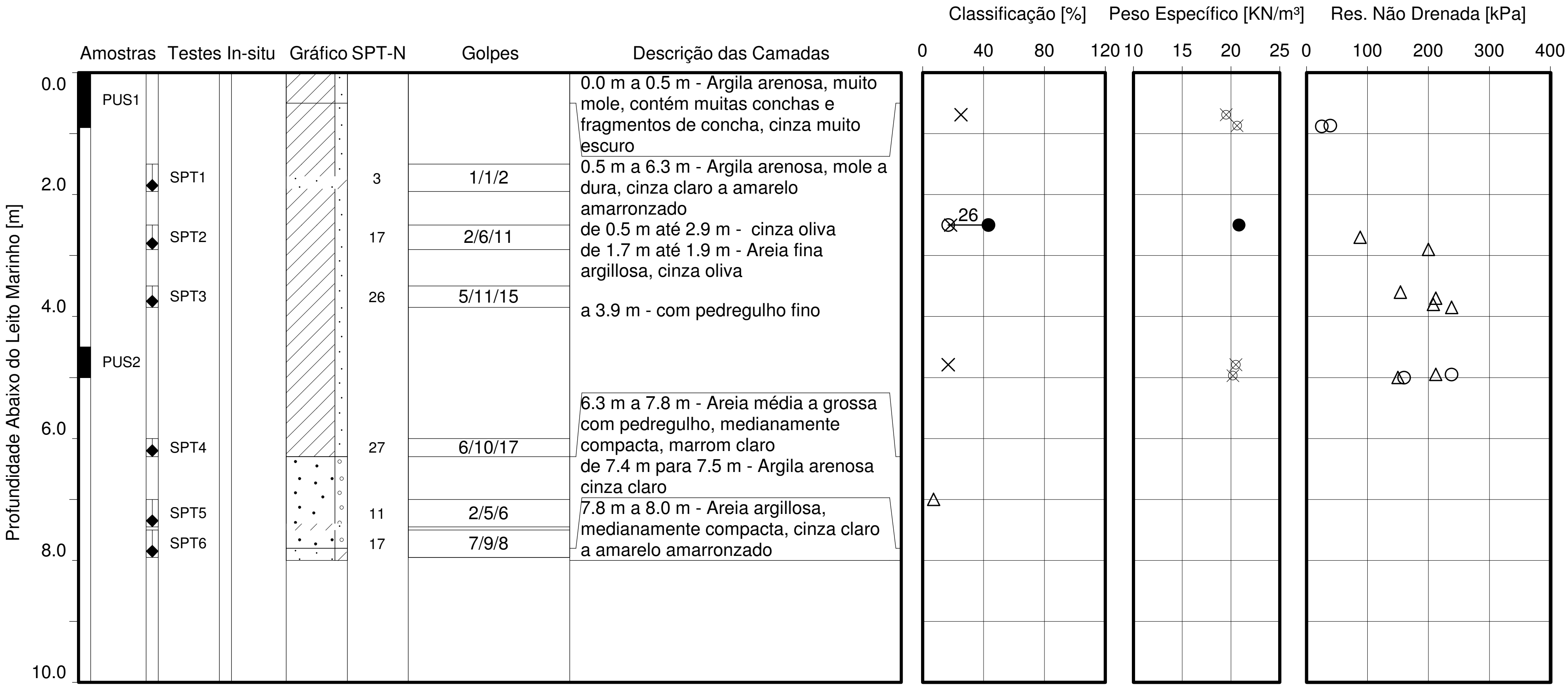
BOLETIM DE SONDAGEM

FURO POR-02

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Relatório Fugro Nº. VOO-002-REP-001(3PT)

GeODin/VOO-02 LOG 10m.GLO/2015-07-16 16:37:51



Data de início : 10-jun-2015
Método : Percussion borehole drilling, sampling and testing
Recuperação : to 8.0 m profundidade abaixo do leito marinho
Penetração : to 8.0 m profundidade abaixo do leito marinho
Elevação : -7.9 m
Co-ordenadas : 686340 m E 7468053 m N

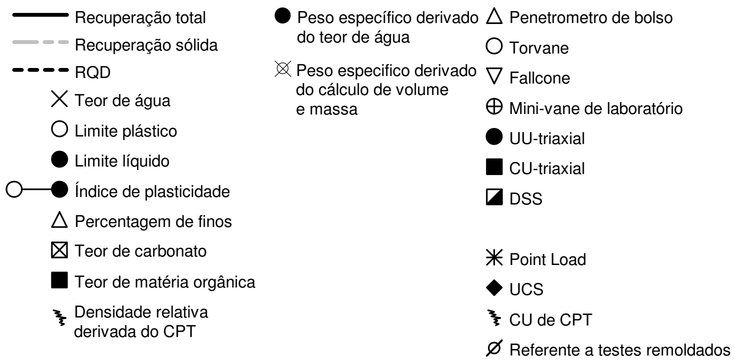


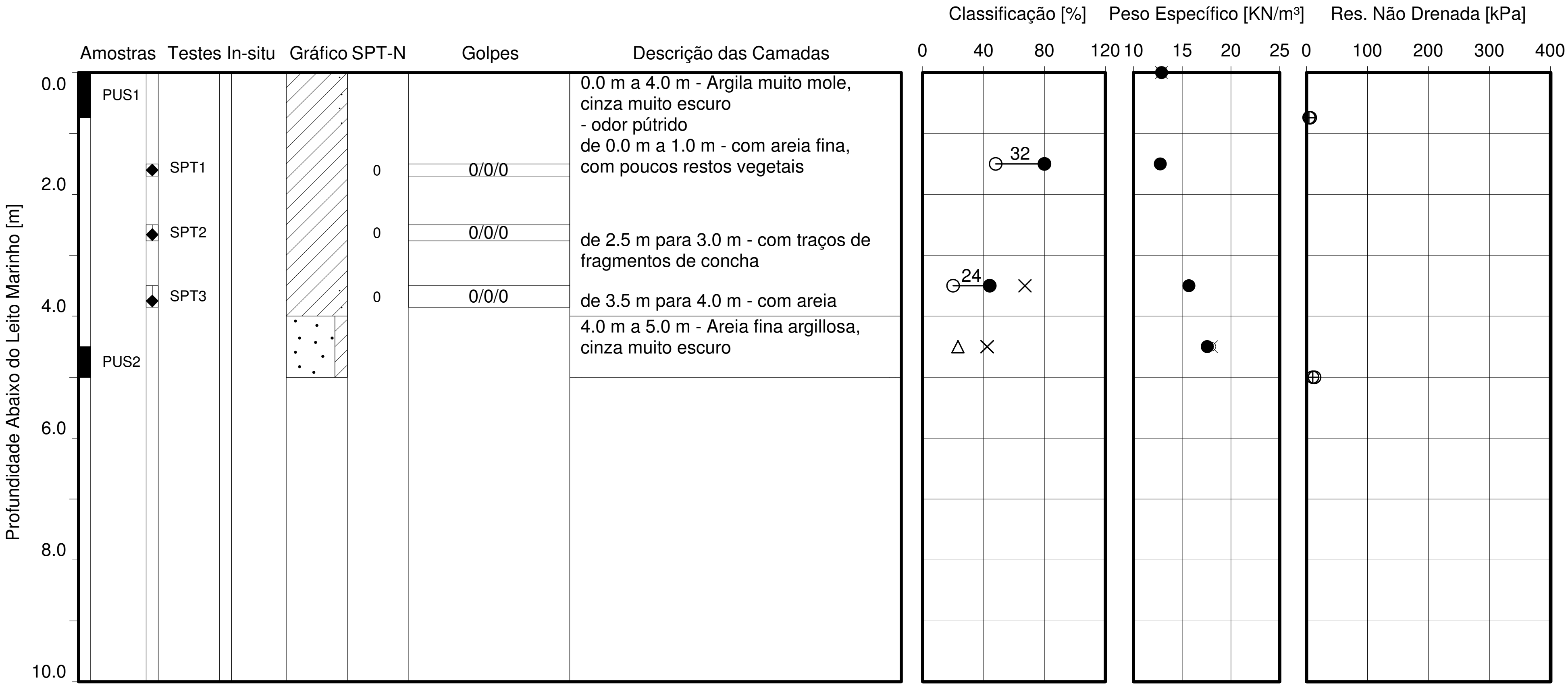
Ilustração A3

BOLETIM DE SONDAGEM

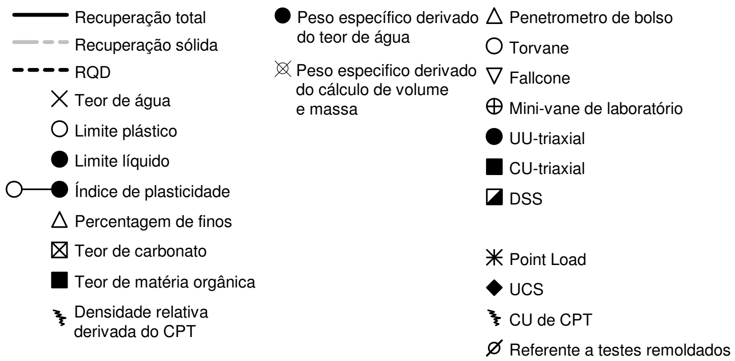
FURO POR-03

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/VOO-02 LOG 10m.GLO/2015-07-16 16:38:12



Data de início : 11-jun-2015
Método : Percussion borehole drilling, sampling and testing
Recuperação : to 5.5 m profundidade abaixo do leito marinho
Penetração : to 5.5 m profundidade abaixo do leito marinho
Elevação : -10.3 m
Co-ordenadas : 687357 m E 7467462 m N

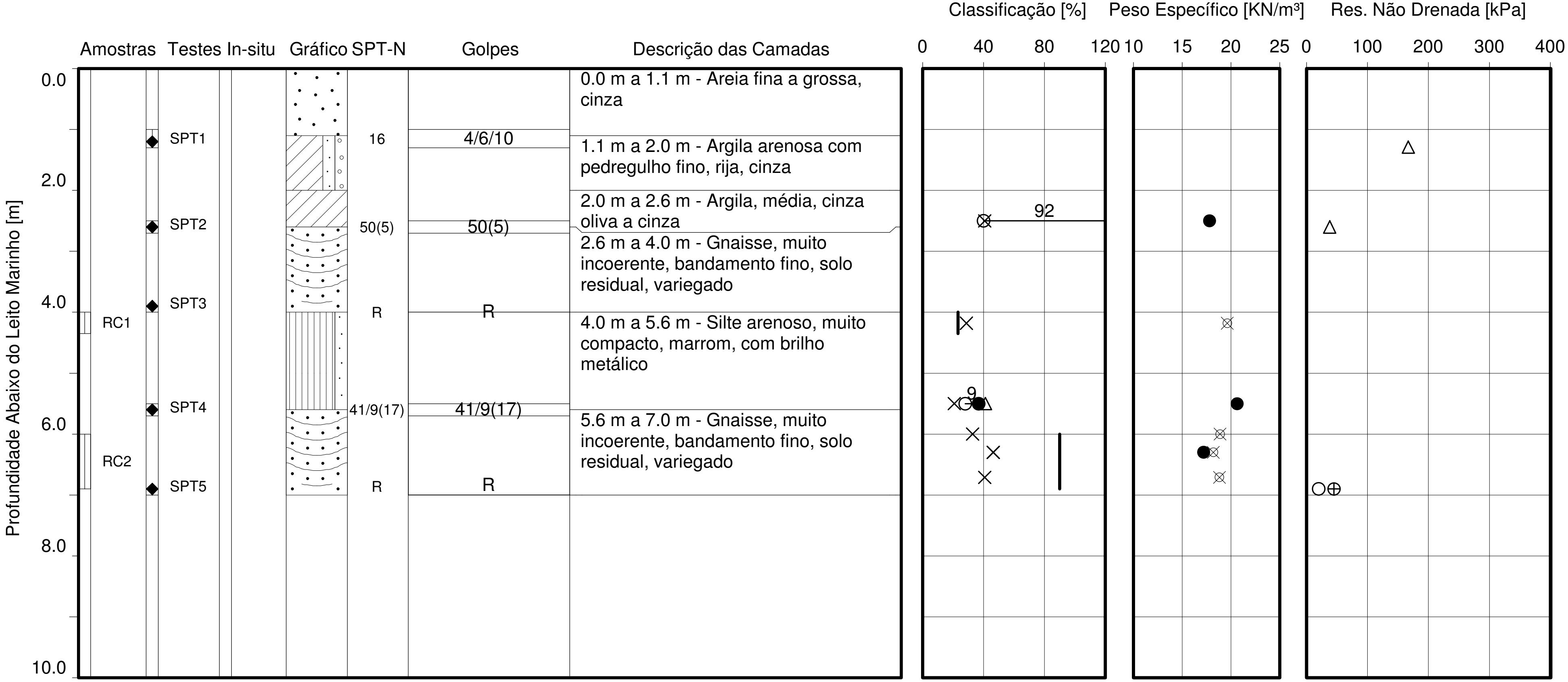


BOLETIM DE SONDAGEM

FURO POR-04

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/VOO-02 LOG 10m.GLO/2015-07-16 16:38:30



Data de início : 09-jun-2015
Método : Percussion borehole drilling, sampling and testing
Recuperação : to 7.0 m profundidade abaixo do leito marinho
Penetração : to 7.2 m profundidade abaixo do leito marinho
Elevação : -8.4 m
Co-ordenadas : 685983 m E 7468255 m N

- Recuperação total
- Recuperação sólida
- RQD
- Teor de água
- Limite plástico
- Limite líquido
- Índice de plasticidade
- Percentagem de finos
- Teor de carbonato
- Teor de matéria orgânica
- Densidade relativa derivada do CPT

- Peso específico derivado do teor de água
- Peso especifico derivado do cálculo de volume e massa

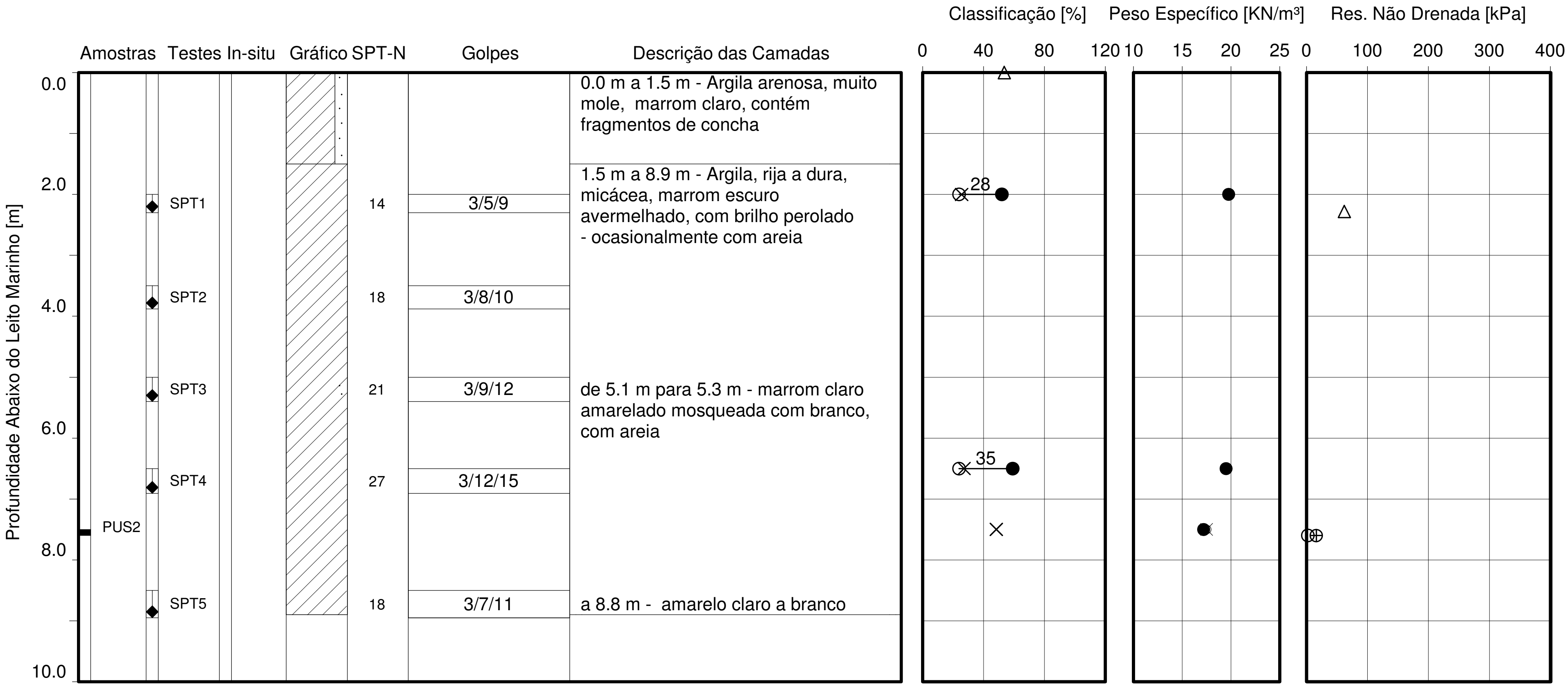
- Penetrometro de bolso
- Torvane
- Fallcone
- Mini-vane de laboratório
- UU-triaxial
- CU-triaxial
- DSS
- Point Load
- UCS
- CU de CPT
- Referente a testes remoldados

BOLETIM DE SONDAGEM

FURO POR-05

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/VOO-02 LOG 10m.GLO/2015-07-16 16:38:47



Data de início : 09-jun-2015
Método : Percussion borehole drilling, sampling and testing
Recuperação : to 8.9 m profundidade abaixo do leito marinho
Penetração : to 8.9 m profundidade abaixo do leito marinho
Elevação : -6.9 m
Co-ordenadas : 685689 m E 7468507 m N

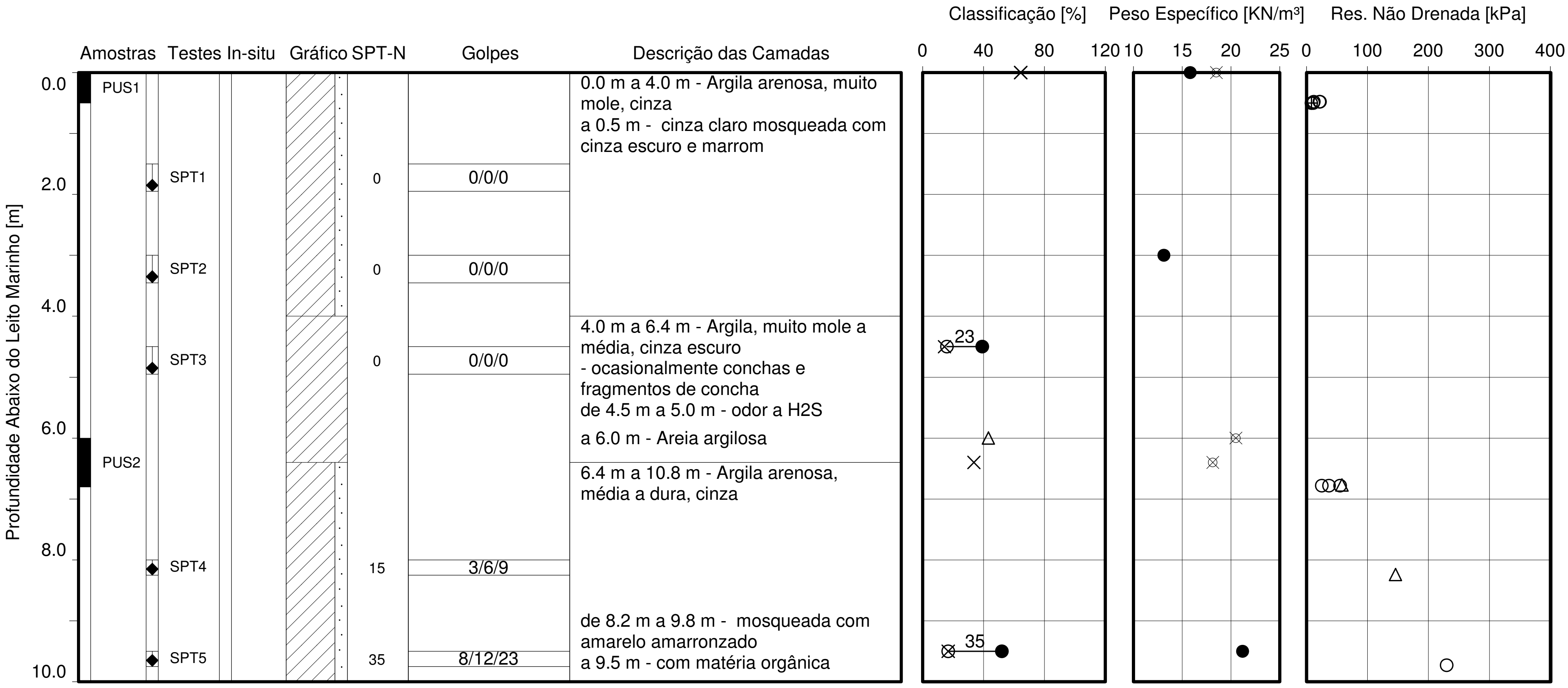
- Recuperação total
- Recuperação sólida
- RQD
- Teor de água
- Limite plástico
- Limite líquido
- Índice de plasticidade
- Percentagem de finos
- Teor de carbonato
- Teor de matéria orgânica
- Densidade relativa derivada do CPT
- Peso específico derivado do teor de água
- Peso especifico derivado do cálculo de volume e massa
- Penetrometro de bolso
- Torvane
- Fallcone
- Mini-vane de laboratório
- UU-triaxial
- CU-triaxial
- DSS
- Point Load
- UCS
- CU de CPT
- Referente a testes remoldados

BOLETIM DE SONDAGEM

FURO POR-06

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/VOO-02 LOG 10m.GLO/2015-07-16 16:39:09



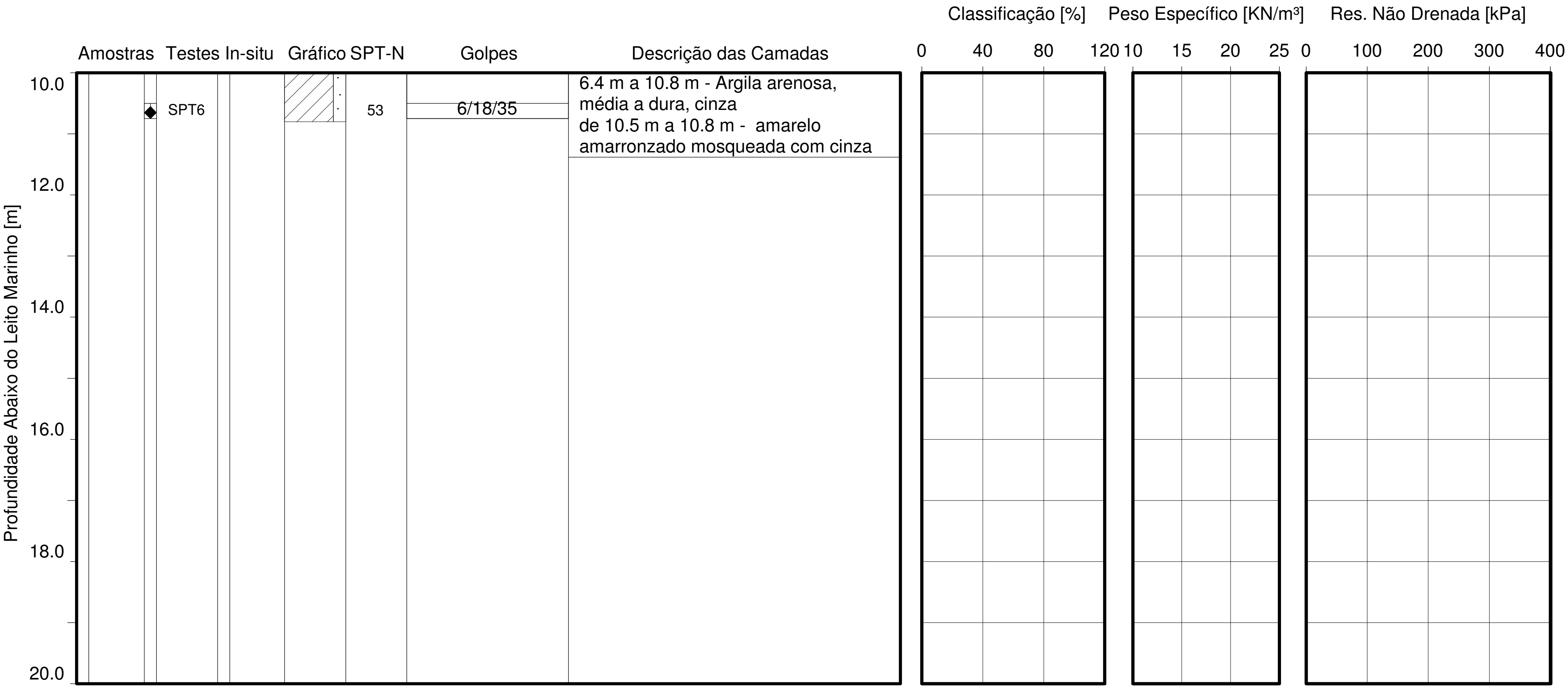
- Recuperação total
- Recuperação sólida
- RQD
- Teor de água
- Limite plástico
- Limite líquido
- Índice de plasticidade
- Percentagem de finos
- Teor de carbonato
- Teor de matéria orgânica
- Densidade relativa derivada do CPT
- Peso específico derivado do teor de água
- Peso especifico derivado do cálculo de volume e massa
- Penetrometro de bolso
- Torvane
- Fallcone
- Mini-vane de laboratório
- UU-triaxial
- CU-triaxial
- DSS
- Point Load
- UCS
- CU de CPT
- Referente a testes remoldados

Data de início	: 06-jun-2015
Método	: Percussion borehole drilling, sampling and testing
Recuperação	: to 10.8 m profundidade abaixo do leito marinho
Penetração	: to 10.9 m profundidade abaixo do leito marinho
Elevação	: -4.7 m
Co-ordenadas	: 684705 m E 7469406 m N

BOLETIM DE SONDAGEM

FURO POR-07

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA



Data de início	: 06-jun-2015
Método	: Percussion borehole drilling, sampling and testing
Recuperação	: to 10.8 m profundidade abaixo do leito marinho
Penetração	: to 10.9 m profundidade abaixo do leito marinho
Elevação	: -4.7 m
Co-ordenadas	: 684705 m E 7469406 m N

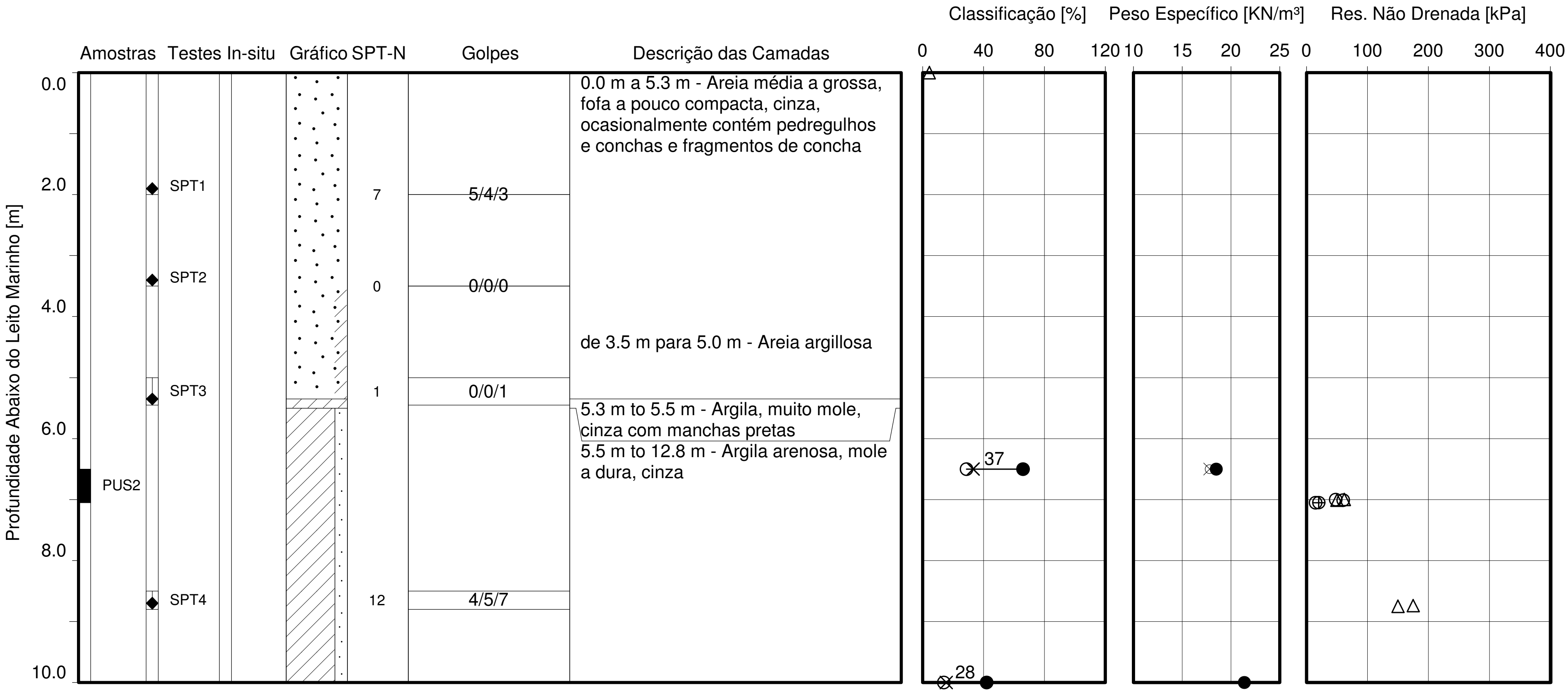
- Recuperação total
- Recuperação sólida
- RQD
- Teor de água
- Limite plástico
- Limite líquido
- Índice de plasticidade
- Percentagem de finos
- Teor de carbonato
- Teor de matéria orgânica
- Densidade relativa derivada do CPT
- Peso específico derivado do teor de água
- Peso especifico derivado do cálculo de volume e massa
- Penetrometro de bolso
- Torvane
- Fallcone
- Mini-vane de laboratório
- UU-triaxial
- CU-triaxial
- DSS
- Point Load
- UCS
- CU de CPT
- Referente a testes remoldados

BOLETIM DE SONDAGEM

FURO POR-07

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/VOO-02 LOG 10m.GLO/2015-07-16 16:39:35



Data de início	: 05-jun-2015
Método	: Percussion borehole drilling, sampling and testing
Recuperação	: to 12.8 m profundidade abaixo do leito marinho
Penetração	: to 12.9 m profundidade abaixo do leito marinho
Elevação	: -3.7 m
Co-ordenadas	: 684599 m E 7469536 m N

Recuperação total
Recuperação sólida
RQD
Teor de água
Limite plástico
Limite líquido
Índice de plasticidade
Percentagem de finos
Teor de carbonato
Teor de matéria orgânica
Densidade relativa derivada do CPT

Peso específico derivado do teor de água
Peso especifico derivado do cálculo de volume e massa

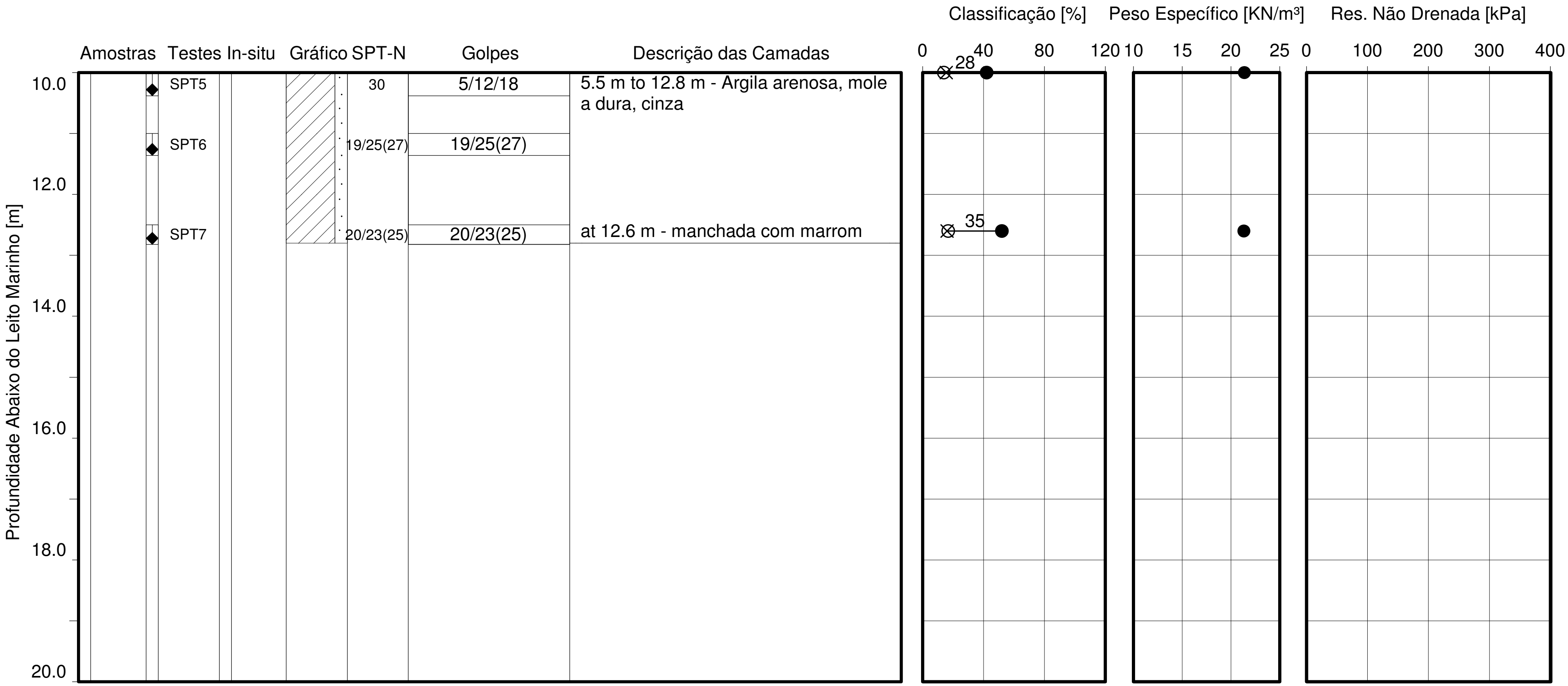
Penetrometro de bolso
Torvane
Fallcone
Mini-vane de laboratório
UU-triaxial
CU-triaxial
DSS
Point Load
UCS
CU de CPT
Referente a testes remoldados

BOLETIM DE SONDAGEM

FURO POR-08

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/VOO-02 LOG 10m.GLO/2015-07-16 16:39:35



Data de início : 05-jun-2015
Método : Percussion borehole drilling, sampling and testing
Recuperação : to 12.8 m profundidade abaixo do leito marinho
Penetração : to 12.9 m profundidade abaixo do leito marinho
Elevação : -3.7 m
Co-ordenadas : 684599 m E 7469536 m N

Recuperação total
Recuperação sólida
RQD
Teor de água
Limite plástico
Limite líquido
Índice de plasticidade
Percentagem de finos
Teor de carbonato
Teor de matéria orgânica
Densidade relativa derivada do CPT

Peso específico derivado do teor de água
Peso especifico derivado do cálculo de volume e massa

Penetrometro de bolso
Torvane
Fallcone
Mini-vane de laboratório
UU-triaxial
CU-triaxial
DSS

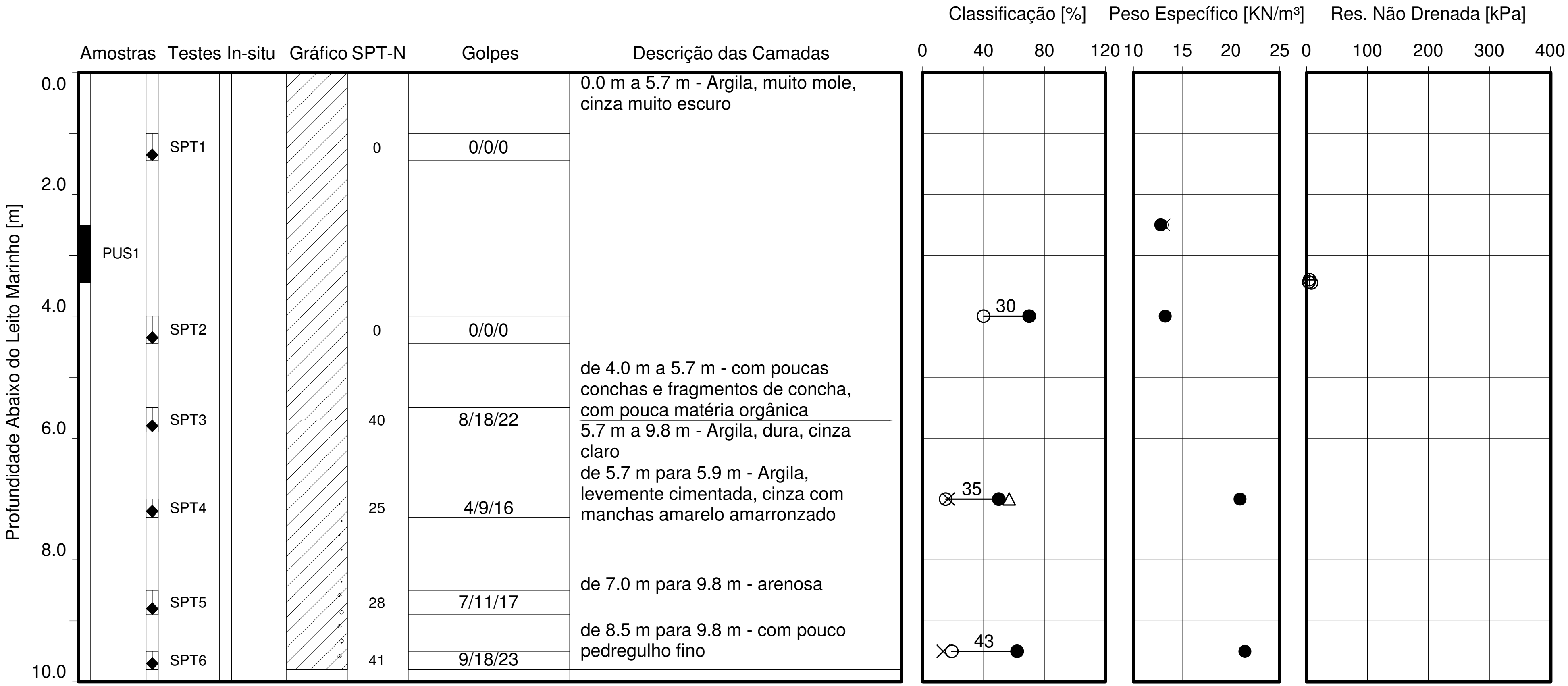
Point Load
UCS
CU de CPT
Referente a testes remoldados

BOLETIM DE SONDAGEM

FURO POR-08

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/VOO-02 LOG 10m.GLO/2015-07-16 16:40:01



Data de início	: 07-jun-2015
Método	: Percussion borehole drilling, sampling and testing
Recuperação	: to 9.8 m profundidade abaixo do leito marinho
Penetração	: to 9.9 m profundidade abaixo do leito marinho
Elevação	: -6.5 m
Co-ordenadas	: 684113 m E 7468827 m N

Recuperação total
Recuperação sólida
RQD
Teor de água
Limite plástico
Limite líquido
Índice de plasticidade
Percentagem de finos
Teor de carbonato
Teor de matéria orgânica
Densidade relativa derivada do CPT

Peso específico derivado do teor de água
Peso especifico derivado do cálculo de volume e massa

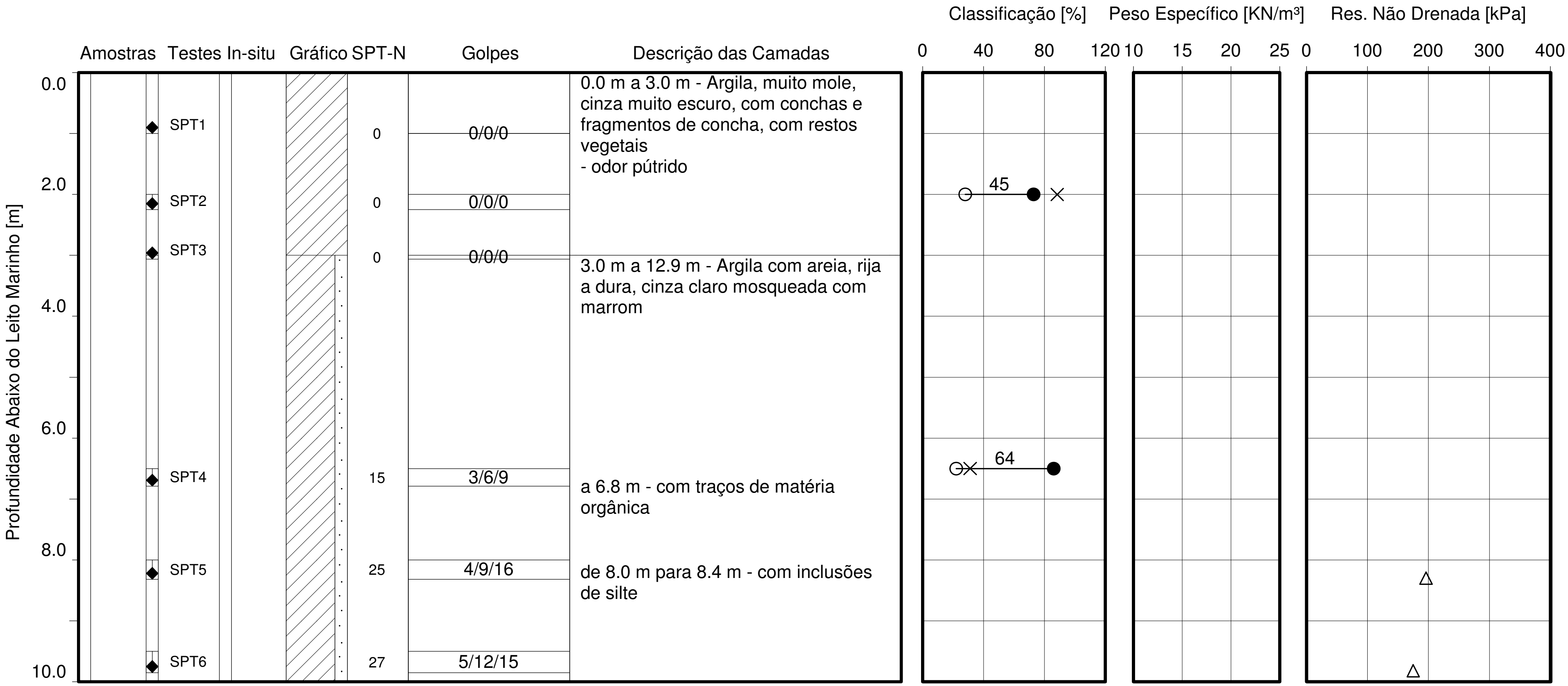
Penetrometro de bolso
Torvane
Fallcone
Mini-vane de laboratório
UU-triaxial
CU-triaxial
DSS
Point Load
UCS
CU de CPT
Referente a testes remoldados

BOLETIM DE SONDAGEM

FURO POR-09

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/VOO-02 LOG 10m.GLO/2015-07-16 16:40:28



Data de início	: 08-jun-2015
Método	: Percussion borehole drilling, sampling and testing
Recuperação	: to 12.9 m profundidade abaixo do leito marinho
Penetração	: to 13.0 m profundidade abaixo do leito marinho
Elevação	: -3.5 m
Co-ordenadas	: 683904 m E 7468601 m N

Recuperação total
Recuperação sólida
RQD
Teor de água
Limite plástico
Limite líquido
Índice de plasticidade
Percentagem de finos
Teor de carbonato
Teor de matéria orgânica
Densidade relativa derivada do CPT

Peso específico derivado do teor de água
Peso especifico derivado do cálculo de volume e massa

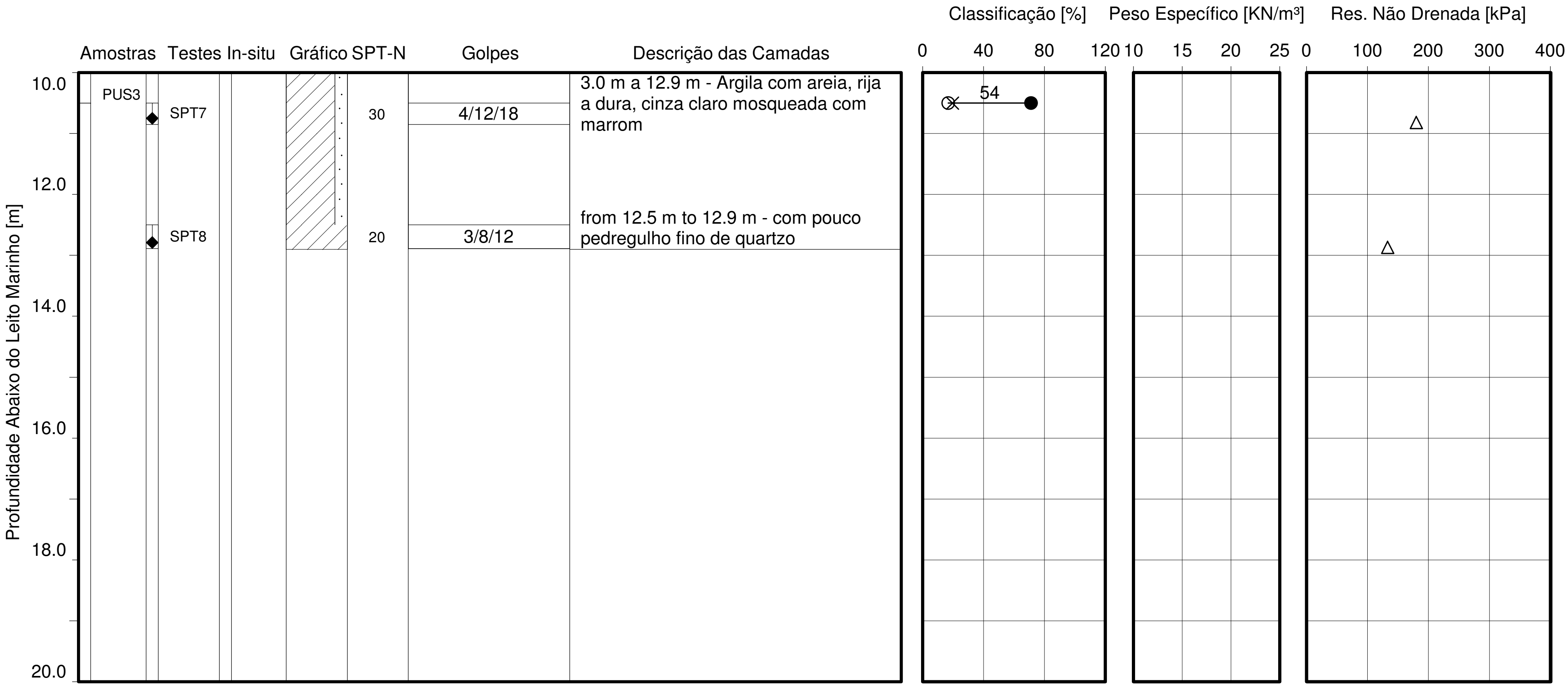
Penetrometro de bolso
Torvane
Fallcone
Mini-vane de laboratório
UU-triaxial
CU-triaxial
DSS
Point Load
UCS
CU de CPT
Referente a testes remoldados

BOLETIM DE SONDAGEM

FURO POR-10

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/VOO-02 LOG 10m.GLO/2015-07-16 16:40:28



Data de início : 08-jun-2015
Método : Percussion borehole drilling, sampling and testing
Recuperação : to 12.9 m profundidade abaixo do leito marinho
Penetração : to 13.0 m profundidade abaixo do leito marinho
Elevação : -3.5 m
Co-ordenadas : 683904 m E 7468601 m N

- Recuperação total
- Recuperação sólida
- RQD
- Teor de água
- Limite plástico
- Limite líquido
- Índice de plasticidade
- Percentagem de finos
- Teor de carbonato
- Teor de matéria orgânica
- Densidade relativa derivada do CPT

- Peso específico derivado do teor de água
- Peso especifico derivado do cálculo de volume e massa

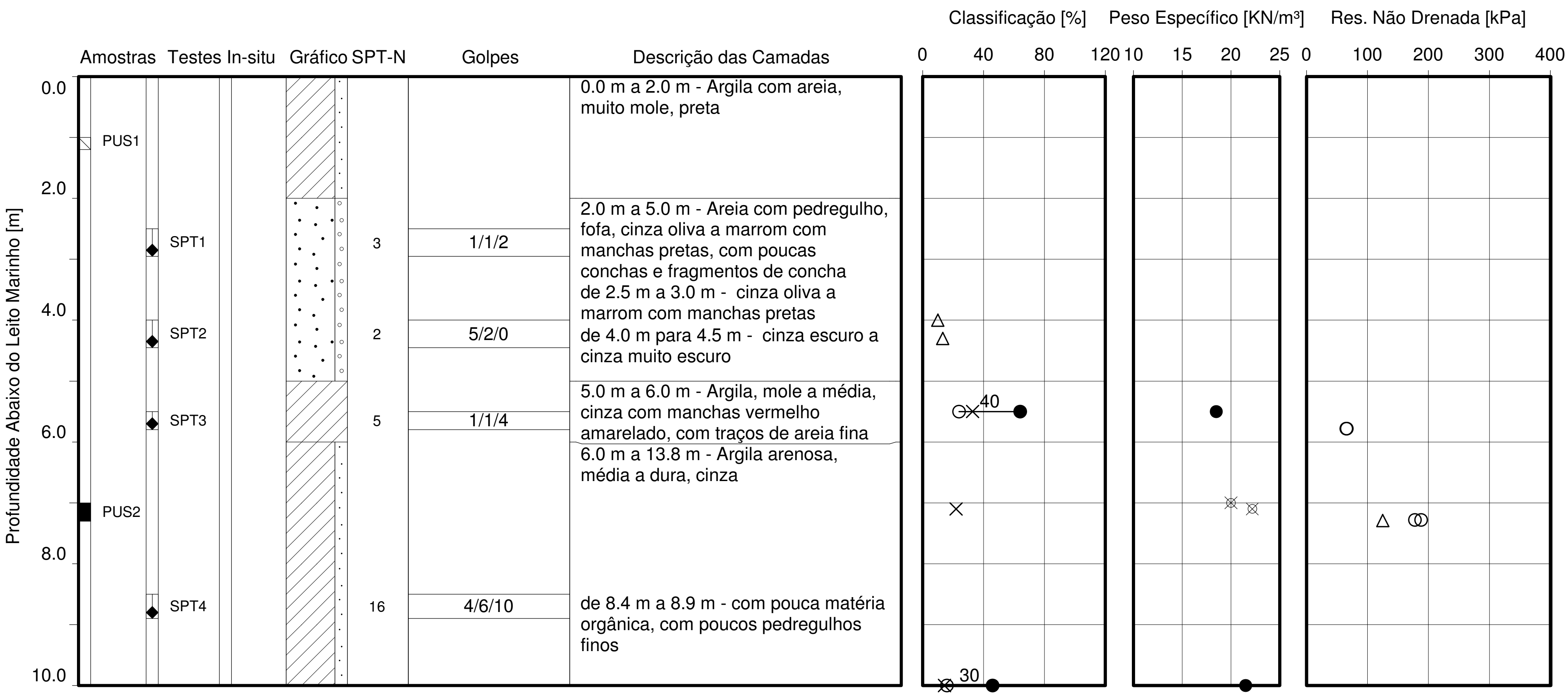
- Penetrometro de bolso
- Torvane
- Fallcone
- Mini-vane de laboratório
- UU-triaxial
- CU-triaxial
- DSS
- Point Load
- UCS
- CU de CPT
- Referente a testes remoldados

BOLETIM DE SONDAGEM

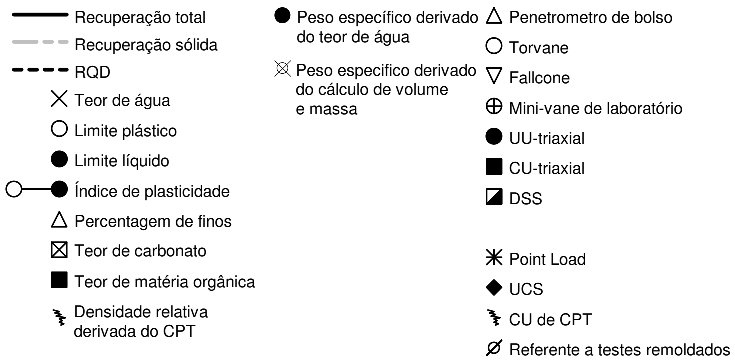
FURO POR-10

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/VOO-02 LOG 10m.GLO/2015-07-16 16:40:52



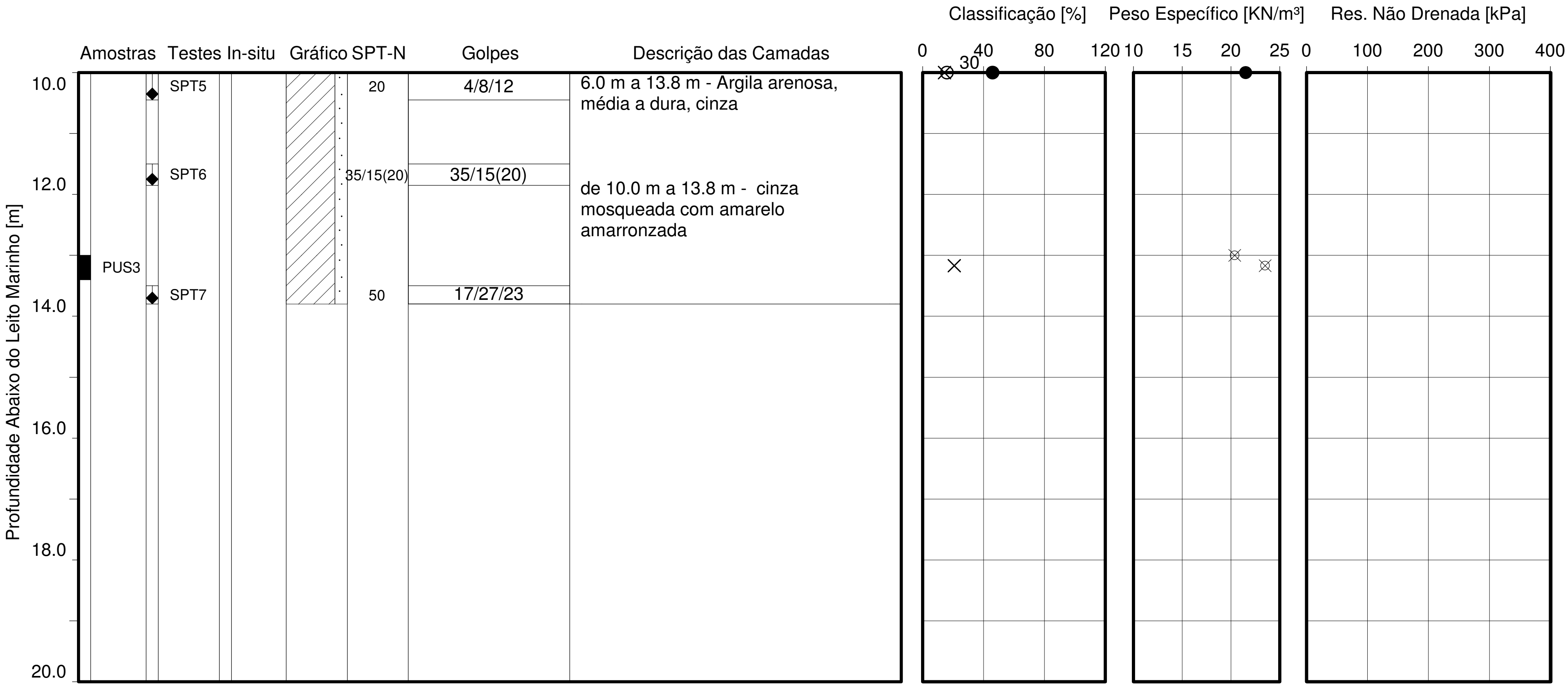
Data de início : 08-jun-2015
Método : Percussion borehole drilling, sampling and testing
Recuperação : to 13.8 m profundidade abaixo do leito marinho
Penetração : to 14.0 m profundidade abaixo do leito marinho
Elevação : -1.6 m
Co-ordenadas : 683732 m E 7468392 m N



BOLETIM DE SONDAGEM

FURO POR-11

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA



Data de início	: 08-jun-2015
Método	: Percussion borehole drilling, sampling and testing
Recuperação	: to 13.8 m profundidade abaixo do leito marinho
Penetração	: to 14.0 m profundidade abaixo do leito marinho
Elevação	: -1.6 m
Co-ordenadas	: 683732 m E 7468392 m N

- Recuperação total
- Recuperação sólida
- RQD
- Teor de água
- Limite plástico
- Limite líquido
- Índice de plasticidade
- Percentagem de finos
- Teor de carbonato
- Teor de matéria orgânica
- Densidade relativa derivada do CPT

- Peso específico derivado do teor de água
- Peso especifico derivado do cálculo de volume e massa

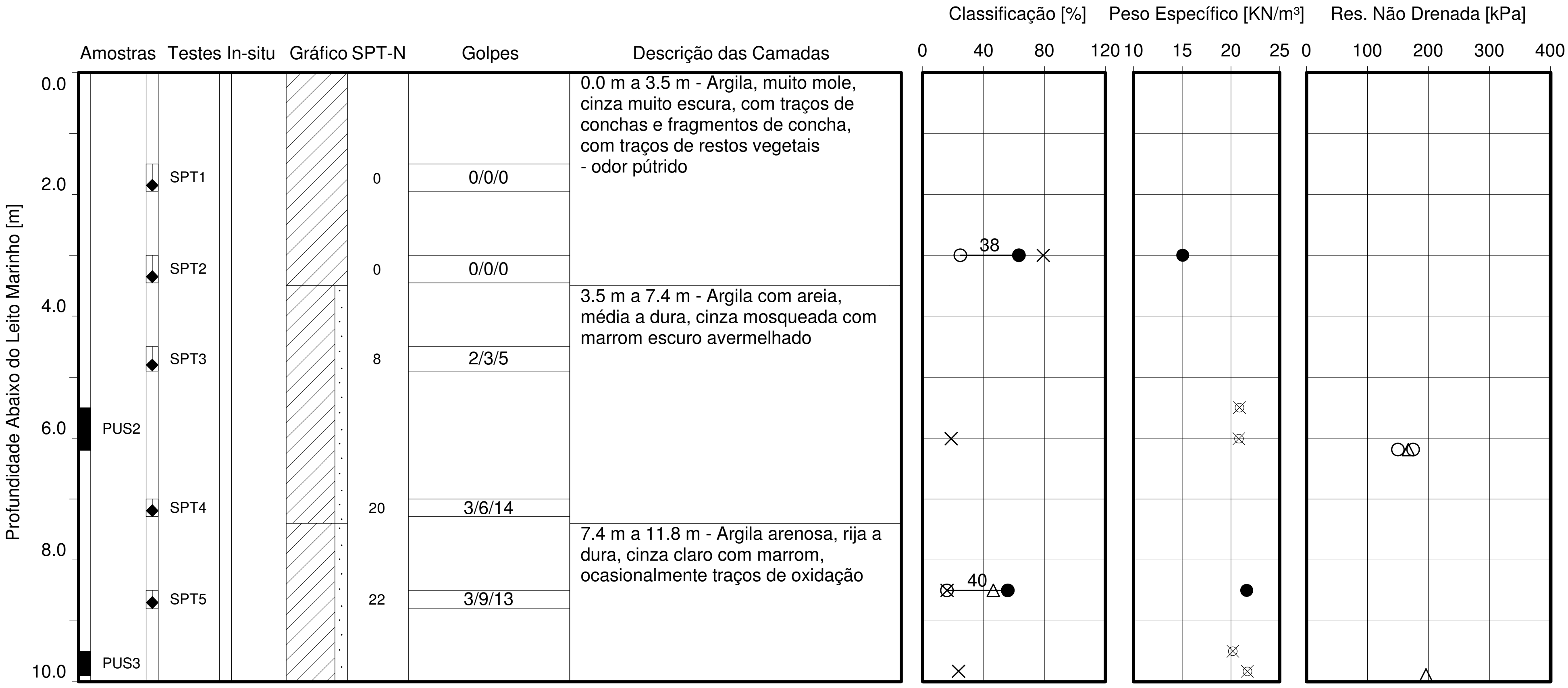
- Penetrometro de bolso
- Torvane
- Fallcone
- Mini-vane de laboratório
- UU-triaxial
- CU-triaxial
- DSS
- Point Load
- UCS
- CU de CPT
- Referente a testes remoldados

BOLETIM DE SONDAGEM

FURO POR-11

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/VOO-02 LOG 10m.GLO/2015-07-16 16:41:16



Data de início	: 07-jun-2015
Método	: Percussion borehole drilling, sampling and testing
Recuperação	: to 11.8 m profundidade abaixo do leito marinho
Penetração	: to 12.0 m profundidade abaixo do leito marinho
Elevação	: -3.7 m
Co-ordenadas	: 684019 m E 7468709 m N

- Recuperação total
- Recuperação sólida
- RQD
- × Teor de água
- ○ Limite plástico
- ● Limite líquido
- ○—● Índice de plasticidade
- △ Percentagem de finos
- ⊠ Teor de carbonato
- ■ Teor de matéria orgânica
- Densidade relativa derivada do CPT

- ● Peso específico derivado do teor de água
- Peso especifico derivado do cálculo de volume e massa

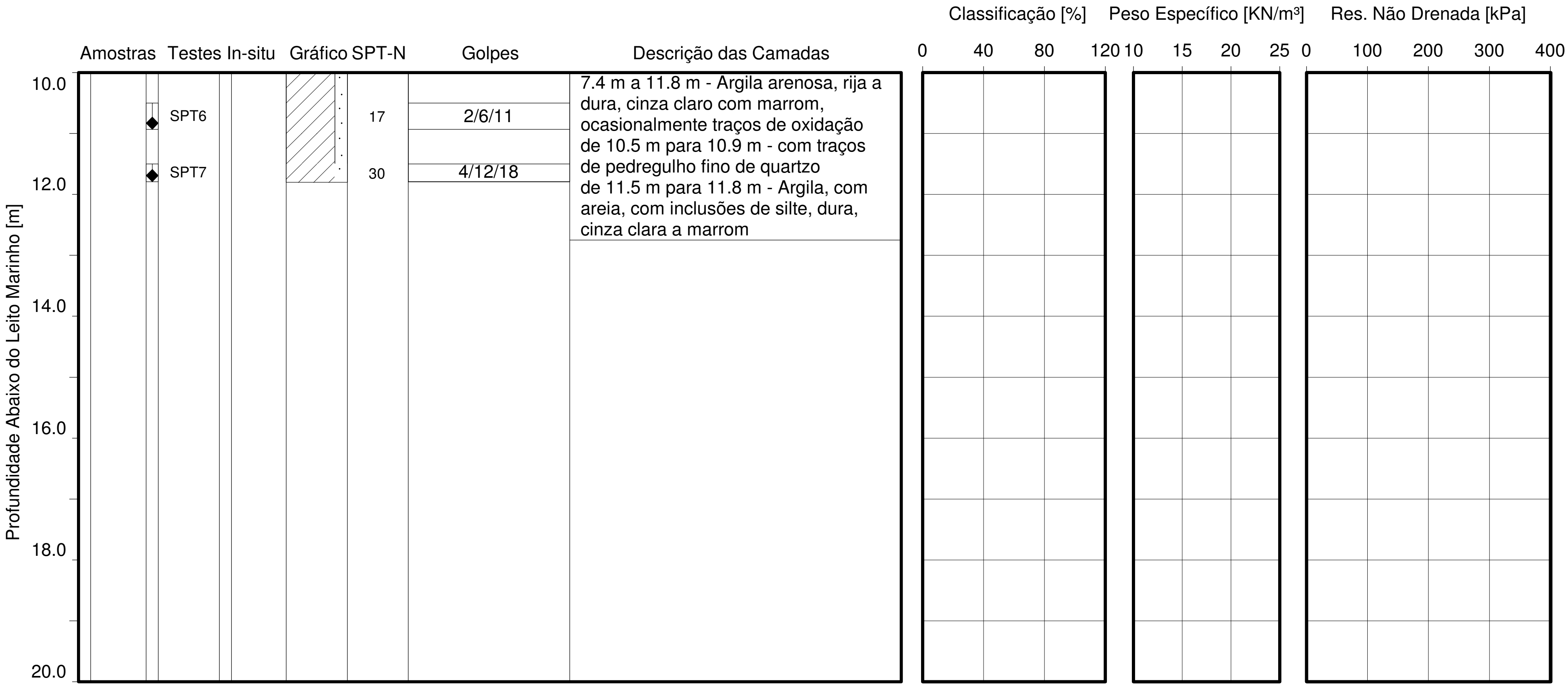
- △ Penetrometro de bolso
- ○ Torvane
- ▽ Fallcone
- ⊕ Mini-vane de laboratório
- ● UU-triaxial
- ■ CU-triaxial
- DSS
- ✳ Point Load
- ◆ UCS
- CU de CPT
- Ø Referente a testes remoldados

BOLETIM DE SONDAGEM

FURO POR-12

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/VOO-02 LOG 10m.GLO/2015-07-16 16:41:16



Data de início	: 07-jun-2015
Método	: Percussion borehole drilling, sampling and testing
Recuperação	: to 11.8 m profundidade abaixo do leito marinho
Penetração	: to 12.0 m profundidade abaixo do leito marinho
Elevação	: -3.7 m
Co-ordenadas	: 684019 m E 7468709 m N

- Recuperação total
- Recuperação sólida
- RQD
- Teor de água
- Limite plástico
- Limite líquido
- Índice de plasticidade
- Percentagem de finos
- Teor de carbonato
- Teor de matéria orgânica
- Densidade relativa derivada do CPT

- Peso específico derivado do teor de água
- Peso especifico derivado do cálculo de volume e massa

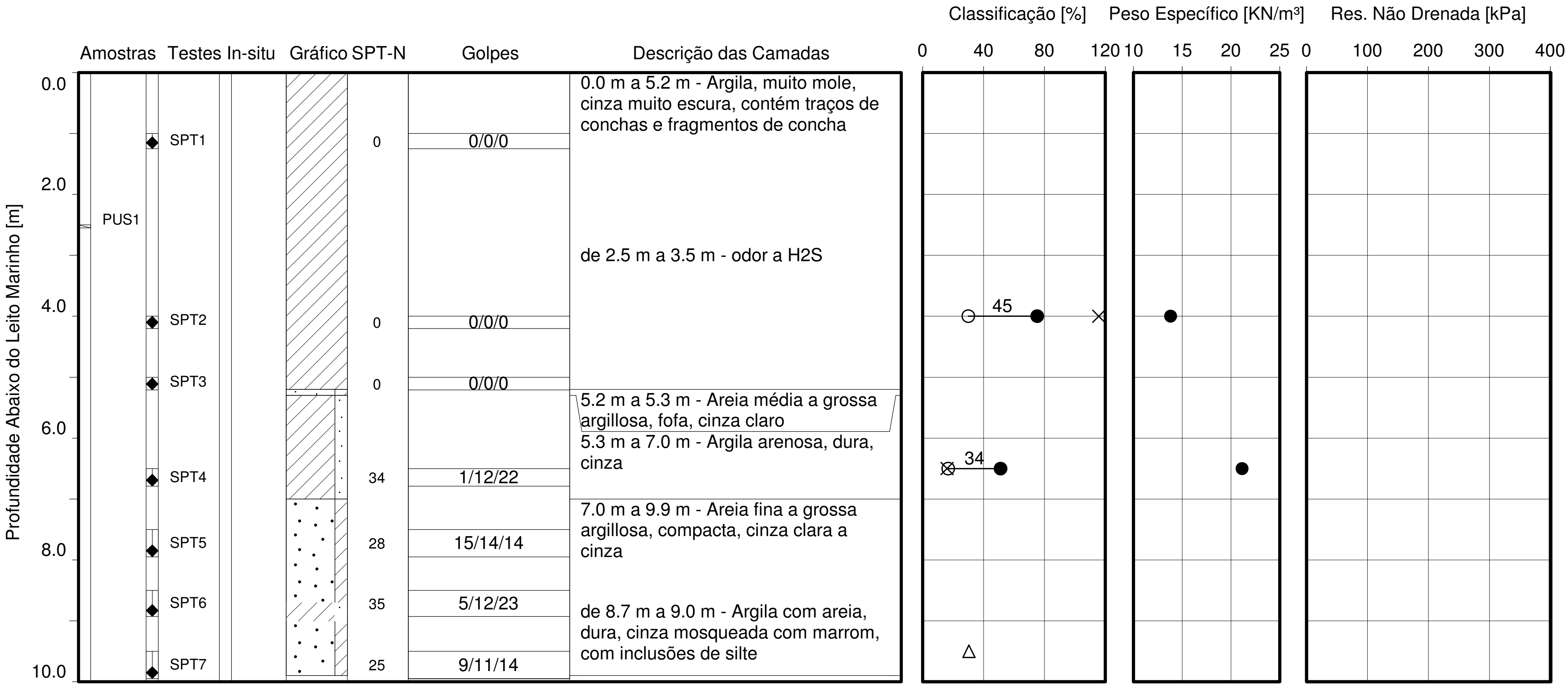
- Penetrometro de bolso
- Torvane
- Fallcone
- Mini-vane de laboratório
- UU-triaxial
- CU-triaxial
- DSS
- Point Load
- UCS
- CU de CPT
- Referente a testes remoldados

BOLETIM DE SONDAGEM

FURO POR-12

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/VOO-02 LOG 10m.GLO/2015-07-16 16:41:38



Data de início	: 06-jun-2015
Método	: Percussion borehole drilling, sampling and testing
Recuperação	: to 9.9 m profundidade abaixo do leito marinho
Penetração	: to 9.9 m profundidade abaixo do leito marinho
Elevação	: -9.4 m
Co-ordenadas	: 684812 m E 7469257 m N

Recuperação total
Recuperação sólida
RQD
Teor de água
Limite plástico
Limite líquido
Índice de plasticidade
Percentagem de finos
Teor de carbonato
Teor de matéria orgânica
Densidade relativa derivada do CPT

Peso específico derivado do teor de água
Peso especifico derivado do cálculo de volume e massa

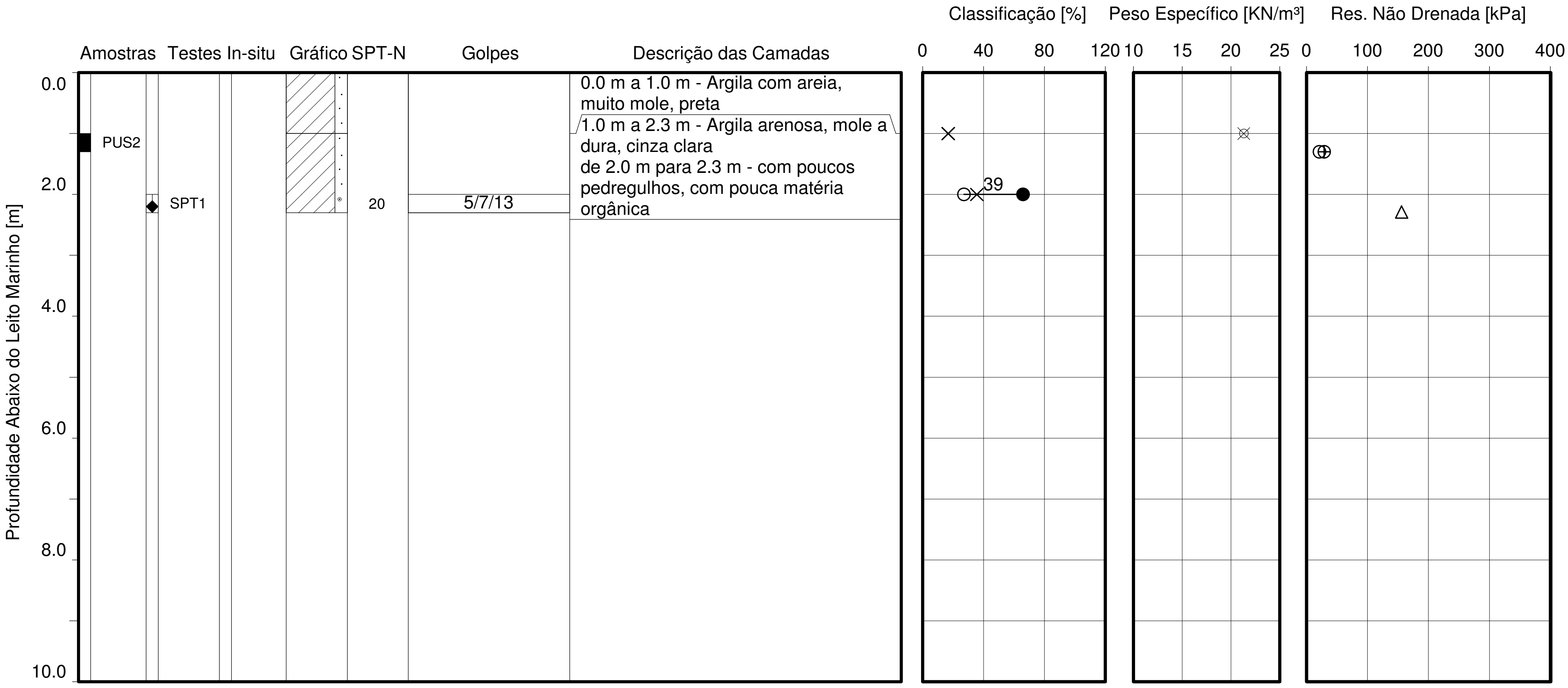
Penetrometro de bolso
Torvane
Fallcone
Mini-vane de laboratório
UU-triaxial
CU-triaxial
DSS
Point Load
UCS
CU de CPT
Referente a testes remoldados

BOLETIM DE SONDAGEM

FURO POR-14

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/VOO-02 LOG 10m.GLO/2015-07-16 16:42:01



Data de início	: 08-jun-2015
Método	: Percussion borehole drilling, sampling and testing
Recuperação	: to 2.3 m profundidade abaixo do leito marinho
Penetração	: to 2.5 m profundidade abaixo do leito marinho
Elevação	: -13.0 m
Co-ordenadas	: 683672 m E 7468500 m N

- Recuperação total
- Recuperação sólida
- RQD
- Teor de água
- Limite plástico
- Limite líquido
- Índice de plasticidade
- Percentagem de finos
- Teor de carbonato
- Teor de matéria orgânica
- Densidade relativa derivada do CPT

- Peso específico derivado do teor de água
- Peso especifico derivado do cálculo de volume e massa

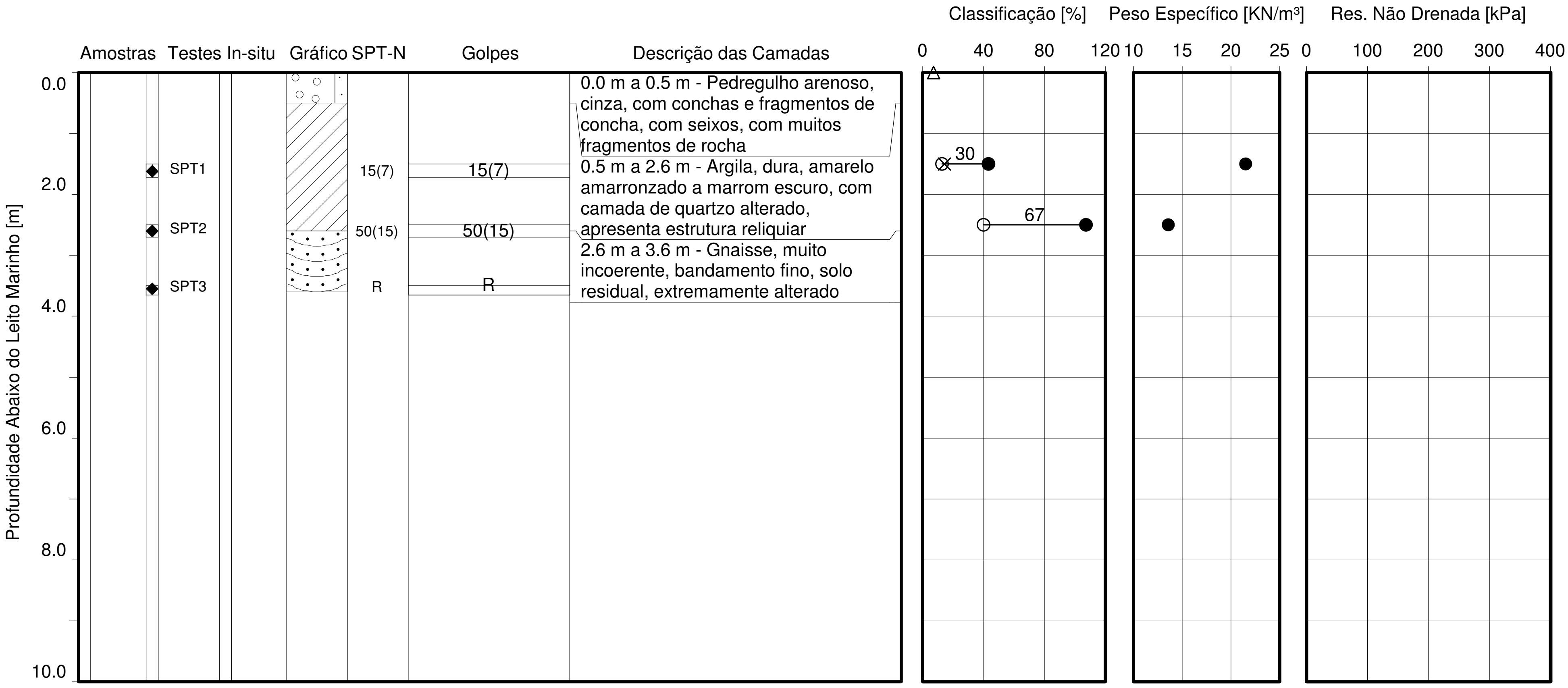
- Penetrometro de bolso
- Torvane
- Fallcone
- Mini-vane de laboratório
- UU-triaxial
- CU-triaxial
- DSS
- Point Load
- UCS
- CU de CPT
- Referente a testes remoldados

BOLETIM DE SONDAGEM

FURO POR-15

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/VOO-02 LOG 10m.GLO/2015-07-16 16:42:24



Data de início	: 10-jun-2015
Método	: Percussion borehole drilling, sampling and testing
Recuperação	: to 3.7 m profundidade abaixo do leito marinho
Penetração	: to 3.7 m profundidade abaixo do leito marinho
Elevação	: -5.6 m
Co-ordenadas	: 688871 m E 7465047 m N

Recuperação total
Recuperação sólida
RQD
Teor de água
Limite plástico
Limite líquido
Índice de plasticidade
Percentagem de finos
Teor de carbonato
Teor de matéria orgânica
Densidade relativa derivada do CPT

Peso específico derivado do teor de água
Peso especifico derivado do cálculo de volume e massa

Penetrometro de bolso
Torvane
Fallcone
Mini-vane de laboratório
UU-triaxial
CU-triaxial
DSS

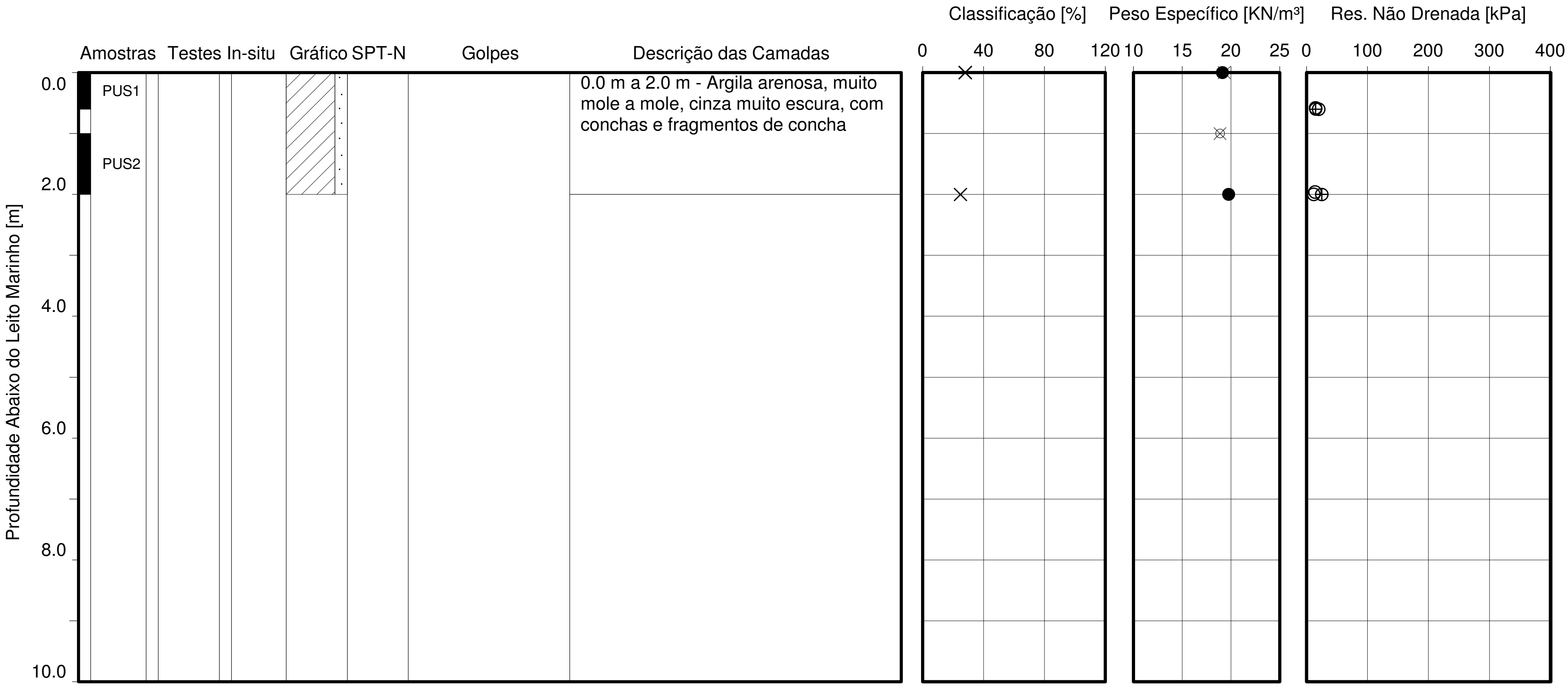
Point Load
UCS
CU de CPT
Referente a testes remoldados

BOLETIM DE SONDAGEM

FURO POR-17

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/VOO-02 LOG 10m.GLO/2015-07-16 16:42:46



Data de início	: 10-jun-2015
Método	: Percussion borehole drilling, sampling and testing
Recuperação	: to 2.0 m profundidade abaixo do leito marinho
Penetração	: to 2.0 m profundidade abaixo do leito marinho
Elevação	: -5.9 m
Co-ordenadas	: 688791 m E 7465252 m N

Recuperação total
Recuperação sólida
RQD
Teor de água
Limite plástico
Limite líquido
Índice de plasticidade
Percentagem de finos
Teor de carbonato
Teor de matéria orgânica
Densidade relativa derivada do CPT

Peso específico derivado do teor de água
Peso especifico derivado do cálculo de volume e massa

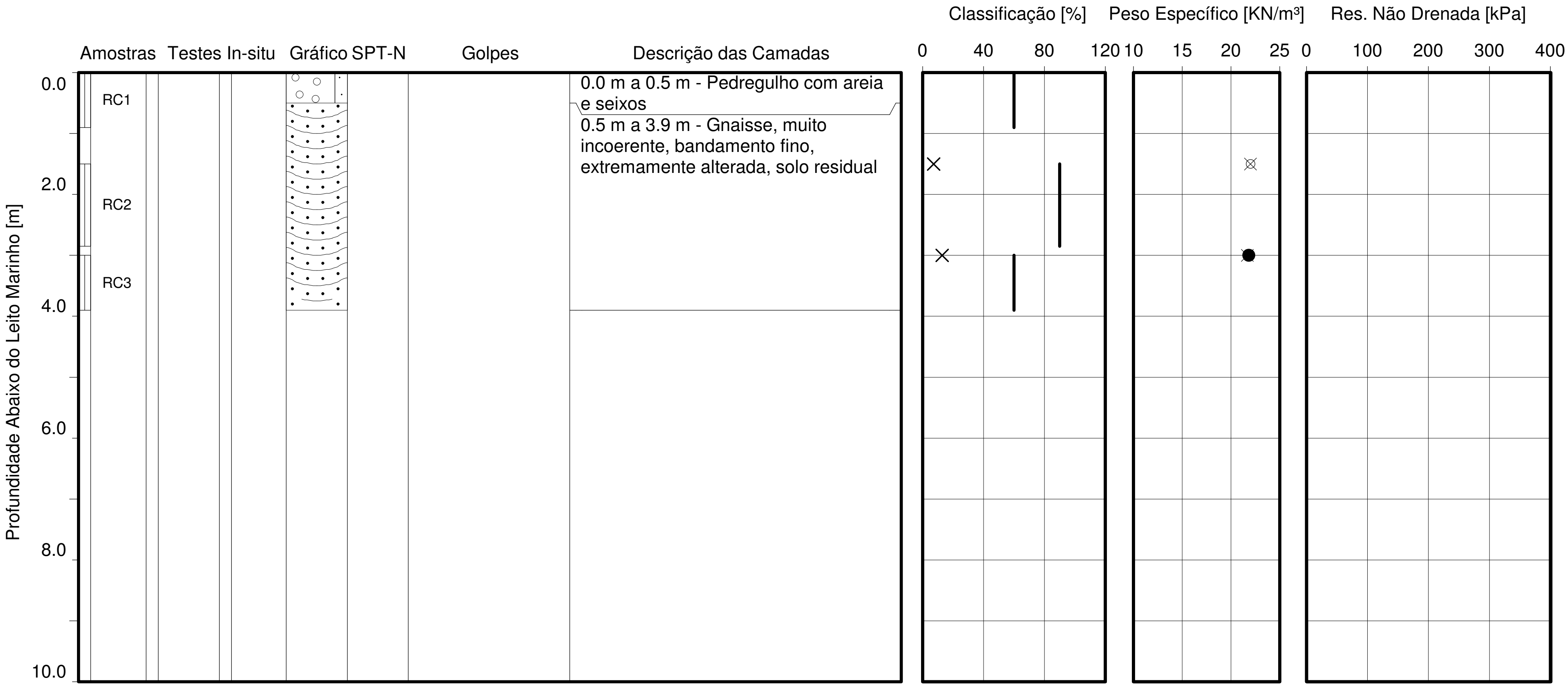
Penetrometro de bolso
Torvane
Fallcone
Mini-vane de laboratório
UU-triaxial
CU-triaxial
DSS
Point Load
UCS
CU de CPT
Referente a testes remoldados

BOLETIM DE SONDAGEM

FURO POR-18

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/VOO-02 LOG 10m.GLO/2015-07-16 16:43:10



Data de início : 12-jun-2015
Método : Rotary borehole drilling, sampling and testing
Recuperação : to 3.9 m profundidade abaixo do leito marinho
Penetração : to 4.5 m profundidade abaixo do leito marinho
Elevação : -3.9 m
Co-ordenadas : 688858 m E 7465034 m N

Recuperação total
Recuperação sólida
RQD
Teor de água
Limite plástico
Limite líquido
Índice de plasticidade
Percentagem de finos
Teor de carbonato
Teor de matéria orgânica
Densidade relativa derivada do CPT

Peso específico derivado do teor de água
Peso especifico derivado do cálculo de volume e massa

Penetrometro de bolso
Torvane
Fallcone
Mini-vane de laboratório
UU-triaxial
CU-triaxial
DSS
Point Load
UCS
CU de CPT
Referente a testes remoldados

BOLETIM DE SONDAGEM

FURO POR-19

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

SEÇÃO B: RESULTADO DOS TESTES IN-SITU

TEXTO - SEÇÃO B: Página

B SONDAGEM DE SIMPLES RECONHECIMENTO COM SPT

B.1 DETALHES

Os SPTs foram feitos conforme a norma brasileira NBR 6484: 1997.

A medição de energia foi feita para atender a norma. A energia transmitida pelos golpes foi medida através do acoplamento de uma haste instrumentada no topo das hastes SPT. A instrumentação é feita com dois acelerómetros e dois medidores de pressão sobre o sistema SPT. Os dados foram coletados e armazenados através do equipamento *Pile Drive Analyzer* (PDA), modelo PAX. O dispositivo recolhe os sinais de força (através dos medidores de deformação) e de velocidade (através dos acelerômetros) gerados pelos golpes. A energia transmitida é máxima calculada pela integral da força pela velocidade de produto ao longo do tempo. Depois de calcular o máximo de energia transmitida é possível calcular a eficiência do golpe. Isto é chamado de ratio de transferência de energia (ETR) e é mostrado em percentagem.

As medições de energia foram realizadas no furos POR-06 e POR-10 nos dias 9 e 10 de junho de 2015. A energia média medida foi de 61,7% no furo POR-06 e 63,0% no furo POR-10. Com os valores apresentados, a correção dos valores SPT fica a critério do cliente.

O relatório completo de medição de energia é mostrado no Apêndice 2, em Português.

B.2 COMENTÁRIOS DOS RESULTADOS

Na maioria das argilas muito moles testadas, o amostrador SPT penetrava apenas pelo seu peso-próprio, significando que nenhum golpe foi registrado para cada 45 cm de penetração.

A amostra SPT a 2,0m no furo POR-08 não teve recuperação. Foi recolhida uma amostra do “*bailer*”.

Os resultados SPT estão em conformidade com os solos amostrados.

B1.3 PRÁTICA PARA O TESTE DE PENETRAÇÃO - SPT

Teste In-Situ – SPT

Procedimento Geral:	Consulte o documento intitulado " *Standard Penetration Test* " (ref. Fugro FEBV/CDE/APP/036), apresentado no Apêndice 1
Sistema de Queda do Martelo:	Martelo de percurso automático
Velocidade de Operação de Rotação do Guincho:	0 a 240 RPM
Hastes de amostragem:	1”
Amostrador Bi-Partido:	Aplicável
Aranha:	Não aplicável
Cone sólido:	Não aplicável
Término do SPT:	Penetração de 45 cm ou impenetrável

Manipulação da amostra

Consulte a sub-seção "Práticas Para a Manipulação de Amostras e Testes de Laboratório" apresentada na seção intitulada "Resultados dos Ensaios de Laboratório"

Referências

Programa de computador GeODin®, apresentação e análise dos dados

NBR 6484:2001: Solo – Sondagem de Simples Reconhecimento com SPT – Método de Ensaio (2001)

SEÇÃO C: RESULTADOS DE ENSAIOS DE LABORATÓRIO

SEÇÃO C1: RESUMO DOS ENSAIOS DE LABORATÓRIO

TEXTO – SEÇÃO C1: Página

C1. RESUMO DOS ENSAIOS DE LABORATÓRIO

C1. RESUMO DOS ENSAIOS DE LABORATÓRIO

C1.1 ENSAIOS REALIZADOS

Somente os testes de índice (PP e TV) foram feitos a bordo da plataforma. Os valores para resistência não drenada ao cisalhamento (s_u), medidos pelos testes torvane e penetrômetro de bolso são apenas indicativos.

Foram pedidos testes em amostras de *Jet Probe* que não foram coletadas pela Fugro. Estas amostras estão identificadas pelas letras “JP” no nome das mesmas.

Os testes realizados no laboratório da Fugro em Curitiba foram os seguintes:

- Peneiramento e sedimentação
- Densidade das partículas
- Peso específico
- Limites de *Atterberg*
- Teor de água
- *Mini-vane* de laboratório
- Compressão uni-axial (UCS)
- Ensaios de carga pontual (*Point Load)*

Alguns dos testes planejados não puderam ser realizados nas amostras inicialmente escolhidas. Sempre que possível, amostras de substituição foram escolhidas. A lista abaixo indica as modificações feitas:

- POR-1 SPT1, Limites de Atterberg: não havia amostra suficiente; foi substituída pela amostra SPT2
- POR-7 SPT2, Limites de Atterberg: não havia amostra suficiente; foi substituída pela amostra SPT3
- POR-JP-13, Peneiramento: não havia amostra suficiente; nenhuma substituição de amostra foi pedida, assim sendo este teste não foi realizado
- POR-JP-32, Limites de Atterberg: não havia amostra suficiente; foi substituída pela amostra POR-JP-23
- POR-19 RC2, UCS: RQD muito fraco, amostra muito fraturada
- POR-19 RC3, UCS: solo não apropriado

C1.2 PRÁTICAS PARA A MANIPULAÇÃO DE AMOSTRAS E ENSAIOS DE LABORATÓRIO

Manipulação inicial da amostra

Amostra indeformada:	Identificação/rotulagem Medição de recuperação Descrição do topo e base da amostra Seladas com cera em ambas as extremidades e colocação de tampas de plástico fixas com fita isolante
Amostra deformada:	Medição de recuperação Descrição da amostra Colocação da amostra em um saco plástico tipo zip e fechá-lo, de maneira hermética Identificação/rotulagem
Amostra de Rocha	Remoção no convés do revestimento metálico Identificação/rotulagem inicial Medição de recuperação e descrição visual

Proteção da amostra

Acondicionamento das amostras indeformadas:	Plástico-bolha colocado ao redor dos tubos para evitar vibrações Caixa de transporte revestida com borracha e poliestireno Todas as amostras colocadas em posição vertical em caixa de transporte etiquetada

Transporte da amostra

Transporte da Amostra:	Retiradas da plataforma Frete rodoviário até o laboratório da Fugro em Curitiba

Laboratório Fugro em Curitiba

Programa de Ensaios:	Descrição visual, ensaios de classificação e resistência
Ajustes ao Programa:	Avaliação da viabilidade de um ensaio (por inspecção visual da amostra). Decisão do laboratório: (1) para prosseguir com o teste, (2) não prosseguir com o teste, (3) para aconselhar adaptações ao procedimento do teste. Selecção de amostra de teste alternativa se a decisão é "não prosseguir", ou quando a conclusão do teste adequado for impraticável.
Processamento e Gerenciamento dos Dados:	Software específicos do laboratório e software GeODin®, conforme o caso. Escalas gráficas selecionadas para atender a apresentação geral de dados. Sem visualização de dados fora dos limites do gráfico, ou seja, alguns valores podem não ser mostrados. Descrição geotécnica é uma interpretação de dados processados disponíveis no momento da preparação. Nível de detalhe e precisão na descrição e interpretação geotécnica

	dependem de fatores tais como resultados do ensaio, tamanho da amostra, qualidade, cobertura, disponibilidade de informações suplementares, e os requisitos do projeto.
Amostra em Tubo:	Extrusão da amostra Execução dos ensaios laboratoriais Se for o caso, seleção e rotulagem das seções de amostra não testada para armazenagem

Armazenagem e Descarte

Armazenagem:	Armazenagem por 2 meses após chegada ao laboratório Armazenadas em temperaturas entre os $+2^{o}C$ e $+35^{o}C$ Protegidas da ação direta do sol
Transporte:	Não aplicável
Descarte:	De acordo com o procedimento do laboratório

C1.3 ENSAIOS DE CLASSIFICAÇÃO

C1.3.1 DETALHES

Ensaios de granulometria foram realizados de acordo com a norma NBR7181.

Os ensaios *torvane*, penetrométricos de bolso e *mini-vane* de laboratório têm uma precisão limitada em silte, argila arenosa e / ou argilas com conchas e fragmentos de conchas. Os resultados dos ensaios realizados no em tais solos devem ser analisadas com cuidado.

Consideraram-se dois métodos para determinação do peso especifico (γ): (1) a medição do peso e volume da amostra e (2) calculado com base no teor de água e densidade de partículas. Ambos os métodos assumem uma saturação completa da amostra.

A densidade de partículas sólidas foi determinada por meio de um picnómetro num número selecionado de amostras. A gravidade específica medida ou a densidade das partículas sólidas está de acordo com os valores tipo para os solos encontrados.

Para obter informações detalhadas sobre os procedimentos dos diferentes ensaios, por favor consulte o documento da Fugro FEBV/CDE/APP/007 no Apêndice I.

C1.3.2 COMENTÁRIOS DOS RESULTADOS

No furo POR-01, amostra RC2, um *mini-vane* de laboratório foi feito para determinar a resistência do solo. O resultado foi muito menor do que o esperado e ocorreu devido a uma camada de argila mole por baixo do material mais duro. Este resultado não é representativo das condições gerais do solo in situ.

Os resultados dos limites de Atterberg mostram que a plasticidade dos solos amostrados varia de baixa plasticidade até extremamente elevada plasticidade.

No furo POR-18, amostra PUS2 e amostra POR-JP-27 os resultados dos limites de Atterberg mostram um solo não-plástico.

C1.4 ENSAIOS DE COMPRESSAO UNI-AXIAL

C1.4.1 DETALHES

Ensaios de resistência à compressão uni-axial (UCS) foram realizados e os resultados são apresentados na secção C3 do presente relatório. A resistência ao corte não drenada dos solos testados foi obtida a partir dos resultados dos UCS realizados e é apresentada nos boletins de sondagem da Seção A.

Algumas amostras inicialmente escolhidas mostraram não ser adequadas para testes, devido à sua natureza friável e / ou a presença de fracturas. Os testes UCS foram então substituídos por ensaios de mini-vane de laboratório de modo a determinar a sua resistência ao corte não-drenada.

C1.4.2 COMENTÁRIOS DOS RESULTADOS

No furo POR-05, devido à natureza do solo da amostra RC1 (silte arenoso), acreditamos que os resultados não são representativos das condições do solo. A partir deste resultado pode-se esperar que o solo testado tenha um comportamento mais ou menos drenante, uma vez que a resistência não drenada tem um valor muito baixo e o solo foi inicialmente descrito como competente. Também os resultados na amostra RC2 provavelmente não são representativos das condições do solo. Espera-se que o solo residual amostrado tenha uma natureza drenante.

C1.5 ENSAIO DE CARGA PONTUAL

C1.5.1 RESULTADOS

Não foi possível encontrar testemunhos adequados para executar ensaios UCS nas amostras coletadas no furo POR-19. Na amostra RC2 isso foi devido ao baixo RQD e alto índice de fraturas e na amostra RC3, após a abertura do revestimento de plástico, observou-se que a maior parte da amostra consiste em um solo residual jovem, em que a estrutura de rocha ainda estava preservada mas já se tornou solo, desintegrando-se com a pressão do dedo. Nessa amostra, havia apenas 5 cm de rocha no topo. O programa foi, portanto, ajustado e ensaios de carga pontual foram realizados. Os resultados são apresentados na tabela abaixo. Para obter informações sobre os procedimentos de teste, por favor consulte o documento Fugro " *Geotechnical Laboratory Tests on Rocks*", apresentado no Apêndice 1.

TABLE 1 – Resultados dos ensaios de carga pontual

Furo	Amostra	Profundidade (m)	Densidade (g/cm³)	Índice de carga pontual - I_s (Mpa)	Is_{50} (MPa)	Comentários
POR-19	RC2	1,5	2,20	0,108	0,00016	Perpendicular à foliação
POR-19	RC2	1,7	2,20	0,204	0,3677	Paralela à foliação
POR-19	RC2	1,9	2,20	0,251	0,45255	Perpendicular à foliação
POR-19	RC3	3,0	2,17	0,046	7,7E-05	Perpendicular à foliação

SEÇÃO C2: RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

LISTA DE ILUSTRAÇÕES NA SEÇÃO C2: Ilustração

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-01

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Push Sample 1	0.00 m to 1.00 m - Argila arenosa, muito mole, cinza a cinza claro mosqueada com amarelo amarronsado - no topo cinza muito escuro	0.00						2.69										
		0.80	15.8 15.8	21.5	20.8													
		1.00													166			
Standard Penetration Test 1	1.50 m to 1.70 m - Argila arenosa cinza oliva com finas intercalações de Areia argillosa cinza oliva	1.50																
		1.60	15.0	21.5														
	1.70 m to 1.95 m - Argila arenosa com pedregulho fino, cinza mosqueada com amarelo amarronzado	1.70																
		1.80													213			
		1.95													179			
Rock Core 1	1.50 m to 3.00 m - Argila arenosa, dura, cinza a cinza claro mosqueada com amarelo amarronzado	1.50																
		3.00													196			
Standard Penetration Test 2	3.00 m to 3.40 m - Argila com areia e pedregulho fino, dura, cinza a cinza claro mosqueada com marron avermelhado	3.00	18.1								19	54	35					
		3.20													171			
		3.40													204			
Rock Core 2	3.00 m to 4.50 m - Argila com areia e pedregulho fino, dura, cinza a cinza claro mosqueada com marron avermelhado	3.00	18.2 18.2	20.6	20.9			2.63										
		4.36																20
		4.50													179			

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

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RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-01

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Rock Core 3	4.50 m to 4.70 m - Argila arenosa, cinza a cinza claro	4.50																
	4.70 m to 4.90 m - Argila arenosa, vermelha a marron avermelhado	4.70																
	4.90 m to 5.10 m - Argila arenosa amarelo amarronsado a cinza claro	4.90																
Standard Penetration Test 3	5.50 m to 5.70 m - Areia fina a grossa argilosa com pedregulho, medianamente compacta, amarelo amarronsado	5.50	23.3 23.3	19.9				2.67						20				
	5.70 m to 5.90 m - Gnaisse, muito incoerente, com bandamento fino, solo residual, amarelo amarronzado, marrom e branco	5.70									29	52	23					

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_U : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

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RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-02

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Push Sample 1	0.00 m to 0.70 m - Argila arenosa, muito mole, cinza muito escuro, com conchas e fragmentos de concha	0.00						2.67										
		0.05	60.7 60.7	16.1	17.0													
		0.69														11		
		0.70														10		13
Standard Penetration Test 1	sem recuperação	1.50																
Push Sample 2	2.50 m to 2.80 m - Argila arenosa, muito mole, cinza muito escuro, com conchas e fragmentos de concha	2.50																
	2.80 m to 3.10 m - Argila arenosa, mole a média, cinza oliva a cinza	2.80																
		2.90	15.6		21.3													
		3.06	27.6 27.6	19.2	19.5			2.65			21	63	42					
		3.09														47		
		3.09														55		
		3.10													38			
Standard Penetration Test 2	4.00 m to 4.30 m - Argila com areia, rija, cinza a cinza claro mosqueada com amarelo amarronzado	4.00	18.7	20.7							23	69	46					
		4.10													121			
		4.20													142			
		4.30													213			
Push Sample 3	5.00 m to 5.80 m - Argila arenosa, dura, cinza a cinza claro	5.00																

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-02

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
		5.59	23.4		21.2													
		5.77			20.1			2.70						70				
		5.79													219	200		

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_U : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-03

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra		Prof.	w	Peso Específico [kN/m³]				ρ_s	Carb.	Org.	Limites de Atterberg			Fines	c_u [kPa]			
No.	Descrições do Solo	Teste [m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	Cont. [%]	Cont. [%]	w_P [%]	w_L [%]	I_p [%]	[%]	PP	TV	FC	LV
Push Sample 1	0.00 m to 0.45 m - Argila arenosa, muito mole, cinza muito escuro, contém muitas conchas e fragmentos de concha	0.00																
	0.45 m to 0.90 m - Argila arenosa, mole, cinza oliva	0.45																
		0.69	25.2		19.5													
		0.87			20.6			2.67								39		
		0.88														25		
Standard Penetration Test 1	1.50 m to 1.70 m - Argila arenosa, mole, cinza oliva	1.50																
	1.70 m to 1.95 m - Areia fina argilosa, cinza oliva	1.70																
Standard Penetration Test 2	2.50 m to 2.90 m - Argila arenosa, rija, cinza a cinza oliva	2.50	18.6	20.8							17	43	26					
		2.70													88			
		2.90													200			
Standard Penetration Test 3	3.50 m to 3.85 m - Argila arenosa, dura, cinza a cinza claro mosquada com cinza oliva a amarelo amarronzado - na base tem pedregulho	3.50																
		3.60													154			
		3.70													213			
		3.80													208			
		3.85													238			
Push Sample 2	4.50 m to 5.00 m - Argila arenosa, dura, cinza claro a amarelo amarronzado	4.50																
		4.79	16.6		20.5													
		4.95													213	238		

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_p : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

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RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-03

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
		4.97			20.2			2.69										
		5.00													150	160		
Standard Penetration Test 4	6.00 m to 6.30 m - Argila arenosa com pedregulho fino, dura, cinza claro a amarelo amarronzado	6.00																
Standard Penetration Test 5	7.00 m to 7.40 m - Areia média a grossa com pedregulho, medianamente compacta, marrom claro	7.00						2.73						7				
	7.40 m to 7.45 m - Argila arenosa, rija, cinza claro	7.40																
Standard Penetration Test 6	7.50 m to 7.75 m - Areia média a Pedregulho fino, medianamente compacta, marrom claro	7.50																
	7.75 m to 7.95 m - Areia argilosa, medianamente compacta, cinza claro a amarelo amarronsado	7.75																

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_U : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-04

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Push Sample 1	0.00 m to 0.74 m - Argila com areia fina, muito mole, cinza muito escuro, com poucos restos vegetais - odor pútrido	0.00	156.2 156.2	12.9	12.9			2.56										
		0.74														6		4
Standard Penetration Test 1	1.50 m to 1.70 m - Argila, muito mole, cinza muito escuro - odor pútrido	1.50	172.6	12.8							48	80	32					
Standard Penetration Test 2	2.50 m to 2.76 m - Argila, muito mole, cinza muito escuro, com traços de fragmentos de concha - odor pútrido	2.50																
Standard Penetration Test 3	3.50 m to 3.85 m - Argila com areia fina, muito mole, cinza muito escuro - odor pútrido	3.50	67.4	15.7							20	44	24					
Push Sample 2	4.50 m to 5.00 m - Areia fina argilosa, fofa, cinza muito escuro	4.50	42.4 42.4	17.6	18.0			2.69						23				
		5.00														13		10

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

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RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-05

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Standard Penetration Test 1	1.00 m to 1.05 m - Areia fina a grossa, cinza	1.00																
	1.05 m to 1.30 m - Argila arenosa com pedregulho fino, rija, cinza	1.05																
		1.29													167			
Standard Penetration Test 2	2.50 m to 2.60 m - Argila, média, cinza oliva a cinza	2.50	41.0	17.8							40	132	92					
	2.60 m to 2.70 m - Gnaisse, muito incoerente, bandamento fino, solo residual, variegado	2.60													38			
Standard Penetration Test 3	sem recuperação	4.00													38			
Rock Core 1	4.00 m to 4.35 m - Argila, dura, marrom, com brilho metálico	4.00																
		4.17						2.70										
		4.18	28.6		19.6													
Standard Penetration Test 4	5.50 m to 5.70 m - Silte arenoso, muito compacto, marrom, com brilho metálico	5.50	20.7	20.7				2.73			28	37	9	41				
Rock Core 2	6.00 m to 6.90 m - Gnaisse, muito incoerente, bandamento fino, solo residual, variegado	6.00	32.9		18.9			2.69										
		6.30	46.2 46.2	17.2	18.2													
		6.71	40.9		18.8													
		6.90														20		45

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_s : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

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RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-05

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra		Prof. Teste	w	Peso Específico [kN/m³]				ρ_s	Carb. Cont.	Org. Cont.	Limites de Atterberg			Fines	c_u [kPa]			
No.	Descrições do Solo	[m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	[%]	[%]	w_P [%]	w_L [%]	I_P [%]	[%]	PP	TV	FC	LV
Standard Penetration Test 5	sem recuperação	7.00													167			

Leg.:

- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

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RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-06

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Bulk Sample 1	0.00 m to 0.25 m - Argila arenosa, muito mole, marrom claro, contém fragmentos de concha	0.00						2.73						54				
Standard Penetration Test 1	2.00 m to 2.30 m - Argila, rija, cinza clara mosqueada com marrom escuro avermelhado, com brilho perolado	2.00	25.7	19.8							24	52	28					
		2.28													63			
Standard Penetration Test 2	3.50 m to 3.88 m - Argila com areia, rija, micácea, branco mosqueada com marrom escuro avermelhado, com traços de pedregulho de quartzo	3.50																
Standard Penetration Test 3	5.00 m to 5.10 m - Argila, rija a dura, micácea, marrom escuro avermelhado, com brilho perolado, com traços de areia	5.00																
	5.10 m to 5.28 m - Argila com areia, rija a dura, marrom claro amarelado mosqueada com branco, com areia	5.10																
	5.28 m to 5.40 m - Argila, rija a dura, micácea, marrom escuro avermelhado, com brilho perolado, com traços de areia	5.28																
Standard Penetration Test 4	6.50 m to 6.91 m - Argila, dura, micácea, marrom escuro avermelhado, com brilho perolado	6.50	27.3	19.5							24	59	35					
Push Sample 2	7.50 m to 7.60 m - Argila, micácea, marrom escuro avermelhado, com brilho perolado	7.50	48.4 48.4	17.2	17.5			2.75										
		7.60														2		16
Standard Penetration Test 5	8.50 m to 8.77 m - Argila, rija, micácea, marrom escuro avermelhado, com brilho perolado	8.50																
	8.77 m to 8.82 m - Argila, rija, amarelo claro a branco	8.77																
	8.82 m to 8.95 m - Argila, rija, micácea, marrom escuro avermelhado, com brilho perolado	8.82																

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

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RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-07

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Push Sample 1	0.00 m to 0.50 m - Argila arenosa, muito mole, cinza claro mosqueada com cinza escuro e marrom escuro	0.00	64.4 64.4	15.8	18.5			2.65										
		0.48														21		
		0.48														22		
		0.48														12		
		0.50														11		8
Standard Penetration Test 1	1.50 m to 1.95 m - Argila arenosa, muito mole, cinza	1.50																
Standard Penetration Test 2	3.00 m to 3.45 m - Argila arenosa, muito mole, cinza	3.00	147.8	13.1														
Standard Penetration Test 3	4.50 m to 4.95 m - Argila, muito mole, cinza esculo, com poucas conchas e fragmentos de concha - odor a H2S	4.50	14.6								16	39	23					
Push Sample 2	6.00 m to 6.80 m - Argila arenosa, média, cinza esculo a cinza	6.00			20.5			2.68						43				
		6.40	33.8		18.1													
		6.77													58			
		6.78														37		
		6.78														55		
		6.78														25		
Standard Penetration Test 4	8.00 m to 8.25 m - Argila arenosa, rija, cinza mosqueada com amarelo amarronsado	8.00																
		8.24													146			

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

FUGRO

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-07

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Standard Penetration Test 5	9.50 m to 9.75 m - Argila arenosa, dura, cinza mosqueada com amarelo amarronsado, com traços de matéria orgânica	9.50	16.6	21.2							17	52	35					
		9.73														230		
Standard Penetration Test 6	10.50 m to 10.75 m - Argila arenosa, dura, amarelo amarronsado mosqueada com cinza	10.50																

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_U : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-08

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra		Prof. Teste	w	Peso Específico [kN/m³]				ρ_s	Carb. Cont.	Org. Cont.	Limites de Atterberg			Fines	c_u [kPa]			
No.	Descrições do Solo			γ_1	γ_2	γ_d min.	γ_d max.				w_P	w_L	I_P		PP	TV	FC	LV
		[m]	[%]					[Mg/m³]	[%]	[%]	[%]	[%]	[%]	[%]				
Bulk Sample 1	0.00 m to 0.20 m - Areia média a grossa com pedregulho, cinza, com conchas e fragmentos de concha	0.00						2.65						5				
Standard Penetration Test 1	sem recuperação	2.00																
Standard Penetration Test 2	sem recuperação	3.50																
Standard Penetration Test 3	5.00 m to 5.35 m - Areia média a grossa com pedregulho, fofa, cinza, com algumas conchas e fragmentos de concha	5.00																
	5.35 m to 5.45 m - Argila, muito mole, cinza com manchas pretas	5.35																
Push Sample 2	6.50 m to 7.05 m - Argila, mole a média, cinza	6.50	33.3 33.3	18.5	17.8			2.68			29	66	37					
		7.00													63	48		
		7.01													50	60		
		7.05														15		20
Standard Penetration Test 4	8.50 m to 8.80 m - Argila, rija, cinza	8.50																
		8.74													175			
		8.75													150			
Standard Penetration Test 5	10.00 m to 10.38 m - Argila, dura, cinza	10.00	15.6	21.4							14	42	28					
Standard Penetration Test 6	11.00 m to 11.36 m - Argila, dura, cinza	11.00																

Leg.:
- w : teor de água
- γ_1 : peso específico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_s : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-08

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

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Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Standard Penetration Test 7	12.50 m to 12.82 m - Argila, dura, cinza - no topo inclusões de marrom	12.50																
		12.60	15.9	21.3							17	52	35					

Leg.:

- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

GeODin/LCTS TT with GD.GLO/2015-07-16 15:28:21

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-09

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra		Prof.	w	Peso Específico [kN/m³]				ρ_s	Carb.	Org.	Limites de Atterberg			Fines	c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Standard Penetration Test 1	1.00 m to 1.45 m - Argila, muito mole, cinza muito escuro	1.00																
Push Sample 1	2.50 m to 3.45 m - Argila, muito mole, cinza muito escuro	2.50	162.4 162.4	12.8	13.1			2.58										
		3.40																5
		3.44														4		
		3.44														4		
		3.45														8		
Standard Penetration Test 2	4.00 m to 4.45 m - Argila, muito mole, cinza muito escuro, com poucas conchas e fragmentos de concha, com pouca matéria orgânica	4.00	137.9	13.2							40	70	30					
Standard Penetration Test 3	5.50 m to 5.90 m - Argila, levemente cimentada, cinza claro com manchas amarelo amarronzado	5.50																
Standard Penetration Test 4	7.00 m to 7.30 m - Argila arenosa com pouco pedregulho, dura, cinza claro	7.00	16.8	21.0				2.64			15	50	35	57				
Standard Penetration Test 5	8.50 m to 8.90 m - Argila com areia e pedregulho, dura, cinza claro	8.50																
Standard Penetration Test 6	9.50 m to 9.80 m - Argila com areia e pedregulho, dura, cinza claro	9.50	13.8	21.4							19	62	43					

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_s : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-10

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/LCTS TT with GD.GLO/2015-07-16 15:28:51

Amostra		Prof. Teste	w	Peso Específico [kN/m³]				ρ_s	Carb. Cont.	Org. Cont.	Limites de Atterberg			Fines	c_u [kPa]			
No.	Descrições do Solo	[m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	[%]	[%]	w_P [%]	w_L [%]	I_P [%]	[%]	PP	TV	FC	LV
Bulk Sample 1	0.00 m to 0.20 m - Argila, muito mole, cinza muito escuro a preto, com conchas e fragmentos de concha, com restos vegetais - odor pútrido	0.00																
Standard Penetration Test 1	sem recuperação	1.00																
Standard Penetration Test 2	2.00 m to 2.25 m - 0.00 m to 0.20 m - Argila, muito mole, cinza muito escuro, com conchas e fragmentos de concha, com restos vegetais - odor pútrido	2.00	88.3								28	73	45					
Standard Penetration Test 3	3.00 m to 3.06 m - Argila, muito mole, cinza	3.00																
Bulk Sample 2	4.50 m to 4.70 m - Argila com areia, cinza claro	4.50																
Standard Penetration Test 4	6.50 m to 6.79 m - Argila com areia, rija, cinza claro mosqueada com marrom, com traços de matéria orgânica	6.50	31.0								22	86	64					
Standard Penetration Test 5	8.00 m to 8.32 m - Argila com areia, dura, cinza claro mosqueada com marrom, com inclusões de silte	8.00																
		8.30													196			
Standard Penetration Test 6	9.50 m to 9.85 m - Argila com areia, dura, cinza claro mosqueada com marrom	9.50																
		9.82													175			
Push Sample 3	no recovery	10.50																
Standard Penetration Test 7	10.50 m to 10.85 m - Argila com areia, dura, cinza claro mosqueada com marrom	10.50	19.6								17	71	54					

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_s : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-10

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
		10.82													180			
Standard Penetration Test 8	12.50 m to 12.89 m - Argila com areia, dura, cinza claro mosqueada com marrom, com pouco pedregulho fino de quartzo	12.50																
		12.87													133			

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

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RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-11

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Push Sample 1	1.00 m to 1.20 m - Argila com areia, muito mole, preta	1.00																
Standard Penetration Test 1	2.50 m to 2.95 m - Areia com pedregulho, fofa, com poucas conchas e fragmentos de concha	2.50																
Standard Penetration Test 2	4.00 m to 4.45 m - Areia com pedregulho, fofa a pouco compacta, cinza muito escuro a cinza escuro, com poucas conchas e fragmentos de concha	4.00						2.65						10				
		4.30						2.66						13				
Standard Penetration Test 3	5.50 m to 5.80 m - Argila, mole, cinza com manchas vermelho amarelado, com traços de areia fina	5.50	32.6	18.5							24	64	40					
		5.78														66		
		5.78														65		
Push Sample 2	7.00 m to 7.30 m - Argila arenosa, rija, cinza	7.00			20.0			2.63										
		7.10	22.0		22.2													
		7.28														188		
		7.28														178		
		7.29													125			
Standard Penetration Test 4	8.50 m to 8.90 m - Argila arenosa, rija, cinza, com pouca matéria orgânica, com poucos pedregulhos finos	8.50																
Standard Penetration Test 5	10.00 m to 10.45 m - Argila arenosa, dura, cinza a cinza claro com manchas amarelo amarronsado	10.00	14.6	21.5							16	46	30					
Standard Penetration Test 6	11.50 m to 11.85 m - Argila arenosa, dura, amarelo amarronsado	11.50																

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-11

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Push Sample 3	13.00 m to 13.40 m - Argila arenosa, dura, cinza a amarelo amarronsado	13.00			20.4			2.63										
		13.17	20.7		23.5													
Standard Penetration Test 7	13.50 m to 13.80 m - Argila arenosa, dura, amarelo amarronsado mosqueada com cinza	13.50																

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_U : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-12

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra		Prof. Teste	w	Peso Específico [kN/m³]				ρ_s	Carb. Cont.	Org. Cont.	Limites de Atterberg			Fines	c_u [kPa]			
No.	Descrições do Solo	[m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	[%]	[%]	w_P [%]	w_L [%]	I_P [%]	[%]	PP	TV	FC	LV
Bulk Sample 1	0.00 m to 0.20 m - Argila, muito mole, cinza muito escura, com traços de conchas e fragmentos de concha, com restos vegetais - odor pútrido	0.00																
Standard Penetration Test 1	1.50 m to 1.95 m - Argila, muito mole, cinza muito escura, com traços de conchas e fragmentos de concha, com traços de restos vegetais - odor pútrido	1.50																
Standard Penetration Test 2	3.00 m to 3.45 m - Argila, muito mole, cinza muito escura, com traços de conchas e fragmentos de concha, com traços de restos vegetais - odor pútrido	3.00	79.1	15.1							25	63	38					
Standard Penetration Test 3	4.50 m to 4.90 m - Argila, média, cinza mosqueada com marrom e vermelho, com traços de cristais de mica - no topo argila arenosa	4.50																
Push Sample 2	5.50 m to 6.20 m - Argila, rija, cinza claro mosqueada com marrom avermelhado, com traços de cristais de mica - ocasionalmente com areia	5.50			20.9			2.70										
		6.01	18.7		20.8													
		6.19														175		
		6.19													167	150		
Standard Penetration Test 4	7.00 m to 7.27 m - Argila, dura, cinza mosqueada com marrom avermelhado - ocasionalmente com areia	7.00																
	7.27 m to 7.29 m - Argila arenosa, cinza	7.27																
Standard Penetration Test 5	8.50 m to 8.80 m - Argila arenosa, dura, cinza manchada com marrom, ocasionalmente traços de oxidação	8.50	15.8	21.6				2.72			16	56	40	46				
Push Sample 3	9.50 m to 9.90 m - Argila arenosa, rija, cinza claro manchada com marrom	9.50			20.2			2.65										
		9.83	23.6		21.7													

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_s : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

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RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-12

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra		Prof. Teste	w	Peso Específico [kN/m³]				ρ_s	Carb. Cont.	Org. Cont.	Limites de Atterberg			Fines	c_u [kPa]			
No.	Descrições do Solo	[m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	[%]	[%]	w_P [%]	w_L [%]	I_P [%]	[%]	PP	TV	FC	LV
		9.89													196			
Standard Penetration Test 6	10.50 m to 10.93 m - Argila arenosa, rija, cinza claro, com traços de pedregulho fino de quartzo	10.50																
Standard Penetration Test 7	11.50 m to 11.79 m - Argila com areia, dura, cinza claro mosqueada com marrom	11.50																

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_s : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-14

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra		Prof. Teste	w	Peso Específico [kN/m³]				ρ_s	Carb. Cont.	Org. Cont.	Limites de Atterberg			Fines	c_u [kPa]			
No.	Descrições do Solo	[m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	[%]	[%]	w_P [%]	w_L [%]	I_P [%]	[%]	PP	TV	FC	LV
Standard Penetration Test 1	1.00 m to 1.25 m - Argila, muito mole, cinza muito escura, com conchas e fragmentos de concha - no topo com areia	1.00																
Push Sample 1	2.50 m to 2.55 m - Argila, muito mole, cinza muito escura - odor a H2S	2.50																
Standard Penetration Test 2	4.00 m to 4.20 m - Argila, muito mole, cinza muito escura, com conchas e fragmentos de concha	4.00	115.7	13.8							30	75	45					
Standard Penetration Test 3	5.00 m to 5.13 m - Argila, muito mole, cinza muito escura, com conchas e fragmentos de concha	5.00																
	5.13 m to 5.21 m - Areia média a grossa argillosa, fofa, cinza claro	5.13																
Standard Penetration Test 4	6.50 m to 6.79 m - Argila arenosa, dura, cinza - no topo manchas marrom	6.50	16.2	21.1							17	51	34					
Standard Penetration Test 5	7.50 m to 7.95 m - Areia média a grossa argillosa, compacta, cinza claro	7.50																
Standard Penetration Test 6	8.50 m to 8.70 m - Areia média a grossa argillosa, medianamente compacta, cinza claro	8.50																
	8.70 m to 8.93 m - Argila com areia, dura, cinza mosqueada com marrom, com inclusões de silte	8.70																
Standard Penetration Test 7	9.50 m to 9.95 m - Areia fina a grossa argillosa, compacta, cinza claro a cinza	9.50						2.63						30				

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_s : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

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RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-15

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Bulk Sample 1	0.00 m to 0.20 m - Argila com areia, muito mole, preta	0.00																
Push Sample 2	1.00 m to 1.30 m - Argila arenosa, mole, cinza clara	1.00	16.7		21.3													
			16.7															
		1.30														21		29
Standard Penetration Test 1	2.00 m to 2.30 m - Argila arenosa, dura, cinza clara, com poucos pedregulhos, com pouca matéria orgânica	2.00	35.8								27	66	39					
		2.29													156			

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_U : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-17

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/LCTS TT with GD.GLO/2015-07-16 15:31:37

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Bulk Sample 1	0.00 m to 0.20 m - Gravel	0.00						2.64						7				
Standard Penetration Test 1	1.50 m to 1.72 m - Argila, dura, branco, amarelo e marrom escuro, com camada de quartzo alterado, apresenta estrutura reliquiar	1.50	14.3	21.5							13	43	30					
Standard Penetration Test 2	2.50 m to 2.70 m - Gnaisse, muito incoerente, bandamento fino, solo residual, extremamente alterado	2.50	125.2	13.6							40	107	67					
Standard Penetration Test 3	3.50 m to 3.65 m - Gnaisse, muito incoerente, bandamento fino, solo residual, extremamente alterado	3.50																

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-18

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra		Prof.	w	Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Push Sample 1	0.00 m to 0.60 m - Argila arenosa, muito mole, cinza muito escura, com conchas e fragmentos de concha	0.00	27.9 27.9	19.1	19.3			2.65										
		0.58														15		
		0.60														20		15
Push Sample 2	1.00 m to 2.00 m - Argila arenosa, muito mole a mole, cinza muito escura, com poucas conchas e fragmentos de concha	1.00			18.9			2.68										
		1.96														14		
		2.00	24.7	19.7												12		25

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_U : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-19

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Rock Core 1	0.00 m to 0.45 m - Pedregulho com areia e seixos	0.00																
	0.45 m to 0.90 m - Gnaisse, muito incoerente, bandamento fino, extremamente alterada, solo residual	0.45																
Rock Core 2	1.50 m to 2.85 m - Gnaisse, muito incoerente, bandamento fino, extremamente alterada, solo residual	1.50	7.3 7.3		22.0													
Rock Core 3	3.00 m to 3.90 m - Gnaisse, muito incoerente, bandamento fino, extremamente alterada, solo residual	3.00	12.9 12.9	21.8	21.7			2.64										

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_U : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

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RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-JP-01

PORT OF RIO DE JANEIRO - GUANABARA BAY

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Grab Sample 1		0.00						2.70						22				

Leg.:

- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-JP-07

PORT OF RIO DE JANEIRO - GUANABAR BAY

Amostra		Prof. Teste	w	Peso Específico [kN/m³]				ρ_S	Carb. Cont.	Org. Cont.	Limites de Atterberg			Fines	c_u [kPa]			
No.	Descrições do Solo	[m]	[%]	γ_1	γ_2	γ_d min.	γ_d max.	[Mg/m³]	[%]	[%]	w_P [%]	w_L [%]	I_P [%]	[%]	PP	TV	FC	LV
Grab Sample 1		1.50						2.65						13				

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-JP-10

PORT OF RIO DE JANEIRO - GUANABARA BAY

Amostra		Prof.	w	Peso Específico [kN/m³]				ρ_s	Carb.	Org.	Limites de Atterberg			Fines	c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Grab Sample 1		3.00						2.65						15				

Leg.:

- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_s : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-JP-15

PORT OF RIO DE JANEIRO - GUANABARA BAY

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Grab Sample 1		0.00	33.1								18	41	23					

Leg.:

- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-JP-17

PORT OF RIO DE JANEIRO - GUANABARA BAY

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Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Grab Sample 1		0.00	79.4															

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso especifico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

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RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-JP-23

PORT OF RIO DE JANEIRO - GUANABARA BAY

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Grab Sample 1		0.00	74.2								21	49	28					

Leg.:

- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_U : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

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RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-JP-27

PORT OF RIO DE JANEIRO - GUANABARA BAY

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Grab Sample 1		0.00	28.0															

Leg.:
- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_U : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

RESULTADOS DOS ENSAIOS DE CLASSIFICAÇÃO

FURO POR-JP-32

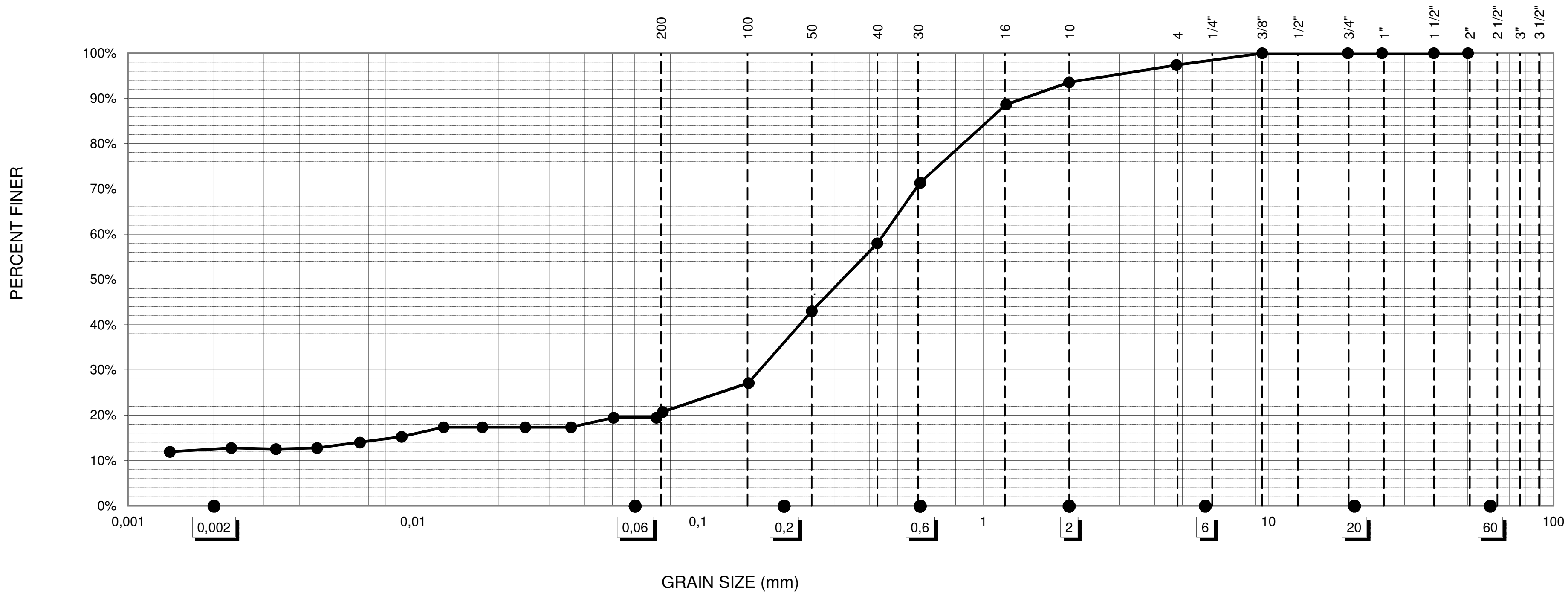
PORT OF RIO DE JANEIRO - GUANABARA BAY

Amostra				Peso Específico [kN/m³]							Limites de Atterberg				c_u [kPa]			
No.	Descrições do Solo	Prof. Teste [m]	w [%]	γ_1	γ_2	γ_d min.	γ_d max.	ρ_s [Mg/m³]	Carb. Cont. [%]	Org. Cont. [%]	w_P [%]	w_L [%]	I_P [%]	Fines [%]	PP	TV	FC	LV
Grab Sample 1		0.00	137.8															

Leg.:

- w : teor de água
- γ_1 : peso especifico derivado do teor de água
- γ_2 : peso específico derivado do volume e peso
- γ_{dmin} : peso específico mínimo
- γ_{dmax} : peso específico máximo
- ρ_S : densidade das partículas
- Carb.Cont. : teor de carbonato
- Org.Cont. : teor de matéria orgânica
- w_P : limite plástico
- w_L : limite liquido
- I_P : índice de plasticidade
- Fines : percentagem de material que passa nos peneiros 63 µm ou 75 µm
- PP : penetrometro de bolso
- TV : torvane
- FC : fall cone
- LV : mini-vane de laboratório
- c_u : resistência ao corte não drenada
- 10r : r referente aos resultados remoldados

(i) GRAIN SIZE DISTRIBUTION



D_{10}	(mm)	N/A
D_{30}	(mm)	0.1680
D_{50}	(mm)	0.3314
D_{60}	(mm)	0.4510
CNU		N/A
CC		N/A

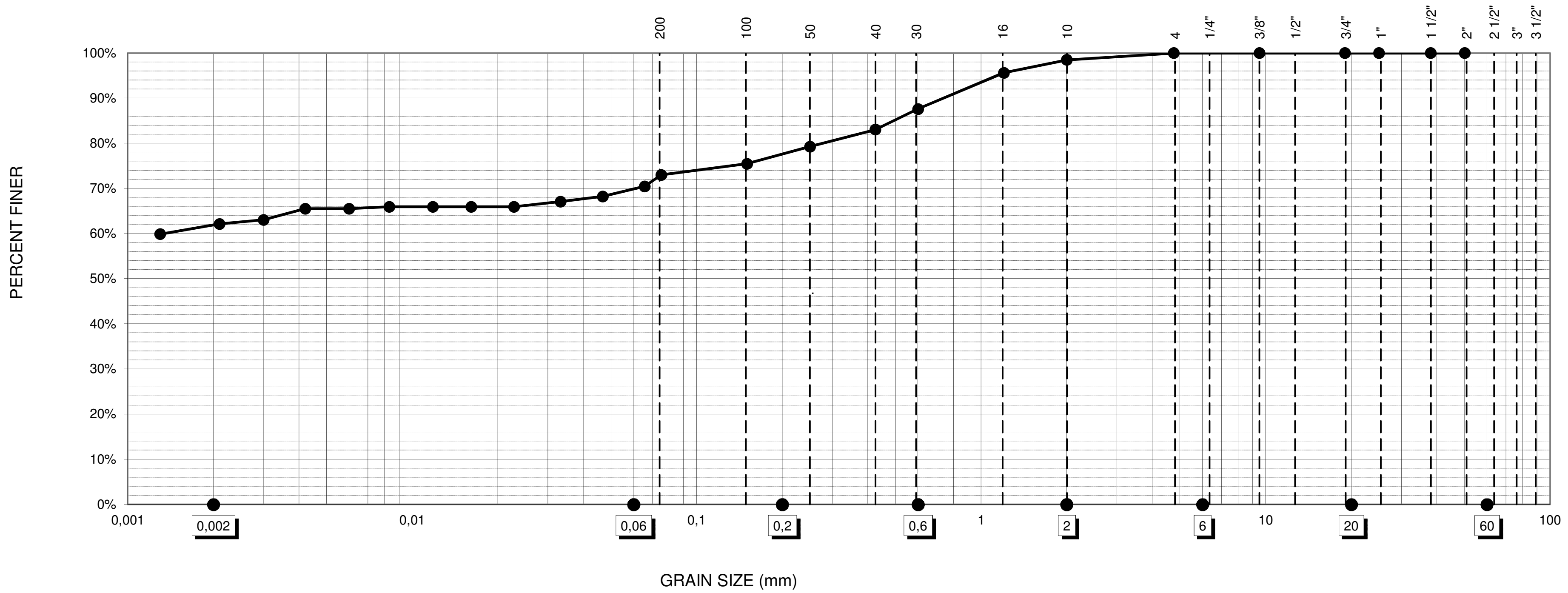
Particle	Clay	Silt	Fine Sand	Medium Sand	Coarse Sand	Gravel	
Diameter (mm)	< 0,002	0,002 ↔ 0,06	0,06 ↔ 0,2	0,2 ↔ 0,6	0,6 ↔ 2,0	2,0 ↔ 60,0	NBR7181
Percent	12.51	6.99	15.58	36.31	22.17	6.44	

FUGRO

GRAIN SIZE DISTRIBUTION

Project:	VOO003
Lab. ID:	S15505
Borehole:	POR01
Sample:	SPT03
Depth of sample (m):	5.50 - 6.00

(i) GRAIN SIZE DISTRIBUTION



D_{10}	(mm)	N/A
D_{30}	(mm)	N/A
D_{50}	(mm)	N/A
D_{60}	(mm)	0.0013
CNU		N/A
CC		N/A

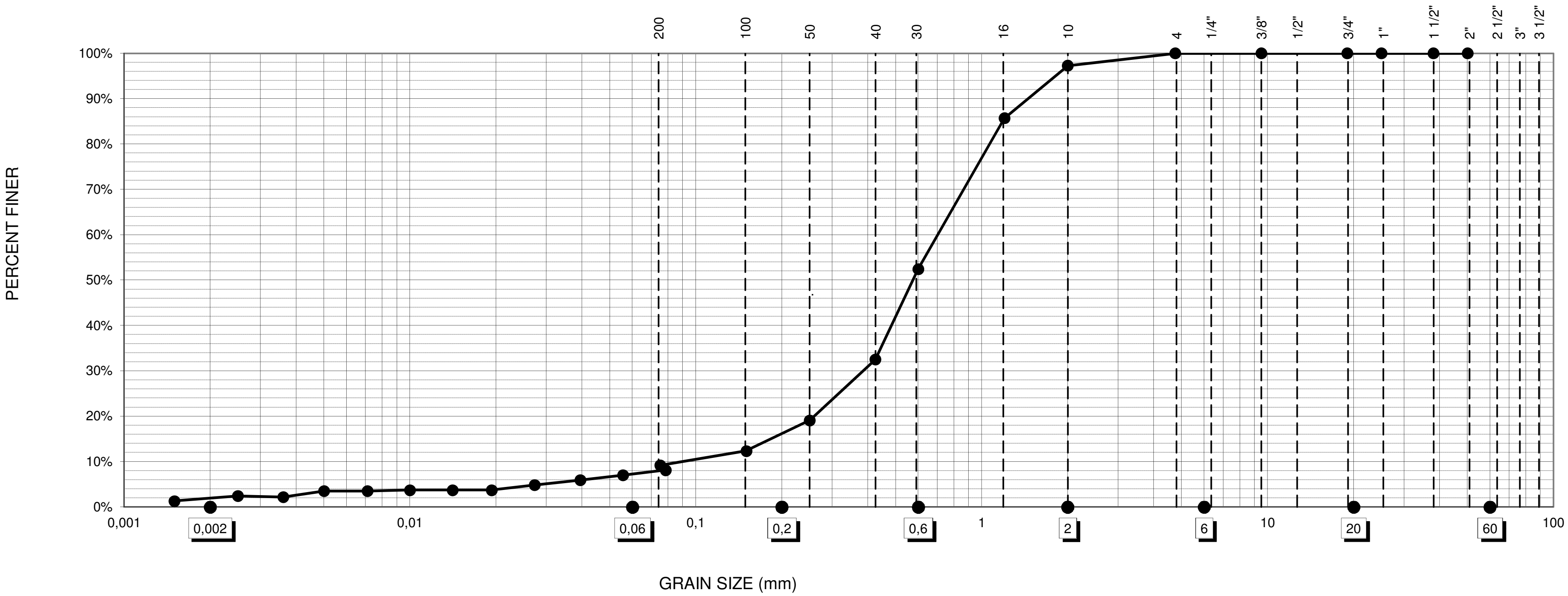
PartIcle	Clay	Silt	Fine Sand	Medium Sand	Coarse Sand	Gravel	NBR7181
Diameter (mm)	< 0,002	0,002 ↔ 0,06	0,06 ↔ 0,2	0,2 ↔ 0,6	0,6 ↔ 2,0	2,0 ↔ 60,0	
Percent	61.86	7.94	7.55	10.25	10.88	1.52	

FUGRO

GRAIN SIZE DISTRIBUTION

Project:	VOO003
Lab. ID:	S15381
Borehole:	POR02
Sample:	PUS03
Depth of sample (m):	5.00

(i) GRAIN SIZE DISTRIBUTION



D_{10}	(mm)	0.0941
D_{30}	(mm)	0.3920
D_{50}	(mm)	0.5784
D_{60}	(mm)	0.7362
CNU		7.82
CC		2.22

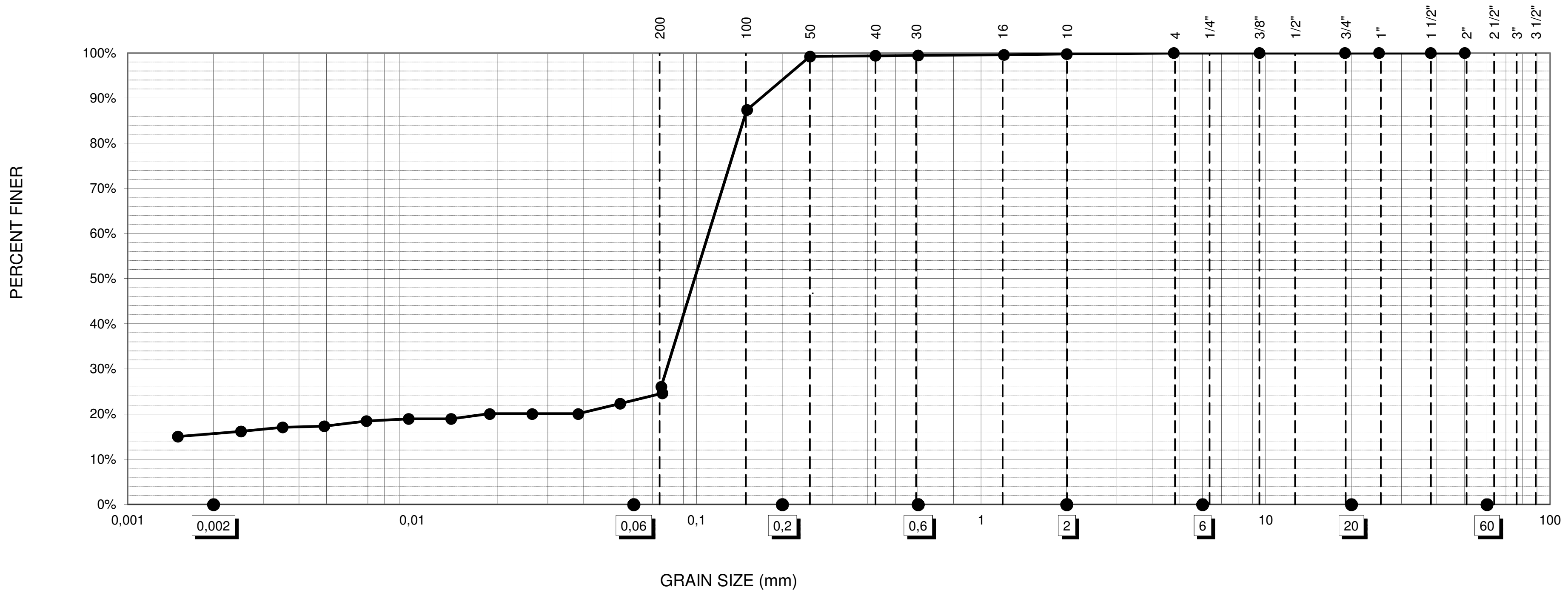
Partlcle	Clay	Silt	Fine Sand	Medium Sand	Coarse Sand	Gravel	NBR7181
Diameter (mm)	< 0,002	0,002 ↔ 0,06	0,06 ↔ 0,2	0,2 ↔ 0,6	0,6 ↔ 2,0	2,0 ↔ 60,0	
Percent	1.87	5.58	8.28	36.73	44.82	2.72	

FUGRO

GRAIN SIZE DISTRIBUTION

Project:	VOO003
Lab. ID:	S15415
Borehole:	POR03
Sample:	-
Depth of sample (m):	7.00 - 7.50

(i) GRAIN SIZE DISTRIBUTION

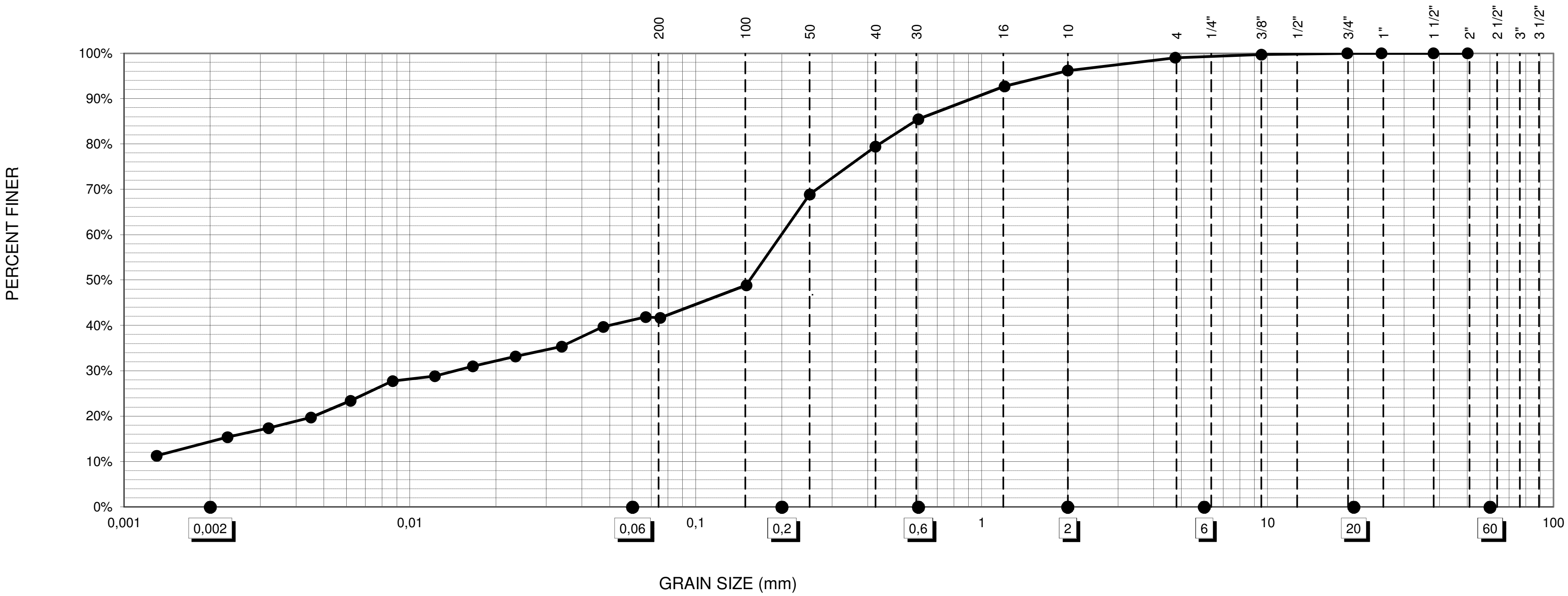


D_{10}	(mm)	N/A
D_{30}	(mm)	0.0798
D_{50}	(mm)	0.1043
D_{60}	(mm)	0.1165
CNU		N/A
CC		N/A

Partlcle	Clay	Silt	Fine Sand	Medium Sand	Coarse Sand	Gravel	NBR7181
Diameter (mm)	< 0,002	0,002 ↔ 0,06	0,06 ↔ 0,2	0,2 ↔ 0,6	0,6 ↔ 2,0	2,0 ↔ 60,0	
Percent	15.63	7.78	69.91	6.15	0.30	0.23	

GRAIN SIZE DISTRIBUTION	**Project:**	VOO003
	Lab. ID:	S15385
	Borehole:	POR04
	Sample:	PUS02
	Depth of sample (m):	4.50 - 5.50

(i) GRAIN SIZE DISTRIBUTION



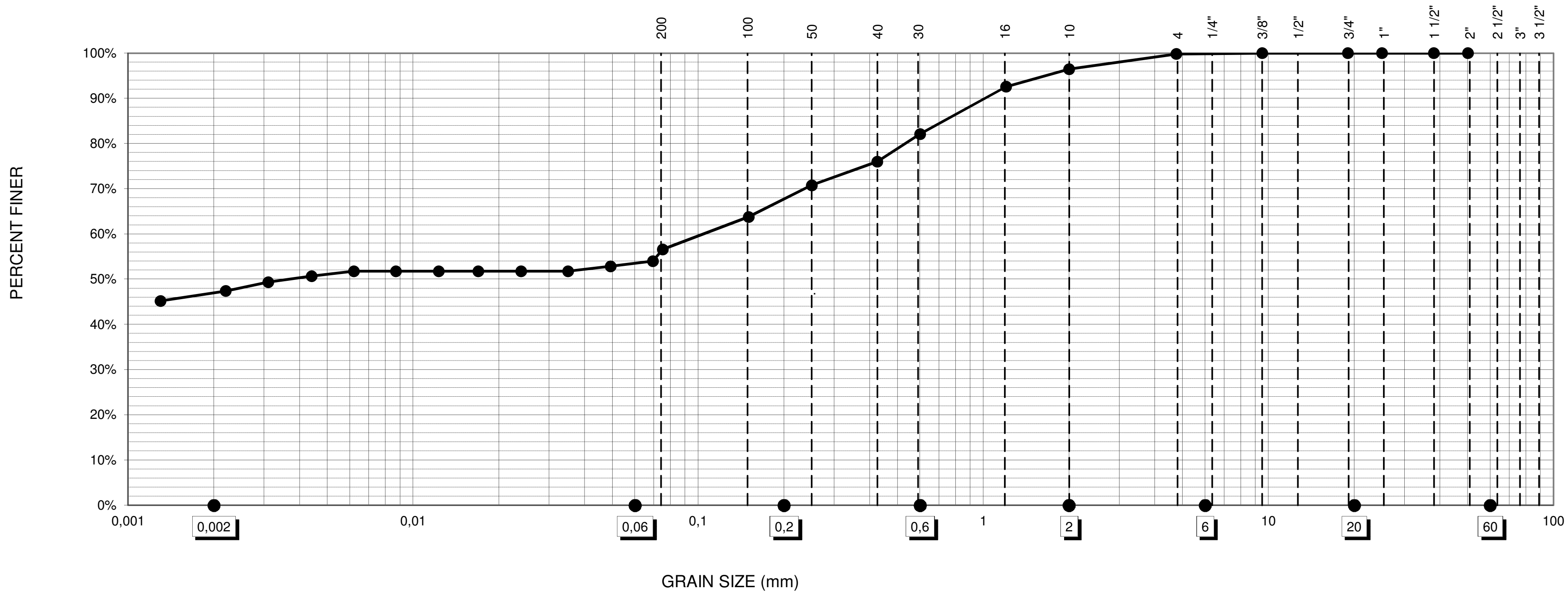
D_{10}	(mm)	N/A
D_{30}	(mm)	0.0145
D_{50}	(mm)	0.1556
D_{60}	(mm)	0.2055
CNU		N/A
CC		N/A

Partlcle	Clay	Silt	Fine Sand	Medium Sand	Coarse Sand	Gravel	NBR7181
Diameter (mm)	< 0,002	0,002 ↔ 0,06	0,06 ↔ 0,2	0,2 ↔ 0,6	0,6 ↔ 2,0	2,0 ↔ 60,0	
Percent	14.18	26.97	17.75	26.60	10.69	3.81	

GRAIN SIZE DISTRIBUTION

Project:	VOO003
Lab. ID:	S15423
Borehole:	POR05
Sample:	SPT04/BAGA 4
Depth of sample (m):	5.50

(i) GRAIN SIZE DISTRIBUTION



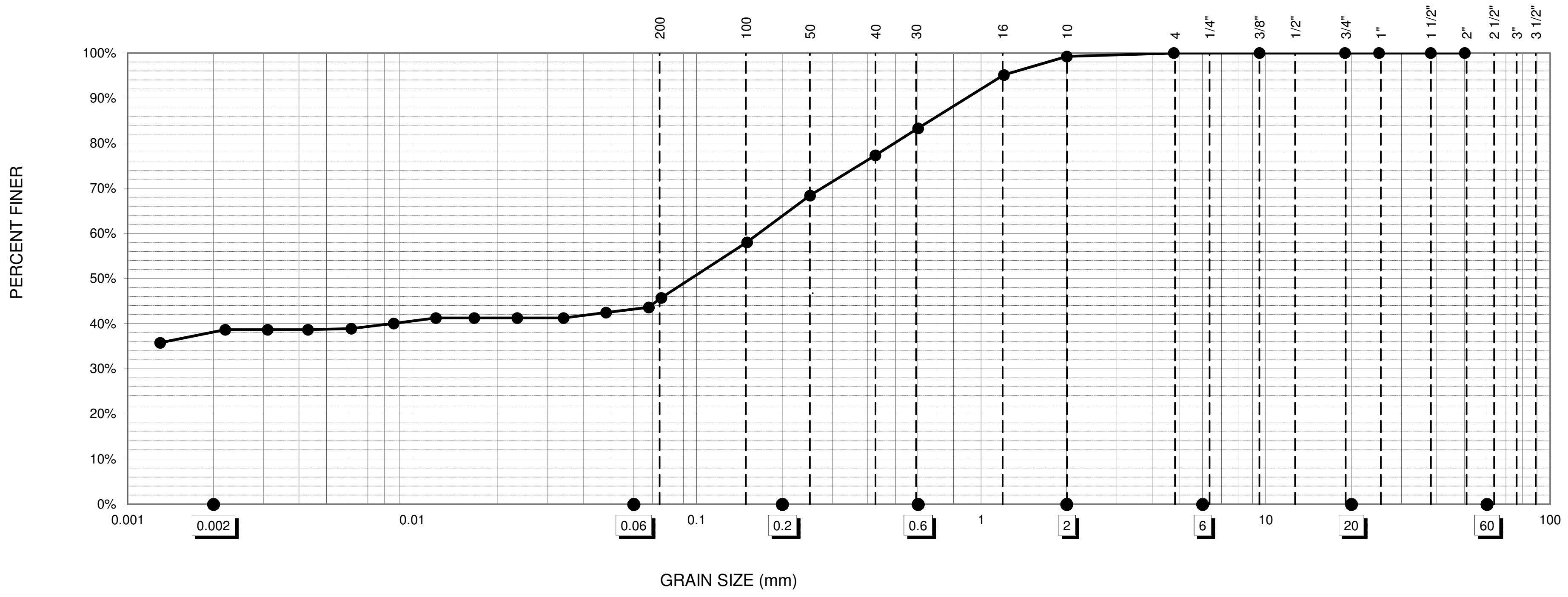
D_{10}	(mm)	N/A
D_{30}	(mm)	N/A
D_{50}	(mm)	0.0037
D_{60}	(mm)	0.1104
CNU		N/A
CC		N/A

Particle	Clay	Silt	Fine Sand	Medium Sand	Coarse Sand	Gravel	
Diameter (mm)	< 0,002	0,002 ↔ 0,06	0,06 ↔ 0,2	0,2 ↔ 0,6	0,6 ↔ 2,0	2,0 ↔ 60,0	NBR7181
Percent	46.91	6.57	13.79	14.83	14.37	3.53	

GRAIN SIZE DISTRIBUTION

Project:	VOO003
Lab. ID:	S15430
Borehole:	POR06
Sample:	BUS01 - MUDLINE
Depth of sample (m):	-

(i) GRAIN SIZE DISTRIBUTION



D_{10}	(mm)	N/A
D_{30}	(mm)	N/A
D_{50}	(mm)	0.1008
D_{60}	(mm)	0.1687
CNU		N/A
CC		N/A

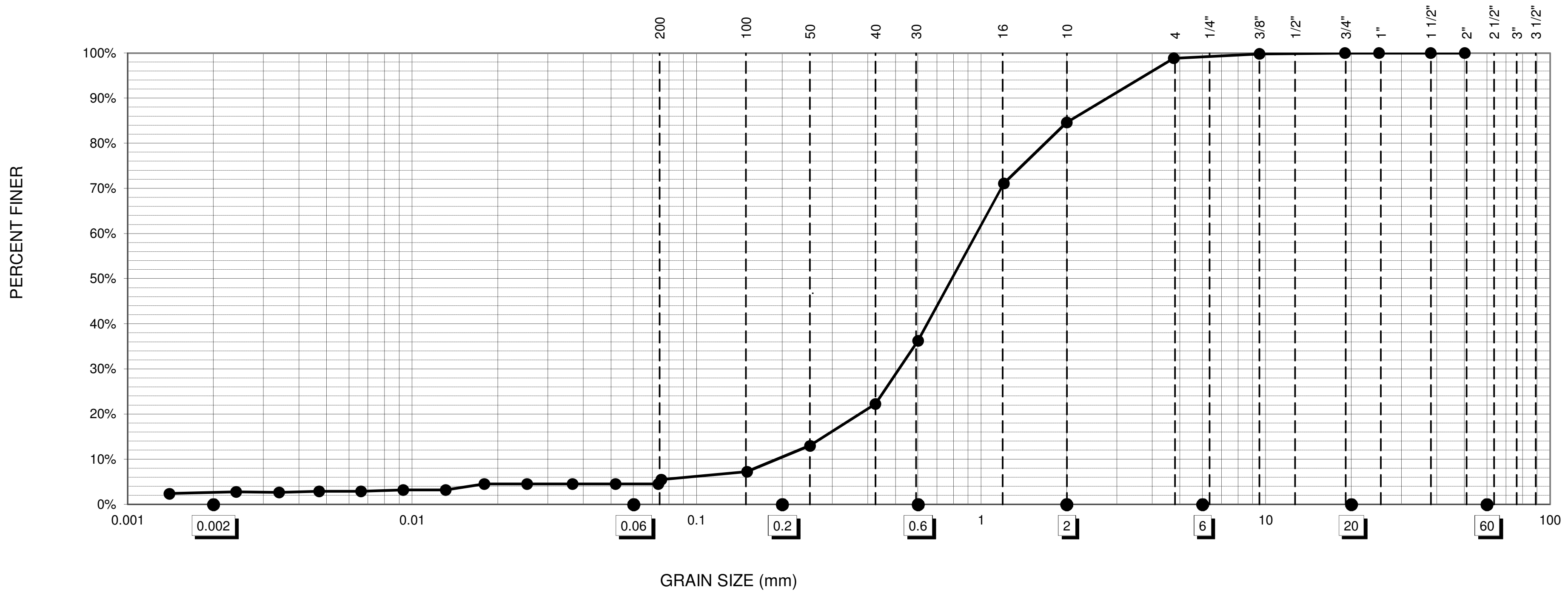
Particle	Clay	Silt	Fine Sand	Medium Sand	Coarse Sand	Gravel	NBR7181
Diameter (mm)	< 0,002	0,002 ↔ 0,06	0,06 ↔ 0,2	0,2 ↔ 0,6	0,6 ↔ 2,0	2,0 ↔ 60,0	
Percent	38.03	5.15	20.07	20.06	15.91	0.78	

FUGRO

GRAIN SIZE DISTRIBUTION

Project:	VOO003
Lab. ID:	S15387
Borehole:	POR07
Sample:	POUS02
Depth of sample (m):	6.00 - 7.00

(i) GRAIN SIZE DISTRIBUTION

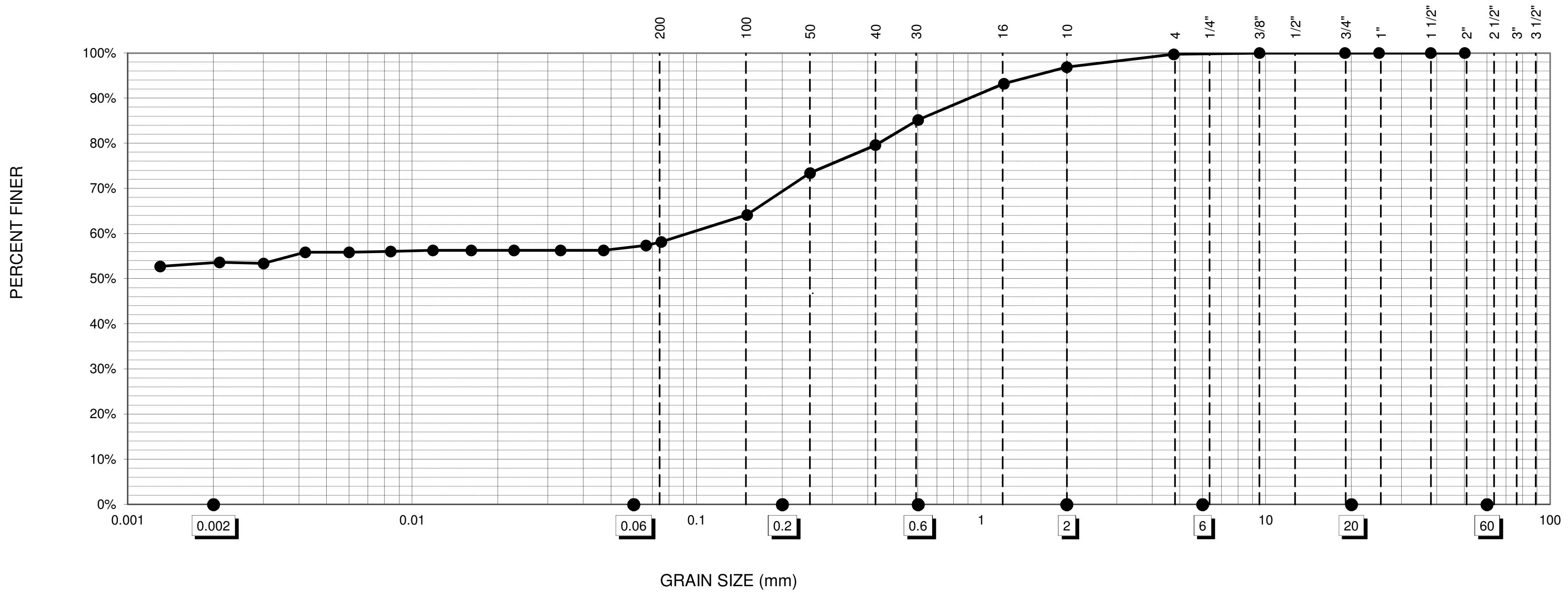


D_{10}	(mm)	0.1973
D_{30}	(mm)	0.5215
D_{50}	(mm)	0.8362
D_{60}	(mm)	1.0086
CNU		5.11
CC		1.37

Partlcle	Clay	Silt	Fine Sand	Medium Sand	Coarse Sand	Gravel	NBR7181
Diameter (mm)	< 0,002	0,002 ↔ 0,06	0,06 ↔ 0,2	0,2 ↔ 0,6	0,6 ↔ 2,0	2,0 ↔ 60,0	
Percent	2.65	1.90	5.60	26.15	48.37	15.33	

FUGRO — **GRAIN SIZE DISTRIBUTION**	**Project:**	VOO003
	Lab. ID:	S15449
	Borehole:	POR08
	Sample:	BUS01
	Depth of sample (m):	0.00 - 1.00

(i) GRAIN SIZE DISTRIBUTION



D_{10}	(mm)	N/A
D_{30}	(mm)	N/A
D_{50}	(mm)	N/A
D_{60}	(mm)	0.0982
CNU		N/A
CC		N/A

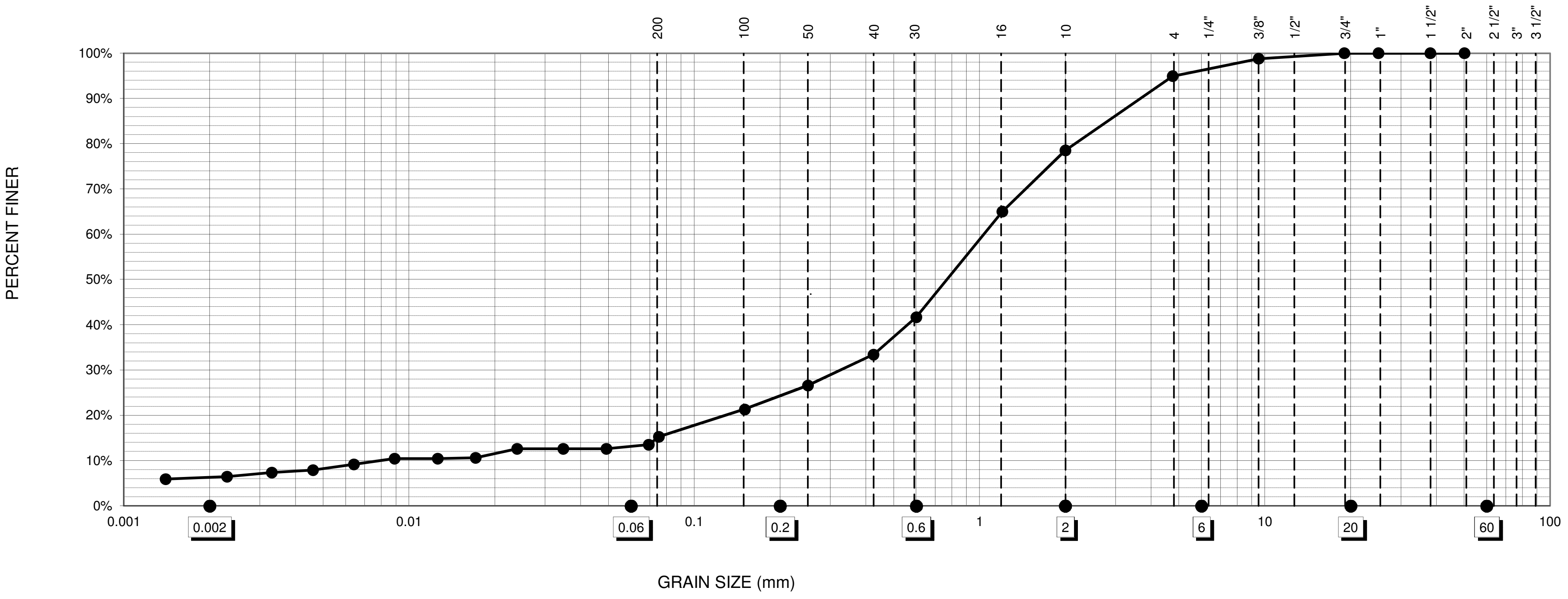
Particle	Clay	Silt	Fine Sand	Medium Sand	Coarse Sand	Gravel	NBR7181
Diameter (mm)	< 0,002	0,002 ↔ 0,06	0,06 ↔ 0,2	0,2 ↔ 0,6	0,6 ↔ 2,0	2,0 ↔ 60,0	
Percent	53.52	3.53	11.72	16.41	11.71	3.11	

FUGRO

GRAIN SIZE DISTRIBUTION

Project:	VOO003
Lab. ID:	S15454
Borehole:	POR09
Sample:	SPT04
Depth of sample (m):	7.00

(i) GRAIN SIZE DISTRIBUTION



D_{10}	(mm)	0.0080
D_{30}	(mm)	0.3365
D_{50}	(mm)	0.8139
D_{60}	(mm)	1.0710
CNU		134.16
CC		13.24

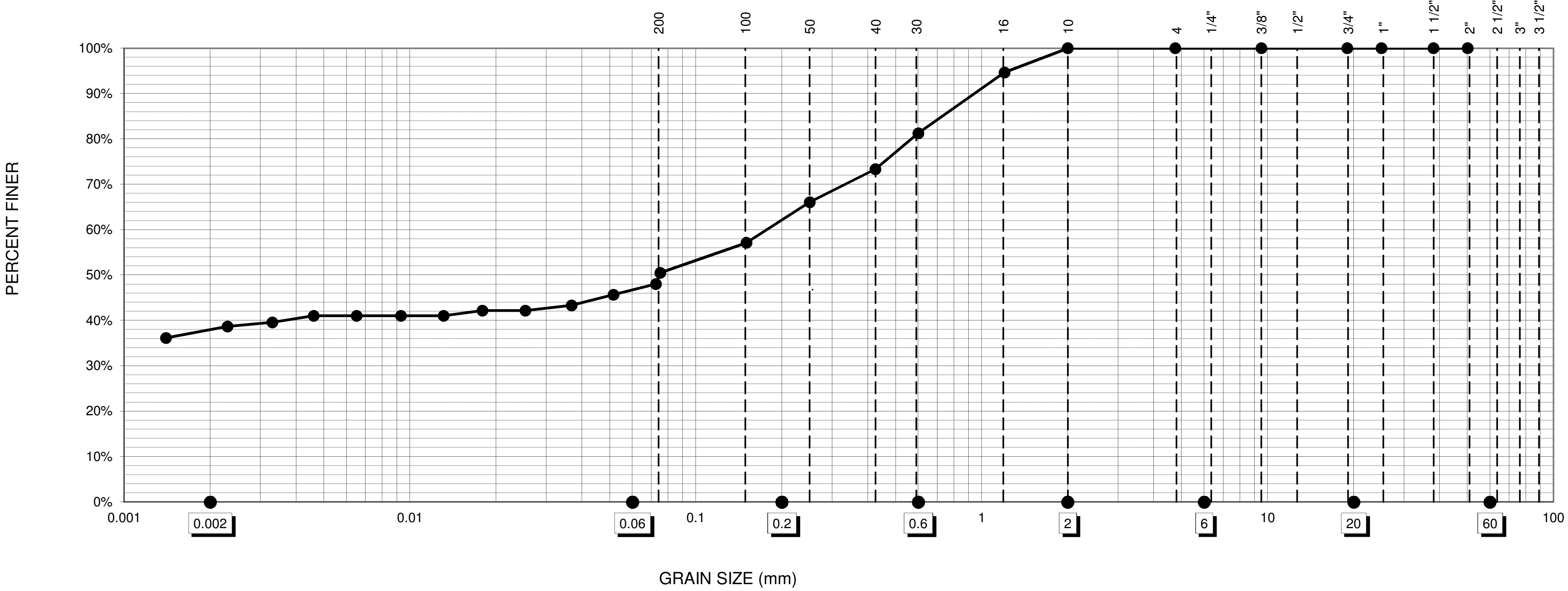
PartIcle	Clay	Silt	Fine Sand	Medium Sand	Coarse Sand	Gravel	NBR7181
Diameter (mm)	< 0,002	0,002 ↔ 0,06	0,06 ↔ 0,2	0,2 ↔ 0,6	0,6 ↔ 2,0	2,0 ↔ 60,0	
Percent	6.31	6.81	10.87	17.69	36.89	21.43	

FUGRO

GRAIN SIZE DISTRIBUTION

Project:	VOO003
Lab. ID:	S15470
Borehole:	POR11
Sample:	SPT02/BAGA 3
Depth of sample (m):	4.30 - 4.45

(i) GRAIN SIZE DISTRIBUTION



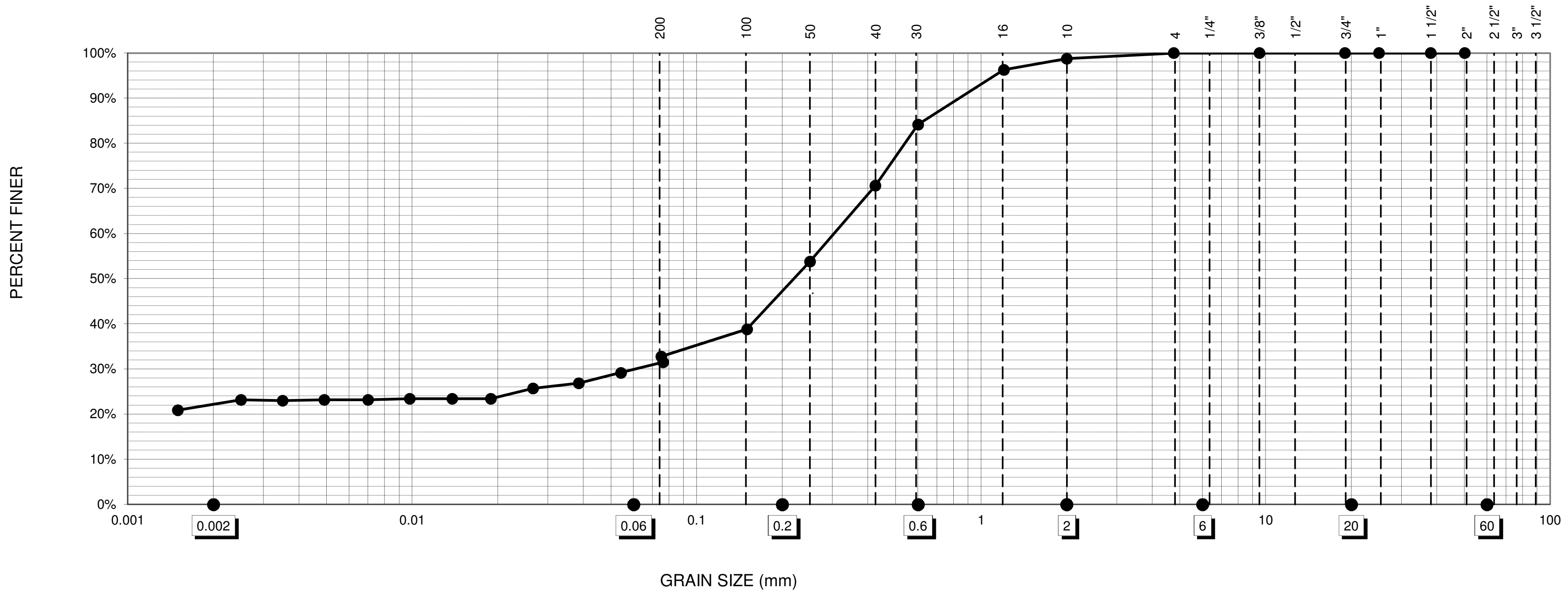
D_{10}	(mm)	N/A
D_{30}	(mm)	N/A
D_{50}	(mm)	0.0745
D_{60}	(mm)	0.1823
CNU		N/A
CC		N/A

Particle	Clay	Silt	Fine Sand	Medium Sand	Coarse Sand	Gravel	NBR7181
Diameter (mm)	< 0,002	0,002 ↔ 0,06	0,06 ↔ 0,2	0,2 ↔ 0,6	0,6 ↔ 2,0	2,0 ↔ 60,0	
Percent	37.83	8.80	14.96	19.66	18.75	0.00	

GRAIN SIZE DISTRIBUTION

Project:	VOO003
Lab. ID:	S15481
Borehole:	POR12
Sample:	SPT05
Depth of sample (m):	8.50 - 8.95

(i) GRAIN SIZE DISTRIBUTION



D_{10}	(mm)	N/A
D_{30}	(mm)	0.0619
D_{50}	(mm)	0.2246
D_{60}	(mm)	0.3144
CNU		N/A
CC		N/A

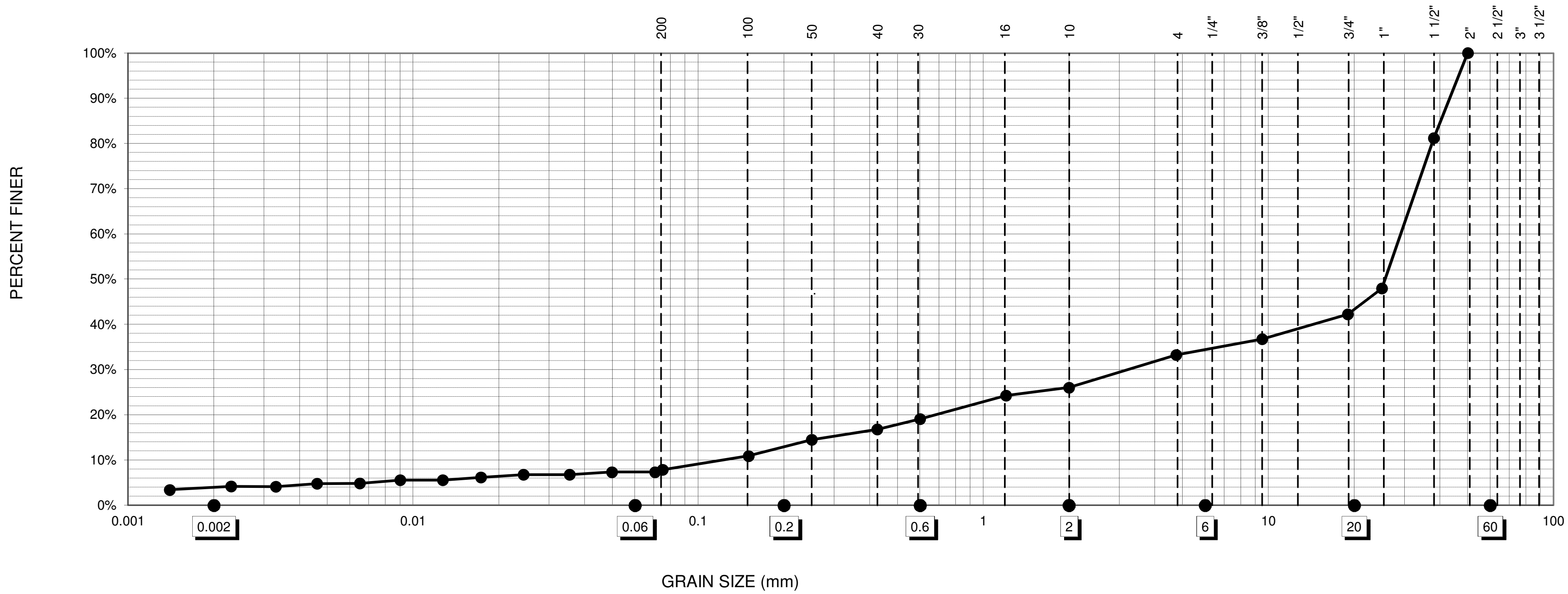
Particle	Clay	Silt	Fine Sand	Medium Sand	Coarse Sand	Gravel	
Diameter (mm)	< 0,002	0,002 ↔ 0,06	0,06 ↔ 0,2	0,2 ↔ 0,6	0,6 ↔ 2,0	2,0 ↔ 60,0	NBR7181
Percent	22.06	8.09	16.17	37.84	14.60	1.24	

FUGRO

GRAIN SIZE DISTRIBUTION

Project:	VOO003
Lab. ID:	S15492
Borehole:	POR14
Sample:	SPT07
Depth of sample (m):	9.50 - 9.95

(i) GRAIN SIZE DISTRIBUTION



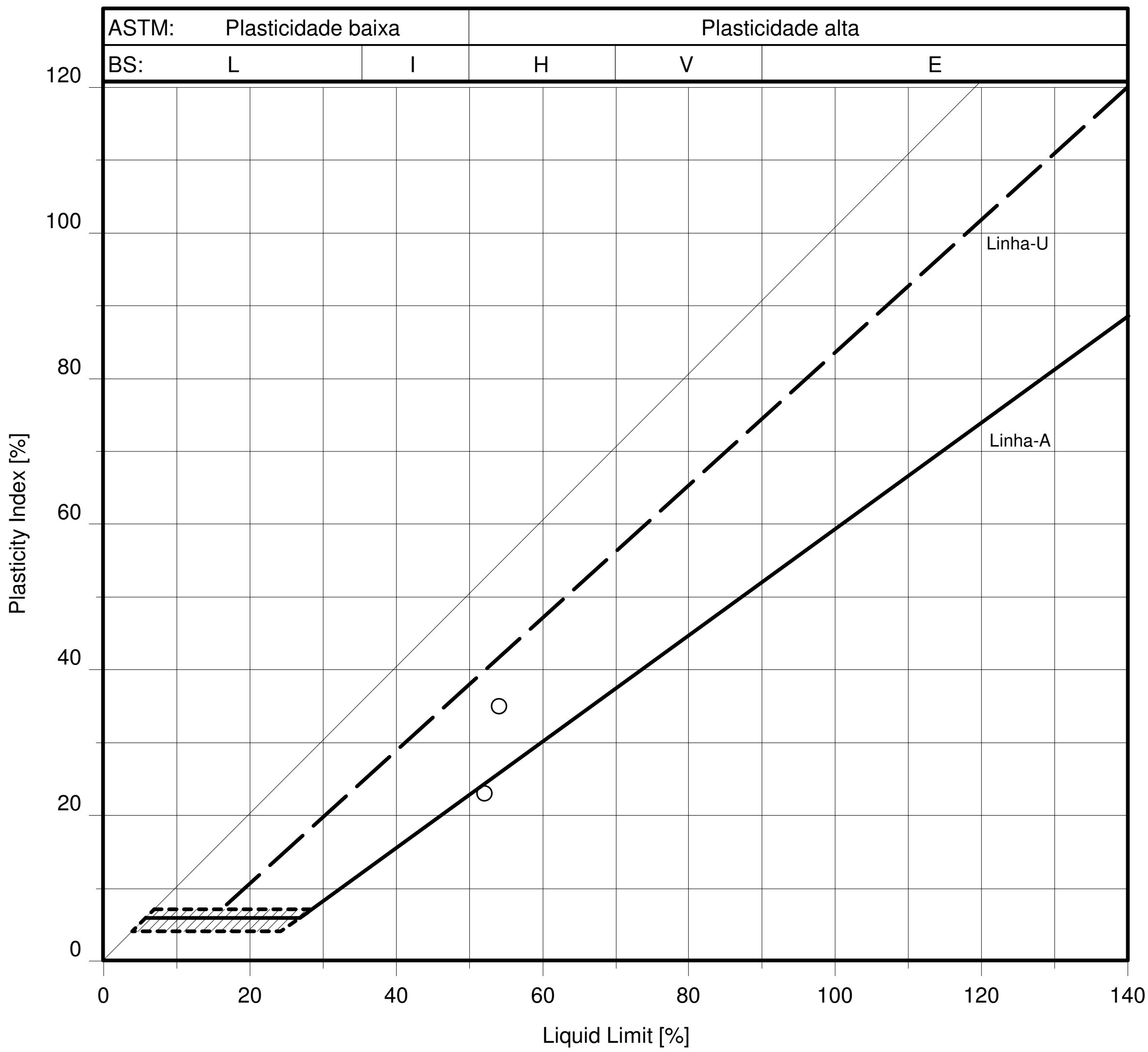
D_{10}	(mm)	0.1274
D_{30}	(mm)	3.5126
D_{50}	(mm)	25.7949
D_{60}	(mm)	29.7105
CNU		233.13
CC		3.26

PartIcle	Clay	Silt	Fine Sand	Medium Sand	Coarse Sand	Gravel	NBR7181
Diameter (mm)	< 0,002	0,002 ↔ 0,06	0,06 ↔ 0,2	0,2 ↔ 0,6	0,6 ↔ 2,0	2,0 ↔ 60,0	
Percent	3.95	3.40	5.37	6.38	6.95	73.95	

FUGRO

GRAIN SIZE DISTRIBUTION

Project:	VOO003
Lab. ID:	S15496
Borehole:	POR17
Sample:	BUS01 - MUDLINE
Depth of sample (m):	-



○ Limites de Atterberg
▨ ASTM CL-ML zona
L Plasticidade baixa
I Plasticidade intermédia
H Plasticidade alta
V Plasticidade muito alta
E Plasticidade extremamente alta
BS British Standard 5930: 1999
ASTM ASTM D2487-06

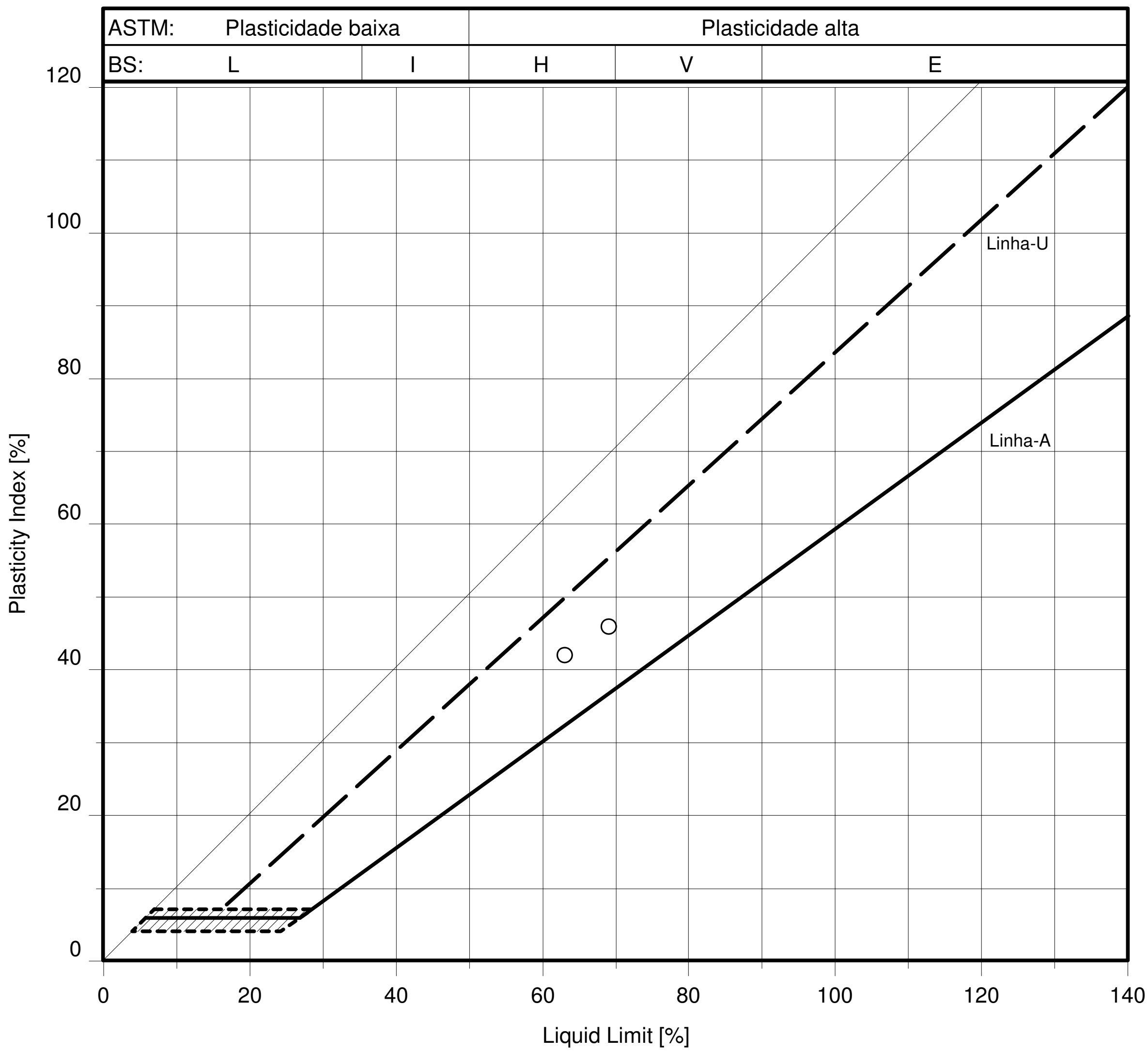
Plasticity index = Índice de plasticidade
Liquid limit = Limite de liquidez

GeODin/Plasticity Chart ASTM_BS 0-140% (Single location).GLO/2015-07-16 17:33:55

PLASTICIDADE

FURO POR-01

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA



○ Limites de Atterberg
▨ ASTM CL-ML zona
L Plasticidade baixa
I Plasticidade intermédia
H Plasticidade alta
V Plasticidade muito alta
E Plasticidade extremamente alta
BS British Standard 5930: 1999
ASTM ASTM D2487-06

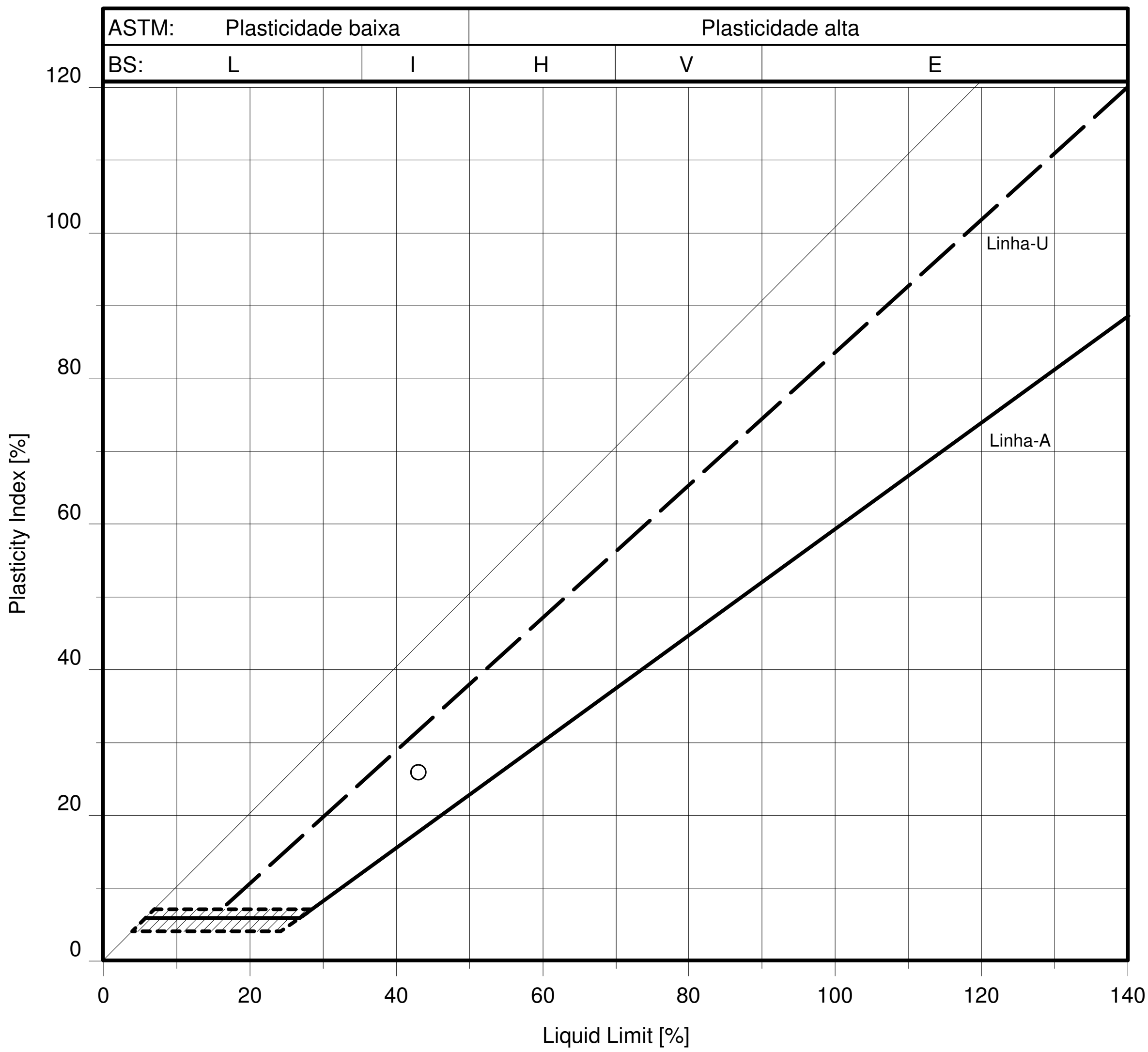
Plasticity index = Índice de plasticidade
Liquid limit = Limite de liquidez

GeODin/Plasticity Chart ASTM_BS 0-140% (Single location).GLO/2015-07-16 17:34:33

PLASTICIDADE

FURO POR-02

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA



○	Limites de Atterberg
▨	ASTM CL-ML zona
L	Plasticidade baixa
I	Plasticidade intermédia
H	Plasticidade alta
V	Plasticidade muito alta
E	Plasticidade extremamente alta
BS	British Standard 5930: 1999
ASTM	ASTM D2487-06

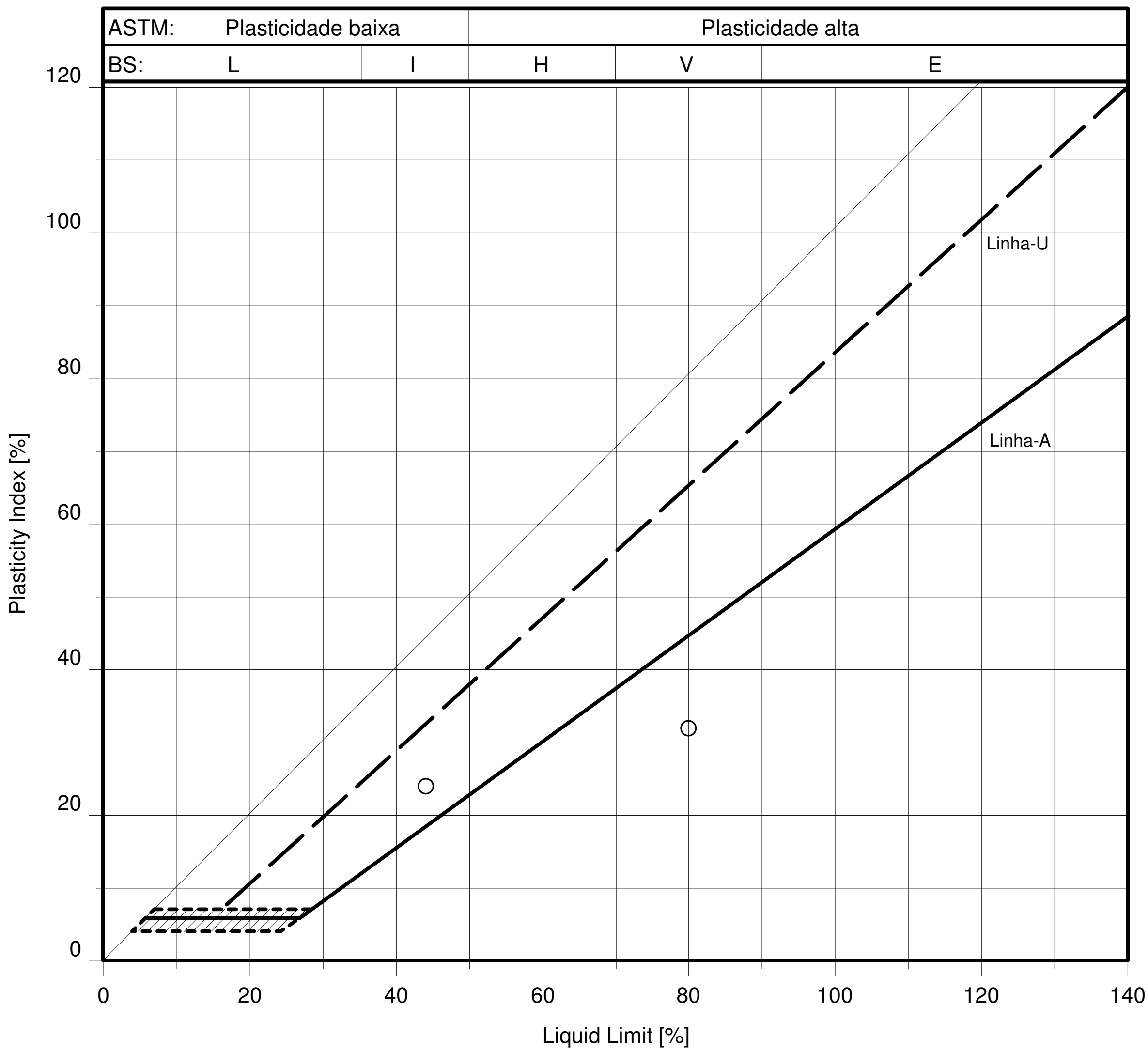
Plasticity index = Índice de plasticidade
Liquid limit = Limite de liquidez

GeODin/Plasticity Chart ASTM_BS 0-140% (Single location).GLO/2015-07-16 17:35:04

PLASTICIDADE

FURO POR-03

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA



○ Limites de Atterberg
▨ ASTM CL-ML zona
L Plasticidade baixa
I Plasticidade intermédia
H Plasticidade alta
V Plasticidade muito alta
E Plasticidade extremamente alta
BS British Standard 5930: 1999
ASTM ASTM D2487-06

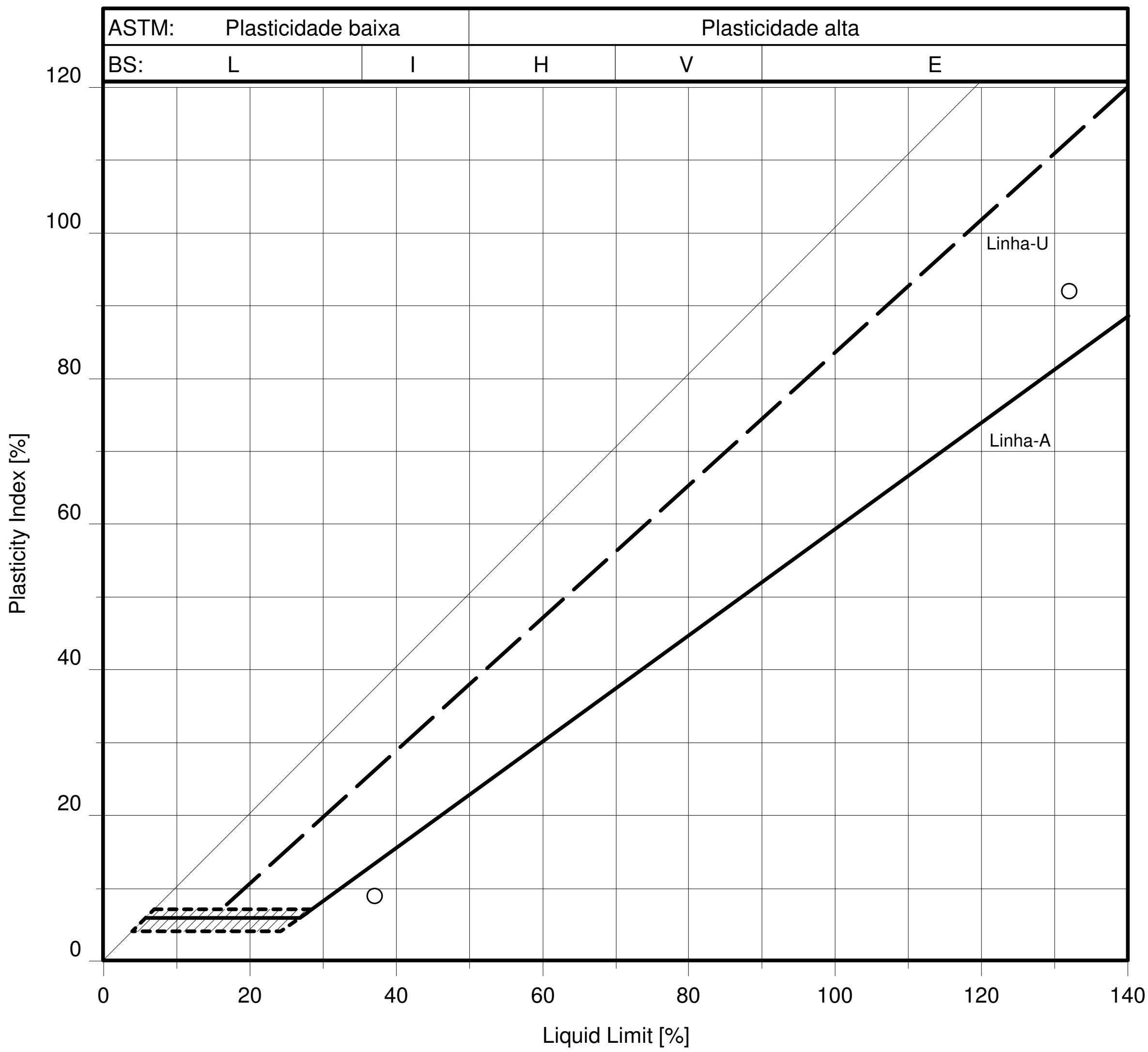
Plasticity index = Índice de plasticidade
Liquid limit = Limite de liquidez

PLASTICIDADE

FURO POR-04

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/Plasticity Chart ASTM_BS 0-140% (Single location).GLO/2015-07-16 17:35:22



○ Limites de Atterberg
ASTM CL-ML zona
L Plasticidade baixa
I Plasticidade intermédia
H Plasticidade alta
V Plasticidade muito alta
E Plasticidade extremamente alta
BS British Standard 5930: 1999
ASTM ASTM D2487-06

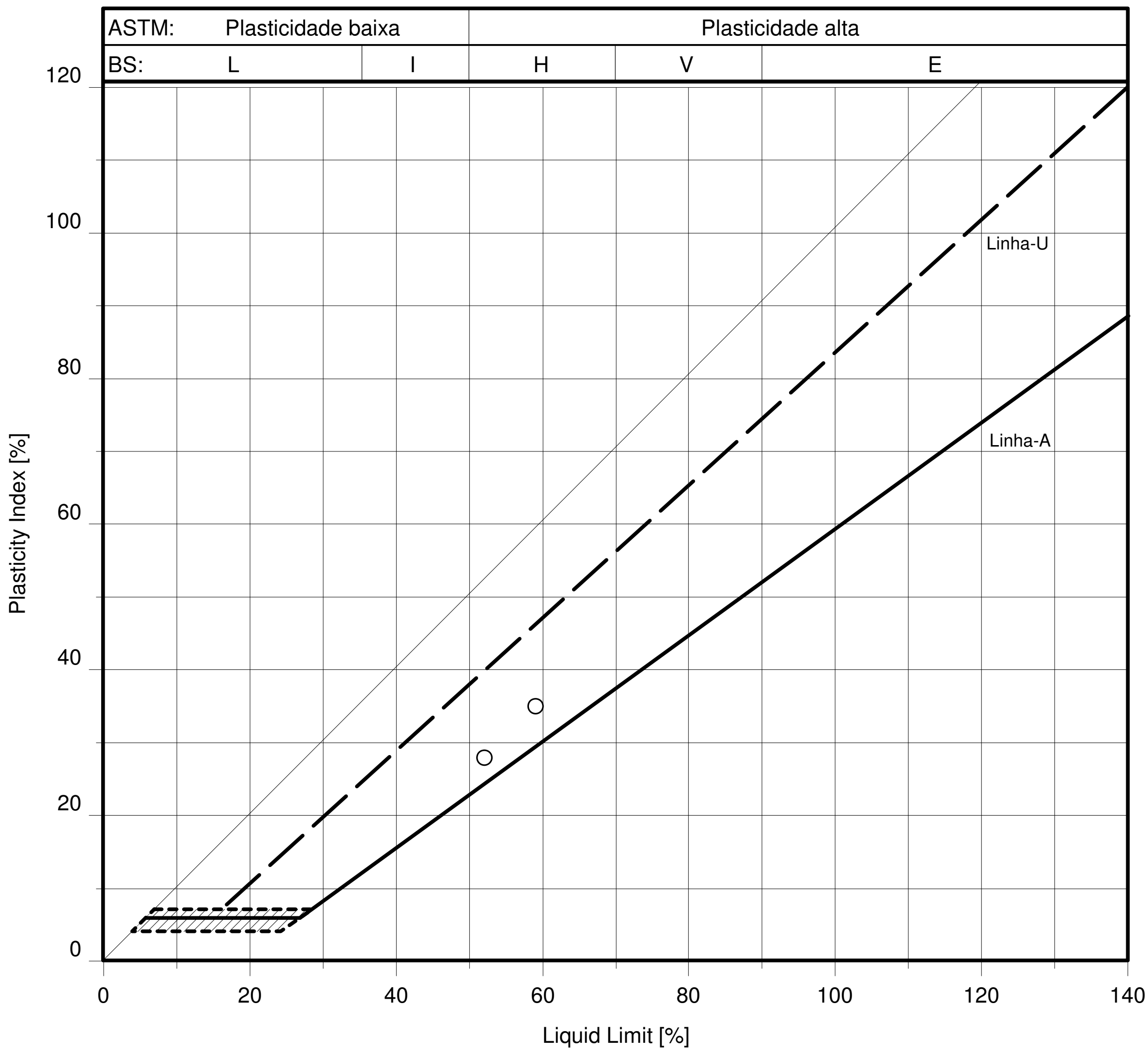
Plasticity index = Índice de plasticidade
Liquid limit = Limite de liquidez

GeODin/Plasticity Chart ASTM_BS 0-140% (Single location).GLO/2015-07-16 17:35:43

PLASTICIDADE

FURO POR-05

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA



○ Limites de Atterberg
▨ ASTM CL-ML zona
L Plasticidade baixa
I Plasticidade intermédia
H Plasticidade alta
V Plasticidade muito alta
E Plasticidade extremamente alta
BS British Standard 5930: 1999
ASTM ASTM D2487-06

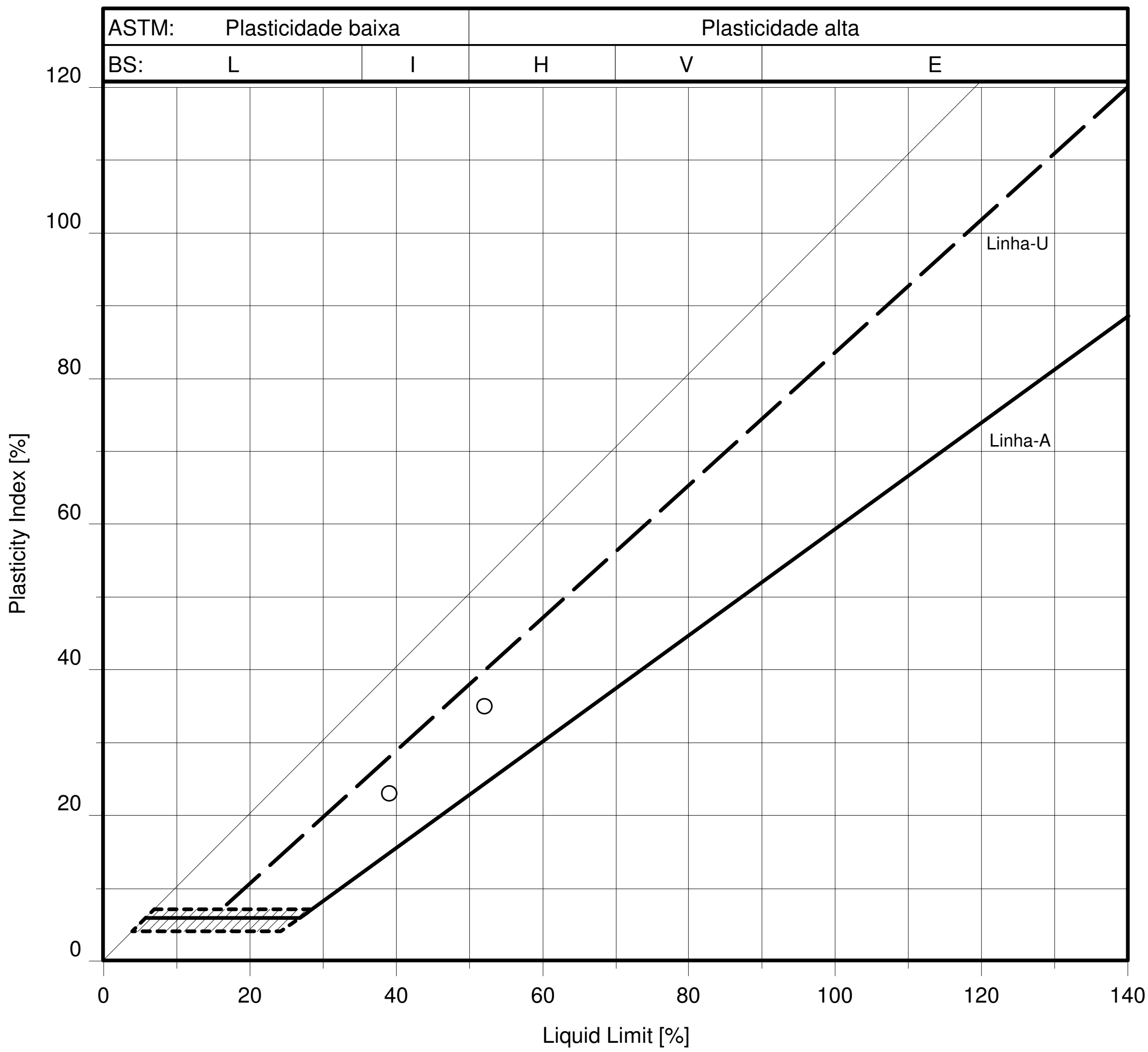
Plasticity index = Índice de plasticidade
Liquid limit = Limite de liquidez

GeODin/Plasticity Chart ASTM_BS 0-140% (Single location).GLO/2015-07-16 17:36:02

PLASTICIDADE

FURO POR-06

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA



○	Limites de Atterberg
▨	ASTM CL-ML zona
L	Plasticidade baixa
I	Plasticidade intermédia
H	Plasticidade alta
V	Plasticidade muito alta
E	Plasticidade extremamente alta
BS	British Standard 5930: 1999
ASTM	ASTM D2487-06

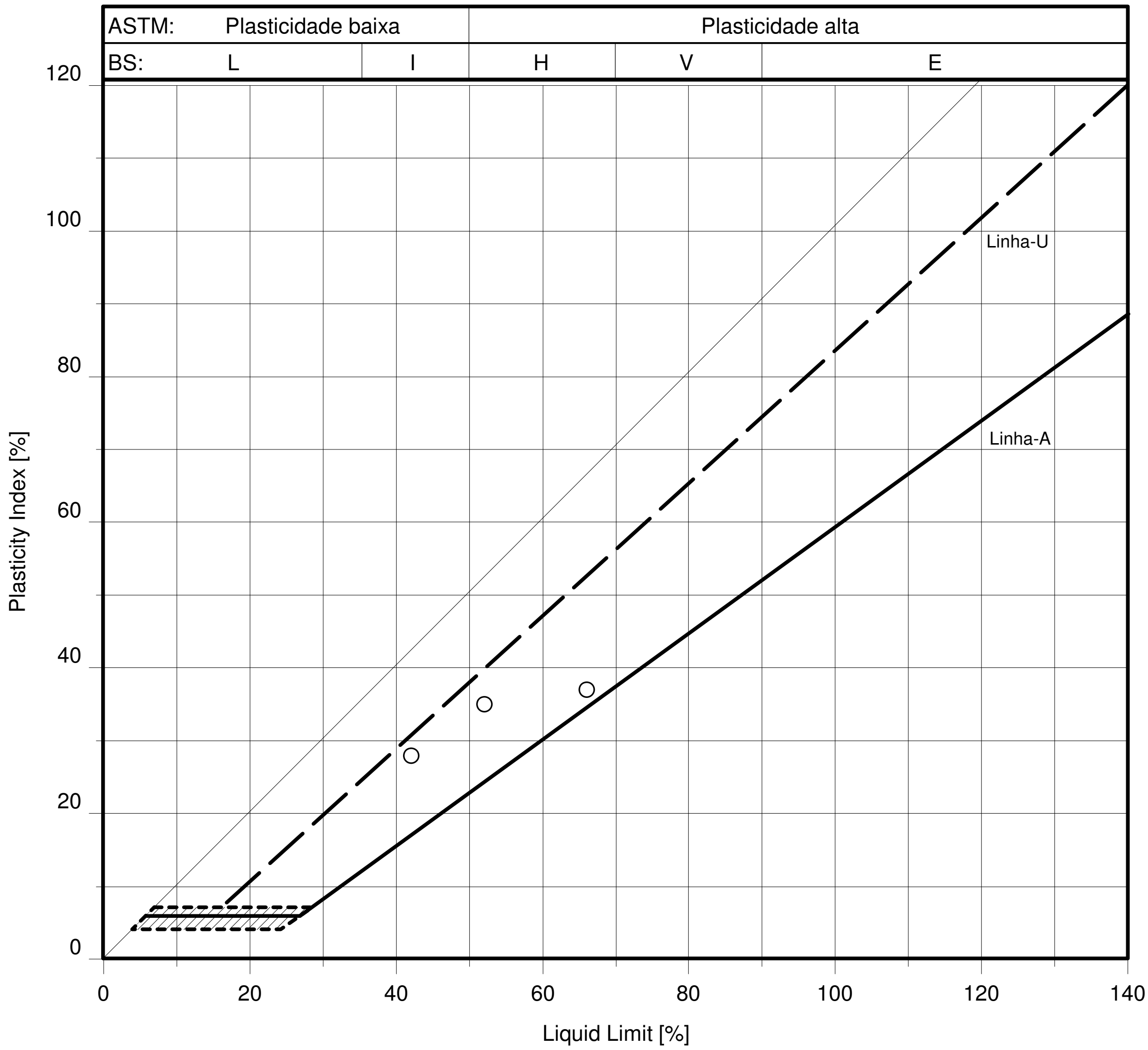
Plasticity index = Índice de plasticidade
Liquid limit = Limite de liquidez

GeODin/Plasticity Chart ASTM_BS 0-140% (Single location).GLO/2015-07-16 17:36:28

PLASTICIDADE

FURO POR-07

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA



○	Limites de Atterberg
▨	ASTM CL-ML zona
L	Plasticidade baixa
I	Plasticidade intermédia
H	Plasticidade alta
V	Plasticidade muito alta
E	Plasticidade extremamente alta
BS	British Standard 5930: 1999
ASTM	ASTM D2487-06

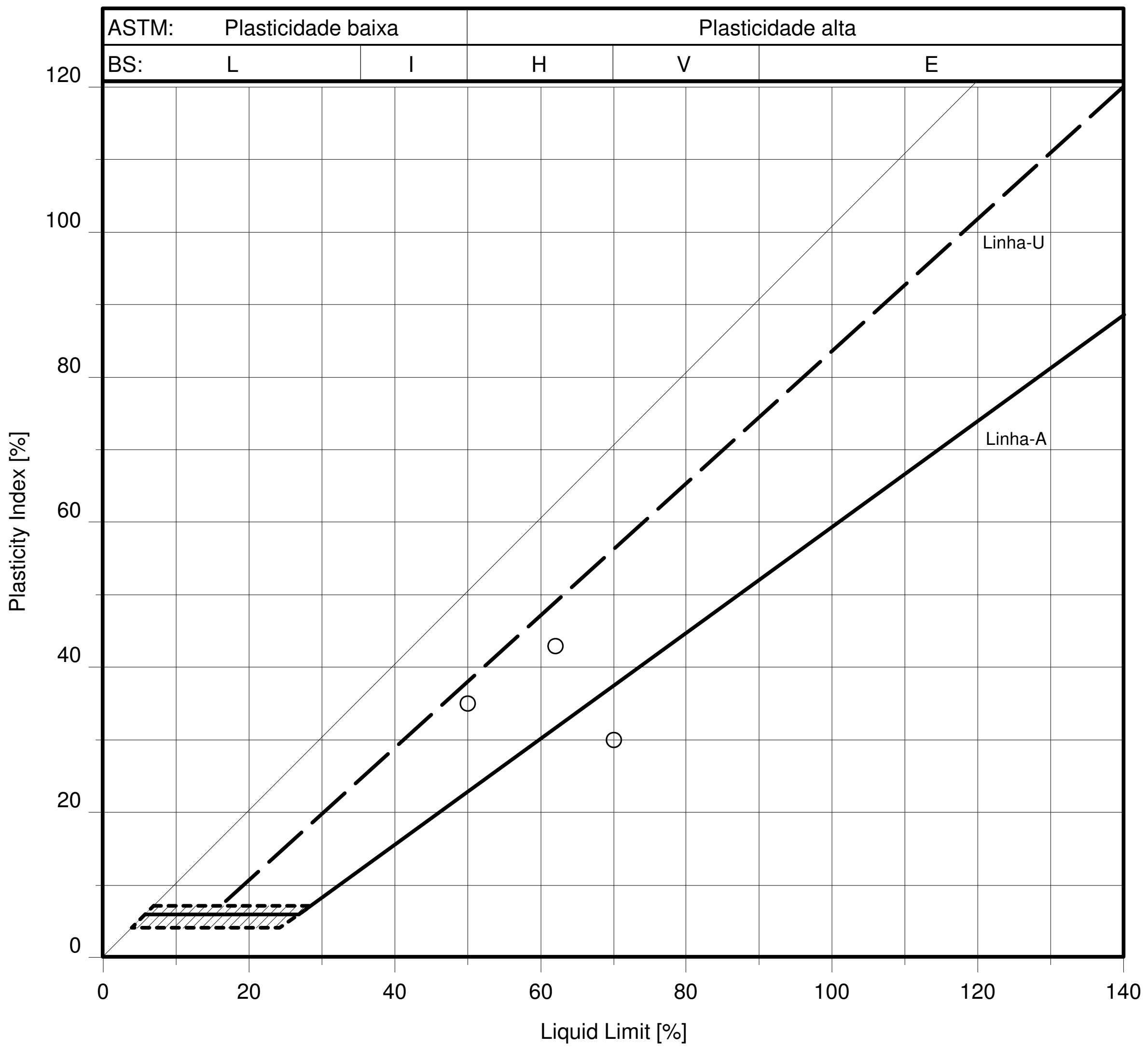
Plasticity index = Índice de plasticidade
Liquid limit = Limite de liquidez

GeODin/Plasticity Chart ASTM_BS 0-140% (Single location).GLO/2015-07-16 17:36:48

PLASTICIDADE

FURO POR-08

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA



○	Limites de Atterberg
▨	ASTM CL-ML zona
L	Plasticidade baixa
I	Plasticidade intermédia
H	Plasticidade alta
V	Plasticidade muito alta
E	Plasticidade extremamente alta
BS	British Standard 5930: 1999
ASTM	ASTM D2487-06

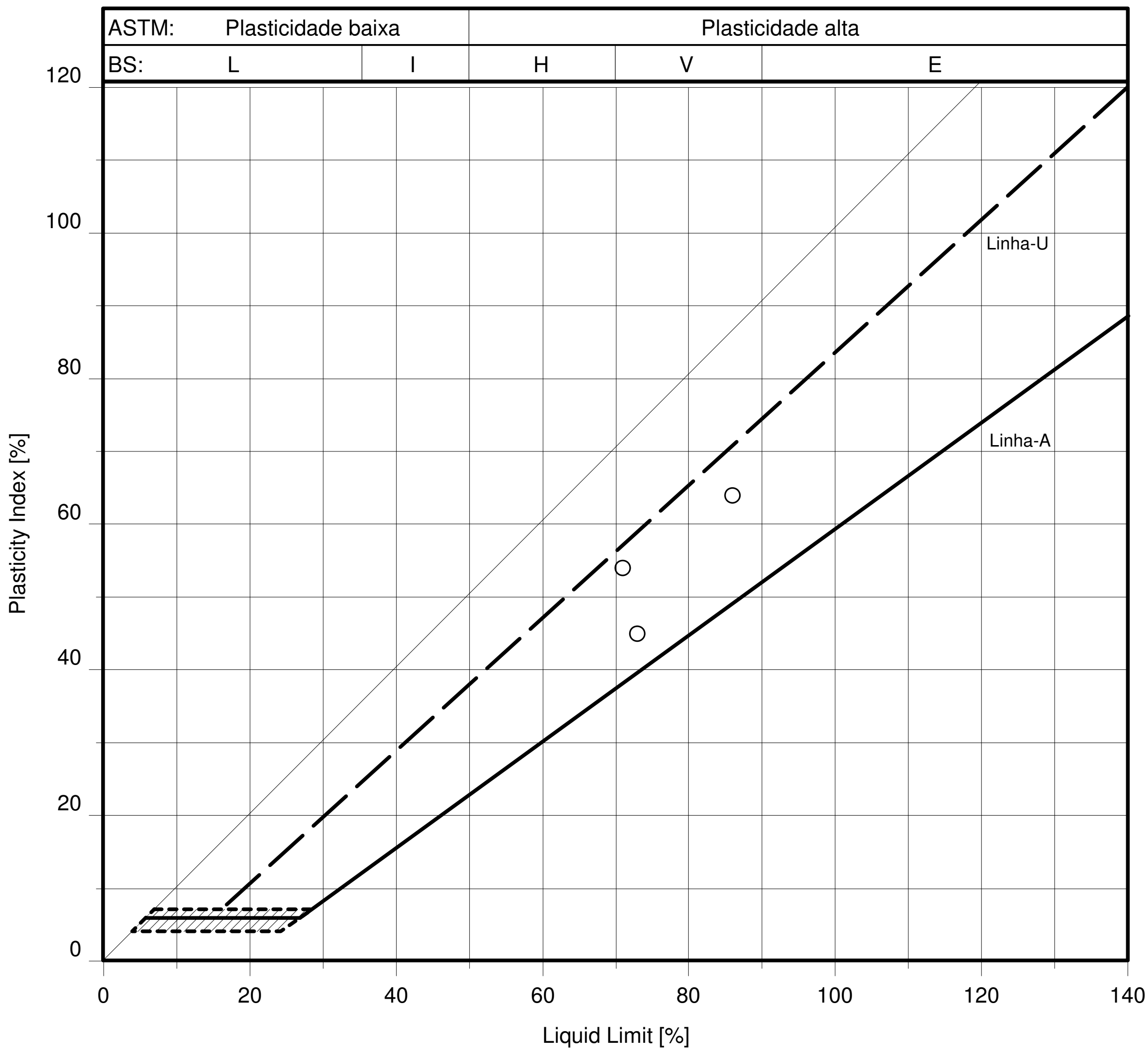
Plasticity index = Índice de plasticidade
Liquid limit = Limite de liquidez

PLASTICIDADE

FURO POR-09

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA

GeODin/Plasticity Chart ASTM_BS 0-140% (Single location).GLO/2015-07-16 17:37:12



○	Limites de Atterberg
▨	ASTM CL-ML zona
L	Plasticidade baixa
I	Plasticidade intermédia
H	Plasticidade alta
V	Plasticidade muito alta
E	Plasticidade extremamente alta
BS	British Standard 5930: 1999
ASTM	ASTM D2487-06

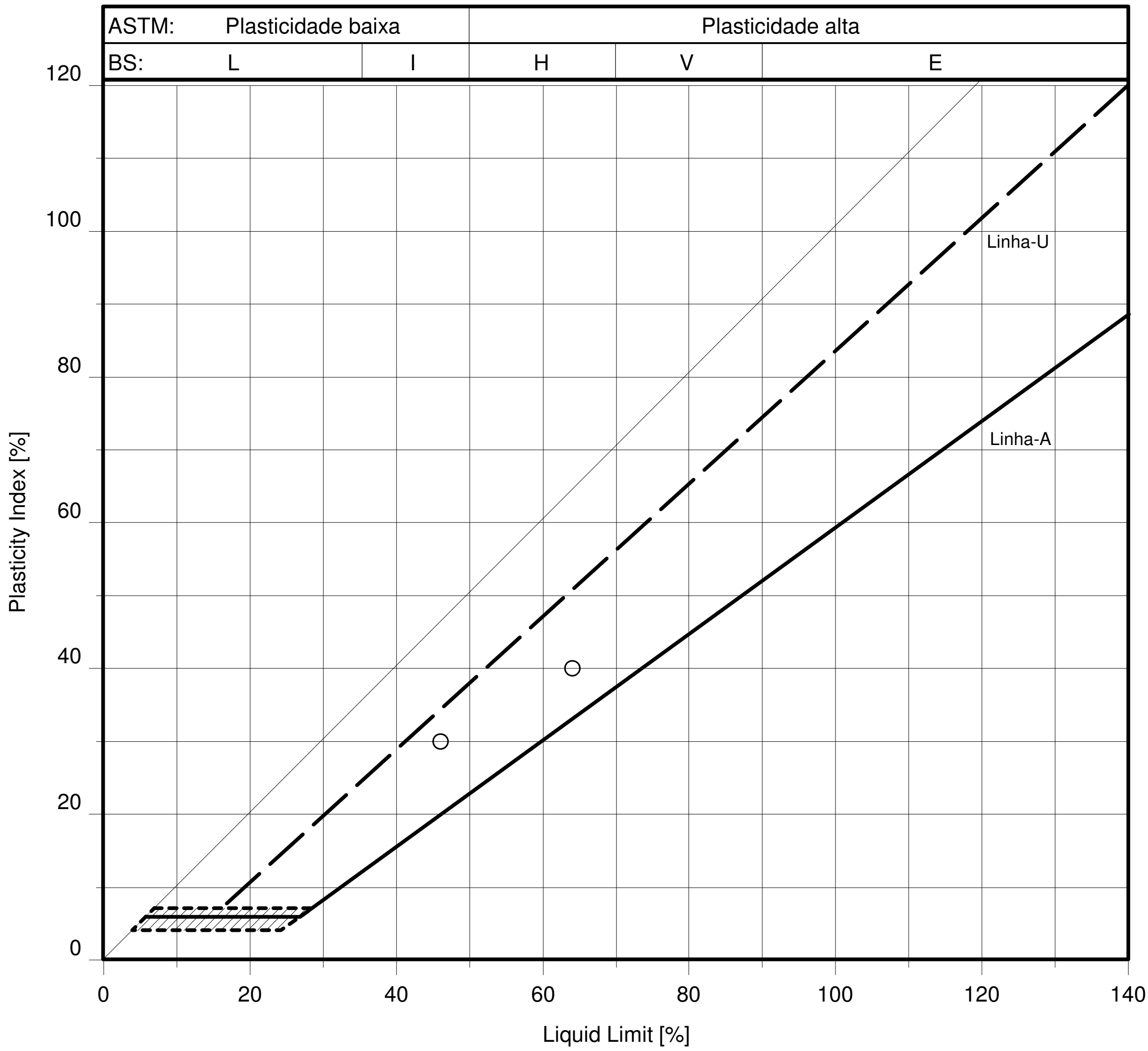
Plasticity index = Índice de plasticidade
Liquid limit = Limite de liquidez

GeODin/Plasticity Chart ASTM_BS 0-140% (Single location).GLO/2015-07-16 17:37:32

PLASTICIDADE

FURO POR-10

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA



○	Limites de Atterberg
▨	ASTM CL-ML zona
L	Plasticidade baixa
I	Plasticidade intermédia
H	Plasticidade alta
V	Plasticidade muito alta
E	Plasticidade extremamente alta
BS	British Standard 5930: 1999
ASTM	ASTM D2487-06

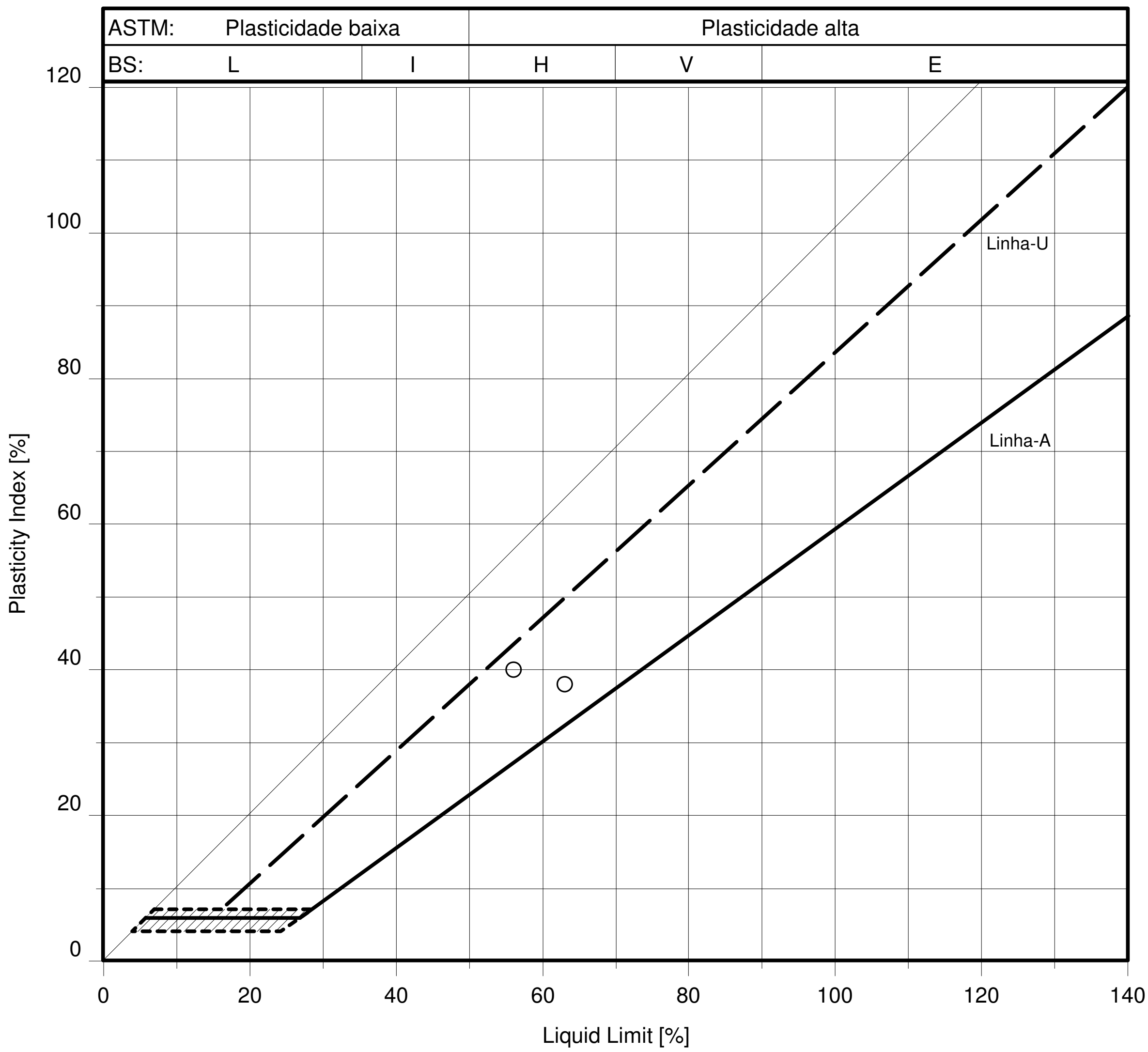
Plasticity index = Índice de plasticidade
Liquid limit = Limite de liquidez

GeODin/Plasticity Chart ASTM_BS 0-140% (Single location).GLO/2015-07-16 17:37:54

PLASTICIDADE

FURO POR-11

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA



○ Limites de Atterberg
▨ ASTM CL-ML zona

L	Plasticidade baixa
I	Plasticidade intermédia
H	Plasticidade alta
V	Plasticidade muito alta
E	Plasticidade extremamente alta
BS	British Standard 5930: 1999
ASTM	ASTM D2487-06

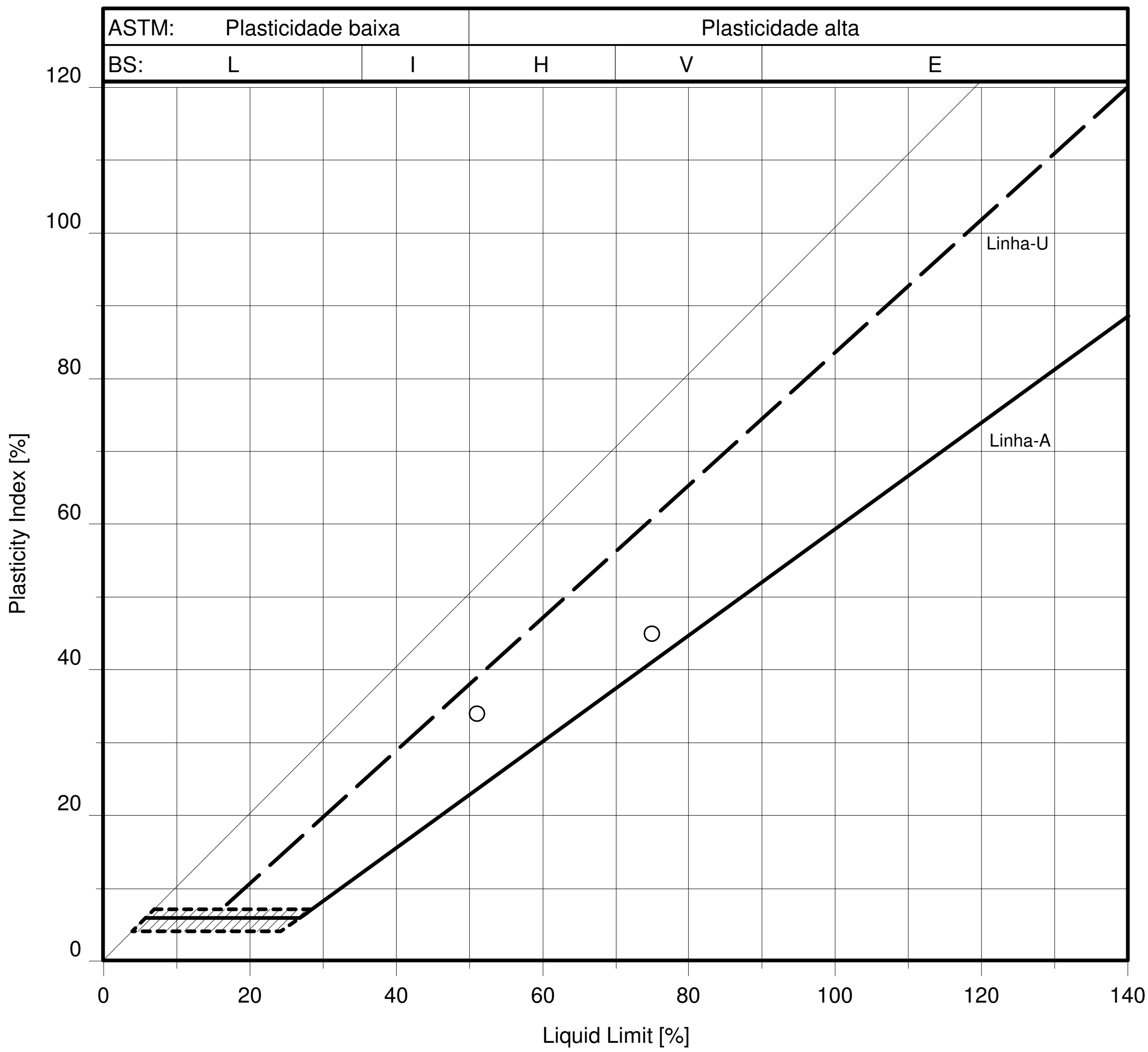
Plasticity index = Índice de plasticidade
Liquid limit = Limite de liquidez

GeODin/Plasticity Chart ASTM_BS 0-140% (Single location).GLO/2015-07-16 17:38:17

PLASTICIDADE

FURO POR-12

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA



○ Limites de Atterberg
▨ ASTM CL-ML zona
L Plasticidade baixa
I Plasticidade intermédia
H Plasticidade alta
V Plasticidade muito alta
E Plasticidade extremamente alta
BS British Standard 5930: 1999
ASTM ASTM D2487-06

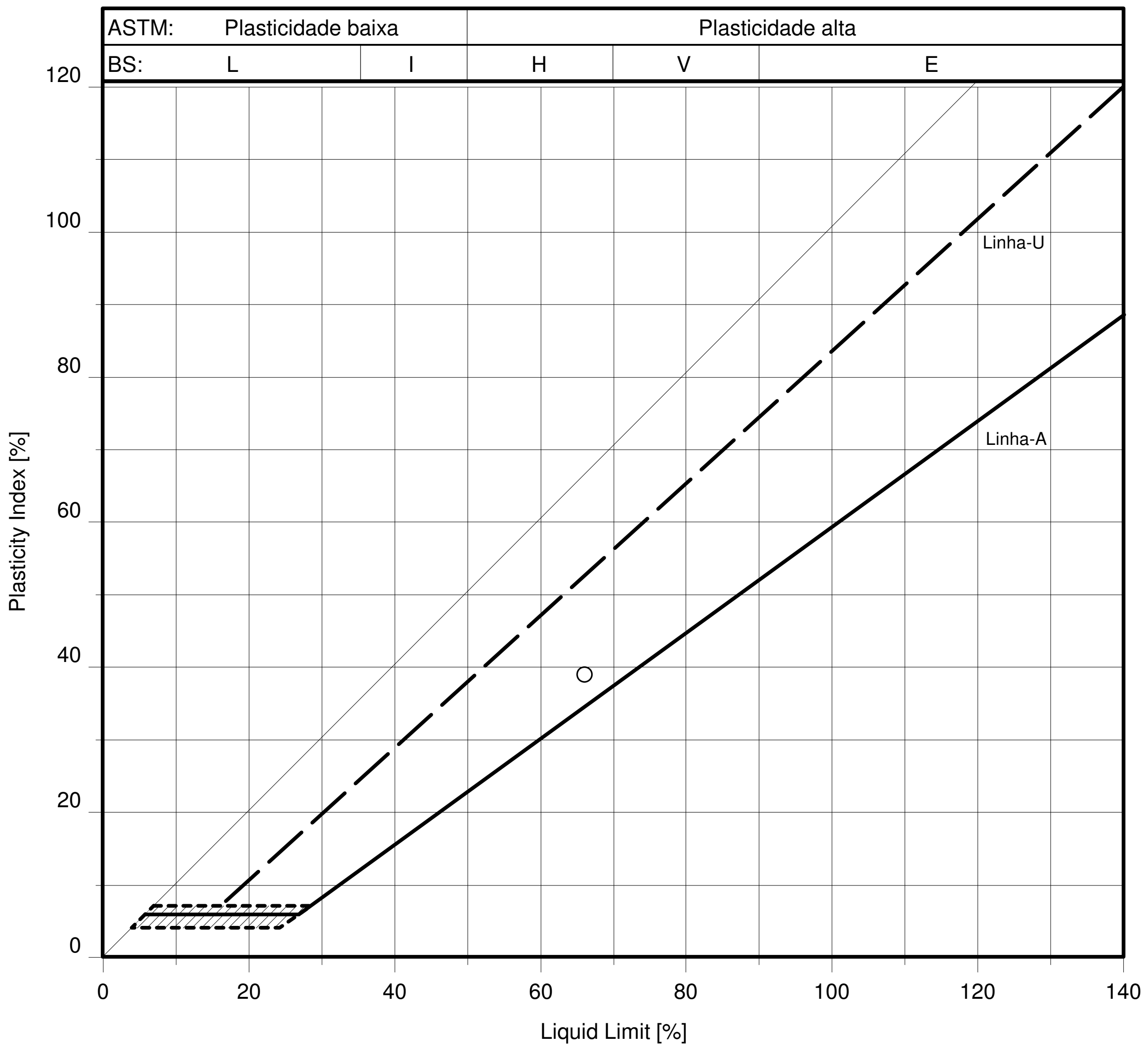
Plasticity index = Índice de plasticidade
Liquid limit = Limite de liquidez

GeODin/Plasticity Chart ASTM_BS 0-140% (Single location).GLO/2015-07-16 17:38:41

PLASTICIDADE

FURO POR-14

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA



○	Limites de Atterberg
▨	ASTM CL-ML zona
L	Plasticidade baixa
I	Plasticidade intermédia
H	Plasticidade alta
V	Plasticidade muito alta
E	Plasticidade extremamente alta
BS	British Standard 5930: 1999
ASTM	ASTM D2487-06

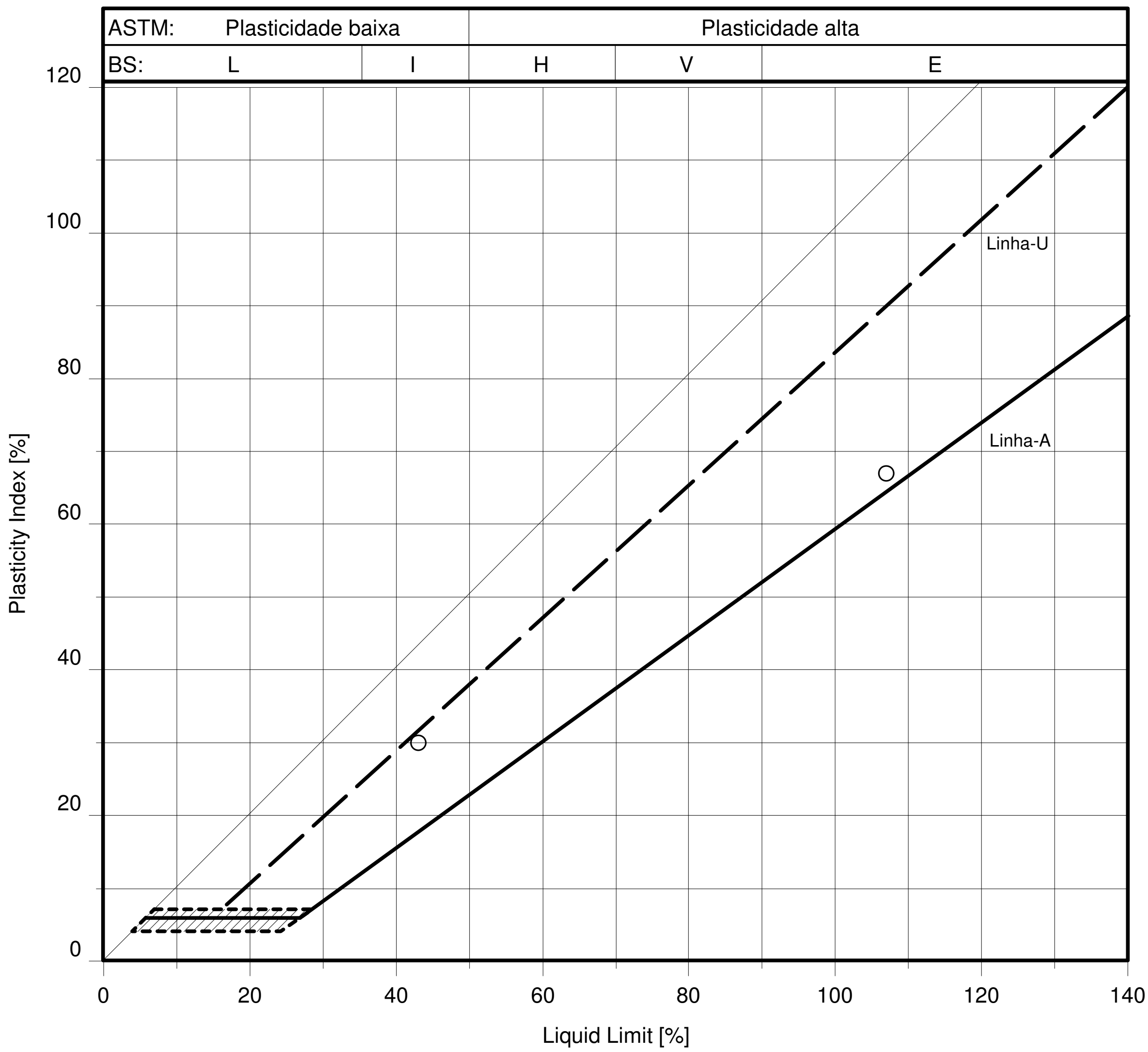
Plasticity index = Índice de plasticidade
Liquid limit = Limite de liquidez

GeODin/Plasticity Chart ASTM_BS 0-140% (Single location).GLO/2015-07-16 17:39:03

PLASTICIDADE

FURO POR-15

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA



○ Limites de Atterberg
ASTM CL-ML zona
L Plasticidade baixa
I Plasticidade intermédia
H Plasticidade alta
V Plasticidade muito alta
E Plasticidade extremamente alta
BS British Standard 5930: 1999
ASTM ASTM D2487-06

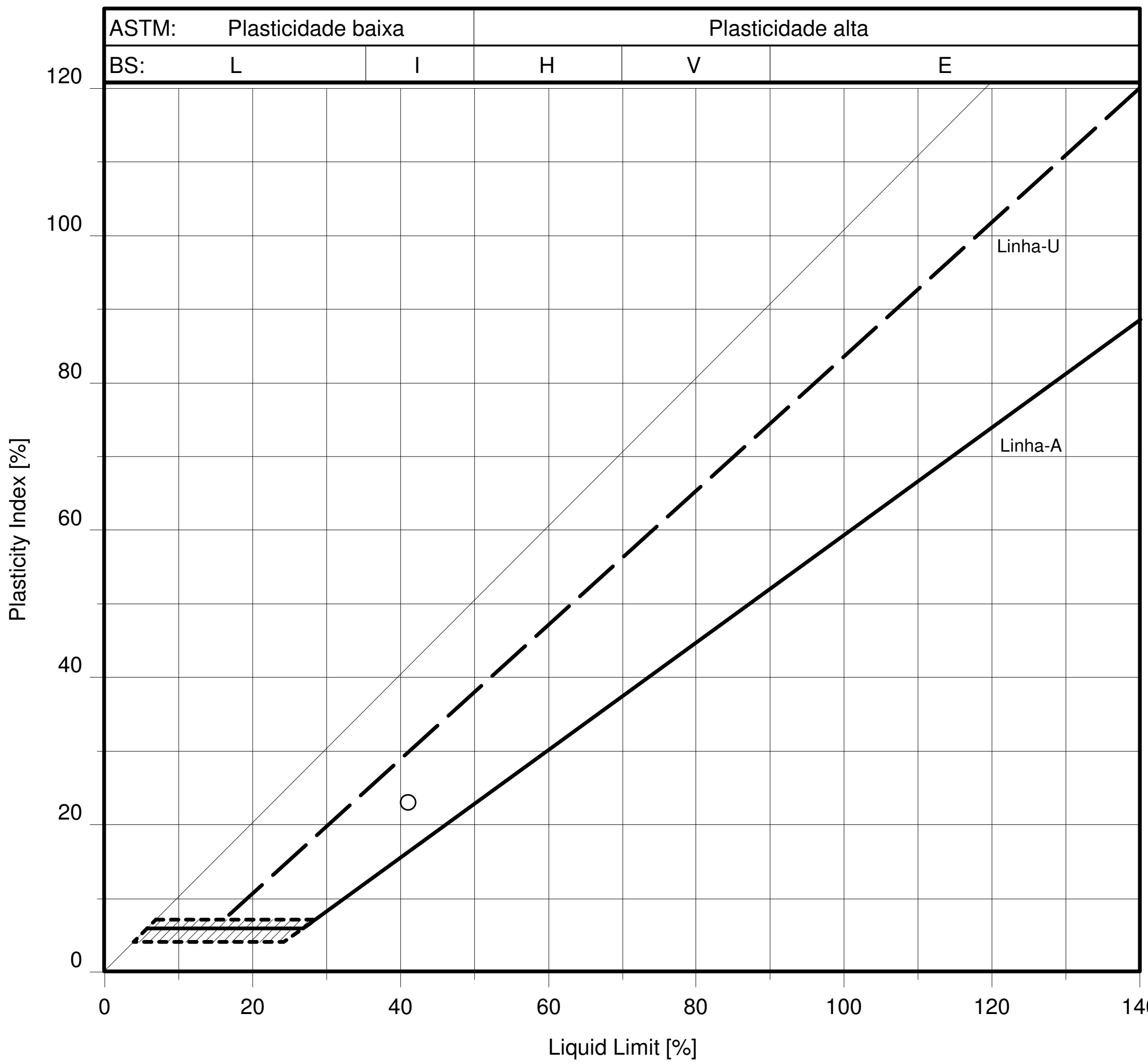
Plasticity index = Índice de plasticidade
Liquid limit = Limite de liquidez

GeODin/Plasticity Chart ASTM_BS 0-140% (Single location).GLO/2015-07-16 17:39:27

PLASTICIDADE

FURO POR-17

PORTO DO RIO DE JANEIRO - BAÍA DE GUANABARA



○	Limites de Atterberg
▨	ASTM CL-ML zona
L	Plasticidade baixa
I	Plasticidade intermédia
H	Plasticidade alta
V	Plasticidade muito alta
E	Plasticidade extremamente alta
BS	British Standard 5930: 1999
ASTM	ASTM D2487-06

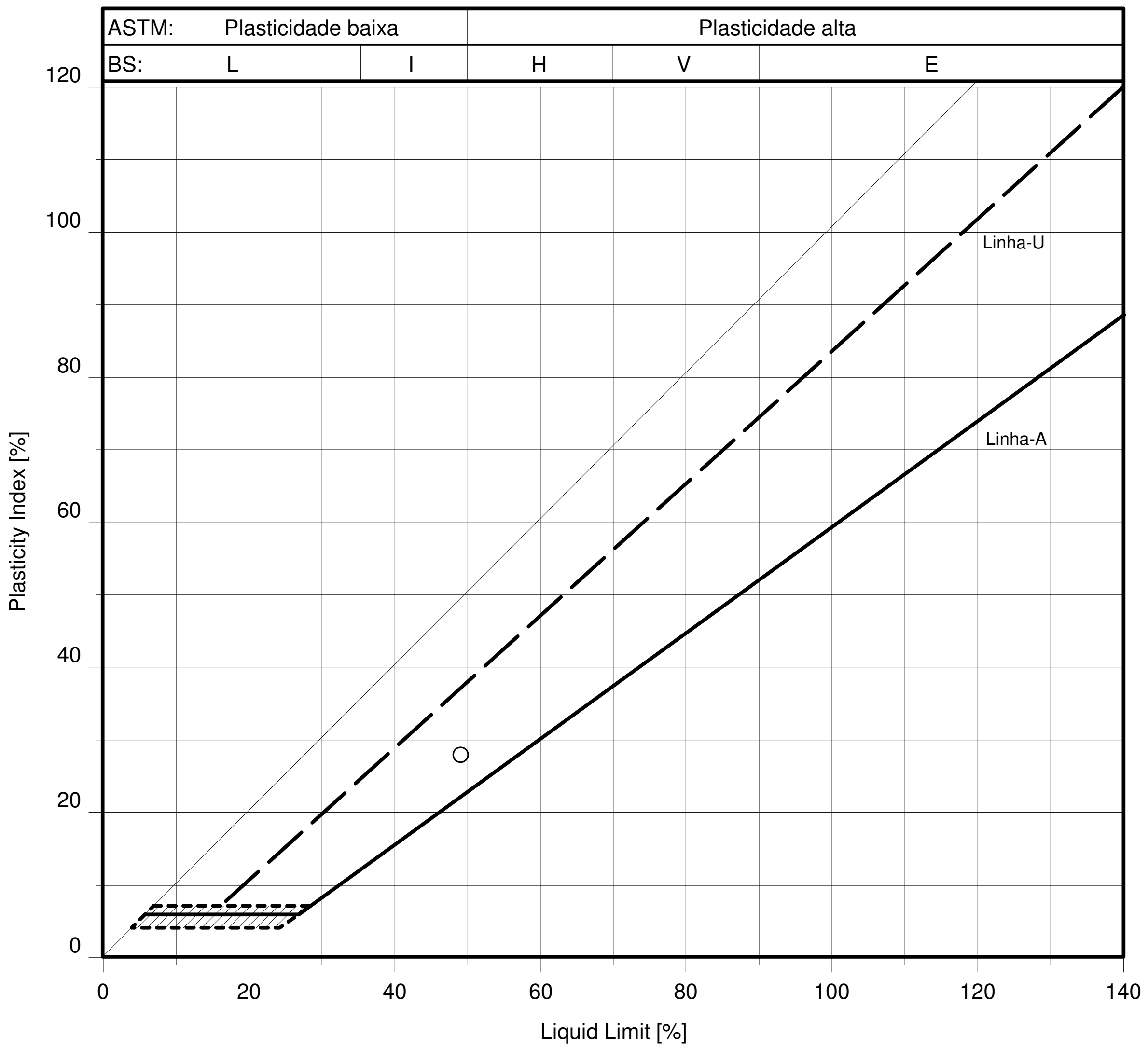
Plasticity index = Índice de plasticidade
Liquid limit = Limite de liquidez

GeODin/Plasticity Chart ASTM_BS 0-140% (Single location).GLO/2015-07-16 17:41:16

PLASTICIDADE

FURO POR-JP-15

PORT OF RIO DE JANEIRO - GUANABARA BAY



○	Limites de Atterberg
▨	ASTM CL-ML zona
L	Plasticidade baixa
I	Plasticidade intermédia
H	Plasticidade alta
V	Plasticidade muito alta
E	Plasticidade extremamente alta
BS	British Standard 5930: 1999
ASTM	ASTM D2487-06

Plasticity index = Índice de plasticidade
Liquid limit = Limite de liquidez

GeODin/Plasticity Chart ASTM_BS 0-140% (Single location).GLO/2015-07-16 17:41:55

PLASTICIDADE

FURO POR-JP-23

PORT OF RIO DE JANEIRO - GUANABARA BAY

SECTION C3: ENSAIOS DE COMPRESSÃO UNI-AXIAL

LISTA DE ILUSTRAÇÕES NA SEÇÃO C3: Ilustração

Unconfined Compression Test

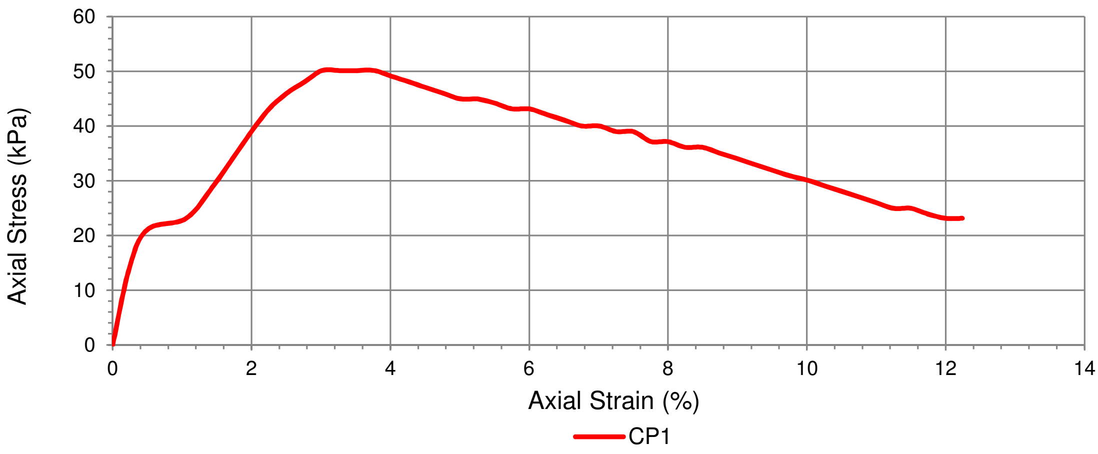
ASTM: D2166-00

Project: VOO003
Register: S15378
Borehole: POR01
Sample: PUS01
Depth of sample (m): 0,00 - 1,00

(i) - CHARACTERISTICS OF SPECIMENS AND TESTS

	Specimen			
Inicial Conditions	**1**	**2**	**3**	**4**
Depth of test (m)	0,80	-	-	-
Initial height, h_0 (mm)	140,00	-	-	-
Diameter, D (mm)	70,00	-	-	-
Area, A (cm^2)	38,48	-	-	-
Volume, V_0 (cm^3)	538,78	-	-	-
Wet Mass, m (g)	1120,65	-	-	-
Moisture Content, w (%)	15,77	-	-	-
Density, γ_n (kN/m^3)	20,80	-	-	-
Dry Density, γ_d (kN/m^3)	17,97	-	-	-
Shearing	**1**	**2**	**3**	**4**
Strain Speed (mm/min)	1,40	-	-	-
Rupture	**1**	**2**	**3**	**4**
Maximum Axial Stress (kPa)	50,15	-	-	-
Undrained Shear Stress (kPa)	25,08	-	-	-
Axial Strain (%)	3,01	-	-	-

(ii) AXIAL STRESS *VERSUS* AXIAL STRAIN



(iii) REMARKS

Unconfined Compression Test

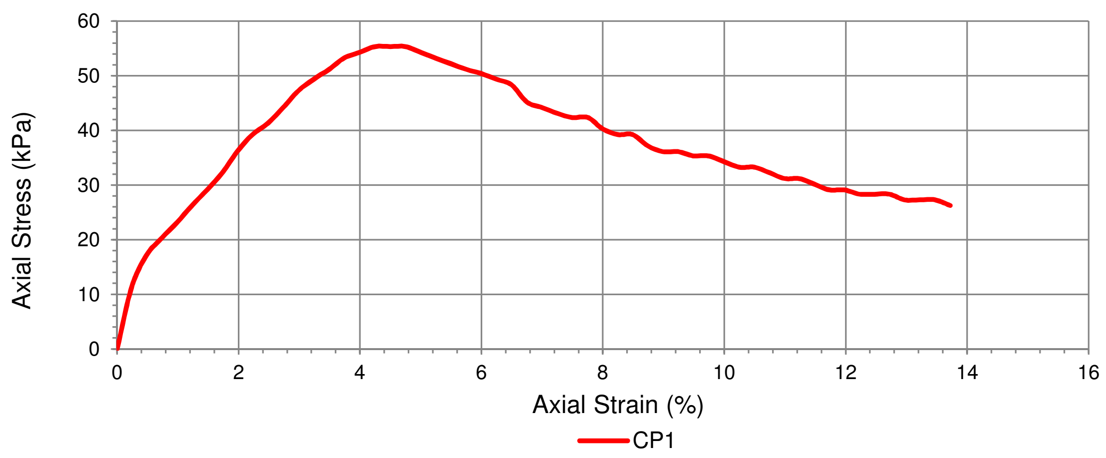
ASTM: D2166-00

Project: VOO003
Register: S15380
Borehole: POR02
Sample: PUS02
Depth of sample (m): 2.50

(i) - CHARACTERISTICS OF SPECIMENS AND TESTS

	Specimen			
Inicial Conditions	**1**	**2**	**3**	**4**
Depth of test (m)	2.90	-	-	-
Initial height, h_0 (mm)	140.00	-	-	-
Diameter, D (mm)	70.00	-	-	-
Area, A (cm^2)	38.48	-	-	-
Volume, V_0 (cm^3)	538.78	-	-	-
Wet Mass, m (g)	1145.12	-	-	-
Moisture Content, w (%)	15.57	-	-	-
Density, γ_n (kN/m^3)	21.25	-	-	-
Dry Density, γ_d (kN/m^3)	18.39	-	-	-
Shearing	**1**	**2**	**3**	**4**
Strain Speed (mm/min)	1.40	-	-	-
Rupture	**1**	**2**	**3**	**4**
Maximum Axial Stress (kPa)	55.35	-	-	-
Undrained Shear Stress (kPa)	27.67	-	-	-
Axial Strain (%)	4.25	-	-	-

(ii) AXIAL STRESS *VERSUS* AXIAL STRAIN



(iii) REMARKS

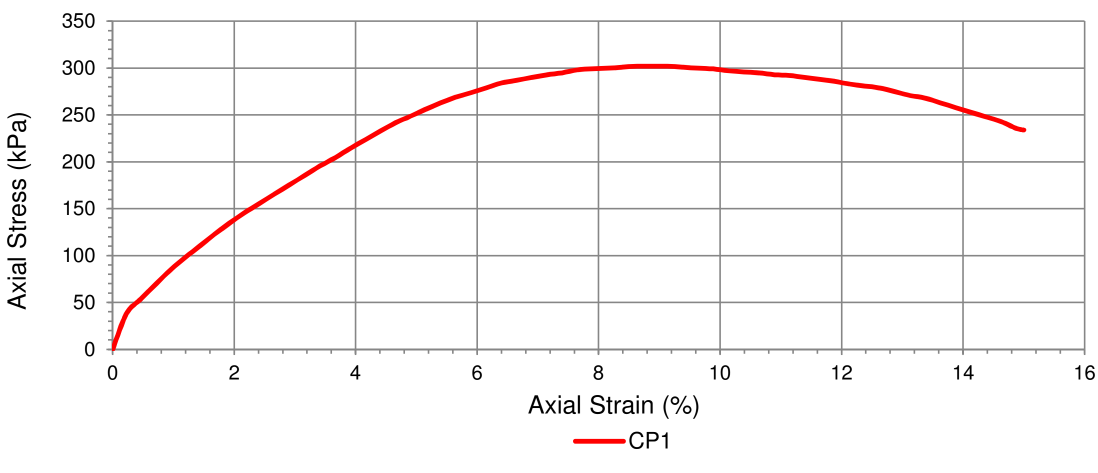
	Unconfined Compression Test
	ASTM: D2166-00

Project: VOO003
Register: S15381
Borehole: POR02
Sample: PUS03
Depth of sample (m): 5.00

(i) - CHARACTERISTICS OF SPECIMENS AND TESTS

	Specimen			
Inicial Conditions	**1**	**2**	**3**	**4**
Depth of test (m)	5.59	-	-	-
Initial height, h_0 (mm)	140.00	-	-	-
Diameter, D (mm)	70.00	-	-	-
Area, A (cm^2)	38.48	-	-	-
Volume, V_0 (cm^3)	538.78	-	-	-
Wet Mass, m (g)	1144.74	-	-	-
Moisture Content, w (%)	23.37	-	-	-
Density, γ_n (kN/m^3)	21.25	-	-	-
Dry Density, γ_d (kN/m^3)	17.22	-	-	-
Shearing	**1**	**2**	**3**	**4**
Strain Speed (mm/min)	1.40	-	-	-
Rupture	**1**	**2**	**3**	**4**
Maximum Axial Stress (kPa)	301.94	-	-	-
Undrained Shear Stress (kPa)	150.97	-	-	-
Axial Strain (%)	8.64	-	-	-

(ii) AXIAL STRESS *VERSUS* AXIAL STRAIN



(iii) REMARKS

Unconfined Compression Test

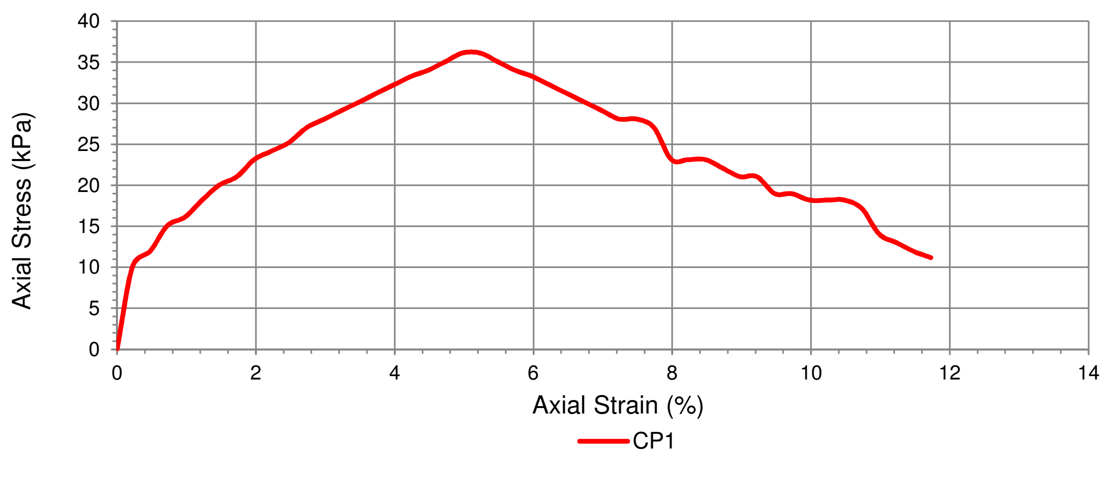
ASTM: D2166-00

Project: VOO003
Register: S15383
Borehole: POR03
Sample: PUS01
Depth of sample (m): 0.00 - 1.00

(i) - CHARACTERISTICS OF SPECIMENS AND TESTS

	Specimen			
Inicial Conditions	**1**	**2**	**3**	**4**
Depth of test (m)	0.69	-	-	-
Initial height, h_0 (mm)	140.00	-	-	-
Diameter, D (mm)	70.00	-	-	-
Area, A (cm^2)	38.48	-	-	-
Volume, V_0 (cm^3)	538.78	-	-	-
Wet Mass, m (g)	1052.00	-	-	-
Moisture Content, w (%)	25.17	-	-	-
Density, γ_n (kN/m^3)	19.53	-	-	-
Dry Density, γ_d (kN/m^3)	15.60	-	-	-
Shearing	**1**	**2**	**3**	**4**
Strain Speed (mm/min)	1.40	-	-	-
Rupture	**1**	**2**	**3**	**4**
Maximum Axial Stress (kPa)	36.12	-	-	-
Undrained Shear Stress (kPa)	18.06	-	-	-
Axial Strain (%)	4.98	-	-	-

(ii) AXIAL STRESS *VERSUS* AXIAL STRAIN



(iii) REMARKS

Unconfined Compression Test

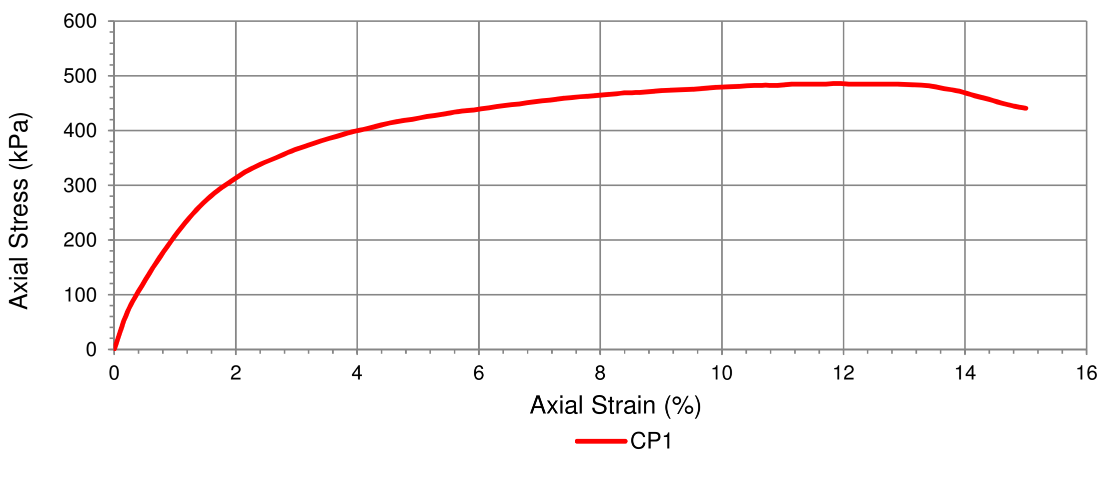
ASTM: D2166-00

Project: VOO003
Register: S15382
Borehole: POR03
Sample: PUS02
Depth of sample (m): 4.50

(i) - CHARACTERISTICS OF SPECIMENS AND TESTS

	Specimen			
Inicial Conditions	**1**	**2**	**3**	**4**
Depth of test (m)	4.79	-	-	-
Initial height, h_0 (mm)	140.00	-	-	-
Diameter, D (mm)	70.00	-	-	-
Area, A (cm^2)	38.48	-	-	-
Volume, V_0 (cm^3)	538.78	-	-	-
Wet Mass, m (g)	1102.46	-	-	-
Moisture Content, w (%)	16.63	-	-	-
Density, γ_n (kN/m³)	20.46	-	-	-
Dry Density, γ_d (kN/m³)	17.54	-	-	-
Shearing	**1**	**2**	**3**	**4**
Strain Speed (mm/min)	1.40	-	-	-
Rupture	**1**	**2**	**3**	**4**
Maximum Axial Stress (kPa)	485.91	-	-	-
Undrained Shear Stress (kPa)	242.95	-	-	-
Axial Strain (%)	11.90	-	-	-

(ii) AXIAL STRESS *VERSUS* AXIAL STRAIN



(iii) REMARKS

Unconfined Compression Test

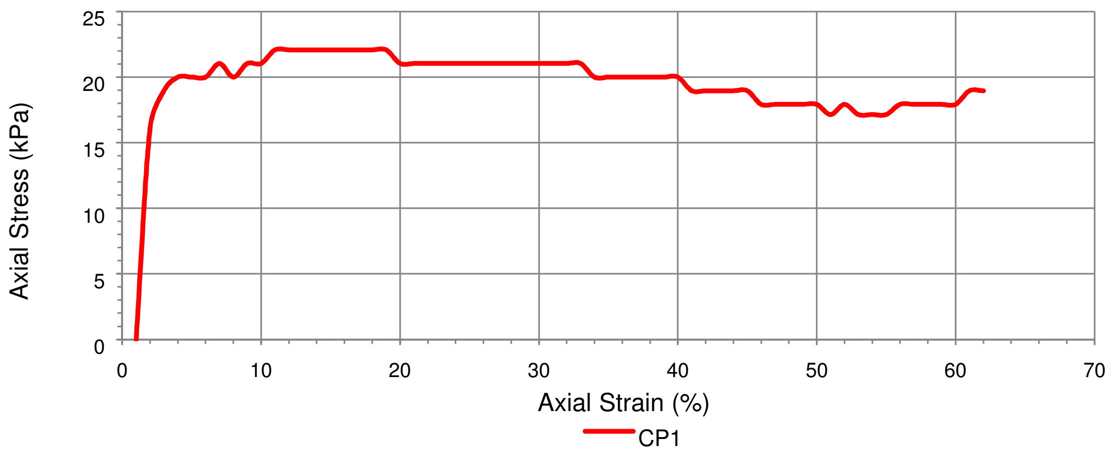
ASTM: D2166-00

Project: VOO003
Register: S15405
Borehole: POR05
Sample: RC01
Depth of sample (m): 4,00 - 5,50

(i) - CHARACTERISTICS OF SPECIMENS AND TESTS

	Specimen			
Inicial Conditions	**1**	**2**	**3**	**4**
Depth of test (m)	4,17	-	-	-
Initial height, h_0 (mm)	140,00	-	-	-
Diameter, D (mm)	70,00	-	-	-
Area, A (cm^2)	38,48	-	-	-
Volume, V_0 (cm^3)	538,78	-	-	-
Wet Mass, m (g)	1058,04	-	-	-
Moisture Content, w (%)	28,60	-	-	-
Density, γ_n (kN/m³)	19,64	-	-	-
Dry Density, γ_d (kN/m³)	15,27	-	-	-
Shearing	**1**	**2**	**3**	**4**
Strain Speed (mm/min)	1,40	-	-	-
Rupture	**1**	**2**	**3**	**4**
Maximum Axial Stress (kPa)	22,09	-	-	-
Undrained Shear Stress (kPa)	11,04	-	-	-
Axial Strain (%)	2,47	-	-	-

(ii) AXIAL STRESS *VERSUS* AXIAL STRAIN



(iii) REMARKS

Unconfined Compression Test

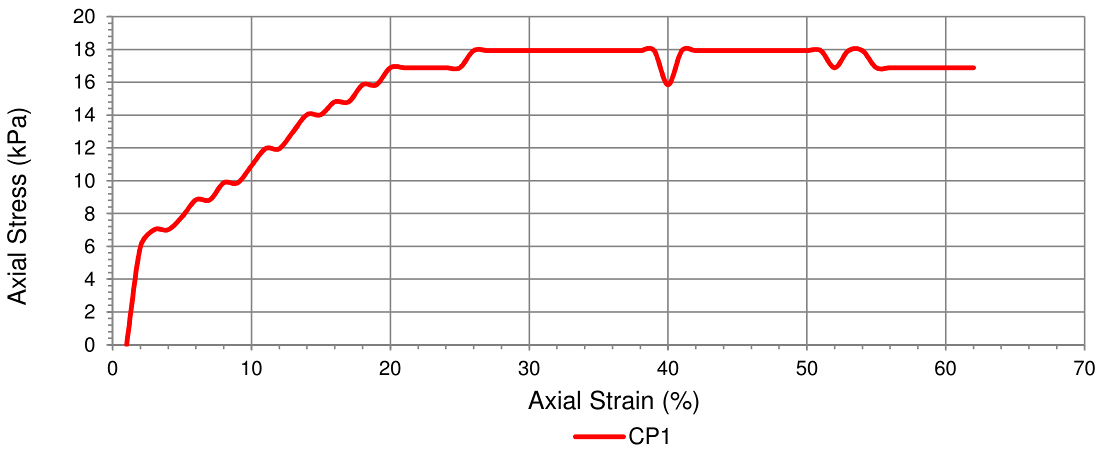
ASTM: D2166-00

Project: VOO003
Register: S15406
Borehole: POR05
Sample: RC02
Depth of sample (m): 6,00 - 7,00

(i) - CHARACTERISTICS OF SPECIMENS AND TESTS

	Specimen			
Inicial Conditions	**1**	**2**	**3**	**4**
Depth of test (m)	6,00	-	-	-
Initial height, h_0 (mm)	140,00	-	-	-
Diameter, D (mm)	70,00	-	-	-
Area, A (cm^2)	38,48	-	-	-
Volume, V_0 (cm^3)	538,78	-	-	-
Wet Mass, m (g)	1017,98	-	-	-
Moisture Content, w (%)	32,90	-	-	-
Density, γ_n (kN/m³)	18,89	-	-	-
Dry Density, γ_d (kN/m³)	14,22	-	-	-
Shearing	**1**	**2**	**3**	**4**
Strain Speed (mm/min)	1,40	-	-	-
Rupture	**1**	**2**	**3**	**4**
Maximum Axial Stress (kPa)	17,93	-	-	-
Undrained Shear Stress (kPa)	8,96	-	-	-
Axial Strain (%)	6,23	-	-	-

(ii) AXIAL STRESS *VERSUS* AXIAL STRAIN



(iii) REMARKS

Unconfined Compression Test

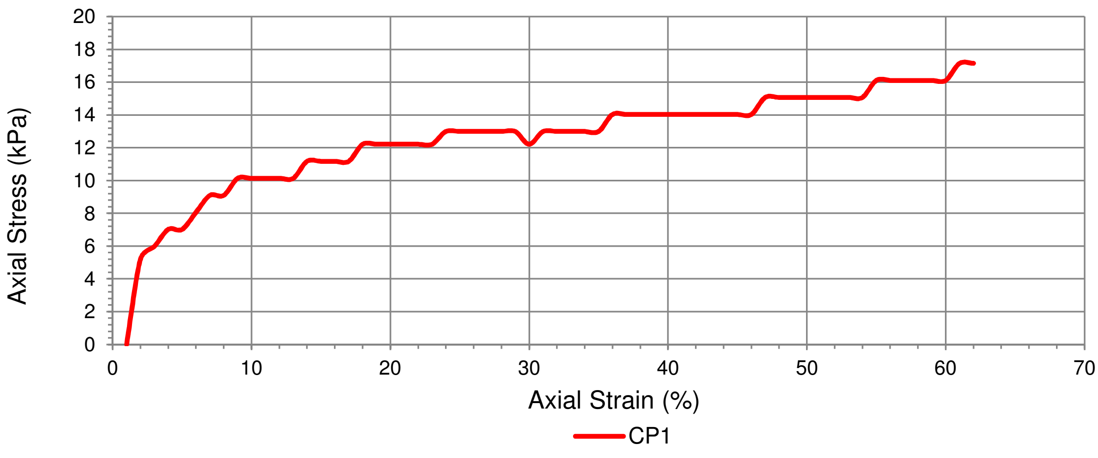
ASTM: D2166-00

Project: VOO003
Register: S15406
Borehole: POR05
Sample: RC02
Depth of sample (m): 6.00 - 7.00

(i) - CHARACTERISTICS OF SPECIMENS AND TESTS

	Specimen			
Inicial Conditions	**1**	**2**	**3**	**4**
Depth of test (m)	6,71	-	-	-
Initial height, h_0 (mm)	140,00	-	-	-
Diameter, D (mm)	70,00	-	-	-
Area, A (cm^2)	38,48	-	-	-
Volume, V_0 (cm^3)	538,78	-	-	-
Wet Mass, m (g)	1014,54	-	-	-
Moisture Content, w (%)	40,90	-	-	-
Density, γ_n (kN/m³)	18,83	-	-	-
Dry Density, γ_d (kN/m³)	13,36	-	-	-
Shearing	**1**	**2**	**3**	**4**
Strain Speed (mm/min)	1,40	-	-	-
Rupture	**1**	**2**	**3**	**4**
Maximum Axial Stress (kPa)	17,15	-	-	-
Undrained Shear Stress (kPa)	8,57	-	-	-
Axial Strain (%)	14,95	-	-	-

(ii) AXIAL STRESS *VERSUS* AXIAL STRAIN



(iii) REMARKS

Unconfined Compression Test

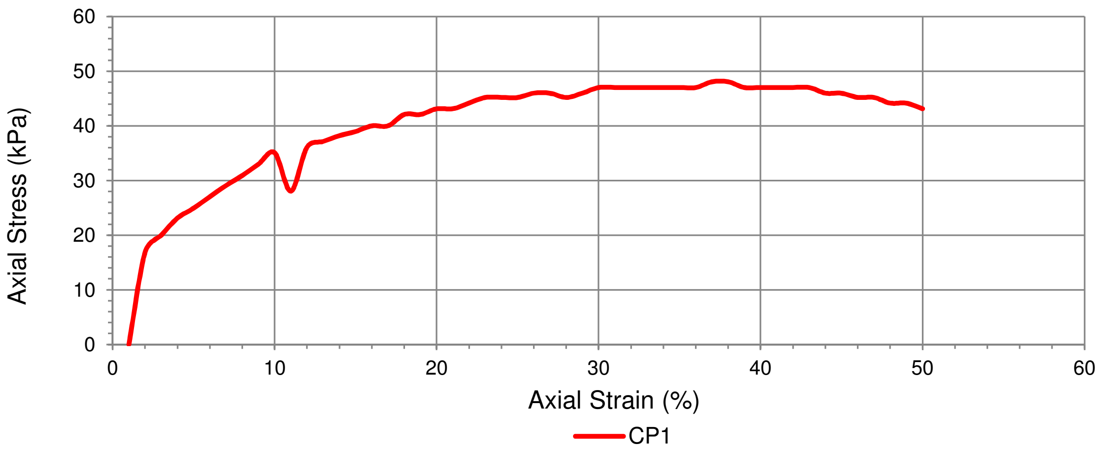
ASTM: D2166-00

Project: VOO003
Register: S15387
Borehole: POR07
Sample: PUS02
Depth of sample (m): 6,00 - 7,00

(i) - CHARACTERISTICS OF SPECIMENS AND TESTS

	Specimen			
Inicial Conditions	**1**	**2**	**3**	**4**
Depth of test (m)	-			-
Initial height, h_0 (mm)	140.00	-	-	-
Diameter, D (mm)	70.00	-	-	-
Area, A (cm^2)	38.48	-	-	-
Volume, V_0 (cm^3)	538.78	-	-	-
Wet Mass, m (g)	975.29	-	-	-
Moisture Content, w (%)	33.80	-	-	-
Density, γ_n (kN/m³)	18.10	-	-	-
Dry Density, γ_d (kN/m³)	13.53	-	-	-
Shearing	**1**	**2**	**3**	**4**
Strain Speed (mm/min)	1.40	-	-	-
Rupture	**1**	**2**	**3**	**4**
Maximum Axial Stress (kPa)	48.07	-	-	-
Undrained Shear Stress (kPa)	24.04	-	-	-
Axial Strain (%)	9.68	-	-	-

(ii) AXIAL STRESS *VERSUS* AXIAL STRAIN



(iii) REMARKS

Unconfined Compression Test

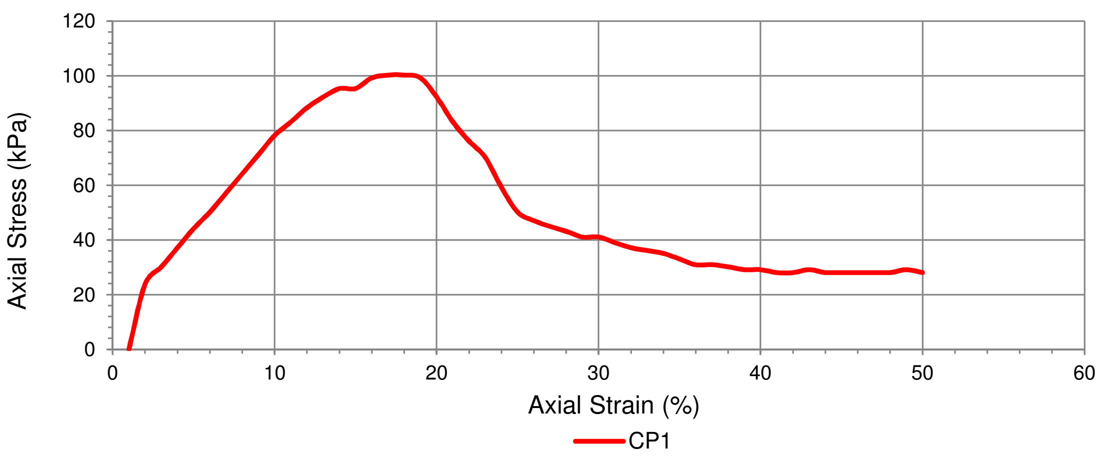
ASTM: D2166-00

Project: VOO003
Register: S15391
Borehole: POR11
Sample: PUS03
Depth of sample (m): 13.00

(i) - CHARACTERISTICS OF SPECIMENS AND TESTS

	Specimen			
Inicial Conditions	**1**	**2**	**3**	**4**
Depth of test (m)	13.17	-	-	-
Initial height, h_0 (mm)	140.00	-	-	-
Diameter, D (mm)	70.00	-	-	-
Area, A (cm^2)	38.48	-	-	-
Volume, V_0 (cm^3)	538.78	-	-	-
Wet Mass, m (g)	1265.45	-	-	-
Moisture Content, w (%)	20.67	-	-	-
Density, γ_n (kN/m³)	23.49	-	-	-
Dry Density, γ_d (kN/m³)	19.46	-	-	-
Shearing	**1**	**2**	**3**	**4**
Strain Speed (mm/min)	1.40	-	-	-
Rupture	**1**	**2**	**3**	**4**
Maximum Axial Stress (kPa)	100.30	-	-	-
Undrained Shear Stress (kPa)	50.15	-	-	-
Axial Strain (%)	4.01	-	-	-

(ii) AXIAL STRESS *VERSUS* AXIAL STRAIN



(iii) REMARKS

Unconfined Compression Test

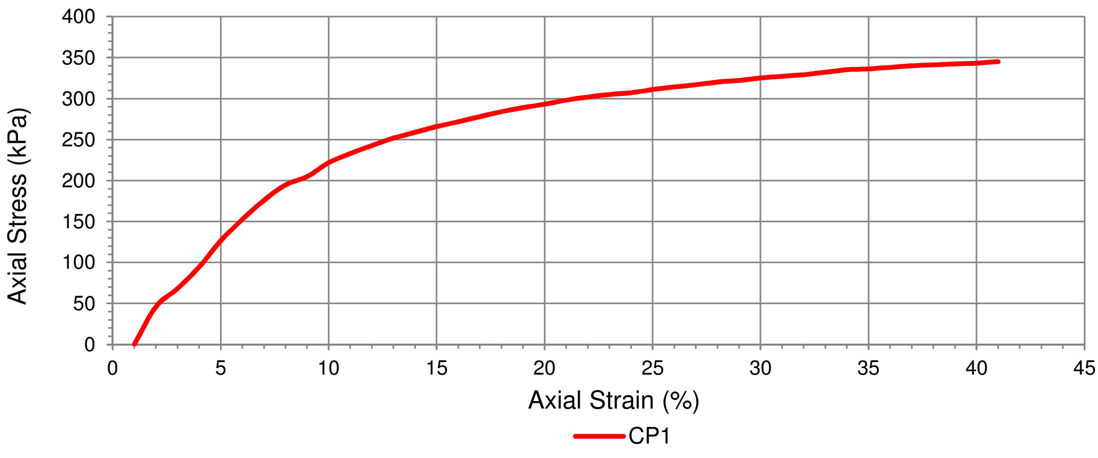
ASTM: D2166-00

Project: VOO003
Register: S15392
Borehole: POR11
Sample: PUS02
Depth of sample (m): 7,00

(i) - CHARACTERISTICS OF SPECIMENS AND TESTS

	Specimen			
Inicial Conditions	**1**	**2**	**3**	**4**
Depth of test (m)	7,10	-	-	-
Initial height, h_0 (mm)	140,00	-	-	-
Diameter, D (mm)	70,00	-	-	-
Area, A (cm^2)	38,48	-	-	-
Volume, V_0 (cm^3)	538,78	-	-	-
Wet Mass, m (g)	1194,21	-	-	-
Moisture Content, w (%)	22,00	-	-	-
Density, γ_n (kN/m³)	22,16	-	-	-
Dry Density, γ_d (kN/m³)	18,17	-	-	-
Shearing	**1**	**2**	**3**	**4**
Strain Speed (mm/min)	1,40	-	-	-
Rupture	**1**	**2**	**3**	**4**
Maximum Axial Stress (kPa)	345,07	-	-	-
Undrained Shear Stress (kPa)	172,54	-	-	-
Axial Strain (%)	9,98	-	-	-

(ii) AXIAL STRESS *VERSUS* AXIAL STRAIN



(iii) REMARKS

Unconfined Compression Test

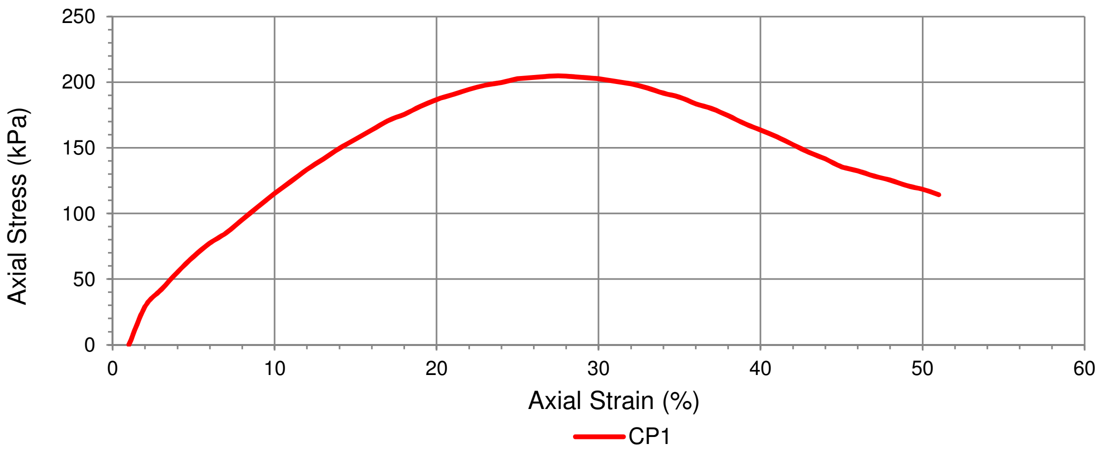
ASTM: D2166-00

Project: VOO003
Register: S15393
Borehole: POR12
Sample: PUS03
Depth of sample (m): 9,50 - 10,00

(i) - CHARACTERISTICS OF SPECIMENS AND TESTS

	Specimen			
Inicial Conditions	**1**	**2**	**3**	**4**
Depth of test (m)	9,83	-	-	-
Initial height, h_0 (mm)	140,00	-	-	-
Diameter, D (mm)	70,00	-	-	-
Area, A (cm^2)	38,48	-	-	-
Volume, V_0 (cm^3)	538,78	-	-	-
Wet Mass, m (g)	1169,97	-	-	-
Moisture Content, w (%)	23,57	-	-	-
Density, γ_n (kN/m³)	21,72	-	-	-
Dry Density, γ_d (kN/m³)	17,57	-	-	-
Shearing	**1**	**2**	**3**	**4**
Strain Speed (mm/min)	1,40	-	-	-
Rupture	**1**	**2**	**3**	**4**
Maximum Axial Stress (kPa)	204,76	-	-	-
Undrained Shear Stress (kPa)	102,38	-	-	-
Axial Strain (%)	6,47	-	-	-

(ii) AXIAL STRESS *VERSUS* AXIAL STRAIN



(iii) REMARKS

Unconfined Compression Test

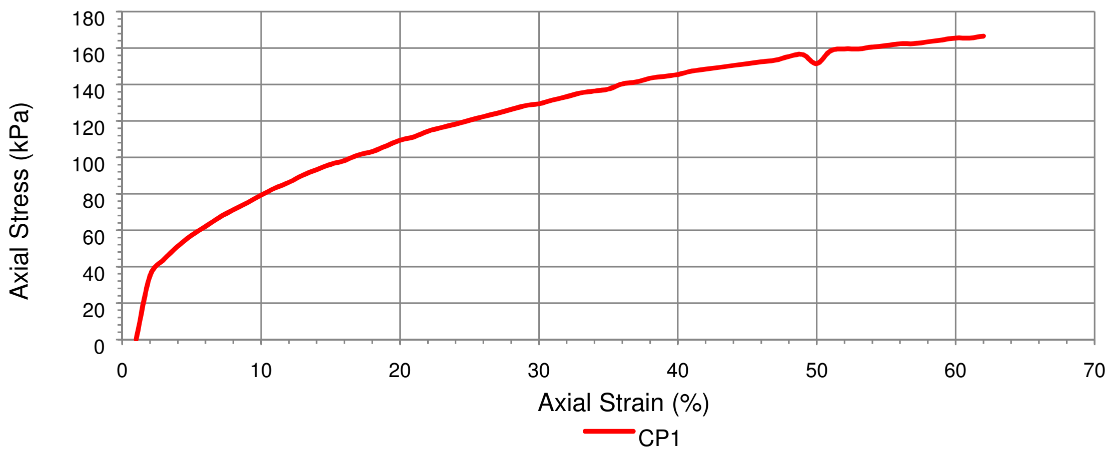
ASTM: D2166-00

Project: VOO003
Register: S15394
Borehole: POR12
Sample: PUS02
Depth of sample (m): 5,50 - 6,50

(i) - CHARACTERISTICS OF SPECIMENS AND TESTS

	Specimen			
Inicial Conditions	**1**	**2**	**3**	**4**
Depth of test (m)	6,01	-	-	-
Initial height, h_0 (mm)	140,00	-	-	-
Diameter, D (mm)	70,00	-	-	-
Area, A (cm^2)	38,48	-	-	-
Volume, V_0 (cm^3)	538,78	-	-	-
Wet Mass, m (g)	1121,13	-	-	-
Moisture Content, w (%)	18,67	-	-	-
Density, γ_n (kN/m³)	20,81	-	-	-
Dry Density, γ_d (kN/m³)	17,54	-	-	-
Shearing	**1**	**2**	**3**	**4**
Strain Speed (mm/min)	1,40	-	-	-
Rupture	**1**	**2**	**3**	**4**
Maximum Axial Stress (kPa)	166,56	-	-	-
Undrained Shear Stress (kPa)	83,28	-	-	-
Axial Strain (%)	15,00	-	-	-

(ii) AXIAL STRESS *VERSUS* AXIAL STRAIN



(iii) REMARKS

SEÇÃO D: RELATÓRIOS DE POSICIONAMENTO

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	**Skate IIIC REV1**
Project Name	**Skate IIIC Brazil**
Project Number	**150303 Skate IIIC Brazil**
Offset Name	**Rotary Table**
Sampling Started	**11-Jun-2015 14:33:26 (local)**
Sampling Ended	**11-Jun-2015 14:38:27 (local)**
Comment	**at 14:30**

DML = 13.6 m
DWL = 1.5 m

Results

	Mean	Standard Deviation
Local Latitude	**22°53'25.0158"S**	
Local Longitude	**43°10'34.1255"W**	
Ellipsoidal Height	**-4.45 m**	
Local Easting	**687084.26 m**	**0.01 m**
Local Northing	**7467467.40 m**	**0.02 m**
Orthometric Height	**-4.45 m**	**0.04 m**
WGS84 Latitude	**22°53'25.0158"S**	
WGS84 Longitude	**43°10'34.1255"W**	
Ellipsoidal Height	**-4.45 m**	
Quality	**1.23**	**0.13 m**
Depth	**0.00 m**	**0.00 m**
Heading	**106.23°T**	**0.44°**

Line Navigation Data

Line Name	**N/A**
Chainage	N/A
Cross Track	N/A

Point Navigation Data

Point Name	**POR-1**
Range TO	1.32 m
Bearing TO	251.46°T

Observations

Total 296
Used 296

Geodetic Parameters

Geodetic Datum	**WGS84**		
Ellipsoid	**WGS84**		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	**Universal Transverse Mercator Zone: 23**		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°42'34.6581"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	11-Jun-2015 13:12:50 (local)
Sampling Ended	11-Jun-2015 13:17:50 (local)
Comment	at 12:00

DML = 12.1 m
DWL = 1.1

Results

	Mean	Standard Deviation
Local Latitude	22°53'23.3873"S	
Local Longitude	43°10'41.6086"W	
Ellipsoidal Height	-4.75 m	
Local Easting	686871.61 m	0.01 m
Local Northing	7467520.14 m	0.01 m
Orthometric Height	-4.75 m	0.07 m
WGS84 Latitude	22°53'23.3873"S	
WGS84 Longitude	43°10'41.6086"W	
Ellipsoidal Height	-4.75 m	
Quality	0.95	0.05 m
Depth	0.00 m	0.00 m
Heading	94.96°T	0.64°

Line Navigation Data

Line Name	N/A
Chainage	N/A
Cross Track	N/A

Point Navigation Data

Point Name	POR-2
Range TO	2.32 m
Bearing TO	36.09°T

Observations

Total	299
Used	299

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°42'31.6972"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	10-Jun-2015 09:34:56 (local)
Sampling Ended	10-Jun-2015 09:39:56 (local)
Comment	@ 9:10 am

DML = 10.0 m
DWL = 0.9 m

Results

	Mean	Standard Deviation
Local Latitude	22°53'06.2896"S	
Local Longitude	43°11'00.4806"W	
Ellipsoidal Height	-4.87 m	
Local Easting	686340.24 m	0.01 m
Local Northing	7468052.71 m	0.01 m
Orthometric Height	-4.87 m	0.04 m
WGS84 Latitude	22°53'06.2896"S	
WGS84 Longitude	43°11'00.4806"W	
Ellipsoidal Height	-4.87 m	
Quality	0.90	0.00 m
Depth	0.00 m	0.00 m
Heading	150.62°T	0.58°

Line Navigation Data

Line Name	N/A
Chainage	N/A
Cross Track	N/A

Point Navigation Data

Point Name	POR-3
Range TO	1.27 m
Bearing TO	282.32°T

Observations

Total	299
Used	299

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°42'23.8508"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	11-Jun-2015 22:54:24 (local)
Sampling Ended	11-Jun-2015 22:59:24 (local)
Comment	DTW - 0.8m

DTM - 12.2m
D/CD - 2.39m
D/MSL - 1.7
0m

Results

	Mean	Standard Deviation
Local Latitude	22°53'25.0665"S	
Local Longitude	43°10'24.5479"W	
Ellipsoidal Height	-4.82 m	
Local Easting	687357.20 m	0.02 m
Local Northing	7467462.46 m	0.02 m
Orthometric Height	-4.82 m	0.02 m
WGS84 Latitude	22°53'25.0665"S	
WGS84 Longitude	43°10'24.5479"W	
Ellipsoidal Height	-4.82 m	
Quality	1.10	0.00 m
Depth	0.00 m	0.00 m
Heading	213.95°T	0.30°

Line Navigation Data		Point Navigation Data	
Line Name	N/A	Point Name	POR-4
Chainage	N/A	Range TO	3.52 m
Cross Track	N/A	Bearing TO	244.73°T

Observations
Total 300
Used 300

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°42'38.3882"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	09-Jun-2015 12:03:08 (local)
Sampling Ended	09-Jun-2015 12:08:08 (local)
Comment	at 11:40

DML = 10.2
DWL = 0.9

Results

	Mean	Standard Deviation
Local Latitude	22°52'59.8436"S	
Local Longitude	43°11'13.1042"W	
Ellipsoidal Height	-5.02 m	
Local Easting	685982.89 m	0.01 m
Local Northing	7468255.43 m	0.01 m
Orthometric Height	-5.02 m	0.03 m
WGS84 Latitude	22°52'59.8436"S	
WGS84 Longitude	43°11'13.1042"W	
Ellipsoidal Height	-5.02 m	
Quality	1.01	0.02 m
Depth	0.00 m	0.00 m
Heading	309.25°T	1.56°

Line Navigation Data		Point Navigation Data	
Line Name	N/A	Point Name	POR-5
Chainage	N/A	Range TO	4.13 m
Cross Track	N/A	Bearing TO	95.24°T

Observations
Total 301
Used 301

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°42'18.7495"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	09-Jun-2015 20:33:09 (local)
Sampling Ended	09-Jun-2015 20:38:15 (local)
Comment	DTM - 8.8m, DTW - 0.8m

Deck above CD - 2.27, Deck above MSL - 1.60

Results

	Mean	Standard Deviation
Local Latitude	22°52'51.7951"S	
Local Longitude	43°11'23.5248"W	
Ellipsoidal Height	-4.90 m	
Local Easting	685688.93 m	0.01 m
Local Northing	7468506.66 m	0.01 m
Orthometric Height	-4.90 m	0.03 m
WGS84 Latitude	22°52'51.7951"S	
WGS84 Longitude	43°11'23.5248"W	
Ellipsoidal Height	-4.90 m	
Quality	1.11	0.02 m
Depth	0.00 m	0.00 m
Heading	303.83°T	0.42°

Line Navigation Data		Point Navigation Data	
Line Name	N/A	Point Name	POR-6
Chainage	N/A	Range TO	1.66 m
Cross Track	N/A	Bearing TO	176.96°T

Observations

Total	300
Used	300

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°42'14.4596"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	06-Jun-2015 10:13:46 (local)
Sampling Ended	06-Jun-2015 10:18:46 (local)
Comment	D/ML = 6.60m

D/WI = 1.60m
D Above MSL =1.80m

Results

	Mean	Standard Deviation
Local Latitude	22°52'22.9560"S	
Local Longitude	43°11'58.4266"W	
Ellipsoidal Height	-4.73 m	
Local Easting	684705.00 m	0.01 m
Local Northing	7469405.94 m	0.01 m
Orthometric Height	-4.73 m	0.04 m
WGS84 Latitude	22°52'22.9560"S	
WGS84 Longitude	43°11'58.4266"W	
Ellipsoidal Height	-4.73 m	
Quality	0.90	0.00 m
Depth	0.00 m	0.00 m
Heading	290.54°T	0.62°

Line Navigation Data		Point Navigation Data	
Line Name	N/A	Point Name	POR-7
Chainage	N/A	Range TO	0.06 m
Cross Track	N/A	Bearing TO	354.65°T

Observations
Total 294
Used 294

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°42'00.0423"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	05-Jun-2015 15:18:55 (local)
Sampling Ended	05-Jun-2015 15:23:57 (local)
Comment	D/ML =6.00m

D/WL =2.35m
D Above MSL =3.65

Results

	Mean	Standard Deviation
Local Latitude	22°52'18.7655"S	
Local Longitude	43°12'02.2100"W	
Ellipsoidal Height	-2.88 m	
Local Easting	684598.74 m	0.02 m
Local Northing	7469536.16 m	0.02 m
Orthometric Height	-2.88 m	0.04 m
WGS84 Latitude	22°52'18.7655"S	
WGS84 Longitude	43°12'02.2100"W	
Ellipsoidal Height	-2.88 m	
Quality	1.35	0.42 m
Depth	0.00 m	0.00 m
Heading	270.66°T	0.99°

Line Navigation Data		Point Navigation Data	
Line Name	N/A	Point Name	POR-8
Chainage	N/A	Range TO	0.31 m
Cross Track	N/A	Bearing TO	120.19°T

Observations
Total 300
Used 300

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°41'58.4492"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	07-Jun-2015 14:10:33 (local)
Sampling Ended	07-Jun-2015 14:15:33 (local)
Comment	DWL = 0.6

DML = 6.6
at 9:55 am

Results

	Mean	Standard Deviation
Local Latitude	22°52'42.0045"S	
Local Longitude	43°12'18.9566"W	
Ellipsoidal Height	-5.51 m	
Local Easting	684112.69 m	0.01 m
Local Northing	7468827.15 m	0.01 m
Orthometric Height	-5.51 m	0.04 m
WGS84 Latitude	22°52'42.0045"S	
WGS84 Longitude	43°12'18.9566"W	
Ellipsoidal Height	-5.51 m	
Quality	0.89	0.02 m
Depth	0.00 m	0.00 m
Heading	273.07°T	0.43°

Line Navigation Data

Line Name	N/A
Chainage	N/A
Cross Track	N/A

Point Navigation Data

Point Name	POR-9
Range TO	3.42 m
Bearing TO	74.85°T

Observations

Total	300
Used	300

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°41'52.6056"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	08-Jun-2015 20:05:57 (local)
Sampling Ended	08-Jun-2015 20:10:58 (local)
Comment	DTM - 5.4m, DTW - 0.8m, Deck above MSL - 1.57, Deck above CD - 2.28

Results

	Mean	Standard Deviation
Local Latitude	22°52'49.4467"S	
Local Longitude	43°12'26.1739"W	
Ellipsoidal Height	-4.89 m	
Local Easting	683904.20 m	0.01 m
Local Northing	7468600.73 m	0.02 m
Orthometric Height	-4.89 m	0.05 m
WGS84 Latitude	22°52'49.4467"S	
WGS84 Longitude	43°12'26.1739"W	
Ellipsoidal Height	-4.89 m	
Quality	1.59	0.26 m
Depth	0.00 m	0.00 m
Heading	208.85°T	0.32°

Line Navigation Data

Line Name	N/A
Chainage	N/A
Cross Track	N/A

Point Navigation Data

Point Name	POR-10
Range TO	2.10 m
Bearing TO	213.99°T

Observations

Total	300
Used	300

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°41'50.0119"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	08-Jun-2015 13:20:12 (local)
Sampling Ended	08-Jun-2015 13:25:13 (local)
Comment	D/ML=3.50m

D/WL=1.10
Water Depth 2.10m
DL above
MSL=1.92
Time = 11:45

Results

	Mean	Standard Deviation
Local Latitude	22°52'56.2940"S	
Local Longitude	43°12'32.1260"W	
Ellipsoidal Height	-4.69 m	
Local Easting	683731.99 m	0.01 m
Local Northing	7468392.17 m	0.01 m
Orthometric Height	-4.69 m	0.05 m
WGS84 Latitude	22°52'56.2940"S	
WGS84 Longitude	43°12'32.1260"W	
Ellipsoidal Height	-4.69 m	
Quality	0.91	0.03 m
Depth	0.00 m	0.00 m
Heading	121.82°T	0.65°

Line Navigation Data		Point Navigation Data	
Line Name	N/A	Point Name	POR-11
Chainage	N/A	Range TO	4.17 m
Cross Track	N/A	Bearing TO	179.15°T

Observations
Total 294
Used 294

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°41'47.8929"		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	07-Jun-2015 20:50:42 (local)
Sampling Ended	07-Jun-2015 20:55:49 (local)
Comment	DTM - 5.5m, DTW - 0.8m, Deck above CD - 2.25, Deck above MSL - 1.62

Results

	Mean	Standard Deviation
Local Latitude	22°52'45.8713"S	
Local Longitude	43°12'22.2034"W	
Ellipsoidal Height	-4.90 m	
Local Easting	684018.70 m	0.01 m
Local Northing	7468709.33 m	0.01 m
Orthometric Height	-4.90 m	0.03 m
WGS84 Latitude	22°52'45.8713"S	
WGS84 Longitude	43°12'22.2034"W	
Ellipsoidal Height	-4.90 m	
Quality	1.10	0.00 m
Depth	0.00 m	0.00 m
Heading	189.80°T	0.28°

Line Navigation Data		Point Navigation Data	
Line Name	N/A	Point Name	POR-12
Chainage	N/A	Range TO	4.05 m
Cross Track	N/A	Bearing TO	334.45°T

Observations

Total	300
Used	300

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°41'51.4538"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	06-Jun-2015 20:35:52 (local)
Sampling Ended	06-Jun-2015 20:41:00 (local)
Comment	DML - 11.7m

DTW - 2.0m
DCD - 3.30
DMSL - 2.63

Results

	Mean	Standard Deviation
Local Latitude	22°52'27.7697"S	
Local Longitude	43°11'54.6052"W	
Ellipsoidal Height	-3.91 m	
Local Easting	684812.12 m	0.01 m
Local Northing	7469256.54 m	0.01 m
Orthometric Height	-3.91 m	0.02 m
WGS84 Latitude	22°52'27.7697"S	
WGS84 Longitude	43°11'54.6052"W	
Ellipsoidal Height	-3.91 m	
Quality	1.10	0.00 m
Depth	0.00 m	0.00 m
Heading	60.71°T	0.68°

Line Navigation Data

Line Name	N/A
Chainage	N/A
Cross Track	N/A

Point Navigation Data

Point Name	POR-14
Range TO	4.60 m
Bearing TO	56.91°T

Observations

Total 300
Used 300

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°42'01.6684"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	11-Jun-2015 00:54:50 (local)
Sampling Ended	11-Jun-2015 00:59:53 (local)
Comment	DTM - 7.9m, DTW - 1.1m

D/MSL - 1.79, D/CD - 2.42

Results

	Mean	Standard Deviation
Local Latitude	22°54'42.9607"S	
Local Longitude	43°09'30.3664"W	
Ellipsoidal Height	-4.75 m	
Local Easting	688871.41 m	0.01 m
Local Northing	7465047.15 m	0.02 m
Orthometric Height	-4.75 m	0.05 m
WGS84 Latitude	22°54'42.9607"S	
WGS84 Longitude	43°09'30.3664"W	
Ellipsoidal Height	-4.75 m	
Quality	1.10	0.00 m
Depth	0.00 m	0.00 m
Heading	230.79°T	0.49°

Line Navigation Data		Point Navigation Data	
Line Name	N/A	Point Name	POR-17
Chainage	N/A	Range TO	3.45 m
Cross Track	N/A	Bearing TO	203.40°T

Observations

Total	300
Used	300

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°43'01.7885"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	10-Jun-2015 17:51:35 (local)
Sampling Ended	10-Jun-2015 17:56:35 (local)
Comment	at 17:50

D/ML=7.5
D/Wl = 0.800

Results

	Mean	Standard Deviation
Local Latitude	22°54'36.3487"S	
Local Longitude	43°09'33.2865"W	
Ellipsoidal Height	-5.65 m	
Local Easting	688790.75 m	0.11 m
Local Northing	7465251.58 m	0.09 m
Orthometric Height	-5.65 m	0.04 m
WGS84 Latitude	22°54'36.3487"S	
WGS84 Longitude	43°09'33.2865"W	
Ellipsoidal Height	-5.65 m	
Quality	0.86	0.05 m
Depth	0.00 m	0.00 m
Heading	272.45°T	0.51°

Line Navigation Data		Point Navigation Data	
Line Name	N/A	Point Name	POR-18
Chainage	N/A	Range TO	2.59 m
Cross Track	N/A	Bearing TO	173.68°T

Observations
Total 301
Used 301

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°43'00.4549"		
Calculation Mode	Spheroidal		

Starfix Mean Position Report v4.02.21

Vessel

Vessel Name	Skate IIIC REV1
Project Name	Skate IIIC Brazil
Project Number	150303 Skate IIIC Brazil
Offset Name	Rotary Table
Sampling Started	12-Jun-2015 10:49:51 (local)
Sampling Ended	12-Jun-2015 10:54:52 (local)
Comment	at 9:50

DWL = 1.5m
DML = 6.6 m

Results

	Mean	Standard Deviation
Local Latitude	22°54'43.4073"S	
Local Longitude	43°09'30.8480"W	
Ellipsoidal Height	-4.17 m	
Local Easting	688857.52 m	0.01 m
Local Northing	7465033.58 m	0.01 m
Orthometric Height	-4.17 m	0.04 m
WGS84 Latitude	22°54'43.4073"S	
WGS84 Longitude	43°09'30.8480"W	
Ellipsoidal Height	-4.17 m	
Quality	1.06	0.05 m
Depth	0.00 m	0.00 m
Heading	217.86°T	0.43°

Line Navigation Data

Line Name	N/A
Chainage	N/A
Cross Track	N/A

Point Navigation Data

Point Name	POR 19
Range TO	1.54 m
Bearing TO	73.60°T

Observations

Total 297
Used 297

Geodetic Parameters

Geodetic Datum	WGS84		
Ellipsoid	WGS84		
Semi-Major Axis	6378137.000		
Inverse Flattening	298.2572235630		
Eccentricity^2	0.006694379990141		
DX	0.0000m	RX	0.0000 arc seconds
DY	0.0000m	RY	0.0000 arc seconds
DZ	0.0000m	RZ	0.0000 arc seconds
D Scale	0.0000ppm		
Rotation Convention	+RZ=-RLongitude		
Projection	Universal Transverse Mercator Zone: 23		
Latitude of Origin	0°00'00.0000"N		
Longitude of Origin	45°00'00.0000"W		
False Easting	500000.000m		
False Northing	10000000.000m		
Convergence	- 0°43'01.6140"		
Calculation Mode	Spheroidal		

SEÇÃO E: DIRETRIZES PARA USO DO RELATÓRIO

ÍNDICE

INTRODUCTION

Fugro Engineers B.V. (FEBV) prepared this report. FEBV is a Fugro N.V. Group operating company. FEBV specialises in providing geotechnical information and engineering advice for on-land, nearshore and offshore construction projects. FEBV will hereafter be referred to as Fugro.

This document provides guidelines, recommendations and limitations regarding the use of information in this report. The cost of geotechnical data acquisition, interpretation and monitoring is a small portion of the total cost of a construction project. By contrast, the costs of correcting a wrongly designed programme or mobilising alternative construction methods are often far greater than the cost of the original investigation. Attention and adherence to the guidelines and recommendations presented in this guide and in the geotechnical report can reduce delays and cost overruns related to geotechnical factors.

This guide applies equally to the use of geotechnical and multi-disciplinary project information and advice.

REQUIREMENTS FOR QUALITY GEOTECHNICAL INVESTIGATIONS

Fugro follows ISO 9001 quality principles for project management. Project activities usually comprise part of specific phases of a construction project. The quality plan for the entire construction project must incorporate geotechnical input in every phase - from the feasibility planning stages to project completion. The parties involved must do the following.

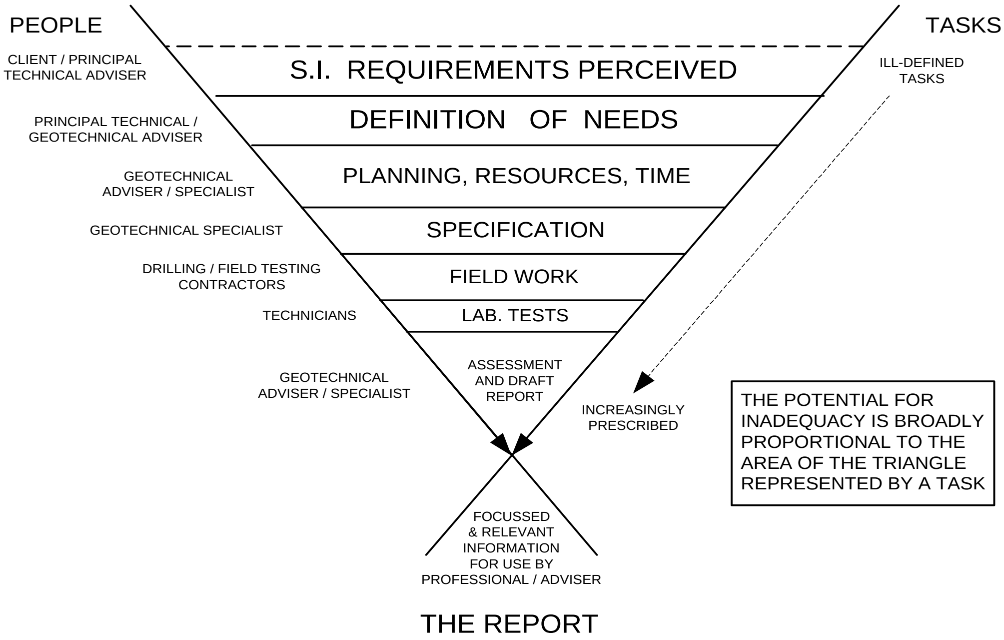
– Provide complete and accurate information necessary to plan an appropriate geotechnical site investigation.
– Describe the purpose(s), type(s) and construction methods of planned structures in detail.
– Provide the time, financial, personnel and other resources necessary for the planning, execution and follow-up of a site investigation programme.
– Understand the limitations and degree of accuracy inherent in the geotechnical data and engineering advice based upon these data.
– During all design and construction activities, be aware of the limitations of geotechnical data and geotechnical engineering analyses/advice, and use appropriate preventative measures.
– Incorporate all geotechnical input in the design, planning, construction and other activities involving the site and structures. Provide the entire geotechnical report to parties involved in design and construction.
– Use the geotechnical data and engineering advice for only the structures, site and activities which were described to Fugro prior to and for the purpose of planning the geotechnical site investigation or geotechnical engineering analysis programme.

AUTHORITY, TIME AND RESOUCES NECESSARY FOR QUALITY GEOTECHNICAL INVESTIGATIONS

To ensure compliance with these requirements, there must be adequate designation of authority and accountability for geotechnical aspects of construction projects. This way, an appropriate investigation can be performed, and the use of the results by project design and construction professionals can be optimised.

Figure 1 illustrates the importance of the initial project phases in ensuring that adequate geotechnical information is gathered for a project. The initial phases, when site investigation requirements are defined and resources are allocated, are represented by more than 50% of the Quality triangle (Figure 1). Decisions and actions made during these phases have a large impact of the outcome and thus the potential of the investigation to meet project requirements.

Figure 1: Quality of Geotechnical Site Investigation (adapted from SISG[1]).



DATA ACQUISITION AND MONITORING PROGRAMMES

Geotechnical investigations are operations of discovery. Investigation should proceed in logical stages. Planning must allow operational adjustments deemed necessary by newly available information. This observational approach permits the development of a sound engineering strategy and reduces the risk of discovering unexpected hazards during or after construction.

GEOTECHNICAL INFORMATION – DATA TYPES AND LIMITATIONS

1. RELIABILITY OF SUPPLIED INFORMATION

Geotechnical engineering can involve the use of information and physical material that is publicly available or supplied by the Client. Examples are geodetic data, geological maps, geophysical records, earthquake data, earlier borehole logs and soil samples. Fugro endeavours to identify potential anomalies, but does not independently verify the accuracy or completeness of public or Client-supplied information unless indicated otherwise. This information, therefore, can limit the accuracy of the report.

2. COMPLEXITY OF GROUND CONDITIONS

There are hazards associated with the ground. An adequate understanding of these hazards can help to minimize risks to a project and the site. The ground is a vital element of all structures which rest on or in the ground. Information about ground behaviour is necessary to achieve a safe and economical structure. Often less is known about the ground than for any other element of a structure.

3. GEOTECHNICAL INVESTIGATION - SPATIAL COVERAGE LIMITATIONS

Geotechnical investigations collect data at specific test locations. Interpretation of ground conditions between test locations is a matter of extrapolation and judgement based on geotechnical knowledge and experience, but actual conditions in untested areas may differ from predictions. For example, the interface between ground materials may be far more gradual or abrupt than a report indicates. It is not realistic to expect a geotechnical investigation to reveal or anticipate every detail of ground conditions. Nevertheless, an

1 Site Investigation Steering Group SISG (1993), "Site Investigation in Construction 2: Planning, Procurement and Quality Management", Thomas Telford, London.

investigation can reduce the residual risk associated with unforeseen conditions to a tolerable level. If ground problems do arise, it is important to have geotechnical expertise available to help reduce and mitigate safety and financial risks.

4. ROLE OF JUDGEMENT AND OPINION IN GEOTECHNICAL ENGINEERING

Geotechnical engineering is less exact than most other design disciplines, and requires extensive judgement and opinion. Therefore, a geotechnical report may contain definitive statements that identify where the responsibility of Fugro begins and ends. These are not exculpatory clauses designed to transfer liabilities to another party, but they are statements that can help all parties involved to recognise their individual responsibilities and take appropriate actions.

COMPLETE GEOTECHNICAL REPORT SHOULD BE AVAILABILE TO ALL PARTIES INVOLVED

To prevent costly construction problems, construction contractors should have access to the best available information. They should have access to the complete original report to prevent or minimize any misinterpretation of site conditions and engineering advice (Halligan et al.[1]). To prevent errors or omissions that could lead to misinterpretation, geotechnical logs and illustrations should not be redrawn, and users of geotechnical engineering information and advice should confer with the authors when applying the report information and/or recommendations.

GEOTECHNICAL INFORMATION IS PROJECT-SPECIFIC

Fugro's investigative programmes and engineering assessments are designed and conducted specifically for the Client described project and conditions. Thus this report presents data and/or recommendations for a unique construction project. Project-specific factors for a structure include but are not limited to:

- location
- size and configuration of structure
- type and purpose or use of structure
- other facilities or structures in the area.

Any factor that changes subsequent to the preparation of this report may affect its applicability. A specialised review of the impact of changes would be necessary. Fugro is not responsible for conditions which develop after any factor in site investigation programming or report development changes.

For purposes or parties other than the original project or Client, the report may not be adequate and should not be used.

CHANGES IN SUBSURFACE CONDITIONS AFFECT THE ACCURACY / SUITABILITY OF THE DATA

Ground is complex and can be changed by natural phenomena such as earthquakes, floods, seabed scour and groundwater fluctuations. Construction operations at or near the site can also change ground conditions. This report considers conditions at the time of investigation. Construction decisions must consider any changes in site conditions, regulatory provisions, technology or economic conditions subsequent to the investigation. In general, two years after the report date, the information may be considered inaccurate or unreliable. A specialist should be consulted regarding the adequacy of this geotechnical report for use after any passage of time.

1 Halligan D.W., Hester W.T., Thomas H.R., (1987), "Managing Unforeseen Site Conditions", ASCE Journal of Construction Engineering and Management, Vol. 113, No. 2, pp. 273-287.

APÊNDICE 1: DESCRIÇÕES DE MÉTODOS E PRÁTICAS

ÍNDICE Referência

Este apêndice apresenta declarações de método e terminologia que geralmente são familiares a usuários experientes das informações.

Os documentos apresentados neste apêndice estão em inglês.

INTRODUCTION

This document describes borehole activities for a geotechnical project. The activities comprise borehole drilling and, optionally (1) in-situ testing in borehole and/or (2) sampling and sample handling.

The common drilling techniques for onshore and nearshore projects are:
- Open-hole drilling: a drilling method whereby all material within the diameter of the borehole is cut, such as open-hole rotary drilling, cable percussion drilling and auger drilling.
- Open-hole rotary drilling: an open-hole drilling method whereby ground at the bottom of the borehole is cut by a drill bit rotated on the bottom of a borehole, and drill fluid is pumped down to the drill bit through the hollow drill pipe.
- Cable percussion drilling: an open-hole drilling method whereby ground at the bottom of the borehole is broken up by percussive action of a bailer, clay cutter or chisel, and brought to the surface by the bailer or clay cutter.
- Auger drilling: an open-hole drilling method whereby ground at the bottom of the borehole is cut and brought to the surface by auger flights.
- Core drilling: a rotary drilling method that cuts out cylindrical ground samples.

The common drilling techniques for an offshore project are open-hole rotary drilling and core drilling. Offshore core drilling is by either piggyback or by downhole system. Piggyback core drilling uses drilling techniques whereby the drill pipe for open-hole rotary drilling acts as drill casing and as support for the drill rig. Downhole core drilling uses a core barrel that latches in a bottomhole assembly for open-hole rotary drilling.

A wide range of in-situ tests is available for boreholes. Examples are the Standard Penetration Test (SPT), the pressuremeter test for onshore and nearshore boreholes and the Cone Penetration Test (CPT) for offshore boreholes. This document describes such tests as an integral part of borehole activities, but gives no test details. Separate descriptions apply, if appropriate.

The common sampling techniques are drive sampling and/or push sampling of an open-tube sampler, and push sampling in case of a PISTON SAMPLER. Sampling of cuttings from drilling may be feasible for some types of drilling techniques.

Borehole activities are based on ISO, CEN, BSI and ASTM standards.

DRILLING APPARATUS

GENERAL

Descriptions of common borehole drilling apparatus are as follows:
- Drilling Equipment: any equipment that provides a suitably clean open hole before insertion of downhole sampling and/or testing apparatus and ensures that sampling and/or testing is performed in undisturbed ground.
- Drill Rig: machine capable of providing:
  . rotation, feed and retraction to drill pipe, casing and/or auger,
  . drill fluid pumping capacity, as required,
  . sampler or test apparatus insertion.
- Drill Casing: cylindrical pipe with one or more of the following purposes:
  . to support the sides of a borehole,
  . to support drill pipe above ground surface in case of over-water drilling,
  . to promote return of drilling fluid.
- Drill Pipe: cylindrical pipe connecting drill rig and drill bit.
- Drill Collar: thick-walled drill pipe providing self-weight thrust for the drill bit.
- Drill Bit: device attached to drill pipe and used as a cutting tool to drill into the ground.
- Bottom Hole Assembly: lower section of offshore drill pipe and drill bit, shaped to permit latching of downhole in-situ testing and sampling apparatus.

An optional facility for rotary drilling is analogue or digital recording of MWD (Measure-While-Drilling) parameters, such as penetration rate, torque and drill fluid pressure.

CORING

Core drilling is a ground investigation technique comprising simultaneous drilling and sampling. Descriptions of apparatus are as follows:

- Single Tube Core Barrel: hollow steel tube with a head at the upper end threaded for drill pipe, and a threaded connection for the core bit at the lower end.
- Double Tube Core Barrel: assembly of two concentric steel tubes joined at the upper end by means of a swivel arranged to permit rotation of the outer tube without causing rotation of the inner tube; the upper end of the outer tube is threaded for drill pipe and the lower end is threaded for the core bit.
- Double Tube Core Barrel with Retrievable Inner Tube: double tube core barrel that permits retrieval of the core-laden inner tube assembly to the surface through matching drill pipe without the need for withdrawal of the drill pipe.
- Core Bit: device attached to the core barrel and used as a cutting tool to drill into the ground.
- Core Catcher: device that assists retention of core in the core barrel.
- Core Box: box with longitudinal separators for the protection and storage of core.

OFFSHORE OPERATIONS

Offshore drilling can require additional apparatus, in particular when drilling from a vessel:

- Seabed Reaction Frame: seafloor-based apparatus capable of providing one or more of the following:
  - improved horizontal and vertical control of the drill pipe
  - re-entry of a borehole by drill pipe after earlier retraction
  - vertical reaction for the drill pipe during downhole testing and sampling
  - vertical reaction for hard-tie rigging.
- Heave Compensator: apparatus to compensate the drill pipe for vertical motion of a drill rig mounted on a vessel.
- Hard-tie Rigging: special rigging system incorporating a seabed reaction frame and a heave compensator, for heave-compensated drilling with low drill bit load and/or increased depth control of the drill bit.

SAMPLING APPARATUS

DRIVE SAMPLING

- Drive-Weight Assembly: Device consisting of hammer, hammer fall guide, anvil and hammer drop system.
- Hammer: impact mass, which is successively lifted and dropped to provide the energy that accomplishes sampler penetration.
- Hammer Fall Guide: guide arrangement for the fall of the hammer.
- Anvil: drive-head which the hammer strikes and through which the hammer energy passes into the sampling rods.
- Hammer Drop System: pick-up and release mechanism by which lifting and dropping of the hammer is accomplished.
- Cathead: rotating drum in a rope-cathead hammer drop system around which a rope is wrapped to lift and drop the hammer by successively tightening and loosening the rope turns around the drum.
- Self-Tripping Release: hammer drop system that ensures a free fall of the hammer after lifting by a cable or rope.
- Free-Fall Winch: hammer drop system that permits a free release of the rotating drum of the winch around which a cable is wrapped to lift and drop the hammer.
- Hydraulic Percussion: hammer drop system that provides rapid impact hammer blows by fluid flow.
- Sampling Rods: rods that connect the drive-weight assembly to the sampler head.

PUSH SAMPLING APPARATUS

- Sampler Insertion Equipment: apparatus providing relatively rapid continuous penetration force.
- Reaction Equipment: reaction for the sampler insertion equipment.
- Sampling Rods: rods that connect the sampler insertion equipment to the sampler head.

SAMPLER

- Open-Tube Sampler: sampler with tube that is open at one end and fitted to the sampler head at the other end.
- PISTON SAMPLER: sampler with close-fitting sliding piston that is held stationary during penetration of a flush sample tube into ground.
- Sampler Head: coupling between sampling rods and sample tube, and containing a non-return valve to allow free exit of water and air above sample.
- Sample Tube: cylindrical tube with cutting edge or cylindrical tube fitted with separate cutting shoe.
- Thin-Walled Sample Tube: sample tube with area ratio of less than 15% and inside clearance ratio of less than 1%.
- Thick-Walled Sample Tube: sample tube not meeting the requirements of a thin-walled sample tube.
- Core Catcher: device that assists retention of the sample in the sample tube.

Table 1 shows dimensions of common tube samplers.

TABLE 1 - DIMENSIONS OF SAMPLERS

Sampler type	Inside diameter D_1 [mm]	Outside diameter D_2 [mm]	Inside diameter D_3 [mm]	Wall thickness [mm]	Area ratio A_r [%]	Inside clearance ratio C_r [%]	Tube length [mm]	Sample length [mm]
Piston	72	76	72	2.0	11	0	1028	845
Thin-walled 3 inch tube	72	76	72	2.0	11	0	1028	950
Thin-walled 5^o - 10^o tube	72	76	72	2.0	11	0	1028	950
Thick-walled 3 inch tube	72	80	72	4	24	0	1028	950
Thin-walled 2 inch tube	54	57	54	1.5	11	0	1028 and 645	950 and 570
Thick-walled 2 inch tube	53	60.3	53.1	3.6	29	0	645	570
Rapid PISTON SAMPLER	56	77	58	10.5	89	3.9	3222	3050
Hammer Sampler 2 inch splitspoon	40	51	41	5	63	2.5	600	600
Hammer Sampler 3 inch splitspoon	61	76.1	63.5	6.3	56	4.1	600	600
Fugro CORER® 67 mm tube	66	76.1	67	3	42	3	2031	1884
Fugro CORER® 54 mm tube	53.7	63	54	3.6	38	0.7	1000	950

Notes

1. D_1 = inside diameter of the cutting shoe.
2. D_2 = greatest outside diameter of the sample tube and/or cutting shoe.
3. D_3 = inside diameter of the flush portion of the sample tube or liner.
4. “Length” dimension considers manufactured length. Re-use of a sampler may lead to shortening, for example to reshape cutting edge.
5. Thin walled 5^o - 10^o tube is equivalent to conventional thin-walled 3 inch tube except for specially machined cutting edge with 5^o and 10^o taper to reduce sampling disturbance.
6. Penetration of Rapid PISTON SAMPLER is by pressurising drill string (with minimum length of 55 m) and controlled fracturing of shear pins in the sampler, giving estimated impact velocity in the order of 10 m/s.
7. Machined cutting edge of Rapid PISTON SAMPLER has taper of 10^o.
8. Penetration of Fugro CORER® is by self-weight supplemented by mud-driven hammering.
9. Machined cutting edge of Fugro CORER® (54 mm) has taper of 7^o.
10. Fugro CORER® (54 mm) also allows use of conventional 2 inch sample tubes.

The definitions of area ratio and inside clearance ratio are as follows:

Area Ratio: Indication of volume of ground displaced by the sample tube, calculated as follows:

$$A_r = [(D_2^2 - D_1^2)/D_1^2] \times 100$$

where:
A_r = area ratio expressed as percentage
D_2 = greatest outside diameter of the sample tube and/or cutting shoe
D_1 = inside diameter of the cutting shoe.

Inside Clearance Ratio: Indication of clearance of sample inside the sample tube, calculated as follows:

$$C_r = [(D_3 - D_1)/D_1] \times 100$$

where:
C_r = inside clearance ratio expressed as percentage
D_3 = inside diameter of the flush portion of the sample tube or liner
D_1 = inside diameter of the cutting shoe.
The worst case of manufacturing tolerances applies for calculation of C_r.

PROCEDURE

Figure 1 summarises the procedure for boreholes. The procedure includes several stages, as follows:

BOREHOLE SET-UP STAGE

- assignment of borehole details such as location, target borehole depth, types of apparatus, sequence of sampling
- positioning of drill rig at assigned location
- selection of drilling, sampling or in-situ testing stage.

The subsequent stage is one of the following:

OPEN-HOLE DRILLING STAGE

- open-hole drilling
- borehole logging, such as drill bits and drill fluids used, borehole size and depth, drilling observations
- borehole water level, where practicable
- selection of subsequent drilling, sampling or in-situ testing stage.

IN-SITU TESTING STAGE

- in-situ test
- logging, such as test depth and test parameters
- selection of subsequent drilling stage.

SAMPLING STAGE

- sampling
- logging, such as sample depth and visual description of samples where available for inspection at the time of sampling
- sample handling
- selection of subsequent drilling stage.

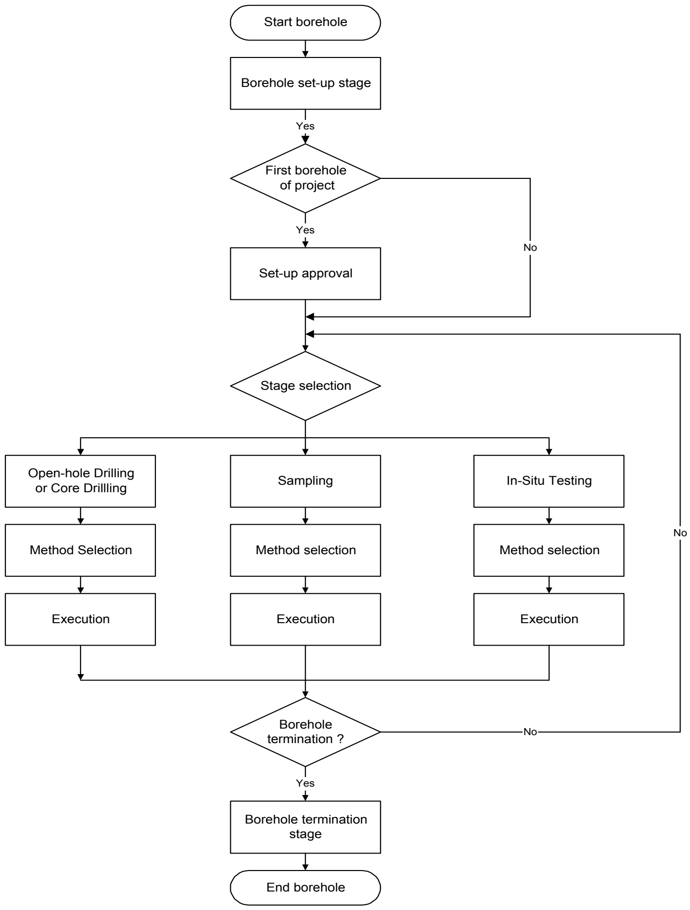


Figure 1 - Flow chart

CORE DRILLING STAGE

- core drilling
- operational logging, such as drill bits and drill fluids used, borehole size and depth, drilling observations
- borehole water level, where practicable
- core logging, such as recovery and visual description
- core handling
- selection of subsequent drilling, sampling or in-situ testing stage.

BOREHOLE TERMINATION STAGE

- termination of borehole
- backfilling of borehole, if appropriate
- data processing.

Set-up requires a reasonably flat, accessible, ground surface with a slope of 5^{o} or less. In other cases, set-up is at discretion of equipment operator, considering risks such as damage to apparatus or safety of personnel. Most onshore drilling systems have levelling facilities allowing a vertical start of drilling. Seabed reaction frames used for offshore drilling activities have no levelling facilities. Drill pipe passage through a seabed reaction frame must be (near-)vertical.

The sampling stage or the core drilling stage may result in no-recovery or partial recovery of a sample due to unfavourable conditions for the deployment of a particular sampler. A subsequent sampling event at the same depth or immediately below the initial sampling depth is a separate sampling activity, unless specifically agreed otherwise or unless no specific evidence shows departure from the agreed procedure for the earlier activity.

Criteria for borehole termination are as follows, unless specifically agreed otherwise:

- as instructed by Client
- reaching target penetration
- drilling progress rate of less than 1m/hour based on half-hourly observation
- circumstances at discretion of system operator, such as risk of damage to apparatus or safety of personnel

whichever occurs first and as applicable.

RESULTS

GEOTECHNICAL LOG

The geotechnical log or borehole log contains the geotechnical descriptions of the encountered strata, and the borehole water level measurements, if applicable. In addition, it may include the principal details of the borehole operational activities.

The penetration depth of a (vertical) borehole is defined as the deepest point reached by drilling, sampling or in-situ testing. The recovery depth of a borehole is the deepest point for which sample or test data are presented.

Unless indicated otherwise, recovery of a tube sample or a core sample is assumed to be continuous from the starting depth of sampling. In other words, the geotechnical log ignores possible plugging, flow-in and/or wash-out.

MWD PARAMETERS

Optional presentation of MWD parameters for rotary drilling is usually in graphical format. Interpretation of MWD parameters can help characterisation of ground conditions such as cemented strata, weak rock and formations with cavities.

GEOTECHNICAL DESCRIPTION

The geotechnical description, including the strata boundaries, is an interpretation of the processed data available at the time of the preparation of the geotechnical log. Subsequent processing and integration of supplementary ground investigation data may require adjustment of the log. Supplementary information can include:

- geological information
- geophysical data
- results of nearby boreholes and in-situ tests
- laboratory test results
- analysis of drilling parameters such as torque, feed, drill fluid pressure and drilling time.

Level of detail and accuracy in geotechnical description depend on factors such as sample size, quality, coverage of samples and test data, availability of supplementary information, and project requirements. For example, geotechnical descriptions prepared for the purpose of a pile foundation may differ from those prepared for a pipeline.

Any graphical presentation of test results considers values within the scale limits only. No automatic scaling applies, unless indicated otherwise.

WATER LEVEL

Water level measurements taken in boreholes can be valuable. Interpretation of water levels requires due caution. They may or may not be representative of the ground water levels. In any case, water levels apply to the time and date of the measurements only. They will vary due to seasonal and other environmental influences, including construction activities.

SAMPLE QUALITY

Additional documentation of borehole operational activities can include further details on drilling, sampling and in-situ testing. In particular, details of sampling techniques and samplers can be important for the evaluation of the results of laboratory tests.

An example is the open-tube sampler fitted with a thin-walled sample tube of 50 mm to 100 mm diameter. The sample quality (BSI, 1999) is typically undisturbed, Class 2, for very soft fine-grained soil and Class 1 for firm to very stiff fine-grained soil. The sample quality for coarse-grained soils is typically disturbed, Class 3. For a thick-walled sample tube, the sample quality for fine-grained soil is typically one class worse than for a thin-walled tube. A PISTON SAMPLER with a thin-walled sample tube allows Class 1 sample quality for very soft fine-grained soil.

The classification system for sample quality recognises 5 classes on the basis of feasibility of specific geotechnical identification and laboratory tests. A summary of these classes is as follows:
Class 1: undisturbed: strength, stiffness and consolidation
Class 2: undisturbed: layering, permeability, unit weight
Class 3: disturbed: water content
Class 4: disturbed: particle size analysis, Atterberg limits, soil type
Class 5: disturbed: stratigraphy
The higher class includes the laboratory tests of the lower classes.

Comments on Class 1 and Class 2 fine-grained soil samples are as follows:

- Some sample disturbance is inevitable because of the required sampling process and subsequent on-site and laboratory sample handling.
- Silt soil is more sensitive to disturbance than clay soil.
- Sample disturbance typically increases with increasing total stress conditions applicable to the in-situ soil. Negative pore pressures develop after sampling, upon reduction of total stresses. The resulting effective stresses within the sample cause sample disturbance. Sample disturbance may thus increase with sampling depth or with increasing water depth for offshore boreholes.
- Reduction in water pressure occurring after sampling causes a change in equilibrium between dissolved gasses, gas bubbles and gas hydrates, where present. The amount of gas release increases with water pressure. This may result in increased sample disturbance, in particular for deep-water sites.

ASTM International (2002) provides descriptions for rock core quality as follows:
TCR Total Core Recovery: the total core length divided by the core run length
SCR Solid Core Recovery: the total length of the pieces of solid core that have a complete circumference divided by the core run length
RQD Rock Quality Designation: the total length of the pieces of sound core over 100 mm long along the centreline divided by the core run lengths per stratum or core run; sound core includes core with obvious drilling breaks
I_F Fracture Index: spacing of natural discontinuities.

Table 2 shows a classification of rock quality according to ASTM International (2002).

TABLE 2 CLASSIFICATION OF ROCK QUALITY

RQD	Classification of Rock Quality
0 to 25%	Very poor
25 to 50%	Poor
50 to 75%	Fair
75 to 90%	Good
90 to 100%	Excellent

Sample quality may change with time and storage conditions. The type of soil or rock will influence the degree of change. For example, exposure to air may initiate chemical processes, such as rapid oxidisation of organic soil.

SYMBOLS

The geotechnical log contains a graphic log of the ground conditions. Figures 2 through 4 present details for soils, cementation degrees and rocks. In addition, the geotechnical log may show specific symbols for sampling and in-situ testing. Figure 5 presents details.

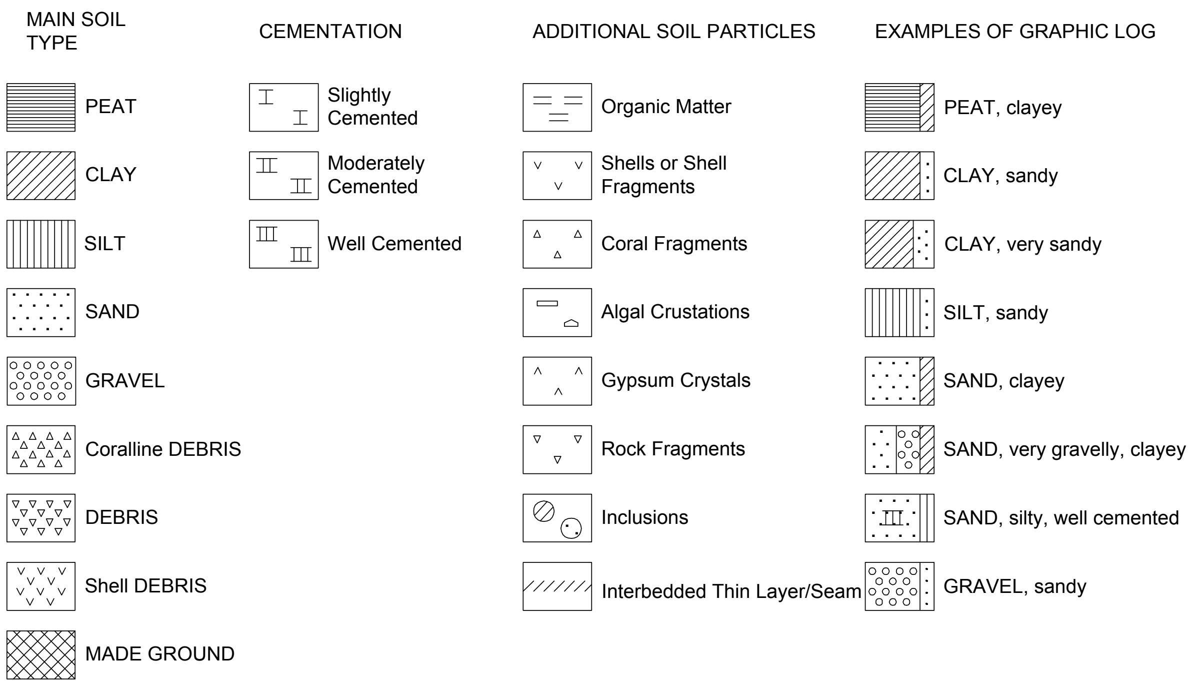


Figure 2 - Symbols for soils

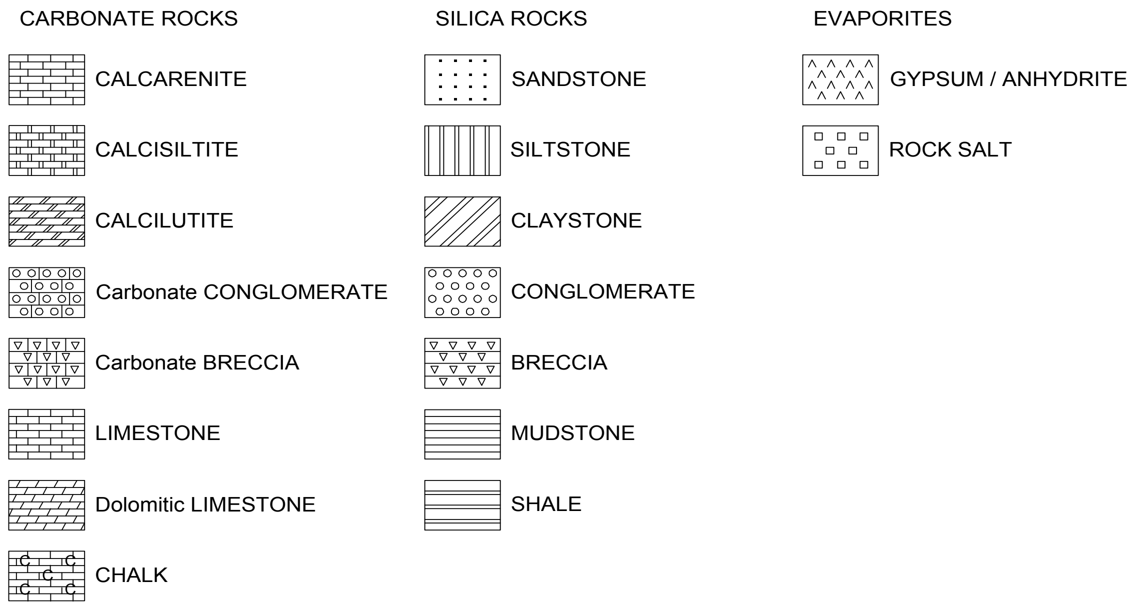


Figure 3 - Symbols for sedimentary rocks

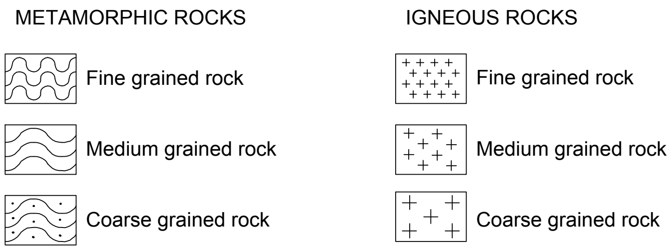


Figure 4 - Symbols for metamorphic and igneous rocks

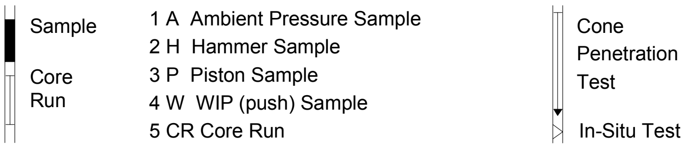


Figure 5 - Symbols for identification of samples and in-situ tests

REFERENCES

ASTM International (1995), “Standard Practices for Preserving and Transporting Soil Samples", ASTM D 4220-95 (Re-approved 2000).

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INTRODUCTION

Fugro employs a range of industry-standard classification systems with additional refinements. The more important systems are:

- British Standard 5930 (BS, specifically Section 6 Paragraphs 41 to 43 on Description of soils) published in 1999.
- American Society for Testing and Materials (ASTM) Standards D 2487-11 (Classification of soils for Engineering Purposes) and D 2488-09a (Description and Identification of Soils – Visual-Manual Procedure).
- International Standard ISO 14688-1:2002 (Geotechnical Investigation and Testing - Identification and Classification of Soil: Identification and Description) and International Standard ISO 14688-2:2004 (Principles for a Classification).

The standards are similar, as they are (1) based on the Unified Classification System (Casagrande, 1948), (2) rely on a range of relatively simple visual and manual observations and (3) classify soils according to particle-size distribution and plasticity. Laboratory particle-size distribution and Atterberg limits tests are used to confirm the observations. In addition, the standards include organic soils characterization under soil particle type description.

Significant differences between the standards include the particle-size boundaries and the degree to which plasticity is used as a basis for description. Other differences include the format and order of the soil description.

This document describes a classification convention that is consistent with either the BS or ASTM standard, and that produces soil descriptions, which can be converted to the other standard. In addition, to describe calcareous soils, Fugro has integrated the carbonate classification system outlined by Clark and Walker (1977) with both British Standard and ASTM systems (Landva et al., 2007). No further information is given about the ISO standards.

British Standard and ASTM systems apply primarily to common terrestrial soils in temperate climates. However, construction activities in coastal areas and offshore can also encounter major carbonate soil deposits. The engineering characteristics of carbonate soil deposits can differ substantially from those of silica-based soil deposits, primarily because of cementation and differences in void ratios (Kolk, 2000).

Appropriate description is necessary. A commonly accepted procedure for calcareous soil deposits is the Clark and walker system, originally developed for the Middle East. This considers particle size, carbonate content and material strength. The particle size classification fits both BS and ASTM system. The carbonate content is an additional feature and the material strength classification relates to common post-depositional alteration of calcareous soil.

This document does not include rock description or specific engineering geological classification systems, such as those for the detailed identification of peat, chalk or micaceous sand.

The main steps of the soil description system are:

1. Measure or estimate particle type as silica-based, organic, or calcareous.
2. For soils that are predominantly silica-based and organic, select BS 5930:1999 or ASTM D 2487 based on local geotechnical practice or project requirements, and follow the appropriate descriptive procedure. For calcareous soils, use the process described by Peuchen et al. (1999).
3. Measure or estimate the particle-size distribution and Atterberg limits (plasticity) for use in defining the principal and secondary soil fractions.
4. Measure or estimate soil strength according to one of the following: (1) relative density of coarse-grained soil, (2) consistency of fine-grained soil, (3) cementation of cemented soil, or (4) lithification of soil undergoing diagenesis.
5. Complete the description using the additional terms for the soil mass characteristics and other features such as bedding, colour, and particle shape.

CALCAREOUS SOIL DESCRIPTION

The procedure considers particle size, carbonate content and material strength. The particle-size classification follows the Unified Soil Classification System. The carbonate content is an additional feature and the material strength classification relates to common post-depositional alteration of calcareous soil.

PARTICLE TYPE

The first determinant for soil description is particle type using Table 1. It mainly differentiates between silica, carbonate and organic soil compositions. The determination of particle type is used for both the BS and the ASTM standard.

TABLE 1 - PARTICLE TYPE

Clay soil	Other Soils	Carbonate Content [%]	Organic Content
--	Silica	< 10	< 1% by weight
Calcareous	Calcareous silica	10 to 50	
Carbonate	Siliceous carbonate	50 to 90	
Carbonate	Carbonate	> 90	
Organic	Organic	--	1% to 30% by weight (BS 5930) $w_{L(oven)}/w_{L(nat)}$ < 0.75 (ASTM D 2488)

Key:
$w_{L(oven)}$: liquid limit of a soil sample after oven drying at 105 °C
$w_{L(nat)}$: liquid limit of a soil sample without oven drying

The description method does not distinguish between types of carbonate material, and assumes that non-carbonate particles are siliceous. Organic soils are further described in the soil description procedures for BS and ASTM (Table 4).

CEMENTATION AND LITHIFICATION

Cementation is the process by which a binding material precipitates in the voids between the grains or minerals. Lithification is the process by which a soil is hardened due to pressure solution and transformation or new grain or mineral growth. Both processes contribute to the formation of rock.

The descriptions for cementation follow the equivalent rock strength classification in Table 2:

TABLE 2 - CEMENTATION

Cementation	Equivalent Rock Strength	
	Description	Uniaxial Compressive Strength σ_c [MPa]
Slightly cemented	very weak	0.3 to 1.25
Moderately cemented	Weak	1.25 to 5.0
Well cemented	Moderately weak	5.0 to 12.5

The term "well cemented" in Table 2 applies to soil, which also shows sublayers with little or no cementation. In case of further lithification, the soil description becomes a rock description using Table 3. The rock strength is only indicative.

TABLE 3 - LITHIFICATION

Carbonate content [%]	Dominant fraction: Clay	Silt	Sand	Gravel	Cobbles	Boulders	σ_c [MPa]
incomplete lithification							
< 10	CLAYSTONE	SILTSTONE	SANDSTONE	CONGLOMERATE	CONGLOMERATE or BRECCIA		0.3 to 12.5
10 to 50	Calcareous CLAYSTONE	Calcareous SILTSTONE	Calcareous SANDSTONE	Calcareous CONGLOMERATE			
50 to 90	Clayey CALCILUTITE	Siliceous CALCISILTITE	Siliceous CALCARENITE	Conglomeratic CALCIRUDITE			
> 90	CALCILUTITE	CALCISILTITE	CALCARENITE	CALCIRUDITE			
complete lithification							
< 50	CLAYSTONE	SILTSTONE	SANDSTONE	GRAVEL CONGLOMERATE	CONGLOMERATE or BRECCIA		>12.5
> 50	Fine-grained Argillaceous LIMESTONE	Fine-grained Siliceous LIMESTONE	Medium grained LIMESTONE	Conglomeratic LIMESTONE			

The Clark and Walker system does not include reef limestone (biolithite). **Reef limestone** represents an in-situ accumulation of biological origin (e.g. coral reef) and consists largely of carbonate skeletal material of colonising organisms. The carbonate content normally exceeds 90%. Classification of strength follows rock description procedures.

SOIL DESCRIPTION USING BS 5930:1999

In the following sections, each of the main characteristics is described in the order most commonly used for soil identification, with some portions of the text quoted (shown within quotation marks) or paraphrased from the BS 5930.

SOIL GROUP (BS)

The soil group subdivides the soils into very coarse, coarse, fine, and organic soils.

Very coarse soils consist of cobbles and boulders, with particles larger than 60 mm in diameter. These soil particles are rarely sampled using standard soil sampling techniques. They are described separately, and not included when determining the proportions of the other soil components.

The initial classification of silica soils as coarse or fine is based on the percentage of fine particles after the very coarse particles are removed. In BS 5930, the boundary between coarse (i.e. sands and gravels) and fines (i.e. silts and clays) is 0.060 mm (60 µm). When the soil contains approximately 35% or more fines, it is described as a fine soil; further classification of the fine soil as a clay or silt depends on the plasticity of the soil. When the soil contains less than about 35% fine material, it is usually described as a coarse soil. “The boundary between fine and coarse soils is approximate, as it depends on the plasticity of the fine fraction and the grading of the coarse fraction.”

Organic soils contain usually small quantities of dispersed organic matter that can have a significant effect on soil plasticity. Organic soil descriptions in BS 5930 are based on an organic content by weight determined by loss on ignition. Where organic matter is present as a secondary constituent, the following terms are used:

TABLE 4 - ORGANIC SOIL DESCRIPTIONS

Term	Organic content [% by weight]	Typical colour
Slightly organic clay or silt	2 to 5	Grey
Slightly organic sand	1 to 3	Same as mineral
Organic clay or silt	5 to 10	Dark grey
Organic sand	3 to 5	Dark grey
Very organic clay or silt	> 10	Black
Very organic sand	> 5	Black

Soils with organic contents up to approximately 30% by weight and water contents up to about 250% behave as mineral soils and are described using the terms given in the lower portion of Table 4.

Peat consists predominantly of plant remains, is usually dark brown or black, and has a distinctive smell. It is generally classified according to the degree of decomposition (fibrous, pseudo-fibrous, or amorphous) and strength (firm, spongy, or plastic). When encountered, reference can also be made to the classification given in ASTM Standard Procedure D 4427.

PRINCIPAL SOIL TYPE AND PARTICLE SIZE (BS)

Coarse-Grained Soils

The principal soil type in coarse-grained soils is sand if the dry weight of the sand fraction (0.06 mm to 2 mm particle sizes) exceeds that of the gravel fraction (2 mm to 60 mm particle sizes), and vice versa for gravel.

As an addition to the BS 5930 classification, coarse-grained soils are described as well-graded or poorly-graded based on the grain-size distribution curve, using the coefficient of uniformity (C_U) and, to a lesser extent, the coefficient of curvature (C_C), as follows:

- Sands with ≤12% fines are <u>well-graded</u> when $C_U \geq 6$ and C_C is between 1 and 3.
- Sands are <u>poorly-graded</u> for other values of C_U and C_C.
- Gravels with ≤12% fines are <u>well-graded</u> when $C_U \geq 4$ and C_C is between 1 and 3.
- Gravels are <u>poorly-graded</u> for other values of C_U and C_C.

For coarse-grained soils with fines contents > 12%, these terms are not used.

Sands and gravels are sub-divided into coarse, medium, and fine, as defined in Table 5.

TABLE 5 - SIZE FRACTION DESCRIPTIONS FOR COARSE-GRAINED SOILS

Soil	Particle diameter range [mm]		
	Coarse	Medium	Fine
Gravel	60 to 20	20 to 6	6 to 2
Sand	2 to 0.6	0.6 to 0.2	0.2 to 0.06

Fine-Grained Soils

Fine-grained soils are classified as clay or silt according to the results of Atterberg limits tests. A fine-grained soil is classified as clay if:

$$I_P \geq 6 \text{ and } I_P \geq 0.73(w_L-20)$$

where:
I_P = plasticity index [%]
w_L = liquid limit [%]

Otherwise the dominant soil fraction is silt. The equation $I_P = 0.73(w_L-20)$ represents the "A-line" in a plasticity chart. The plasticity chart may also show a “U-line” defined as $I_P = 0.9\,(w_L-8)$ and $w_L \geq 16$, according to Casagrande (1948). The U-line represents an approximate upper limit of correlation between plasticity index and liquid limit for natural soils.

The following additional descriptors (as used in the ASTM soil description procedure) are added:

- Clays with liquid limits of 50% or higher are described as “fat.”
- Clays with liquid limits below 50% are described as “lean.”
- Silts with liquid limits of 50% or higher are termed “elastic silt.”
- Silts with liquid limits below 50% are simply “silts.”

The term “silty clay” is not used, since BS 5930 explicitly states that silt and clay “are to be mutually exclusive.”

Particle Shape

The description of particle shape includes terms for form, angularity, and surface texture. These terms are the same for BS 5930 as for ASTM D 2488. Reference should be made to the corresponding ASTM section of this document.

COMPOSITE (SECONDARY) SOIL TYPES (BS)

BS 5930 defines procedures for assigning secondary soil fractions to coarse-grained soils that are identical for sand and gravel, except that the secondary soil type is sandy when the principal soil type is gravel and vice versa. For fine-grained soils (silt and clay) there is a single procedure for assigning secondary soil fractions. The ranges for the percentages of the secondary constituents are similar to, though different from, those defined by ASTM.

If the principal soil type is sand, secondary soil fractions may be gravelly and silty or clayey (e.g. silty sand). Similarly, if the principal soil type is clay, secondary soil fractions may be sandy or gravelly. Table 6 (from BS 5930) gives the terms to be used for ranges of secondary constituents.

TABLE 6 - DESCRIPTIVE TERMS AND RANGES FOR SECONDARY CONSTITUENTS

Term	Principal soil type	Approximate proportion of secondary constituent	
		Coarse soil	Fine soil
Slightly clayey or silty	SAND and/or GRAVEL		< 5%
Clayey or silty			5% to 20%
Very clayey or silty			> 20% (1)
Slightly sandy or gravelly		< 5%	
Sandy or gravelly		5% to 20%	
Very sandy or gravelly		> 20%	
Slightly sandy and/or gravelly	SILT or CLAY	< 35%	
Sandy and/or gravelly		35% to 65%	
Very sandy and/or gravelly		> 65% (2)	

Notes: (1) or can be described as fine soil depending on engineering behaviour
(2) or can be described as coarse soil depending on engineering behaviour.

COLOUR (BS)

Soil colours are described using the Munsell Soil Colour Charts (Gretag-Macbeth, 2000).

The Munsell colour is arranged according to three variables known as Hue, Value and Chroma. The Hue notation of a colour indicates its relation to red, yellow, green, blue and purple. The Value notation indicates the relative lightness. The Chroma notation indicates the intensity of the colour.

BEDDING/STRATIGRAPHY (BS)

Layers of different soil types within a stratum are called bedding units, and are described in terms of the unit thickness. In an otherwise homogeneous soil, these can be identified as bedding planes or as colour changes, and not necessarily as discontinuities.

Table 7 (from BS 5930) gives terms for bedding/stratigraphy.

TABLE 7 - DESCRIPTIVE TERMS FOR BEDDING/STRATIGRAPHY

Stratified	Bedding	Interbedded	Thickness [mm]
Very thick beds	Very thick bedded	very thickly interbedded	>2000
Thick beds	Thickly bedded	Thickly interbedded	600 to 2000
Medium beds	Medium bedded	Medium interbedded	200 to 600
Thin beds	Thinly bedded	Thinly interbedded	60 to 200
Very thin beds	Very thinly bedded	Very thinly interbedded	20 to 60
Thick laminae	Thickly laminated	Thickly interlaminated	6 to 20
Thin laminae	Thinly laminated	Thinly interlaminated	<6

Strata with alternating or different beds or laminations can be described as interbedded or interlaminated. Where the soil types are approximately equal, both terms can be used (e.g. thinly interlaminated SAND and CLAY).

Partings are bedding surfaces that separate easily, and typically are laminae of no appreciable thickness. The spacing between partings is described in the same terms as for spacing of discontinuities (Table 8).

DISCONTINUITIES/STRUCTURE (BS)

Discontinuities include fissures and shear planes, and the descriptor refers to the mean spacing between such discontinuities in a soil mass. A soil is “fissured” when it breaks into blocks along unpolished discontinuities, and “sheared” when it breaks into blocks along polished discontinuities (which is equivalent to a slickensided soil). The spacing description ranges from extremely closely spaced (less than 20 mm) to very widely spaced (over 2000 mm). No other descriptive terms are used. An example would be: Firm grey very closely fissured fine sandy calcareous CLAY with many silt partings.

The spacing terms are also used for distances between partings, isolated beds or laminae, desiccation cracks, rootlets, etc.

TABLE 8 - SPACING OF DISCONTINUITIES

Term	**Mean spacing range [mm]**
Very widely	Over 2000
Widely	600 to 2000
Medium	200 to 600
Closely	60 to 200
Very closely	20 to 60
Extremely closely	Under 20

DENSITY/COMPACTNESS OF GRANULAR SOILS (BS)

Usually, soil description offers little evidence about the density condition of coarse-grained cohesionless (granular) soil samples. The reason for this is the substantial sampling disturbance incurred during conventional sampling operations such as push sampling, percussion sampling, and vibrocoring. Complementary investigation techniques, such as Cone Penetration Tests (CPT), are usually necessary. The strength of a cohesionless soil is normally measured as a function of its relative density (also termed compactness or density index). Relative density is the ratio of the difference between the void ratios of a cohesionless soil in its loosest state and existing natural state to the difference between its void ratio in the loosest and densest states.

Relative density (compactness) is referred to in BS 5930:1999 only in terms of N-values obtained by the Standard Penetration Test (which is not conducted in offshore site investigations). Rather than using SPT-based values, it is common practice to interpret relative density on the basis of CPT results. Ranges of relative density are given in Table 9. These ranges are in common use in the industry. They were originally given in Lambe and Whitman (1979) and in the API RP 2A guidelines generally used for offshore pile design. These terms also apply to cohesionless fine-grained soils.

TABLE 9- RANGE OF RELATIVE DENSITY OF GRANULAR SOILS

Term	**Range of relative density [%]**
Very loose	Less than 15
Loose	15 to 35
Medium dense	35 to 65
Dense	65 to 85
Very dense	Greater than 85

STRENGTH OF COHESIVE SOILS (BS)

The strength of cohesive soils is given in terms of undrained shear strength, using the terms and ranges given in Table 10, with an additional level to cover “very hard” soils.

TABLE 10 - UNDRAINED SHEAR STRENGTH SCALE FOR COHESIVE SOILS (BS 5930:1999)

Term	**Undrained shear strength**	
	[kPa]	**[ksf] (1)**
Very soft	Less than 20	Less than 0.4
Soft	20 to 40	0.4 to 0.8
Firm	40 to 75	0.8 to 1.5
Stiff	75 to 150	1.5 to 3.0
Very stiff	150 to 300	3.0 to 6.0
Hard	300 to 600	6.0 to 12.0
Very hard (2)	Greater than 600	Greater than 12.0

Notes: (1) Unit conversion added to table
(2) Added for global practice.

MINOR CONSTITUENTS (BS)

Percentages of minor constituents within the soil, such as shell or wood fragments, or small soil inclusions (such as partings or pockets), can be quantified using the terms “with trace”, “with few”, “with” and “with many” (in increasing order). These terms are usually added at the end of the main soil description (e.g. with many shell fragments, with silt pockets, etc.); exceptions are terms such as “shelly”, which are more appropriate before the soil group name. For beds of material within a soil matrix, the terminology for spacing and thickness of beds is used. For individual particles of soil or material within a soil matrix, the terms “partings” and “pockets” are used.

SOIL ODOUR (BS)

Describing the odour from soil samples as they are retrieved or extruded on board ship can be useful. Terms used to describe the odour are H_2S, “musty”, “putrid” and “chemical”. It must be emphasised that soil odour descriptions are unlikely to be fully consistent, because of factors such as variations in sample handling, ambient conditions at time of sample description, and strong dependence on a person’s ability to detect and identify odour.

SOIL DESCRIPTION USING ASTM D 2487 AND D 2488

The identification and description of silica soils in the ASTM system consists primarily of a group name and symbol, which are based on the particle-size distribution and the Atterberg limits test results, and the results of other laboratory classification tests.

The main standard for soil description, D 2487 Classification of Soils for Engineering Purposes, is applicable to naturally-occurring soils passing a 3-in. (75-mm) sieve, and identifies three major soil types: coarse-grained, fine-grained, and highly organic soils. The major soil types are further subdivided into 15 specific basic soil groups.

An accompanying Standard, D 2488, outlines the Description and Identification of Soils using a Visual-Manual Procedure. This standard is used primarily in the field, where full particle-size distribution curves and Atterberg limits values are not available. It gives guidance for detailed descriptions of soil particles and soil conditions (e.g. colour, structure, strength, cementation, etc), which are not included in D 2487.

Soil types with particles larger than 75 mm (i.e. cobbles and boulders) are not included in the Standards, but are identified.

SOIL TYPES (ASTM)

The initial classification of silica soils as coarse-grained or fine-grained is based on the percentage fines, expressed as the percentage of dry weight of the total sample after the very coarse particles are removed, as with BS 5930. However, ASTM has defined the coarse-fine boundary as 0.075 mm (75 µm).

The soil is coarse-grained (sand or gravel) if the percentage fines is 50% or less. Otherwise, the soil is fine-grained (silt or clay) – the classification is not based on plasticity.

Coarse-grained soils are classified further as either sand or gravel using the results of particle-size distribution tests.

Fine-grained soils are classified further as silt or clay on the basis of the liquid limit and plasticity index (from Atterberg limits tests).

The soil is an organic soil if it contains sufficient quantities of dispersed organic matter that it has an influence on the liquid limits of the fines component after oven-drying, as outlined in the BS Section. The definition of peat is similar to that in BS 5930 and it is generally classified according to the degree of decomposition and strength. When encountered, reference should be made to the classification given in ASTM D 4427.

SOIL GROUP NAME AND SYMBOL (ASTM)

Coarse-Grained Soils

For coarse-grained soils, the dominant soil fraction is sand if the dry weight of the sand fraction, i.e. particle sizes from 0.075 mm to 4.75 mm, exceeds that of the gravel fraction, i.e. particles ranging from 4.75 mm to 75 mm, and vice versa for gravel.

Coarse-grained soils with ≤12% fines are also described as well-graded or poorly-graded based on the particle-size distribution curve, using the coefficient of uniformity (C_U) and, to a lesser extent, the coefficient of curvature (C_C) as follows:

- Sands are well-graded when $C_U \geq 6$ and C_C is between 1 and 3.
- Sands are poorly-graded for other values of C_U and C_C.
- Gravels are well-graded when $C_U \geq 4$ and C_C is between 1 and 3.
- Gravels are poorly-graded for other values of C_U and C_C.

For coarse-grained soils with fines contents >12%, these terms are not used.

Sands and gravels are also sub-divided into coarse, medium, and fine, as defined in Table 11.

TABLE 11 - SIZE FRACTION DESCRIPTIONS FOR COARSE-GRAINED SOILS

Soil	Particle diameter range [mm]		
	Coarse	Medium	Fine
Gravel	75 to 19	-	19 to 4.75
Sand	4.75 to 2.0	2.0 to 0.425	0.425 to 0.075

The predominant size fractions present are identified, and the absence of size range descriptors means that fine, medium, and coarse fractions are all present in roughly equal proportions.

Fine-Grained Soils

Fine-grained soils are classified as clay or silt according to the results of Atterberg limits tests. A soil is inorganic clay if: $I_P \geq 6$ and $I_P \geq 0.73(w_L-20)$

where:
I_P = plasticity index [%]
w_L = liquid limit [%]

The A-line and U-line in a plasticity chart are as described in the BS section.

Clays with liquid limit $w_L < 50$ and plasticity index $I_P > 7$ are further classified as lean clay, and given the group symbol “CL”. Clays with liquid limits $w_L \geq 50$ are further classified as fat clay, and are given the group symbol “CH”.

A soil is classified as a silt when it plots below the A-line or the plasticity index $I_P < 4$. Silts with liquid limit $w_L < 50$ are given the group symbol “ML”. Silts with liquid limits $w_L \geq 50$ are further classified as elastic silt, and are given the group symbol “MH”.

Soils are classified as silty clay where the liquid limit versus plasticity index plots on or above the A-line but where the plasticity index falls within the range $4 \leq I_P \leq 7$, i.e. the hatched zone in the lower left-hand corner of the plasticity chart. Silty clays are given the Group Symbol “CL-ML”.

Organic Soils

For both clay and silt, or the fines component of a coarse-grained soil, the additional term organic applies if the ratio of the liquid limit of a sample (or the fines portion of the sample) after oven drying at 105° C to the liquid limit without oven drying is less than 0.75.

Organic soils are classified in a manner similar to that for inorganic soils for plots of the liquid limit (not oven dried) versus plasticity index with respect to the A-line. Organic clays and silts with liquid limit $w_L < 50$ are given the same group symbol “OL”. Organic clays and silts with liquid limits $w_L \geq 50$ are given the group symbol “OH”.

Coarse-grained soils containing fine organic material are described using the term “with organic fines”.

SECONDARY SOIL TYPE (ASTM)

Secondary soil type descriptions follow the ranges given in Table 12. No other terms are used, though combinations of these terms are.

TABLE 12 - DESCRIPTIVE TERMS AND RANGES FOR SECONDARY CONSTITUENTS

Term	Principal soil type	Term	Approximate proportion of secondary constituent	
			Coarse soil	Fine soil
	SAND and/or GRAVEL(1)			< 5%
	SAND and/or GRAVEL(1)	with clay or silt		5% to 12%
Clayey or Silty	SAND and/or GRAVEL(1)			> 12%
	SAND and/or GRAVEL(1)		<15% gravel or sand	
	SAND and/or GRAVEL(1)	with gravel or sand	≥15% gravel or sand	
	SILT or CLAY		< 15%	
	SILT or CLAY	with sand or gravel(1)	15% to 29%	
Sandy and/or gravelly(1)	SILT or CLAY		≥30%	

Note: (1) choice depends on which has higher percentage.

PARTICLE SHAPE (ASTM)

The description of particle shape includes references to form, angularity, and surface texture. These terms are normally used only for gravels, cobbles, and boulders, though in some cases for coarse sands.

The form (or shape) of coarse particles is described as flat, elongated, or both.

Flat: Width/Thickness > 3
Elongated: Length/Width > 3
Flat and elongated meets both criteria. These terms are not used if the criteria are not strictly met.

Angularity terms are usually only applied to particles gravel-size and larger (Table 13, from ASTM D 2488).

TABLE 13 - ANGULARITY OF COARSE-GRAINED PARTICLES

Term	Criteria
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular	Particles are similar to angular description but have rounded edges
Subrounded	Particles have nearly plane sides but have well-rounded corners and edges
Rounded	Particles have smoothly curved sides and no edges

The surface texture of coarse particles are described as rough or smooth.

COLOUR (ASTM)

As noted for BS 5930 (BS section), soil colours are described using the Munsell Soil Colour Charts (Gretag-Macbeth, 2000).

SOIL ODOUR (ASTM)

The same descriptive terms suggested for BS 5930 (BS Section) are used with the ASTM Standards. It must be emphasised that soil odour descriptions are unlikely to be fully consistent, because of factors such as variations in sample handling, ambient conditions at time of sample description, and strong dependence on a person's ability to detect and identify odour.

STRENGTH OF COHESIVE SOILS (ASTM)

Descriptions of cohesive soil strength are not part of the ASTM classification system; however soil strength is incorporated whenever available from laboratory or in situ test results and interpretation. The boundaries for undrained shear strength ranges in current use in North American practice are given in Table 14. These boundaries are lower than those used with BS 5930.

TABLE 14 - UNDRAINED SHEAR STRENGTH SCALE FOR COHESIVE SOILS (1)

Term	Undrained shear strength	
	[kPa]	[ksf] (2)
Very soft	Less than 12.5	Less than 0.25
Soft	12.5 to 25	0.25 to 0.50
Firm	25 to 50	0.50 to 1.0
Stiff	50 to 100	1.0 to 2.0
Very stiff	100 to 200	2.0 to 4.0
Hard	200 to 400	4.0 to 8.0
Very hard (3)	Greater than 400	Greater than 8.0

Notes: 1) from Terzaghi and Peck (1967)
2) ksf used primarily for US projects
3) the upper boundary for "Hard", and the "Very hard" range have been added.

DENSITY/COMPACTNESS OF GRANULAR SOILS (ASTM)

Tables of recommended values and descriptors for relative density are not provided in the ASTM Standards, but in practice relative density is often interpreted on the basis of cone penetration test results. The same ranges of relative density (compactness) as those recommended for use with BS 5930 (see BS Section) are used.

DISCONTINUITIES/STRUCTURE (ASTM)

Criteria for describing soil structure are provided in ASTM D 2488, and in Table 15 along with additional terms in use in the geotechnical industry.

TABLE 15 - DESCRIPTIVE TERMS FOR SOIL STRUCTURE

Term	Description
Slickensided	Fracture or shear planes (or planes of weakness) that appears slick and glossy.
Fissured	Cohesive soil that breaks into blocks along unpolished planes (discontinuities), often filled with a different material. The fill material is noted.
Blocky	Cohesive soil that breaks into small angular lumps along polished planes (discontinuities) which resist further breakdown.
Gassy	Soil has a porous nature and there is evidence of gas, such as blisters.
Expansive	Visibly expands after sampling. Degree of expansion is estimated and noted.
Platy	A stratified appearance when the soil can be broken into thin horizontal plates.
Cemented	Material grains bound together forming an intact mass.

The distance between the fissures, shear planes, and expansion cracks is noted using the terms in Table 8.

BEDDING/STRATIGRAPHY (ASTM)

The terminology for bedding thickness and stratigraphic description used in North American offshore practice is more detailed than outlined in ASTM D 2488, and is different from BS 5930. In Table 16, the descriptive terms have been further defined and integrated with BS 5930 terminology.

TABLE 16 - DESCRIPTIVE TERMS FOR BEDDING THICKNESS AND INCLUSIONS

Term	Bedding thickness	
	[mm]	[inch]
Pocket	Inclusion of material of different texture that is smaller than the diameter of the sample	
Parting	< 3	1/8
Lamina	3 to < 6	1/8 to < 0.25
Laminated(1)	Alternating partings or laminae of different soil types in equal proportion	
Lens	6 to < 20	0.25 to < 0.75
Seam	20 to < 76	0.75 to < 3
Layer	Greater than 76	Greater than 3
Stratified(2)	Alternating lenses, seams or layers of different soil types in equal proportion	
Intermixed	Soil sample composed of pockets of different soil types, and laminated or stratified structure is not evident	

Notes: (1) Equivalent to “Interlaminated” term used in BS 5930:1999
(2) Equivalent to “Interbedded” term used in BS 5930:1999.

MINOR CONSTITUENTS (ASTM)

Minor constituents within a soil, such as shell or wood fragments, or small quantities of soil particles (not secondary soil types), are typically more relevant to the site geology or to laboratory testing procedures than to soil behaviour. Since the terms and percentages are not defined in either BS 5930 or ASTM D 2487/8, the terms “with trace”, “with few”, “with”, “with many” are used as a guide.

WRITTEN SOIL DESCRIPTIONS

Although soils are classified in the order of the characteristics described in the preceding sections, written descriptions are given in a different order in both Standards. To bring as much consistency as possible to the soil descriptions, Fugro selected a single preferred order of terms, which most closely resembled the majority of the descriptions used in Fugro offices around the world.

In this description, the principal soil type is given last as the soil name, with most other terms written as adjectives. The principal soil type is given in upper-case.

The preferred order of terms for a soil description are:
1. Density/compactness/strength.
2. Discontinuities.
3. Bedding.
4. Colour.
5. Secondary (composite) soil types.
6. Particle shape.
7. Particle size.
8. PRINCIPAL SOIL TYPE.

with:
9. Minor constituents (can be inserted in front of the principal soil type, such as “shelly”).
10. Soil odour.

For example: Firm closely-fissured dark olive grey sandy calcareous CLAY with few silt pockets. Where used, the Group Symbol is part of the soil description, e.g. loose poorly-graded fine to medium SAND with silt (SP-SM).

PARTICULATE DEPOSITS

The geological origin of a single particle type allows the following descriptions (optional):

Clastic: sediment transported and deposited as grains of inorganic origin. Typical clastic particles are:
- quartz grains: clear or milky white and ranging from very angular to very rounded; commonly a frosted surface for wind-blown grains
- feldspar grains: varying in colour from milky white to light yellowish brown
- mica flakes: varying in colour from gold-coloured to dark brown
- dark mineral grains: usually of igneous or metamorphic origin with undetermined mineralogy
- silicate grains: undetermined mineralogy
- rock fragments: including fragments of carbonate rock
- debris: deposit of rock fragments of a variety of particle sizes which may include sand and finer fractions; typical examples are rock debris and coral debris

Organic: remains of plants and animals that consists mainly of carbon compounds

Bioclastic: sediment transported and deposited as grains of organic origin. Examples of bioclastic particles are:
- Calcareous algae: crustal or nodular growths or erect and branching forms produced by lime-secreting algae; microstructures include layered, rectangular structures and internal fine tube-like structures.
- Foraminifera: hard sediment test (external skeleton) consisting of calcite or aragonite and produced by unicellular organisms; commonly less than 1 mm in diameter, multi-chambered and intact.
- Sponge spicules: spicules of siliceous sponges in a variety of rayed shapes; dimensions ranging from less than 1 mm to over 1 cm in length but usually less than 1 mm in width.
- Corals: commonly consisting of small fibres set perpendicular to the walls and septal surfaces; mainly aragonite composition for relatively recent forms; conversion of aragonite to calcite for earlier corals, usually with consequent loss of original structural details.
- Echinoids: hard part of echinoids consisting of a plate or skeletal element forming a single crystal of calcite; five-rayed internal symmetry for spines of echinoids; typical widths ranging from several mm to a few cm.
- Bryozoans: chambered cell-like structures that are considerably coarser than those of calcareous algae; either aragonite or calcite composition; possible cell in-fill consisting of clear calcite and/or micrite.
- Bivalves and Gastropods: Mollusk shells, chiefly of aragonite composition; inner layer of aragonite protected by an outer layer of calcite for some bivalve shells and gastropods.

Oolitic: sediment consisting of solid, round or oval, highly polished and smooth coated grains, which may or may not have a nucleus. The coating consists of chemically precipitated aragonite, possibly converted to calcite. Ooliths have concentric structures and may also have radial structures. The grains are generally less than 2 mm diameter.

Pelletal: sediment consisting of well rounded grains of ellipsoidal shape and no specific internal structure. The composition is clay to silt-sized carbonate material, which is probably the excretion product of sediment eating organisms. Pellets may have an oolitic crust. The grains are generally less than 2 mm diameter.

STRUCTURE OF NON PARTICULATE DEPOSITS

Reef: soil or rock formed by in-situ accumulation or build-up of carbonate material by colonial organisms such as polyps (coral), algae (algal mats or balls) and sponges.

Orthochemical: orthochemical components precipitated during or after deposition. These components can include: (1) pyrite spherulites and grains, (2) crystal euhedra of anhydride or gypsum, (3) replacement patches and nodular masses of anhydrite and gypsum. Single grains are rare.

GEOLOGICAL INFORMATION

Specific geological terms can assist the geotechnical soil description by providing information on stratigraphy, origin (genesis) or regional significance (optional). Examples are:

- time stratigraphy, such as Eemian and Pleistocene,
- lithostratigraphy, such as Yarmouth Roads Formation
- depositional environment, such as Marine, Glacio-lacustrine and Residual Soil
- regional significance, such as Chalk and Mud.

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INTRODUCTION

The Standard Penetration Test (SPT) is a combined sampling and in-situ test technique for within a borehole. It includes driving a split-barrel sampler to obtain a ground sample and a measure of the resistance of the ground to penetration of the sampler.

The test method provides a ground sample for identification purposes and for laboratory tests that allow the use of disturbed samples. In addition, there are many geotechnical correlations, which relate SPT blow count, or N-value, and geotechnical behaviour.

SPT APPARATUS

Descriptions of common SPT apparatus are as follows:

- Drive-Weight Assembly: device consisting of hammer, hammer fall guide, anvil and hammer drop system.
- Hammer: impact mass of 63.5 kg which is successively lifted and dropped over 0.76 m to provide the energy that accomplishes the sampling and penetration.
- Hammer Fall Guide: guide arrangement for the fall of the hammer.
- Anvil: drive-head which the hammer strikes and through which the hammer energy passes into the sampling rods.
- Hammer Drop System: pick-up and release mechanism by which lifting and dropping of the hammer is accomplished.
- Cathead: rotating drum in a rope-cathead hammer drop system around which a rope is wrapped to lift and drop the hammer by successively tightening and loosening the rope turns around the drum.
- Self-Tripping Release: mechanism that ensures a free fall of the hammer.
- Sampling Rods: rods that connect the drive-weight assembly to the split barrel sampler or solid cone.
- Split Barrel Sampler: flush sampler with 35 mm I.D. (lined) or 38 mm I.D. (unlined) and 51 mm O.D., of minimum 0.5 m length and with a longitudinal split.
- Split Liner: internal lining of the split barrel sampler.
- Core Catcher: device that assists retention of the sample in the split barrel sampler.
- Solid Cone: conical part having a 60^{o} apex angle that replaces the drive shoe of the split barrel sampler under special conditions.

PROCEDURE

The procedure for a Standard Penetration Test includes the following:

- advancement of the borehole to the selected test depth, while maintaining the drill fluid at or above the in-situ ground water level
- lowering of the split barrel sampler and sampling rods into the borehole and positioning of the drive weight assembly
- marking of the sampling rods in three successive 0.15 m increments
- driving the split barrel sampler with the hammer and counting the number of blows applied in each increment until one of the following stop criteria in the procedure of choice occurs:

	ASTM D 1586-11	**BS EN ISO 22476-3:2005**	**BS 1377:Part 9:1990 pre-Amd 2***
Seating drive (150 mm)	Number of blows for penetration of 150 mm or 50 blows, whichever is reached first. Driving is terminated if after 10 successive blows no advance is observed.	Number of blows for penetration of 150 mm	Number of blows for penetration of 150 mm or 25 blows, whichever is reached first
Test drive (2 increments of 150 mm)	Number of blows for penetration of each 150 mm increment. If 150 mm has not been achieved after 50 blows, terminate the increment. Driving is also terminated if a total of 100 blows is reached, including the seating drive.	Number of blows for penetration of 300 mm. If 300 mm has not been achieved after 50 successive blows (or 100 in soft rock), terminate the test drive, record blow count and actual penetration achieved.	Number of blows for penetration of 300 mm. If 300 mm has not been achieved after 50 successive blows (or 100 in soft rock), terminate the test drive, record blow count and actual penetration achieved.

	ASTM D 1586-11	BS EN ISO 22476-3:2005	BS 1377:Part 9:1990 pre-Amd 2*
	Driving is terminated for an increment if after 10 successive blows no advance is observed.		
Remarks	Record seating and test drive blows for 150 mm increments	Record seating and test drive blows for 150 mm increments	Record seating and test drive blows for 75 mm increments

* BS 1377:Part 9:1990 was partially replaced by ISO 22476-3:2005. If however the driving of the seating drive is not reasonably possible following ISO 22476-3:2005, guidelines of BS 1377:Part 9:1990 may be adopted (Hepton and Gosling, 2008).

RESULTS

SAMPLE

The following comments apply to the sample:
- Sample description is applicable.
- Sample quality (CEN, 2007) is typically disturbed, Class 3 for cohesive soil and Class 4 for cohesionless soil.

The classification system for sample quality recognises 5 classes on the basis of feasibility of specific geotechnical identification and laboratory tests. A summary of these classes is as follows:
Class 1: undisturbed: strength, stiffness and consolidation
Class 2: undisturbed: layering, permeability, unit weight
Class 3: disturbed: water content
Class 4: disturbed: particle size analysis, Atterberg limits, soil type
Class 5: disturbed: stratigraphy
The higher class includes the laboratory tests of the lower classes.

PENETRATION RESISTANCE

The initial 0.15 m penetration is the seating drive. The N-value or the standard penetration resistance is the sum of the number of blows required for the second and third 0.15 m increments.

If the sampler penetration is less than 0.45 m then the results include:
- the number of blows per each complete increment
- the number of blows per partial increment
- the depth of penetration for the partial increment.

For this situation, it is common practice (Decourt, 1989) to apply linear extrapolation to a blow count for 300 mm penetration to obtain the "N-value". This extrapolation usually takes account of the blow count for the seating drive.

The results can include the initial self-weight penetration of the split barrel sampler below the bottom of the borehole, if significant.

INTERPRETATION

Geotechnical practice may require correction factors for comparative studies and/or to account for regional variations in practice. The more important correction factors are effective in-situ vertical stress, overconsolidation ratio, particle size distribution, kinetic energy, enthru energy and critical (rod) length. For example, the so-called N60-value denotes an N-value corrected to 60% enthru energy.

BSI (1999) presents a commonly used correlation between N-value and relative density of sands and gravels, as follows:

Descriptive Term	N-value
Very loose	0 to 4
Loose	4 to 10
Medium dense	10 to 30
Dense	30 to 50
Very dense	>50

This correlation excludes corrections for rod energy and vertical effective stress, unless specifically stated otherwise. Skempton (1986) presents recommendations for more fundamental correlation between N-value and relative density.

Cole and Stroud (1976) suggest an approximate correlation between N-value and clay and rock strength.

Experience (e.g. Peuchen and NeSmith, 2004) indicates that SPT results can no longer be interpreted with confidence when rod length exceeds about 25 m. This observation is based on comparative studies between SPT, Cone Penetration Tests (P/CPT) and Cone Pressuremeter Tests (CPMT) to beyond 100 m depth. A possible mitigation measure is to apply N-value adjustment on the basis of downhole energy measurement. Alternatively, PCPT technology and separate sampling may be applied. Equivalent SPT values can then be obtained, if required, by application of correlations such as published by Robertson et al. (1983) and Kulhawy and Mayne (1990).

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ISSUE 11

TESTING PRACTICE

GENERAL

This document summarises geotechnical laboratory test methods for soil.

Fugro strives to arrange testing in registered laboratories with formal accreditation. This document summarises test methods used by the Fugro geotechnical laboratory at Leidschendam, The Netherlands, registered by STERLAB, the Dutch national body for laboratory accreditation, under number L165 for areas as described in the accreditation. Test methods used by on-site laboratories and other in-office laboratories are often identical or generally equivalent.

Laboratory tests are carried out in general accordance with standards published by ASTM International (ASTM), British Standards Institution (BSI) and International Organization for Standardization (ISO). In-house test procedures adopted for some tests are generally based on published recommendations for which no standards are available. References are indicated for each test, with the principal reference listed first. Detailed work instructions and calibration details are available for inspection at the laboratory.

Some of the laboratory tests allow various optional procedures. These procedures are not applicable, unless specifically agreed.

SAMPLE REQUIREMENTS

The feasibility of a particular laboratory test relates to the sampling practice and sample handling for a particular soil and depends on factors such as soil type, available amount of sample material and sample quality. Usually, a reasonable estimate of test feasibility is possible at the time of sampling. A further refinement is possible in the laboratory prior to testing and, in some cases, only after testing. The limitations of feasibility estimates may lead to rejection of samples for testing upon inspection in the laboratory or may result in appropriate comments on test results after completion of testing.

The adopted classification system for sample quality is according to BSI (1999) and ISO (2006). The classification system recognises 5 classes on the basis of feasibility of specific geotechnical identification and laboratory tests. A summary of these classes is as follows:
Class 1: undisturbed: strength, stiffness and consolidation
Class 2: undisturbed: permeability, unit weight, boundaries of strata - fine
Class 3: disturbed: water content
Class 4: disturbed: particle size analysis, Atterberg limits, boundaries of strata - broad
Class 5: disturbed: sequence of layers
The higher class includes the laboratory tests of the lower class.

An indication of ***undisturbed*** (intact) sample quality may be obtained from consolidation of a test specimen, for example in an oedometer or triaxial cell. Table 1 presents a method according to Lunne et al. (1997) based on $\Delta e/e_0$. Here, Δe represents the change in void ratio Δe from initial value (e_0) to the void ratio at in-situ stress conditions.

TABLE 1 - CRITERIA FOR EVALUATION OF UNDISTURBED SAMPLE QUALITY

Overconsolidation Ratio	$\Delta e/e_0$			
	Very Good to Excellent	Good to Fair	Poor	Very Poor
1 to 2	< 0.04	0.04 to 0.07	0.07 to 0.14	> 0.14
2 to 4	< 0.03	0.03 to 0.05	0.05 to 0.10	> 0.10

The presented sample disturbance criteria are based on tests on marine clays in the depth range 5 m to 25 m, with plasticity index in the range 10% to 55%, water content 30% to 90% and overconsolidation ratios of 1 to 4. The criteria must be used with caution for soils outside this range.

GEOTECHNICAL INDEX TESTING

WATER CONTENT

The water content is determined by drying selected moist/wet soil material for at least 18 hours to a constant mass in a 110°C drying oven. The difference in mass before and after drying is used as the mass of the water in the test material. The mass of material remaining after drying is used as the mass of the solid particles. The ratio of the mass of water to the measured mass of solid particles is the water content of the material. This ratio can exceed 1 (or 100%).

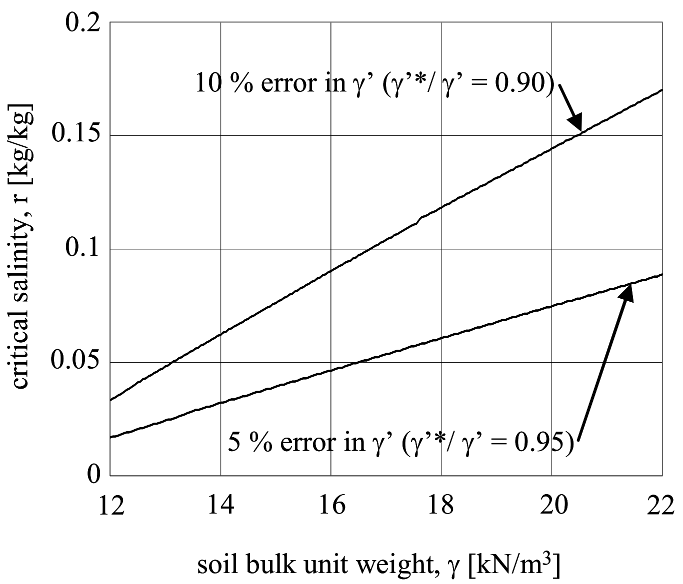
Test references: ASTM D2216-10, BS 1377: Part 2: 1990, ISO/TS 17892-1:2004

UNIT WEIGHT – VOLUME-MASS CALCULATION

Measurement of volume and mass of a soil sample allows calculation of unit weight. For fine-grained (cohesive) soils, a soil specimen is generally obtained from a standard steel cylinder with cutting edge, which is pushed manually into the extruded soil sample. Preference is given to a 100 ml cylinder (area ratio of 12%), but a volume of 33.3 ml (area ratio of 21%) may be used when insufficient homogeneous sample is available. If possible, a specimen of coarse-grained (non-cohesive) soil is obtained by selecting a part of a cylindrical soil sample, trimming the end surfaces, and measuring height and diameter. This method also applies to fine-grained specimens selected for strength and/or stiffness (e.g. triaxial and oedometer) tests.

Unit weight γ (kN/m^3) refers to unit weight of the soil specimen at the water content at the time of test.

The method excludes correction for pore water salinity r (contains dissolved solids), in-situ pressure and temperature. The diagram below provides an indication of error in calculated submerged unit weight γ' versus submerged unit weight corrected for salinity, γ'^* (Kay et al., 2005). Typical seawater salinity is 35 g salt per kg seawater (r = 0.035). Correction for salinity is optional.



Optionally, dry unit weight γ_d, is calculated from the mass of oven-dried soil and the initial specimen volume.

Test references: BS 1377: Part 2: 1990, ASTM D7263-09

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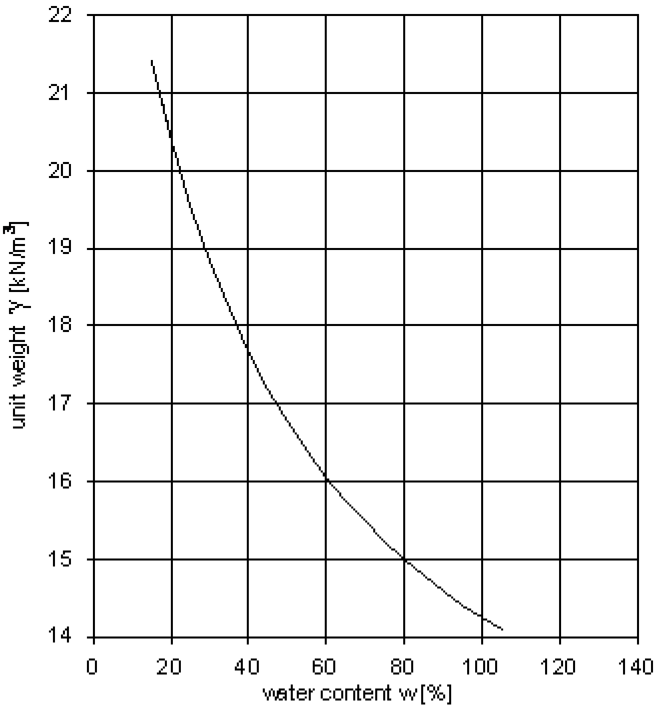
UNIT WEIGHT – DERIVED FROM WATER CONTENT

Water content (w) measurement allows estimation of soil unit weight (γ) on fully saturated samples. This practice requires input on density of solid particles and presumes saturation of non-saline pore water.



Correction for (high) pore water salinity (contains dissolved solids) is optional.

Test reference: In-house

DENSITY OF SOLID PARTICLES – CONVENTIONAL PYCNOMETER

The density of the solid particles of an oven-dried soil sample is determined by means of a stoppered-bottle pycnometer, using distilled water. The method is considered applicable to solid particles that are not soluble in water. For soils with a high organic content, a different liquid may be selected. Soils with high pore water salinity (contain dissolved solids) require use of a gas pycnometer. This is optional.

Test references: BS 1377: Part 2: 1990, ASTM D854-10

GRAIN SHAPE

Grain shape is determined by microscopic comparison of both grain roundness and sphericity with standard grain shapes. The standard shapes are presented together with the test results.

Test reference: In-house

PARTICLE SIZE ANALYSIS

Particle size analysis can be performed by means of sieving and/or hydrometer readings. Sieving is carried out for particles that would be retained on a 0.063 mm sieve, while additional hydrometer readings may be carried out when a significant fraction of the material passes a 0.063 mm sieve.

In a sieve analysis, the mass of soil retained on each sieve is determined, and expressed as a percentage of the total mass of the sample. Prior to sieving, samples are treated with a dispersing agent (sodium hexameta-phosphate), rinsed on a 0.063 mm sieve and dried.

The hydrometer method allows measurement of the density of a suspension consisting of fine-grained soil particles and distilled water, to which a dispersion agent is added. This suspension is mixed using a high speed stirrer. Testing is performed in a thermostatically controlled water bath (25° ± 0.5°). The particle size is calculated according to Stokes' Law for a single sphere, on the basis that particles of a particular diameter were at the surface of the suspension at the beginning of sedimentation and had settled to the level at which the hydrometer is measuring the density of the suspension. These calculations require a value for the density of solid particles. Generally, a value of 2.65 t/m^3 is assumed. When other values are used, this is included in the laboratory report. The hydrometer results for selected particle sizes are presented as a percentage of the total mass of the soil sample.

Particle size is presented on a logarithmic scale so that two soils having the same degree of uniformity are represented by curves of the same shape regardless of their positions on the particle size distribution plot. The general slope of the distribution curve may be described by the coefficient of uniformity C_u, where $C_u = D_{60}/D_{10}$, and the coefficient of curvature C_c, where $C_c = (D_{30})^2/D_{10} \times D_{60}$. D_{60}, D_{30}, and D_{10} are effective particle sizes indicating that 60%, 30%, and 10% respectively of the particles (by weight) are smaller than the given effective size.

Combined presentation of results from hydrometer readings and sieving normally requires data harmonising in the area of overlap, i.e. near the 0.06 mm particle size.

Test references: ISO/TS 17892-4:2004, BS 1377: Part 2: 1990, ASTM D422-63 (2007)

PERCENTAGE FINES

The Percentage Fines test identifies the proportions of fine grained (< 0.06 mm) and coarse-grained (> 0.06 mm) particle sizes of a soil sample by wet sieving through a 0.063 mm sieve. Prior to sieving, the sample is treated with a dispersing agent. The Percentage Fines is defined as the ratio of dry mass of soil passing the 0.063 mm sieve to the dry mass of the total soil sample, expressed as a percentage.

Test references: BS 1377: Part 2: 1990, ASTM D422-63 (2007)

ATTERBERG LIMITS

Atterberg limits are determined on soil specimens with a particle size of less than 0.425 mm. If necessary, coarser material is removed by dry sieving. The Atterberg limits refer to arbitrarily defined boundaries between the liquid and plastic states (Liquid Limit, w_L), and between the plastic and brittle states (Plastic Limit, w_P) of fine grained soils. They are expressed as water content, in percent.

The liquid limit is defined as the water content at which a pat of soil placed in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove, when the cup is subjected to 25 standard shocks. The one-point liquid limit test is usually carried out. Distilled water may be added during soil mixing to achieve the required consistency.

The plastic limit is defined as the water content at which a soil can no longer be deformed by rolling into 3 mm diameter threads without crumbling.

The range of water contents over which a soil behaves plastically is the Plasticity Index, I_P. This is the difference between the liquid limit and the plastic limit (w_L-w_P).

Test references: BS 1377: Part 2: 1990, ASTM D4318-10

MINIMUM INDEX UNIT WEIGHT

The minimum index unit weight (γ_{dmin}) of cohesionless soil is determined from the mass of oven-dry material that is deposited by slowly withdrawing a soil-filled funnel from a standard mould of either 70 ml or 550 ml volume.

Test reference: In-house

MAXIMUM INDEX UNIT WEIGHT - IMPACT COMPACTION

The maximum index unit weight (γ_{dmax}) of cohesionless soil is determined from the mass of oven-dry, compacted soil in a standard mould. The soil is compacted in 5 layers, with each layer being subjected to respectively 5, 10, 20, 40 and 80 blows from a standard, hand-held hammer.

Equipment dimensions are as follows. Preference is given to the large mould, but application depends on size of sample.

	70 ml mould	554 ml mould
Hammer mass [g]	185	750
Drop height [mm]	300	390
Cross-sectional area [mm^2]	1000	38,500

Reference: In-house

MAXIMUM INDEX UNIT WEIGHT – VIBRATING HAMMER

The maximum index unit weight (γ'_{dmax}) is obtained by compacting soil that has been passed through a 4 mm sieve into a mould at a range of water contents. The first sample is thoroughly mixed with water, to produce a soil with a 4% water content, and then compacted in three equal layers using a vibrating hammer for a period of one minute per layer. The top section of the mould is removed and the sample levelled in the bottom section of the mould. The unit weight of the sample is calculated and a representative portion of soil is removed for water content determination.

The test is repeated at four further water contents. By determining the dry unit weight achieved at each water content, a maximum dry unit weight may be estimated.

Test reference: BS 1377: Part 4:1990

GEO-CHEMICAL TESTING

ORGANIC MATTER CONTENT – DICHROMATE OXIDATION METHOD

An oven-dried (50°C) soil sample is mixed with potassium dichromate solution and left for 30 min to allow the oxidation of organic matter to proceed. The solution is titrated with a ferrous sulphate solution (to determine the amount of excess potassium dichromate). The organic matter content is defined as the ratio of the total volume of potassium dichromate solution used to oxidize the organic matter in the soil sample to the mass of the initial dried soil sample (Walkley and Black's method). It is expressed as a percentage.
Note: soils containing sulphides or chlorides have been found to yield inaccurate (too high) organic matter content measurements using this procedure.

Test references: BS 1377: Part 3: 1990:3

CARBONATE CONTENT – GAS VOLUME

The carbonate content is determined by drying selected soil material to a constant mass in a 110°C drying oven, and measuring the volume of dissipated carbon dioxide (CO_2) upon reaction of the soil with hydrochloric acid (HCl). The carbonate content is calculated from calibration values, and expressed as a percentage of dry mass of the original soil.

Test reference: ISO 10693:2004

CARBONATE CONTENT - GAS PRESSURE

The carbonate content is determined by using a dried or a natural soil specimen and measuring the pressure of dissipated carbon dioxide (CO_2) upon reaction of the soil with hydrochloric acid (HCl). The carbonate content is calculated from the mass of the specimen and the pressure increase after reaction by comparison with calibration values. For a natural soil, a correction factor is applied to correct for water content. Carbonate content is expressed as a percentage of dry mass of the original soil.

Test reference: ASTM D4373-02 (2007)

WATER-SOLUBLE SULPHATE CONTENT – GRAVIMETRIC METHOD

The water-soluble sulphate content of a soil sample is determined on a test portion that has been sieved and crushed through a 2 mm sieve and oven dried to 110°C. The test portion is mixed with distilled water to prepare a 2:1 water:soil extract.

In the gravimetric method, barium chloride solution is added to the water:soil extract and the precipitated barium sulphate is collected, dried and weighted. The sulphate content is then calculated from the mass of the material used in the analysis and the mass of the barium sulphate precipitated. BS presents the results in SO_3 [g/l] and AASTHO in SO_4 [mg/kg].

If a 2:1 water:soil extract is prepared, one can convert sulphites (SO_3) into sulphates (SO_4) by multiplying SO_3 by a factor 1.2. For extractions other than a 2:1 the multiplying factor is different.

Test reference: BS 1377: Part 3:1990, AASHTO T290-95-UL (2007)

WATER-SOLUBLE CHLORIDE CONTENT – MOHR'S METHOD

The water-soluble chloride content of a soil sample is determined on a test portion that has been sieved and crushed through a 2 mm sieve and oven dried to 110°C. The test portion is mixed with distilled water to prepare a 2:1 water:soil extract.

In the Mohr's method chloride ion will precipitate with silver nitrate. The chloride reacts with the silver ion before any silver chromate forms, due to the lower solubility of silver nitrate. The potassium chromate indicator reacts with excess silver ion to form a red silver chromate precipitate. The end point is the appearance of the first permanent orange colour. The chloride content is expressed as a percentage by mass of dry soil.

This test method is suitable for analyzing solutions with a pH between 6.0 and 8.5.

Test reference: BS 1377: Part 3: 1990, AASHTO T291-94-UL (2008)

COMPRESSIBILITY TESTING

OEDOMETER - INCREMENTAL LOADING

The oedometer test covers determination of the rate and magnitude of consolidation of a laterally restrained soil specimen, which is axially loaded in increments of constant stress until the excess pore water pressures have dissipated for each increment. Normally, each load increment is maintained for 24 hours.

The test is generally carried out on undisturbed (intact) cohesive specimens using a consolidometer (oedometer) apparatus, which is placed in a thermostatically controlled room (10°C). Selection of mounting method depends on soil characteristics. Soils that show a tendency to swell, such as peat or overconsolidated clays, are mounted dry. Moist sponges are placed in the oedometer cell to retain sample moisture conditions. Other samples are usually mounted using the wet mounting method. Distilled water is added to the cell when loads are applied to the loading arm. When required, the initial load is increased to prevent swell.

Key parameters that can be obtained from this test are the preconsolidation pressure σ'_p and the coefficient of consolidation c_v. The preconsolidation pressure is estimated using the graphical Casagrande construction. The root time method or the log time method is used for determination of c_v. Other parameters that may be derived from this test are the compression index C_c, the coefficient of volume compressibility m_v and the vertical permeability k_v.

Test references: ASTM 2435/2435M -11, BS 1377: Part 5: 1990

OEDOMETER - CONSTANT RATE OF STRAIN

The Constant Rate of Strain (CRS) oedometer test covers determination of the rate and magnitude of consolidation of a laterally restrained soil specimen when it is drained axially and subjected to controlled deformation loading. The rate of deformation is selected so that excess pore water pressures are between 3% and 20% of the applied axial stress. Drainage of pore water is permitted from the top of the specimen and pore water pressures are measured at the bottom of the specimen. The test is generally carried out on undisturbed (intact) cohesive specimens using a consolidometer, in a thermostatically controlled room (20°C).

Key parameters that can be obtained from this test are the preconsolidation pressure σ'_p and the coefficient of consolidation c_v as a function of axial stress. The preconsolidation pressure is estimated using the graphical Casagrande procedure, while the coefficient of consolidation is determined analytically from the measurements of axial stress, strain and excess pore water pressure. Other parameters that may be derived from this test are the compression index C_c, the coefficient of volume compressibility m_v and the coefficient of vertical permeability k_v.

Test reference: ASTM D4186-06

STRENGTH INDEX TESTING

TORVANE AND POCKET PENETROMETER

The torvane and pocket penetrometer are small hand-held instruments for rapid strength index testing of fine grained (cohesive) soils. The torvane test is carried out by pressing a standard vane into the soil and measuring the minimum torque required to rotate the vane. The vane size can be selected to suit the expected torque up to an equivalent undrained shear strength of the soil of 250 kPa. The undrained shear strength is correlated to the measured torque by vane size and torvane spring constant.

The pocket penetrometer test consists of pressing a small solid cylinder into the soil, to a specified penetration. The maximum force required for penetration is correlated to the undrained shear strength. The size of the cylinder can be selected so that undrained shear strength readings of up to 900 kPa can be taken.

Test reference: ISO 22475-1:2006

HAND VANE

The hand vane allows index testing for undrained shear strength of cohesive soil. The tool is similar to the laboratory miniature vane except for reduced control: manual penetration and rotation of the vane.

Several different measurements of undrained shear strength are possible:

a) Intact: undisturbed undrained shear strength as measured on an intact specimen.
b) Intact–residual: measured post-peak during initial shearing of an intact specimen.
c) Intact–vane-remoulded: measured after multiple rotations of the hand vane after completion of the intact test.
d) Hand-remoulded: steady state (post-peak if exists) resistance of a hand-remoulded test specimen.
e) Hand-remoulded–cane-remoulded: steady state resistance of a hand-remoulded specimen measured after applying multiple vane rotations.

Different values of the remoulded shear strength are often obtained from the different measurement methods.

A specimen may be tested in the sample tube in which it was taken, in a block sample or in a mould after removal from a sampler. The test apparatus consists of a rectangular vane with a short push rod for penetration into the soil. The vane is then slowly rotated by hand and the maximum torsional moment is recorded. Various vane sizes can be selected depending on the consistency of the specimen. Calculation of undrained shear strength is based on a cylindrical failure surface for which uniform stress distributions are assumed. The equation for undrained shear strength is as follows:

$$c_U = \frac{T_{max}}{\pi D^2 \left(\frac{1}{2} H + \frac{1}{6} D \right)}$$

where:

c_u	= peak undrained shear strength	[kPa]
T_{max}	= maximum torsional moment	[kNm]
D	= vane diameter	[m]
H	= vane height	[m]

Test reference: in-house

LABORATORY MINIATURE VANE

The laboratory miniature vane test allows determination of undrained shear strength of cohesive soil. CEN (2007) classifies the laboratory miniature vane as a strength index test.

Several different measurements of undrained shear strength are possible:
a) Intact: undisturbed undrained shear strength as measured on an intact specimen.
b) Intact–residual: measured post-peak during initial shearing of an intact specimen.
c) Intact–vane-remoulded: measured after multiple rotations of the vane after completion of the intact test.
d) Hand-remoulded: steady state (post-peak if exists) resistance of a hand-remoulded test specimen.
e) Hand-remoulded–cane-remoulded: steady state resistance of a hand-remoulded specimen measured after applying multiple vane rotations.

Different values of the remoulded shear strength are often obtained from the different measurement methods.

A specimen may be tested in the sample tube in which it was taken or in a mould after extrusion from the sample tube. The sample tube or mould is mounted in the test apparatus and a rectangular vane is lowered into the soil. The vane is then rotated at 10°/min (BS 1377) or at 60°/min to 90°/min (ASTM D4648) and the maximum torsional moment is recorded. A continuous record of rotation versus torsional moment can also be made if required (optional). Various vane sizes can be selected depending on the consistency of the specimen. Calculation of undrained shear strength is based on a cylindrical failure surface for which uniform stress distributions are assumed. The equation for undrained shear strength is as follows:

$$c_U = \frac{T_{max}}{\pi D^2 \left(\frac{1}{2} H + \frac{1}{6} D \right)}$$

where:

c_u	= peak undrained shear strength	[kPa]
T_{max}	= maximum torsional moment	[kNm]
D	= vane diameter	[m]
H	= vane height	[m]

Test references: BS 1377: Part 7: 1990, ASTM D4648-10

STRENGTH TESTING

RING SHEAR - SOIL/STEEL INTERFACE

Ring shear interface tests are performed on remoulded or reconstituted (compacted) soils to infer the residual friction angle, also called the constant volume friction angle (δ_{cv}), on a soil-steel interface.

The ring shear apparatus enables an annular specimen of soil, 5 mm thick with internal and external diameters of 70 mm and 100 mm, respectively, to be subjected to rotational shear.

First, the sample is consolidated to selected stress conditions. Then, it is sheared at a rate of 500 mm/min (fast shear), followed by 50 mm/min, up to a relative displacement of at least one metre. The sample is then resting for a period of 24h and after that is again consolidated to its selected stress conditions. Finally, the sample is sheared at a slower rate of 0.018 mm/min under drained conditions.

The presentation of the test results includes a plot of stress ratio and angle of shearing resistance versus displacement, both for fast and slow shear.

Test reference: BS 1377: Part 7: 1990, Jardine et al. (2005) (Appendix A)

DIRECT SIMPLE SHEAR (DSS)

Simple shear tests provide a simulation of the plane strain mode of shearing for undisturbed (intact), remoulded or reconstituted (compacted) specimens. Key features of the DSS test are essentially constant horizontal dimensions of the specimen in the direction of shear, and modelling of undrained behaviour by drained tests in which a constant volume is maintained by varying the axial pressure.

The direct simple shear test is carried out on a cylindrical specimen of 66 mm diameter and 16 mm to 19 mm height depending on the test apparatus. Lateral confinement of the specimen is provided by a membrane in combination with a stack of brass shearing washers, or by a reinforced membrane. There are no facilities for applying back pressure and control of drainage.

The specimens are sheared at constant volume. It is assumed that the change in axial stress is equivalent to the change in pore pressure for an undrained test where the total axial stress is kept constant.

Test results include horizontal shear stresses and strains, and equivalent pore pressures.

Test reference: ASTM D6528-07

DIRECT SHEAR – SOIL/SOIL INTERFACE

Direct shear testing (or shear box testing) is a method for determining drained soil resistance (angle of internal friction, φ') for cohesionless and cohesive soils.

The soil to be tested is placed in a split mould, with internal dimensions of 60 mm by 60 mm. A porous stone and loading plate are placed on top of the specimen and a normal load is applied to the specimen. The sample is then sheared, by displacing the top half of the split mould relative to the bottom half, at a rate of displacement preventing significant excess pore water pressures to be generated. During the test, horizontal displacement, load and vertical displacement are recorded.
On completion of the first stage, the specimen is removed from the mould and the unit weight and water content are determined. Two further tests may then performed, at the same unit weight, but with increased normal loads.

The test results are presented in the form of graphs of horizontal displacement versus shear stress and normal stress versus maximum shear stress.

Test reference: BS1377: Part 7: 1990

UNCONSOLIDATED UNDRAINED TRIAXIAL (UU)

This type of test is usually performed on undisturbed (intact) samples of cohesive soils. CEN (2007) classifies the UU test as strength index test. Depending on the consistency of the cohesive material, the test specimen is prepared by trimming the sample or by pushing a mould into the sample. A latex membrane with a thickness of approximately 0.2 mm is placed around the specimen. A lateral confining pressure of 600 kPa to 1000 kPa is maintained during axial compression loading of the specimen. Consolidation and drainage of pore water during testing is not allowed. The test is deformation controlled (strain rate of 60%/h), single stage, and stopped when an axial strain of 15% is achieved. The deviator stress is calculated from the measured load assuming that the specimen deforms as a right cylinder.

The presentation of test results includes a plot of deviator stress versus axial strain. The undrained shear strength, c_u, is taken as half the maximum deviator stress. When a maximum stress has not been reached at strains of less than 15%, the stress at 15% strain is used to calculate undrained shear strength.

To determine strength sensitivity, the test may be repeated on remoulded (compacted) specimens. When possible, the tested undisturbed specimen is kneaded in the membrane, and then reshaped in a mould prior to testing. Stiff to hard specimens are cut into pieces, and reconstituted (compacted) by tamping the pieces in layers into a mould, until the original specimen dimensions are obtained. The sensitivity is the ratio of shear strength of undisturbed soil to shear strength of remoulded soil, $c_u/c_{u;r}$.

Test references: ASTM D2850-03a (2007), BS 1377: Part 7: 1990 (Clause 8)

CONSOLIDATED UNDRAINED TRIAXIAL (CIU AND CAU)

The consolidated undrained triaxial test offers the opportunity to derive both undrained and drained strength parameters for undisturbed (intact) or remoulded (compacted) specimens. Specimens are generally prepared by trimming cohesive samples to the required dimensions. The wet mounting method is used, which includes use of wet porous disks and a water-filled drainage system.

Test procedures include specimen saturation, consolidation and compression loading. For cohesive soils, filter paper strips are attached to the specimen circumference to promote drainage during consolidation. Saturation is obtained by incrementing cell pressure and back pressure. The degree of saturation is checked by the pore water pressure response to small variations in cell pressure.

In case of isotropic consolidation (CIU) the specimen is usually consolidated to a stress level equivalent to the mean in-situ stress estimated for the appropriate sample depth. For anisotropic consolidation (CAU), the specimen is consolidated to the estimated vertical and horizontal effective stresses. Various consolidation stages may be adopted to simulate the consolidation history and the effects of the expected loading sequence.

Specimen shearing is carried out under conditions of constant axial strain rate, while monitoring axial load and pore water pressure. A strain rate of 4%/h is generally applied, except when consolidation was slow, in which case a smaller strain rate is applied. The deviator stress is calculated from the measured load assuming the specimen deforms as a right cylinder. The shearing stage is terminated on the basis of effective principal stress ratio (ratio of effective axial stress to effective lateral stress σ'_1/σ'_3), or when an axial strain of 15% is reached. The CIU test may consist of three consolidation and shearing stages of increasing stress level. These stages may be performed on a single specimen or on three separate specimens.

The presentation of test results includes stress-strain curves, effective stress paths, pore water pressures and shear strength parameters. Stress paths are presented in terms of the Cambridge p'-q space where p' is the mean effective stress defined as $(\sigma'_1+2\sigma'_3)/3$ and q is the principal stress difference or deviator stress, $\sigma'_1-\sigma'_3$. The undrained shear strength is defined as half the deviator stress at failure, $c_u = q/2$ and is reported for the following failure criteria:

1) maximum deviator stress
2) maximum stress ratio q/p'.

When a maximum stress has not been reached at strains of less than 15%, the stress at 15% strain is used to calculate undrained shear strength. The secant angle of internal friction, φ', is determined from $q = Mp'$ where $M = (6\sin\varphi')/(3-\sin\varphi')$. This definition assumes a zero effective cohesion intercept and may be applied to M_{max} but also to other values of M and corresponding values of q and p'. For tests with three shearing stages, angles of internal friction may be determined for each stage separately, and from a straight line approximation of the failure points of the three stages. The latter method also provides a value for the effective cohesion intercept c'.

Test references: NEN 5117, ASTM D2850-03a (2007), BS 1377: Part 8: 1990 (Clause 4, 5, 6, 7)

CONSOLIDATED DRAINED TRIAXIAL (CID AND CAD)

Consolidated drained triaxial compression tests are generally performed on samples of cohesionless soils. The specimen of dry soil is prepared in the rubber membrane on the base of the triaxial cell, without the use of side drains. Soil particles larger than 20% of the diameter of the specimen are removed. Specimens are prepared by tamping thin layers of soil to a density approximating the estimated in-situ dry density. To saturate the specimen, CO_2 gas is used to expel the air and subsequently de-aired water is used to expel the CO_2 gas. The specimen is further saturated by incrementing cell pressure and back pressure, until the pore pressure response to a cell pressure increment (B-factor) indicates saturation is complete. The specimen is then isotropically or anisotropically consolidated (CID and CAD respectively).

After consolidation the sample is sheared by applying axial load at a sufficiently slow rate to permit drainage (usually 6%/h). The lateral confining pressure is kept constant during each loading stage. Pore pressure measurements are made at the bottom to check if the test is fully drained. The deviator stress is calculated from the measured load assuming the specimen deforms as a right cylinder. The CID test may have three consolidation and loading stages of increasing pressure performed on either a single specimen or on three separate specimens. The CAD test is limited to a single shearing stage. A shearing stage is terminated on the basis of effective stress ratio (ratio of effective axial stress to effective lateral stress, σ'_1/σ'_3), or when an axial strain of 15% is reached.

Results include stress-strain curves, stress paths, and volumetric/shear strain of each loading stage. Stress paths are presented in terms of the Cambridge p'-q space where p' is the mean effective stress defined as $(\sigma'_1+2\sigma'_3)/3$ and q is the principal stress difference or deviator stress, $\sigma'_1-\sigma'_3$.

The secant angle of internal friction, φ', is determined from $q = Mp'$ where $M = (6\sin\varphi')/(3-\sin\varphi')$. This definition assumes zero effective cohesion intercept and may be applied to M_{max} but also to other values of M and corresponding values of q and p'. For tests with three shearing stages, angles of internal friction may be determined for each stage separately, and from a straight line approximation of the failure points of the three stages. The latter method also provides a value for the effective cohesion intercept c'.

Test reference: ASTM D7181-11; BS 1377: Part 8: 1990 (Clause 4, 5, 6, 8)

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TESTING PRACTICE

LABORATORY PRACTICE

This document summarises geotechnical laboratory test methods for rock.

Fugro strives to arrange testing in registered laboratories with formal accreditation. This document summarises test methods used by the Fugro geotechnical laboratory at Leidschendam, The Netherlands, registered by STERLAB, the Dutch national body for laboratory accreditation, under number L165 for areas as described in the accreditation. Test methods used by on-site laboratories and other in-office laboratories are often identical or generally equivalent.

Laboratory tests are carried out in general accordance with standards published by ASTM International (ASTM), Eurocode (EN), and suggested methods published by the International Society of Rock Mechanics (ISRM). In-house test procedures are adopted for some tests, particularly where no standard or suggested method is available. References are indicated for each test, with the principal reference listed first. Detailed work instructions and calibration details are available for inspection at the laboratory.

Some of the laboratory tests allow various optional procedures. These procedures are not applicable, unless specifically agreed.

SAMPLE REQUIREMENTS

The feasibility of a particular laboratory test relates to the agreed sampling practice and sample handling. It depends on factors such as rock type, available amount of sample material and sample quality. Usually, a reasonable estimate of test feasibility is possible at the time of sampling. A further refinement is possible in the laboratory prior to testing and, in some cases, only after testing. The limitations of feasibility estimates may lead to rejection of samples for testing upon inspection in the laboratory or may result in appropriate comments on test results after completion of testing.

GEOTECHNICAL CLASSIFICATION, IDENTIFICATION AND DESCRIPTION

WATER CONTENT

The water content is determined by drying a selected moist/wet rock specimen for at least 18 hours to a constant mass in a drying oven. The normal oven temperature is 110°C. However, rock types with significant amount of gypsum should be tested at 50°C as the bound water may partly dehydrate at temperatures over 105°C. The difference in mass before and after drying is used as the mass of the water in the test material. The mass of material remaining after drying is used as the mass of the solid particles. The ratio of the mass of water to the measured mass of solid particles is the water content of the material. This ratio can exceed 1 (or 100%).

Test reference: ASTM D2216-05.

DENSITY AND POROSITY

Determination of the saturated and dry densities requires saturation of a rock specimen by water immersion in an evacuator. The saturated submerged mass, m_{sub}, is determined while the specimen remains immersed. The specimen is subsequently removed from the immersion bath and surface-dried with a moist cloth. The mass of saturated surface dry sample, m_{sat}, is determined. The specimen is then oven-dried and the dry mass, m_d, is measured. Densities are calculated as follows:

$$\rho_{sat} = m_{sat}\rho_w/(m_{sat}-m_{sub})$$
$$\rho_d = m_d\rho_w/(m_{sat}-m_{sub})$$

where:
ρ_{sat} = saturated density [kg/m^3]
ρ_d = dry density [kg/m^3]
m_d = mass of oven-dry specimen [kg]
ρ_w = density of water [kg/m^3]

m_{sat} = mass of saturated specimen [kg]
m_{sub} = submerged mass of saturated specimen [kg]

The porosity of a rock specimen is calculated from the measured dry density and the density of solid particles:

$$n = 100(\rho_s - \rho_d)/\rho_s$$

where:
n = porosity [%]
ρ_d = dry density [Mg/m^3]
ρ_s = density of solid particles [Mg/m^3]

Test reference: ISRM Suggested Methods.

DENSITY OF SOLID PARTICLES

The density of solid particles (specific gravity) of a rock specimen is determined by means of a stoppered - bottle pycnometer, using distilled water. Pre-treatment of the material in the pycnometer includes oven-drying, crushing and sieving through a 0.15 mm sieve.

Test reference: ISRM Suggested Methods.

MICROSCOPIC DESCRIPTION

Description of a rock specimen is based on microscopic inspection. Generally, microscopic magnifications of between 5x and 50x are used. Results include identification of rock type and principal minerals. Estimates of respective proportions of minerals are included where practicable.

Test reference: ISRM Suggested Methods.

SLAKE-DURABILITY

The slake-durability index test allows assessment of the resistance offered by a rock sample to weakening and disintegration when subjected to standard cycles of drying and wetting. Rock lumps of approximately spherical shape are placed in a standard wire mesh drum and dried in a 110°C drying oven. The oven-dry mass of the sample is determined. Subsequently the wire mesh drum is partially submerged in a trough filled with tap water and rotated for 200 revolutions during a period of 10 minutes. Again, the sample is oven-dried and its mass is determined. Two cycles of drying and wetting are performed. The slake-durability index I_{d2} is defined as the ratio of final to initial dry sample masses, expressed in percent.

Test references: ISRM Suggested Methods, ASTM D4644-04.

UNCONFINED SWELLING STRAIN

This test measures the swelling strain of an unconfined rock specimen upon immersion in water. A rock specimen of cylindrical or block shape is placed in a swelling cell. The cell is equipped with a dial gauge micrometer for measurement of displacements on the central axis of the specimen. The cell is then flooded with water and the swelling displacement recorded as a function of time elapsed. If required, swelling displacements in directions orthogonal to the central axis can also be recorded. Test results consist of the maximum unconfined swelling strain expressed in percent and the direction relative to bedding or foliation. The shape, dimensions and initial water content of the specimen are also presented.

Test reference: ISRM Suggested Methods.

PULSE VELOCITY

This test determines the pulse velocity of propagation of compressional waves in a cylindrical rock specimen. This test may be used to assess the relative quality of the rock specimen and to indicate the presence of voids and discontinuities. The apparatus consists of a pulse generator unit including a pair of transmitter and receiver transducers and a time measuring circuit. The transducers are placed axially on the specimen in such a way that they are located opposite each other. A coupling agent is used so that the transducer diaphragms make good contact with the specimen surface. The transit time and the distance between the transducers are measured. The pulse velocity is calculated as follows:

$$v = L/t$$

where:
v = pulse velocity [m/s]
L = distance between transducers [m]
t = transit time [s]

Test reference: ASTM D 2845-05.

STRENGTH TESTING

POINT LOAD STRENGTH

The point load strength index test offers rapid rock strength classification on site or in the laboratory. Results may be correlated with other strength parameters such as uni-axial tensile and compressive strengths. The point load strength index, $I_{s(50)}$, of rock specimens may be determined on rock core sections (diametral and axial tests), cut blocks (block tests) or irregular lumps (irregular lump tests). The specimens are fractured by application of a concentrated load through a standard pair of spherically truncated conical platens. The applied force to break the sample depends on the orientation and size of the specimen. Hence, to compare results, they are converted to standard values for a 50 mm core, i.e. $I_{s(50)}$ The failure load and specimen dimensions are measured. Test results are calculated as follows:

$$I_s = P/D_e^2$$
$$I_{s(50)} = (D_e/50)^{0.45}\, I_s$$

where:
I_s = uncorrected point load strength [MPa]
P = failure load [N]
D_e = equivalent core diameter [mm]
$I_{s(50)}$ = point load strength index [MPa]

In addition, the strength anisotropy index, $I_{a(50)}$, may be determined. This index is defined as the ratio of mean $I_{s(50)}$ values measured perpendicular and parallel to planes of weakness. Conversion to uni-axial compressive strength (σ_c) is dependent on rock type.

Test references: ISRM Suggested Methods, ASTM D5731-08.

UNI-AXIAL COMPRESSIVE STRENGTH (UCS)

This test determines the uni-axial compressive strength of cylindrical intact rock specimens. The test is intended for classification and characterisation of intact rock. A rock specimen with a height to diameter ratio of 2 to 2.5 is placed in a loading device. The sides of the specimen should be generally smooth and free of abrupt irregularities, with all the elements straight to within 0.5 mm over the full length of the specimen. The ends are cut parallel to each other and at right angles to the longitudinal axis. The end surfaces are lapped flat to a tolerance not to exceed 25 µm. The specimen is subsequently loaded at a constant rate of force or constant rate of strain until failure. Test results are calculated as follows:

$$\sigma_c = P/A$$

where:
σ_c = uni-axial compressive strength [MPa]
P = compressive load required to fracture the specimen [N]
A = initial cross sectional area [mm^2]

Test references: ISRM Suggested Methods, ASTM D 7012-07.

UNI-AXIAL COMPRESSIVE STRENGTH AND DEFORMABILITY (UCS)

This test determines the uni-axial compressive strength and deformability characteristics of cylindrical intact rock specimens. The test is intended for classification and characterisation of intact rock. A rock specimen with a height to diameter ratio of 2 to 3 is placed in a loading device. The specimen is subsequently loaded at a constant rate of force or constant rate of strain until failure. During loading, axial and circumferential strains are measured by two sets of two electrical resistance strain gauges glued to the specimen. Alternatively, strain measurements can consist of axial displacement transducers and a circumferential extensometer. Test results include uni-axial compressive strength, Young's modulus and Poisson's ratio. These are calculated as follows:

$$\sigma_c = P/A$$
$$E_t = \Delta\sigma/\Delta\varepsilon_a$$
$$\nu = -E_t\,(\Delta\varepsilon_d/\Delta\sigma)$$

where:
σ_c = uni-axial compressive strength [MPa]
P = compressive load required to fracture the specimen [N]
A = initial cross sectional area [mm^2]
E_t = tangent Young's modulus at 50% of σ_c [MPa]
σ = uni-axial compressive stress [MPa]
ε_a = axial strain [%]
ν = Poisson's ratio at 50% of σ_c [1]
ε_d = diametric strain [%]

Test references: ISRM Suggested Methods, ASTM D 7012-07.

TRIAXIAL COMPRESSION - MULTIPLE FAILURE STATE

Triaxial compression tests measure the strength of cylindrical intact rock specimens as a function of confining pressure. Triaxial compression with a multiple failure state comprises a single test with a stepwise increase in confining pressure. There is no provision for pore pressure measurements or for drainage of the specimen.

The test procedure is as follows:
- preparation of the specimen to a height to diameter ratio of 2 to 3
- placement of the specimen in the triaxial cell and enclosure by a flexible membrane
- simultaneous increase of the axial load and the confining pressure until the pressure meets the requirements selected for the first stage
- axial load increase at a constant strain rate ranging between 1%/s and 0.1%/s until the axial stress-axial strain curve shows a peak
- single-step increase of the confining pressure to the second stage and axial load increase as for the first stage
- third stage loading as for the second stage, but continued so that the axial stress drops to its residual value
- continuous reduction of the confining pressure so that the axial stress versus confining pressure curve follows the residual strength envelope.

The important test results consist of axial strain versus axial stress and confining pressure versus axial strain curves.

Test reference: ISRM Suggested Methods.

DIRECT SHEAR - ROCK DISCONTINUITY

Direct shear testing of rock discontinuities allows measurement of peak and post-peak shear strengths of a sheared plane, as a function of normal stress. The test apparatus consists of a shear box and ancillary equipment. The selected rock specimen is placed in the shear box so that the direction of the sheared surface coincides with that of the discontinuity. Joint Roughness Class (JRC) is assigned according to Figure 1. The specimen is fixed in the shear box by a fast-setting grout. Both single stage and multistage test techniques may be adopted. For a single stage test, the rock specimen is consolidated under a constant normal load and the normal displacement is recorded as a function of time. After consolidation, the specimen is sheared at a constant rate of displacement, while maintaining a constant normal force. Measurements are made of shear displacement, normal displacement and shear force, as a function of time. Shearing is continued beyond the peak shear force. In multistage tests, the normal load is increased or decreased after the peak shear strength has been attained. The specimen is allowed to consolidate or swell, and shearing is continued from the fixed point of the earlier stage. Resetting to the original position may be carried out if sufficient shear displacement is no longer available. Test results consist of plots of shear stress and normal displacement versus shear displacement. Values of peak and post-peak shear strength and the normal stresses and displacements at which they occur may be derived from these plots. These strengths and stresses are corrected to account for shear displacement. Shear strength parameters such a basic friction angle, apparent friction angle, post-peak friction angle, cohesion intercept and apparent cohesion may be interpreted from a single stage or by combining several stages and tests, as appropriate.

Test references: ISRM Suggested Methods, ASTM D5607-95.

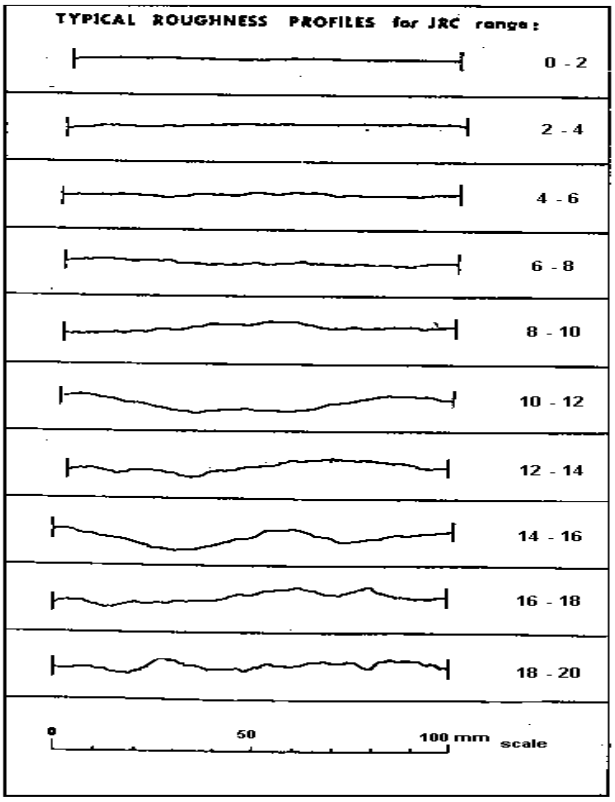

Figure 1: Joint Roughness Classes (JRC)

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CEN European Committee for Standardization (2007), “Eurocode 7 - Geotechnical Design – Part 2: Ground Investigation and Testing”, European Standard EN 1997-2:2007.

INTRODUCTION

This document is a summary of metrological confirmation systems adopted by Fugro for electric in-situ test measuring equipment for geotechnical projects. Metrological confirmation compromises calibration and verification of measuring equipment. A confirmation system demonstrates compliance with reference standards by documenting the metrological characteristics of the measuring equipment, calibration and verification. The metrological confirmation described in ISO 10012:2003 is the basis for Fugro confirmation systems.

Fugro performs a wide range of geotechnical in-situ tests with electrical measuring equipment, including the Pressuremeter Test (PMT), in-situ Vane Test (VST), T-Bar Test (TBT), hydraulic fracturing test, electrical conductivity test and in-situ temperature test. The Cone Penetration Test (CPT) is the most common in-situ test.

In-situ tests are not performed under controlled conditions, thus metrological confirmation processes are used to ensure confidence in the results. The mode of Fugro field control depends on the type of the in-situ test system and the mode of deployment.

This document primarily illustrates the confirmation system for CPT measuring equipment, including the piezo-cone penetrometer (CPTU or PCPT). The principles also apply to in-situ test measuring equipment with other types of probes.

MEASURAND

A measurand is the quantity to be measured. In most cases, this is not equivalent to the inferred value. For example, the principal measurand for a vane test is the torque required for rotation of the vane blade. The inferred value is undrained shear strength. Determination of the undrained shear strength from torque measurement requires a model for failure zone geometry and assumptions about soil behaviour during the test.

The principles for the Cone Penetration Test are similar, but more complex. For example, one of the measurands is cone resistance. This is a quantity calculated from (1) axial force measurement, (2) allowance for internal friction of penetrometer components and (3) geometry.

MEASURING EQUIPMENT

Measuring equipment includes the measuring instruments and the data acquisition system that are necessary to acquire a measurement.

Examples of in-situ test measuring instruments are the vane blade and torque sensor for the VST and the pressuremeter module for the PMT. The measuring instruments for the CPT are the cone penetrometer and the penetration sensor.

The data acquisition system links the electrical output signals from the measuring instrument to the digitally recorded data. This system includes the transmission cable, the connectors, the analogue/digital converter and the data recording software.

METROLOGICAL CHARACTERISTICS OF MEASURING EQUIPMENT

Metrological characteristics of measuring equipment are the factors that contribute to measurement uncertainty. Examples include: range, bias, repeatability, stability, hysteresis, drift, effects of influencing quantities, resolution, threshold, error, and dead band.

CALIBRATION AND CONFIRMATION

The calibration of the measuring instruments takes place in a Fugro calibration laboratory. The calibration facilities use references that are traceable to (inter)national measurement standards. For example, force calibration for a cone penetrometer is traceable to Dutch NMi (Nederlands Meet-instituut) that is certified by the Dutch RvA (Raad voor Accreditatie), which is a member of the International Laboratory Accreditation Cooperation (ILAC). The confirmation interval for a calibration laboratory is 12 months.

For example, calibration and confirmation of a piezo-cone penetrometer considers four components: (1) the load sensors used for determination of cone resistance (q_c) and sleeve friction (f_s), (2) the pressure sensor for determination of water pressure (u), (3) the inclinometer for determination of the inclination of the cone penetrometer from vertical, and (4) the geometry. Practice details are as follows:

1) Load sensors are calibrated by a special test loading facility. The test loading facility provides the calibration factors for the specified measuring range and the zero-load offsets.
2) The pressure sensor is calibrated in a special pressure vessel for cone penetrometers.
3) A special test frame provides calibration data for the inclinometer.
4) Compliance of the geometry of the cone penetrometer to (inter)national standards is verified with vernier calliper length measurements.

INTERVALS BETWEEN METROLOGICAL CONFIRMATION

Metrological confirmation of measuring equipment is generally performed as follows:

(1) Laboratory calibration of the in-situ test probe at given calendar and in-use time intervals.
(2) In-service testing of the penetration (depth) sensor to ensure it conforms to a set standard.
(3) In-service testing of the data acquisition system.

Confirmation intervals are reviewed and adjusted when necessary to ensure continuous compliance with the specified metrological requirements. Each time nonconforming measuring equipment is repaired, adjusted or modified, the interval for its metrological confirmation is reviewed. Table 1 presents a summary of typical confirmation intervals.

TABLE 1 CALIBRATION/CONFIRMATION INTERVALS

Measuring Equipment Component	Calibration/Confirmation Interval (at earliest occurrence)	Records
Measuring Instrument	- 6 months - single project or campaign of projects - in-service testing - suspected non-conformance	- calibration data certificate available on-site and in Fugro calibration laboratory - in-service testing data in project file - monitoring and control data in project file
Data Acquisition System	- in-service testing - suspected non-conformance	- calibration data certificate available on-site and in Fugro calibration laboratory - in-service testing data in project file - monitoring and control data in project file

RECORDS OF METROLOGICAL CONFIRMATION PROCESS

Dated records of the metrological confirmation process are approved by an authorized person to attest to the correctness of the results, as appropriate. These records and corresponding procedures are available to staff and to Clients upon request.

Records of the metrological confirmation process are examined to confirm that each item of measuring equipment satisfies the metrological requirements specified.

The records include the following, as applicable:

1) The description and unique identification of the in-situ test equipment manufacturer, type, serial number.
2) The date on which the metrological confirmation was completed.
3) The assigned interval for metrological confirmation.
4) General review of the in-situ test results for given ground conditions.
5) Visual inspection of the geometry of the measuring instrument and push rods upon retraction.
6) Visual inspection of the transmission cables and connectors.

7) Checks on and monitoring the zero-load offsets before and after each test. These provide an indication of the uncertainty of the test results.
8) Checks on and monitoring the responses of the load and pressure sensors to water depth. Responses provide an indication of the sensor performance.
9) Monitoring the pressure in the hydraulic thrust machine. This permits the calculation of the total force required for penetration.
10) Time checks. The real time on the clock of the recording apparatus provides the basis for recording of some measurands (for example q_c, f_s, u and z). Together, time and penetration measurements permit checks on the standardised penetration rate.

REFERENCES

ISO International Organization for Standardization (2003), "Measurement Management Systems - Requirements for Measurement Processes and Measuring Equipment", International Standard ISO 10012:2003.

INTRODUCTION

This document describes survey of horizontal and elevation/depth reference points for geotechnical and/or environmental data acquisition.

National and international standards for geotechnical and/or environmental data acquisition (as ASTM, BSI, CEN and ISO) require such surveys, but do not describe procedural details. This document summarises common practice.

PROCEDURE

The procedure for positioning survey and depth measurement is typically as follows:

- definition of the type of survey and the target location
- set-up and initial checks of the survey system
- surface positioning survey of the reference point, i.e. the determination of grid co-ordinates
- sub-surface positioning survey, i.e. adjustment of the surface positioning results for underwater offset
- measurement of the water depth
- calculation of elevation relative to a vertical datum, e.g. water level correction.

The activities depend on the project programme. For example, water level correction and sub-surface positioning may not be part of the activities agreed upon.

SURVEY CLASSIFICATIONS

Positioning surveys require specific systems and procedures, such as those presented below for offshore applications. The International Hydrographic Organization (IHO, 2008) defines four orders of hydrographic survey to accommodate different uncertainty requirements (Table 1).

TABLE 1 – SUMMARY OF IHO CLASSIFICATION

IHO Order	Special	1a	1b	2
Description of Areas	Areas where under-keel clearance is critical	Areas shallower than 100 m where under-keel clearance is less critical but features of concern to surface shipping may exist	Areas shallower than 100 m where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area	Areas generally deeper than 100 m where a general description of the seafloor is considered adequate
Maximum Allowable Total Horizontal Uncertainty 95% Confidence Level	2 m	5 m + 5% of depth	5 m + 5% of depth	20 m + 10% of depth
Maximum Allowable Total Vertical Uncertainty 95% Confidence Level	a = 0.25 m b = 0.0075	a = 0.5 m b = 0.013	a = 0.5 m b = 0.013	a = 1.0 m b = 0.023
Full Seafloor Search	Required	Required	Not required	Not required
Feature Detection	Cubic features > 1 m	Cubic features > 2 m in depths up to 40 m; 10% of depth beyond 40 m	Not applicable	Not applicable
Recommended Maximum Line Spacing	Not defined as full seafloor search is required	Not defined as full seafloor search is required	3 x average depth or 25 m, whichever is greater	4 x average depth

Note: The use of coefficients a and b is as follows:

$$\pm\sqrt{[a^2 + (b * d)^2]}$$

where:

a represents that portion of the uncertainty that does not vary with depth
b is a coefficient which represents that portion of the uncertainty that varies with depth
d is the depth
b*d represents that portion of the uncertainty that varies with depth.

Figure 1 illustrates the effect of coefficients a and b.

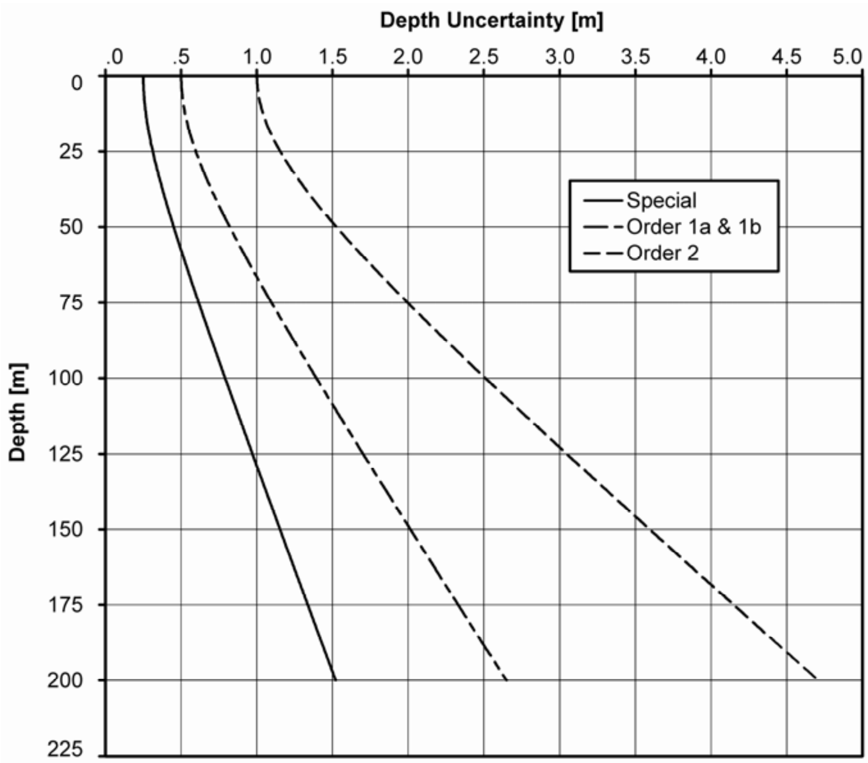

Figure 1 IHO depth uncertainty

IHO Survey Classification - Offshore Practice Examples

The IHO Special Order Survey is exceptional in geotechnical and/or environmental data acquisition. A Special Order system set-up may be comprised of: RTK DGPS; a multibeam echosounder; a motion compensator, and a Conductivity Temperature Depth (CTD) probe. Sub-surface positioning is uncommon in limited water depths.

An IHO Order 1a and 1b survey system set-up may include: high-accuracy DGPS; Long Base Line (LBL) sub-surface positioning; a CTD probe with Digiquartz pressure sensor; a barometer; and a tide gauge.

IHO Order 2 surveys are common in geotechnical and/or environmental data acquisition. Such system set-ups could include: DGPS; Ultra Short Base Line (USBL) sub-surface positioning (IMCA, 2011); CTD probe; single beam echosounder or direct sounding by drill pipe; a motion compensator; and predicted tide correction.

These are examples of the simplest set-ups. Independent measurements are often made using a redundant system. For example, surface position may be determined by two independent DGPS systems or direct sounding by drill pipe and echosounding.

Comments on Uncertainty Budget

IHO Order and offshore system set-ups involve relatively complex uncertainty budgets (uncertainty estimates). IHO considers total propagated uncertainties for the reference point on the seafloor. For example, horizontal positioning must not only consider the uncertainty of a DGPS antenna position, but also uncertainty in offset between antenna and actual position of a tool on the seafloor.

Horizontal positioning

- DGPS - antenna position uncertainty typically in the order of 1 to 2 metres.
- High accuracy DGPS - antenna position uncertainty typically in the order of 0.2 m.
- RTK DGPS – antenna position uncertainty typically in the order of centimetres.
- Gyro compass – uncertainty typically in the order of 0.5^{o} to 1^{o}.

DGPS uncertainty contributions include the geodetic network, vessel dynamics and antenna offset. Continuous logging on location allows some quantification of position uncertainty.

Sub-surface positioning

- LBL system: receiver position uncertainty typically in the order of 1 metre.
- USBL system: uncertainty of typically 0.5 m plus 1% of distance between transducer and transceiver.

Uncertainty contributions include timing, ray bending, sound absorption, noise and offset.

Water depth measurement

- Direct sounding by drill pipe: uncertainty of typically about 1 m plus 0.5% of measured mean water depth.
- Echosounder: uncertainty of typically about 0.3 m plus 1% of measured mean water depth.
- Digiquartz probe: probe position uncertainty of typically about 0.2 m plus 0.1% of measured mean water depth.
- Motion compensator: heave measurements have a typical uncertainty of 0.05 m, and roll and pitch an uncertainty of about 0.1°, relative to the mounting of the unit itself.

The pressure sensor estimates are corrected for atmospheric pressure. The echosounder estimate typically incorporates CTD sound velocity checks, motion compensation, and transducer draught, including vessel squat correction. Vessel squat is a vertical displacement of the hull as a vessel moves, and is determined by water depth and the vessel shape and size. The direct sounding estimate includes uncertainties related to tape measurement, heave, drill pipe length variation due to self-weight and temperature change, drill pipe bending and offset from vertical axis.

Tide correction

- Predicted tides: correction uncertainty typically in the order of 0.2 m to 1 m, depending on tidal range and meteorological circumstances.
- High accuracy DGPS: antenna position uncertainty typically in the order of 0.3 m.
- Tide gauge: correction uncertainty typically in the order of 0.1 m.
- RTK DGPS: antenna position uncertainty typically in the order of 0.1 m.

Uncertainty budgets can be project-specific. Soft soils, for example, can introduce uncertainty in underwater vertical position of measurement. A water pressure measurement tool mounted on an underwater frame may sink into the soil, thus affecting the measurement. Insufficient acoustic contrast between water and soft soil may affect echosounder water depth measurements.

An irregular or sloping seafloor may affect echosounder measurements. An echosounder determines the earliest arrival of acoustic waves within the beam area. The highest points within the beam are assumed to correlate with the seafloor position, and thus yield the "water depth".

Sample and Test Depths

The comments on IHO uncertainty budget apply to a reference point at seafloor. There may be additional uncertainty in the location of a test or sample. The reasons for this include:

- additional measurements. For example, measurement of the length of the drill pipe in case of a downhole sample
- offset of the test or sample location from the reference point, for example due to a towed device or inclined drill pipe.

Peuchen et al. (2005) present the following expression for offshore depth uncertainty assessment:

$$\Delta z = \pm\sqrt{[a^2 + (b * d)^2 + (c * z)^2]}$$

where:
a constant depth uncertainty, i.e. the sum of all uncertainties that do not vary with depth in metres
b uncertainty dependent on water depth, i.e. the sum of all water-depth dependent uncertainties
c uncertainty dependent on test depth, i.e. the sum of all test depth dependent uncertainties
d water depth in metres
z test depth in metres relative to seafloor
Δz test depth uncertainty in metres (95% confidence level)

Tables 2 through 4 present coefficients and accompanying premises.

TABLE 2 - COEFFICIENTS FOR DEPTH UNCERTAINTY ASSESSMENT

Geotechnical System	**Test Depth Uncertainty Δz**		
	a	**b**	**c**
Downhole – favourable	0.4 m	0.003	0.003
Downhole – adverse	1.0 m	0.005	0.004
Seabed – favourable	0.2 m	0	0.01
Seabed – adverse	0.8 m	0	0.02
Note: resolution estimated at 50% of uncertainty			

TABLE 3 - PREMISE TO ESTIMATED TEST DEPTH UNCERTAINTY – DOWNHOLE SYSTEM

Characteristics	**Offshore setting – downhole system**	
	Favourable	**Adverse**
Vessel - horizontal position	Variation within 5 m of target	Variation within 5 m of target
Vessel heave	1 m at “hook” point	3 m at “hook” point
Tidal variation	1.5 m, with correction for tidal variation by pressure sensor mounted on seabed frame	3 m, with correction for tidal variation by pressure sensor mounted on seabed frame
Seafloor	Firm and level	Very soft seabed soils or very rugged seafloor
Drill pipe checkpoint	Touchdown on seabed frame at borehole start	Touchdown on seabed frame at borehole start
Drill pipe bending	None	Minor
Borehole orientation	Vertical	Inclined at average 2^o from vertical from sea level to test depth z

TABLE 4 - PREMISE TO ESTIMATED TEST DEPTH UNCERTAINTY – SEABED SYSTEM

Characteristics	**Offshore setting – seabed system**	
	Favourable	**Adverse**
Vessel - horizontal position	Variation within 5 m of target	Variation within 5 m of target
Vessel heave	1 m at “hook” point	3 m at “hook” point
Tidal variation	1.5 m	3 m
Seafloor	Firm and level	Very soft seabed soils or very rugged seafloor
Orientation of Penetration	Vertical at start, with correction for measured inclination	Inclined at average 5^o from vertical from seafloor to test depth z

Offshore definition of the seafloor (ground surface) is difficult for extremely soft ground. Reaction equipment may penetrate unnoticed into a near-fluid zone of the seabed. Settlement may also continue during testing (Bouwmeester et al., 2009). Seabed frame settlement is likely to be governed by the following factors:

(1) Descent velocity and penetration into seabed, including possible erosion (scouring) caused by seabed frame descent and resulting water overpressures.

(2) Non-centric loading during touchdown and testing.

(3) Variable on-bottom weight of reaction equipment, because of drilling, sampling and testing activities and because of tensioning and hysteresis forces in a heave compensation system.

(4) Consolidation of seabed sediments.

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Symbol	Unit	Quantity
I - GENERAL		
L	m	Length
B	m	Width
D	m	Diameter
d	m	Depth
h	m	Height or thickness
z	m	Penetration or depth below reference level (usually ground surface)
A	m^2	Area
V	m^3	Volume
W	kN	Weight
t	s	Time
v	m/s	Velocity
a	m/s^2	Acceleration
g	m/s^2	Acceleration due to gravity ($g = 9.81\ m/s^2$)
m	kg	Mass
ρ	kg/m^3	Density
π	-	3.1416
e	-	2.71831
ln	-	Natural logarithm
log	-	Logarithm base 10
II - STRESS AND STRAIN		
u	MPa	Pore water pressure
u_o	MPa	Hydrostatic pore pressure relative to seafloor or phreatic surface
σ	kPa	Total stress
σ'	kPa	Effective stress
τ	kPa	Shear stress
$\sigma_1,\sigma_2,\sigma_3$	kPa	Principal stresses
σ'_{ho}	kPa	Effective in-situ horizontal stress
σ_{vo}	kPa	Total in-situ vertical stress relative to ground surface or phreatic surface
σ'_{vo}	kPa	Effective in-situ vertical stress (or p'_o)
σ'_h	kPa	Effective horizontal stress
σ'_v	kPa	Effective vertical stress
r_u	-	Pore pressure ratio [= u/σ_{vo}]
p'	kPa	Mean effective stress [= $(\sigma'_1 + 2\sigma'_3)/3$] or [= $(\sigma'_1 + \sigma'_2 + \sigma'_3)/3$]
q	kPa	Principal deviator stress [= $\sigma'_1 - \sigma'_3$] or [= $\sigma_1 - \sigma_3$]
ε	-	Linear strain
$\varepsilon_1,\varepsilon_2,\varepsilon_3$	-	Principal strains
ε_v	-	Volumetric strain
γ	-	Shear strain
ν	-	Poisson's ratio
ν_u	-	Poisson's ratio for undrained stress change
ν_d	-	Poisson's ratio for drained stress change
E	MPa	Modulus of linear deformation (Young's modulus)
E_u	MPa	Modulus of linear deformation (Young's modulus for undrained stress change)
E_d	MPa	Modulus of linear deformation (Young's modulus for drained stress change)
G	MPa	Modulus of shear deformation (shear modulus)
G_{max}	MPa	Shear modulus at small strain
K	MPa	Modulus of compressibility (bulk modulus)
M	MPa	Constrained modulus [= $1/m_v$]
μ	-	Coefficient of friction
η	kPa.s	Coefficient of viscosity

Symbol	Unit	Quantity

III - PHYSICAL CHARACTERISTICS OF GROUND

(a) Density and Unit weights

γ	kN/m^3	Unit weight of ground (or bulk unit weight or total unit weight)
γ_d	kN/m^3	Unit weight of dry ground
γ_s	kN/m^3	Unit weight of solid particles
γ_w	kN/m^3	Unit weight of water
γ_{pf}	kN/m^3	Unit weight of pore fluid
γ_{dmin}	kN/m^3	Minimum index (dry) unit weight
γ_{dmax}	kN/m^3	Maximum index (dry) unit weight
γ' or γ_{sub}	kN/m^3	Unit weight of submerged ground
ρ	Mg/m^3 [= t/m^3]	Density of ground
ρ_d	Mg/m^3 [= t/m^3]	Density of dry ground
ρ_s	Mg/m^3 [= t/m^3]	Density of solid particles
ρ_w	Mg/m^3 [= t/m^3]	Density of water
D_r	-, %	Relative density [= $\gamma_{dmax}(\gamma_d-\gamma_{dmin})/\gamma_d(\gamma_{dmax}-\gamma_{dmin})$]
v	-	Specific volume [= 1+e]
e	-	Void ratio
e_o	-	Initial void ratio
e_{max}	-	Maximum index void ratio
e_{min}	-	Minimum index void ratio
I_d	-, %	Density index [= $(\gamma_d-\gamma_{dmin})/(\gamma_{dmax}-\gamma_{dmin})$]
R_D	-, %	Dry density ratio [= γ_d/γ_{dmax}]
n	-, %	Porosity
w	%	Water content
S_r	%	Degree of saturation
r	-, g/kg	Salinity of pore fluid [= ratio of mass of salt to mass of pore fluid]
R	g/l	Salinity of fluid [= ratio of mass of salt to volume of distilled water]
s	g/l	Salinity of fluid [= ratio of mass of salt to volume of fluid]
S	g/kg	Salinity of seawater [= ratio of mass of salt to mass of seawater]

(b) Consistency

w_L	%	Liquid limit
w_P	%	Plastic limit
I_P	%	Plasticity index [= $w_L - w_P$]
I_L	%	Liquidity index [= $(w - w_P)/(w_L - w_P)$]
I_C	%	Consistency index [= $(w_L - w)/(w_L - w_P)$]
A	-, %	Activity [= ratio of plasticity index to percentage by weight of clay-size particles]

(c) Particle size

D	mm	Particle diameter
D_n	mm	n percent diameter [n% < D]
C_u	-	Uniformity coefficient [= D_{60}/D_{10}]
C_c	-	Curvature coefficient [= $(D_{30})^2/D_{10}D_{60}$]

(d) Dynamic Properties

v_p	m/s	P-wave velocity (compression wave velocity)
v_s	m/s	S-wave velocity (shear wave velocity)
v_{s1}	m/s	S-wave velocity normalised to 100 kPa in-situ vertical stress
D	-, %	Damping ratio of ground

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Symbol	Unit	Quantity

(e) Hydraulic properties

Symbol	Unit	Quantity
k	m/s	Coefficient of permeability
k_v	m/s	Coefficient of vertical permeability
k_h	m/s	Coefficient of horizontal permeability
i	-	Hydraulic gradient

(f) Thermal and Electrical properties

Symbol	Unit	Quantity
T	°C	Temperature
k	W/(m.K)	Thermal conductivity
a_L	1/°C	Thermal expansion coefficient (linear)
α	m^2/s	Thermal diffusion coefficient
ρ	Ω.m	Electrical resistivity
K	S/m	Electrical conductivity

(g) Magnetic properties

Symbol	Unit	Quantity
B	T	Magnetic flux density (or magnetic induction)

(h) Radioactive properties

Symbol	Unit	Quantity
γ	CPS	Natural gamma ray

IV - MECHANICAL CHARACTERISTICS OF GROUND

(a) Cone Penetration Test (CPT)

Symbol	Unit	Quantity
q_c	MPa	Cone resistance
q_{c1}	MPa	Cone resistance normalised to 100 kPa effective in-situ vertical stress
f_s	MPa	Sleeve friction
f_t	MPa	Sleeve friction corrected for pore pressures acting on the end areas of the friction sleeve
R_f	%	Ratio of sleeve friction to cone resistance
R_{ft}	%	Ratio of sleeve friction to corrected cone resistance (f_s/q_t or f_t/q_t)
u_1	MPa	Pore pressure at the face of the cone
u_2	MPa	Pore pressure at the cylindrical extension above the base of the cone or in the gap between the friction sleeve and the cone
u_2*	MPa	Pore pressure u_2, but derived rather than measured
u_3	MPa	Pore pressure immediately above the friction sleeve or in the gap above the friction sleeve
K	-	Adjustment factor for ratio of pore pressure at u_1 to u_2 location
q_n	MPa	Net cone resistance
q_t	MPa	Corrected cone resistance (or total cone resistance)
B_q	-	Pore pressure ratio
Q_t	-	Normalized cone resistance [= q_n/σ'_{vo}]
F_r	%	Normalized friction ratio [= f_t/q_n]
N_c	-	Cone factor between q_c and c_u
N_k	-	Cone factor between q_n and c_u

(b) Standard Penetration Test (SPT)

Symbol	Unit	Quantity
N	Blows/0.3 m	SPT blowcount
N_{60}	Blows/0.3 m	SPT blowcount normalised to 60% energy
$N_{1,60}$	Blows/0.3 m	SPT blowcount normalised to 60% energy and to 100 kPa effective in-situ vertical stress

Symbol	Unit	Quantity

(c) Strength of soil

c_u	kPa	Undrained shear strength (or s_u)
c_u/σ'_{vo}	-	Undrained strength ratio
κ	kPa/m	Rate of increase of undrained shear strength with depth (linear)
c'	kPa	Effective cohesion intercept
φ'	°(deg)	Effective angle of internal friction
φ'_{cv}	°(deg)	Effective angle of internal friction at large strain
ε_{50}	%	Strain at 50% of peak deviator stress (or ε_c)
E_{50}	MPa	Young's modulus at 50% of peak deviator stress
$c_{u;r}$	kPa	Undrained shear strength of remoulded soil
c_R	kPa	Undrained residual shear strength
S_t	-	Sensitivity [= $c_u/c_{u;r}$ or c_u/c_R]
T_x	-	Thixotropy ratio [$T_x(t) = c_{u;r}(t)/c_{u;r}(t=0)$]
σ'_c	kPa	Effective consolidation pressure
M	-	Gradient of critical state line when projected onto a constant volume plane
A	-	Pore pressure coefficient for anisotropic pressure increment
B	-	Pore pressure coefficient for isotropic pressure increment

(d) Strength of rock

$I_{s(50)}$	MPa	Point load strength index
σ_c	MPa	Uni-axial compressive strength

(e) Consolidation (one dimensional)

σ'_p	kPa	Effective preconsolidation pressure (or effective vertical yield stress in-situ)
σ'_{vy}	kPa	Effective vertical yield stress in-situ (or effective preconsolidation pressure)
C_c	-	Compression index
C_s	-	Swelling index (or re-compression)
CR	-	Primary compression ratio [= $C_c/(1+e_0)$]
RR	-	Recompression ratio [= $C_s/(1+e_0)$]
e_0	-	Void ratio at σ'_{vo}
C_α	-	Coefficient of secondary consolidation (primary compression)
$C_{\alpha s}$	-	Coefficient of secondary consolidation (swell/re-compression)
c_v	m^2/s	Coefficient of consolidation
H	m	Drainage path length
m_v	m^2/MN	Coefficient of volume compressibility
M	MPa	Constrained modulus [= $1/m_v$]
p	kPa	Vertical pressure
OCR	-	Overconsolidation ratio [= σ'_p/σ'_{vo}]
YSR	-	Yield stress ratio [= $\sigma'_{vy}/\sigma'_{vo}$]

V - GEOTECHNICAL DESIGN

(a) Partial factors

γ_m	-	Material factor (partial safety factor)
γ_f	-	Load factor (partial action factor)

(b) Seismicity

a_g	m/s^2	Effective peak ground acceleration (design ground acceleration)
d_g	m	Peak ground displacement
α	-	Acceleration ratio [= a_g/g]
τ_c	kPa	Seismic shear stress

Symbol	Unit	Quantity
(c) Compaction		
ρ_{dmax}	Mg/m^3 [= t/m^3]	Maximum dry density
ρ_{max}	Mg/m^3 [= t/m^3]	Maximum density
w_{opt}	%	Optimum moisture content
(d) Earth pressure		
δ	°(deg)	Angle of interface friction (between ground and foundation)
K	-	Coefficient of lateral earth pressure
K_a	-	Coefficient of active earth pressure
K_{ac}	-	Coefficient of active earth pressure for total stress analysis
K_p	-	Coefficient of passive earth pressure
K_{pc}	-	Coefficient of passive earth pressure for total stress analysis
K_o	-	Coefficient of earth pressure at rest
K_{onc}	-	K_o for normally consolidated soil
K_{ooc}	-	K_o for overconsolidated soil
(e) Foundations		
A	m^2	Total foundation area
A'	m^2	Effective foundation area
B'	m	Effective width of foundation
E_s	MN/m^3	Modulus of subgrade reaction
k	MPa/m	Rate of change of modulus of subgrade reaction E_s with depth z
L'	m	Effective length of foundation
H	MN	Horizontal external force or action
V	MN	Vertical external force or action
M	MN.m	External moment
T	MN.m	External torsion moment
Q	MN	Total vertical resistance of a foundation/pile
Q_p	MN	End-bearing of pile
Q_s	MN	Shaft resistance of pile
q_p	MPa	Unit end-bearing
q_{lim}	MPa	Limit unit end-bearing
f	kPa	Unit skin friction (or q_s)
f_{lim}	kPa	Limit unit skin friction
p	MN/m	Lateral resistance per unit length of pile
p_{lim}	MN/m	Limit lateral resistance per unit length of pile
s	m	Settlement
t	MN/m	Skin friction per unit length of pile
y	mm	Lateral pile deflection
z	mm	Axial pile displacement
α	-	Adhesion factor between ground and foundation (= f/c_u)
β	-	Adhesion factor between ground and foundation (= f/σ'_v or f/σ'_{vo})
δ	°(deg)	Angle of interface friction (between ground and foundation)
δ_{cv}	°(deg)	Constant volume or critical-state angle of interface friction (between ground and foundation)
N_c,N_q,N_γ	-	Bearing capacity factors
K_c,K_q,K_γ	-	Bearing capacity correction factors for inclined forces or actions, foundation shape and depth of embedment
i_c,i_q,i_γ	-	Bearing capacity correction factors for external force inclined from vertical
s_c,s_q,s_γ	-	Bearing capacity correction factors for foundation shape
d_c,d_q,d_γ	-	Bearing capacity correction factors for foundation embedment

Signs:
- A "prime" applies to effective stress.
- A "bar" above a symbol relates to average properties.
- A "dot" above a symbol denotes derivative with respect to time.
- The prefix "Δ" denotes an increment or a change.
- A “star” after a symbol denotes value corrected for pore fluid salinity.

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APÊNDICE 2: MEDIÇÕES DE ENERGIA

1 INTRODUÇÃO

O presente relatório tem o objetivo de apresentar os resultados de medidas de energia dos golpes dos ensaios de SPT. Foram medidas energias dos golpes do sistema mecanizado da perfuratriz Commachio 1200 nos furos POR-06 e POR-10, pertencentes às obras de alargamento do canal dragado da Baía de Guanabara.

As medições foram realizadas acoplando-se uma haste instrumentada com 2 acelerômetros e 2 *strain gages* no sistema do SPT. Os dados foram coletados e armazenados através do equipamento Pile Drive Analyzer, modelo PAX.

Os ensaios foram realizados nos dias 09 e 10 de junho de 2015.

2 ENERGIA DO ENSAIO SPT

2.1 SPT Mecanizado

O ensaio SPT, *Standard Penetration Test*, ou Sondagem de Simples Reconhecimento, é normatizado no Brasil pela NBR 6484. Esta norma preconiza que os golpes devem ser aplicados por um martelo de queda livre com peso de 65 kgf (0,638 kN), com altura de queda de 0,75 m. Portanto, a energia potencial nominal inicial do sistema é de 0,4782 kN.m (considerando a gravidade como 9,81 m/s).

Nos furos POR-06 e POR-10 foram realizados ensaios de SPT através do sistema mecanizado da perfuratriz Commachio 1200.

3 MEDIÇÃO DA ENERGIA

3.1 Medida da Energia dos Golpes

A energia transmitida pelos golpes foi medida através do acoplamento de uma haste instrumentada na porção superior da composição das hastes durante os ensaios. A Figura 1 mostra um detalhe da haste instrumentada utilizada. A instrumentação da haste é composta por 2 acelerômetros e 2 *strain gages*. Durante a aplicação dos golpes, os dados são coletados e armazenados no aparelho *Pile Driving Analyzer*, mostrado na Figura 2.

O aparelho coleta os sinais de força (obtida através dos *strain gages*) e velocidade (obtida através dos acelerômetros) gerados pela aplicação dos golpes. A energia máxima transmitida pelo golpe é calculada através da integral do produto da força pela velocidade ao longo do tempo (tempo de duração do golpe). A Figura 3 apresenta um exemplo de sinal de força e velocidade coletado durante as medições.

Após o cálculo da energia máxima transmitida (EMX) é possível calcular a eficiência do golpe, através da razão entre a EMX e a energia nominal da NBR 6484, que é de 0,4782 kN.m. Esta eficiência é chamada de ETR (*Energy Transfer R*atio), que usualmente é expressa em porcentagem.

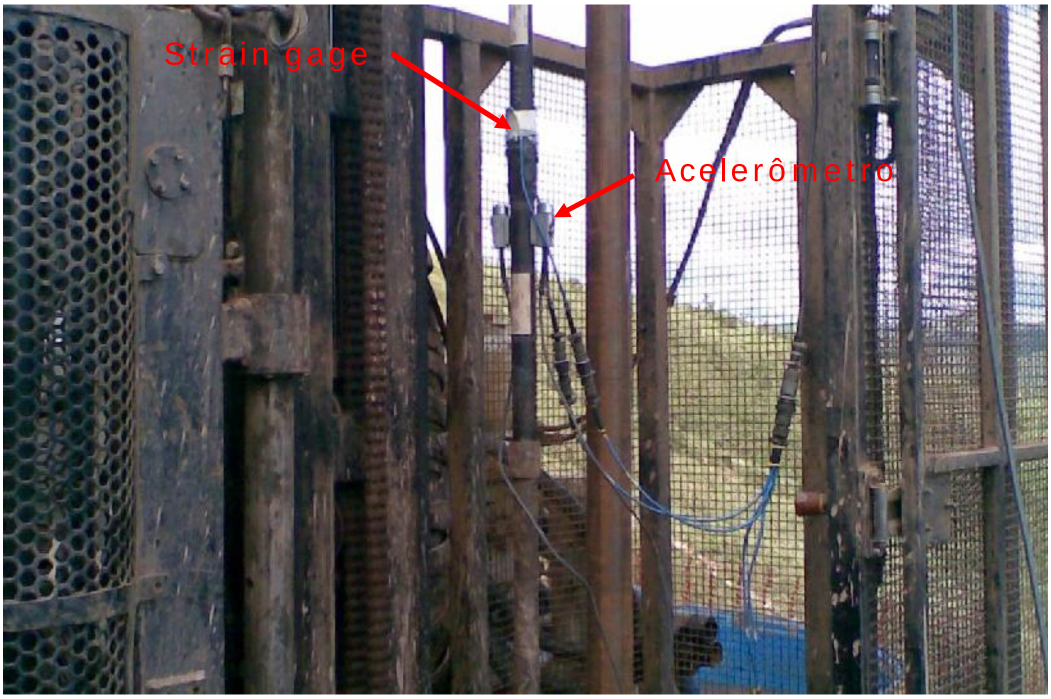


Figura 1 – Detalhe da haste instrumentada.

Figura 2 – *Pile Driving Analyzer.*

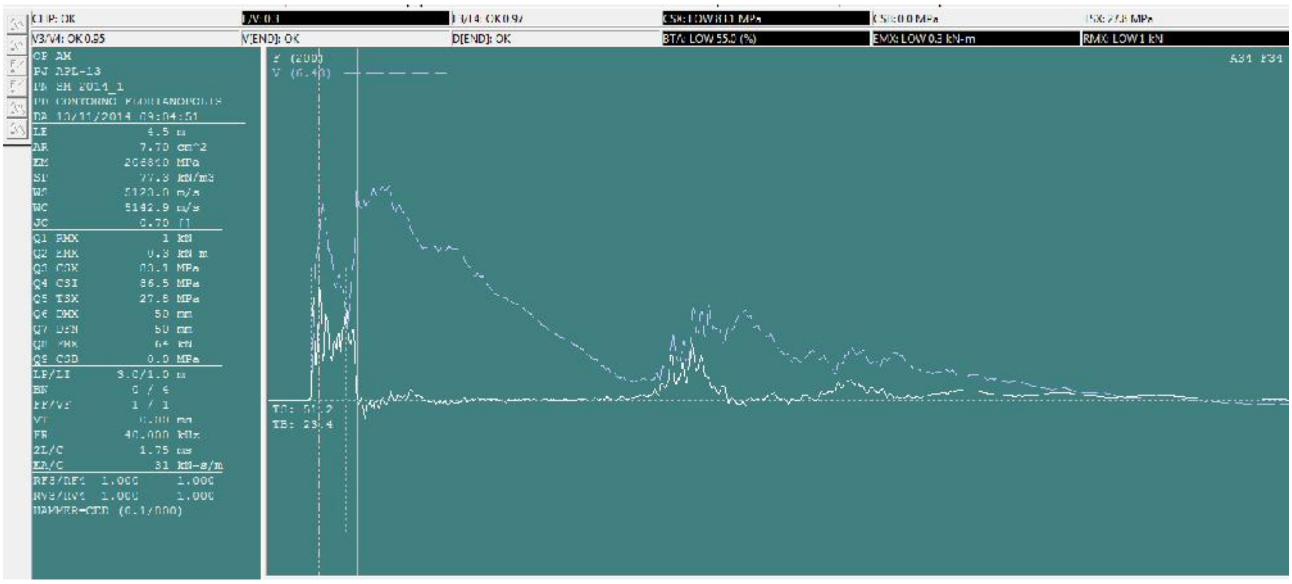


Figura 3 – Curvas de Força e Velocidade.

3.2 Energia do SPT Mecanizado

Foram monitorados um total de 105 golpes da perfuratriz Commachio 1200 no ponto POR-06 e 120 golpes da perfuratriz Commachio 1200 no ponto POR-10, pertencentes às obras de alargamento do canal dragado da Baía de Guanabara. As profundidades do amostrador foram entre 10,8 m e 17,3 m no ponto POR-06 e entre 11,9 m e 17,9 m no ponto POR-10.

A média da energia máxima transmitida pelos golpes foi de 0,2951 kN.m, com um desvio padrão de 0,0083 kN.m , no ponto POR-06 e de 0,3014 kN.m, com um desvio padrão de 0,0092 kN.m, no ponto POR-10.

A eficiência média foi de 61,7% no ponto POR-06 e 63,0% no ponto POR-10.

Os valores de energia (EMX) e eficiência (ETR) de cada um dos golpes monitorados são mostrados no Anexo I. Pode-se utilizar a Distribuição t de Student para estimar a média da energia do sistema avaliado através da seguinte expressão:

$$\bar{x} - t_{\propto/2}.\frac{s}{\sqrt{n}} \leq \mu \leq \bar{x} + t_{\propto/2}.\frac{s}{\sqrt{n}} \quad (1)$$

Onde:
$\bar{x}$ = Média da energia obtida nas medições;
$t_{\propto/2}$ = Valor tabelado, em função dos graus de liberdade e intervalo de confiança;
s = Desvio padrão dos valores obtidos nas medições;
n = Número de medições feitas;
μ = Estimativa da energia do sistema avaliado.

Para o ponto POR-06, o número de graus de liberdade é igual 104 (n-1). Para um nível de confiança de 99,9%, o valor de $t_{\propto/2}$ é 3,3865. Portanto, podemos afirmar, com confiança de 99,9%, que o valor da energia dos golpes do SPT mecanizado da perfuratriz Commachio 1200 está compreendido entre 0,2924 e 0,2978 kN.m. Logo, a eficiência, calculada em relação ao valor de energia padrão da NBR 6484 (0,4782 kN.m) está compreendida entre 61,1 e 62,3%, com valor médio de 61,7%.

Já para o ponto POR-10, o número de graus de liberdade é igual 119 (n-1). Para um nível de confiança de 99,9%, o valor de $t_{\propto/2}$ é 3,3742. Portanto, podemos afirmar, com confiança de 99,9%, que o valor da energia dos golpes do SPT mecanizado da perfuratriz Commachio 1200 está compreendido entre 0,2986 e 0,3043 kN.m. Logo, a eficiência, calculada em relação ao valor de energia padrão da NBR 6484 (0,4782 kN.m) está compreendida entre 62,4 e 63,6%, com valor médio de 63,0%.

4 CONCLUSÕES

O presente relatório apresentou os resultados de medidas de energia dos golpes dos ensaios de SPT. Foram medidas energias dos golpes do sistema mecanizado da perfuratriz Commachio 1200, nos furos POR-06 e POR-10, respectivamente, pertencentes às obras de alargamento do canal dragado da Baía de Guanabara.

As eficiências médias encontradas para os furos monitorados, considerando a energia nominal da NBR 6484 (0,4782 kN.m), foram de 61,7% para o furo POR-06 e 63,0% para o furo POR-10.

ANEXO IA
POR-06 – ENERGIA DOS GOLPES MONITORADOS – COMMACHIO 1200

ANEXO I
PROGRAMA DE INSTRUMENTAÇÃO – RESUMO DOS RESULTADOS

Obra:	ALARGAMENTO DO CANAL DRAGADO
Área/Setor:	BAIA DE GUANABARA
Furo:	POR-06
Tipo de Sondagem:	SPT
Perfuratriz:	COMMACHIO 1200
Martelo:	AUTOMATIC TRIP HAMMER

Date	Time	LP meters	BN	ENERGIA MÁX kN-meters	EFICIÊNCIA (%)	Local
09/06/2015	22:07:05	10,8	1	0,3041	63,6	
09/06/2015	22:07:16	10,8	2	0,2931	61,3	
09/06/2015	22:07:28	10,8	3	0,2887	60,4	
09/06/2015	22:07:41	10,8	4	0,2944	61,6	
09/06/2015	22:07:51	10,8	5	0,2849	59,6	
09/06/2015	22:08:01	10,8	6	0,2923	61,1	
09/06/2015	22:08:12	10,8	7	0,2891	60,5	
09/06/2015	22:08:21	10,8	8	0,2918	61,0	
09/06/2015	22:08:32	10,8	9	0,2806	58,7	
09/06/2015	22:08:43	10,8	10	0,2826	59,1	
09/06/2015	22:08:54	10,8	11	0,2971	62,1	
09/06/2015	22:09:05	10,8	12	0,2867	59,9	
09/06/2015	22:09:18	10,8	13	0,2935	61,4	
09/06/2015	22:09:30	10,8	14	0,2852	59,6	
09/06/2015	22:09:39	10,8	15	0,2908	60,8	
09/06/2015	23:34:11	12,3	16	0,2967	62,0	
09/06/2015	23:34:24	12,3	17	0,3036	63,5	
09/06/2015	23:34:36	12,3	18	0,2936	61,4	
09/06/2015	23:34:46	12,3	19	0,2847	59,5	
09/06/2015	23:35:08	12,3	20	0,2802	58,6	
09/06/2015	23:35:18	12,3	21	0,2919	61,0	
09/06/2015	23:35:32	12,3	22	0,2808	58,7	
09/06/2015	23:35:44	12,3	23	0,2790	58,3	
09/06/2015	23:35:56	12,3	24	0,2851	59,6	
09/06/2015	23:36:06	12,3	25	0,2959	61,9	
09/06/2015	23:36:14	12,3	26	0,2916	61,0	
09/06/2015	23:36:35	12,3	27	0,2899	60,6	
09/06/2015	23:36:45	12,3	28	0,2896	60,6	
09/06/2015	23:36:56	12,3	29	0,2938	61,4	POR-06
09/06/2015	23:37:05	12,3	30	0,3001	62,8	
09/06/2015	23:37:15	12,3	31	0,2987	62,5	
09/06/2015	23:37:24	12,3	32	0,2890	60,4	
09/06/2015	23:37:34	12,3	33	0,2896	60,6	
09/06/2015	23:37:47	12,3	34	0,2940	61,5	
10/06/2015	00:38:40	13,8	35	0,3010	62,9	
10/06/2015	00:38:47	13,8	36	0,2871	60,0	
10/06/2015	00:38:53	13,8	37	0,2875	60,1	
10/06/2015	00:39:05	13,8	38	0,2863	59,9	
10/06/2015	00:39:10	13,8	39	0,3001	62,8	
10/06/2015	00:39:17	13,8	40	0,2825	59,1	
10/06/2015	00:39:26	13,8	41	0,2900	60,6	
10/06/2015	00:39:35	13,8	42	0,2988	62,5	
10/06/2015	00:39:42	13,8	43	0,3054	63,9	
10/06/2015	00:39:49	13,8	44	0,2960	61,9	
10/06/2015	00:39:54	13,8	45	0,2958	61,9	
10/06/2015	00:40:00	13,8	46	0,3019	63,1	
10/06/2015	00:40:05	13,8	47	0,2992	62,6	
10/06/2015	00:40:11	13,8	48	0,2924	61,1	
10/06/2015	00:40:17	13,8	49	0,2866	59,9	
10/06/2015	00:40:28	13,8	50	0,2931	61,3	
10/06/2015	00:40:40	13,8	51	0,2871	60,0	
10/06/2015	00:40:46	13,8	52	0,2929	61,2	
10/06/2015	00:40:53	13,8	53	0,2816	58,9	
10/06/2015	00:40:59	13,8	54	0,2982	62,4	
10/06/2015	00:41:05	13,8	55	0,2923	61,1	
10/06/2015	00:41:10	13,8	56	0,2974	62,2	
10/06/2015	00:41:18	13,8	57	0,2965	62,0	

ANEXO I
PROGRAMA DE INSTRUMENTAÇÃO – RESUMO DOS RESULTADOS

Obra:	ALARGAMENTO DO CANAL DRAGADO
Área/Setor:	BAIA DE GUANABARA
Furo:	POR-06
Tipo de Sondagem:	SPT
Perfuratriz:	COMMACHIO 1200
Martelo:	AUTOMATIC TRIP HAMMER

Date	Time	LP meters	BN	ENERGIA MÁX kN-meters	EFICIÊNCIA (%)	Local
10/06/2015	01:57:17	15,3	58	0,2879	60,2	POR-06
10/06/2015	01:57:23	15,3	59	0,2979	62,3	
10/06/2015	01:57:29	15,3	60	0,3121	65,3	
10/06/2015	01:57:35	15,3	61	0,3110	65,0	
10/06/2015	01:57:41	15,3	62	0,3055	63,9	
10/06/2015	01:57:46	15,3	63	0,3048	63,7	
10/06/2015	01:57:52	15,3	64	0,3035	63,5	
10/06/2015	01:57:58	15,3	65	0,2971	62,1	
10/06/2015	01:58:04	15,3	66	0,3042	63,6	
10/06/2015	01:58:09	15,3	67	0,2937	61,4	
10/06/2015	01:58:17	15,3	68	0,3045	63,7	
10/06/2015	01:58:26	15,3	69	0,2923	61,1	
10/06/2015	01:58:32	15,3	70	0,3109	65,0	
10/06/2015	01:58:38	15,3	71	0,3050	63,8	
10/06/2015	01:58:43	15,3	72	0,3024	63,2	
10/06/2015	01:58:48	15,3	73	0,2866	59,9	
10/06/2015	01:59:07	15,3	74	0,2895	60,5	
10/06/2015	01:59:12	15,3	75	0,2936	61,4	
10/06/2015	01:59:24	15,3	76	0,2975	62,2	
10/06/2015	01:59:29	15,3	77	0,2910	60,8	
10/06/2015	01:59:34	15,3	78	0,3042	63,6	
10/06/2015	01:59:40	15,3	79	0,2897	60,6	
10/06/2015	01:59:45	15,3	80	0,2998	62,7	
10/06/2015	01:59:51	15,3	81	0,2989	62,5	
10/06/2015	01:59:56	15,3	82	0,2969	62,1	
10/06/2015	02:00:01	15,3	83	0,3146	65,8	
10/06/2015	02:00:06	15,3	84	0,2860	59,8	
10/06/2015	02:00:12	15,3	85	0,2958	61,9	
10/06/2015	02:00:17	15,3	86	0,2958	61,9	
10/06/2015	04:09:05	17,3	87	0,3018	63,1	
10/06/2015	04:09:14	17,3	88	0,2892	60,5	
10/06/2015	04:09:22	17,3	89	0,2931	61,3	
10/06/2015	04:09:28	17,3	90	0,3032	63,4	
10/06/2015	04:09:34	17,3	91	0,2838	59,3	
10/06/2015	04:09:41	17,3	92	0,2800	58,5	
10/06/2015	04:09:47	17,3	93	0,2976	62,2	
10/06/2015	04:09:53	17,3	94	0,2878	60,2	
10/06/2015	04:10:00	17,3	95	0,2971	62,1	
10/06/2015	04:10:07	17,3	96	0,3032	63,4	
10/06/2015	04:10:13	17,3	97	0,3023	63,2	
10/06/2015	04:10:20	17,3	98	0,2991	62,5	
10/06/2015	04:10:26	17,3	99	0,3042	63,6	
10/06/2015	04:10:31	17,3	100	0,3076	64,3	
10/06/2015	04:10:37	17,3	101	0,3179	66,5	
10/06/2015	04:10:44	17,3	102	0,2956	61,8	
10/06/2015	04:10:53	17,3	103	0,3020	63,1	
10/06/2015	04:11:02	17,3	104	0,3014	63,0	
10/06/2015	04:11:08	17,3	105	0,3145	65,8	
			Média	0,2951	61,7	
			Desvio padrão	0,0083	1,7	

ANEXO IB
POR-10 – ENERGIA DOS GOLPES MONITORADOS – COMMACHIO 1200

ANEXO I
PROGRAMA DE INSTRUMENTAÇÃO – RESUMO DOS RESULTADOS

Obra:	ALARGAMENTO DO CANAL DRAGADO
Área/Setor:	BAIA DE GUANABARA
Furo:	POR-10
Tipo de Sondagem:	SPT
Perfuratriz:	COMMACHIO 1200
Martelo:	AUTOMATIC TRIP HAMMER

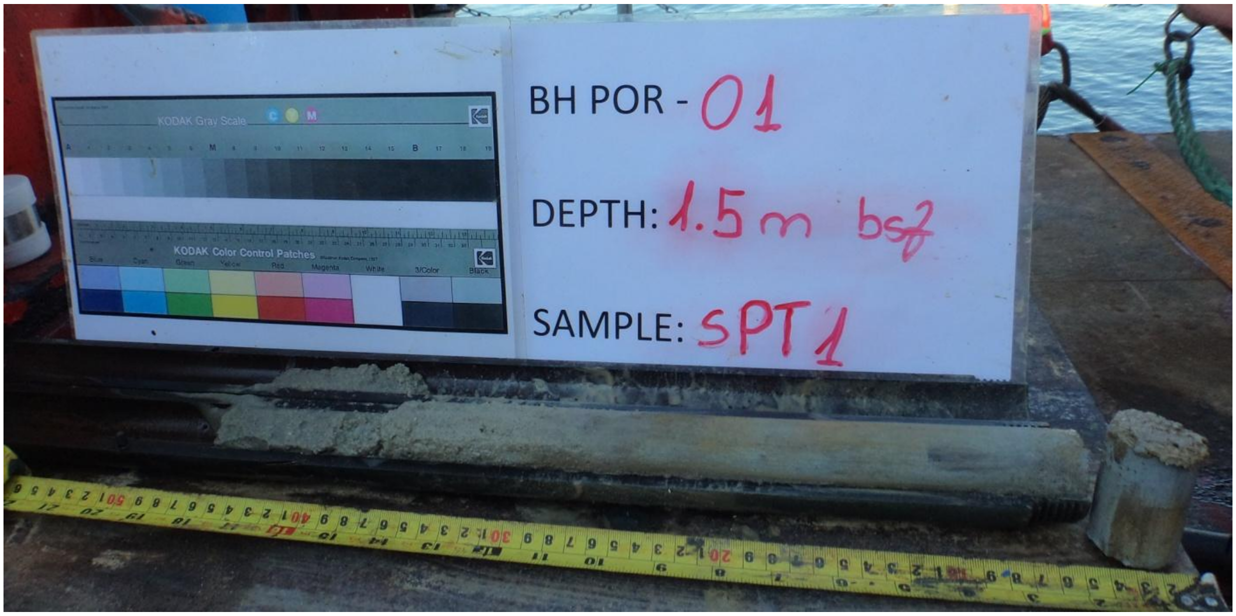
Date	Time	LP meters	BN	ENERGIA MÁX kN-meters	EFICIÊNCIA (%)	Local
09/06/2015	00:09:47	11,9	1	0,2904	60,7	POR-10
09/06/2015	00:09:58	11,9	2	0,3120	65,2	
09/06/2015	00:10:09	11,9	3	0,3053	63,8	
09/06/2015	00:10:18	11,9	4	0,3084	64,5	
09/06/2015	00:10:27	11,9	5	0,3069	64,2	
09/06/2015	00:10:38	11,9	6	0,3135	65,6	
09/06/2015	00:10:48	11,9	7	0,3114	65,1	
09/06/2015	00:10:59	11,9	8	0,3101	64,8	
09/06/2015	00:11:10	11,9	9	0,2974	62,2	
09/06/2015	00:11:20	11,9	10	0,3038	63,5	
09/06/2015	00:11:34	11,9	11	0,3102	64,9	
09/06/2015	00:11:43	11,9	12	0,3051	63,8	
09/06/2015	00:11:53	11,9	13	0,3048	63,7	
09/06/2015	00:12:03	11,9	14	0,3000	62,7	
09/06/2015	00:12:14	11,9	15	0,2933	61,3	
09/06/2015	00:12:23	11,9	16	0,3023	63,2	
09/06/2015	00:12:33	11,9	17	0,3062	64,0	
09/06/2015	00:12:44	11,9	18	0,2953	61,7	
09/06/2015	01:35:55	13,4	19	0,2783	58,2	
09/06/2015	01:36:05	13,4	20	0,2954	61,8	
09/06/2015	01:36:12	13,4	21	0,3014	63,0	
09/06/2015	01:36:20	13,4	22	0,2947	61,6	
09/06/2015	01:36:33	13,4	23	0,2869	60,0	
09/06/2015	01:36:46	13,4	24	0,2837	59,3	
09/06/2015	01:36:55	13,4	25	0,2926	61,2	
09/06/2015	01:37:03	13,4	26	0,2998	62,7	
09/06/2015	01:37:12	13,4	27	0,2931	61,3	
09/06/2015	01:37:18	13,4	28	0,2813	58,8	
09/06/2015	01:37:29	13,4	29	0,3010	62,9	
09/06/2015	01:37:36	13,4	30	0,2800	58,5	
09/06/2015	01:37:44	13,4	31	0,2933	61,3	
09/06/2015	01:38:05	13,4	32	0,2906	60,8	
09/06/2015	01:38:12	13,4	33	0,2948	61,6	
09/06/2015	01:38:19	13,4	34	0,2841	59,4	
09/06/2015	01:38:34	13,4	35	0,2856	59,7	
09/06/2015	01:38:41	13,4	36	0,2899	60,6	
09/06/2015	01:38:48	13,4	37	0,2848	59,6	
09/06/2015	01:38:56	13,4	38	0,2961	61,9	
09/06/2015	01:39:04	13,4	39	0,2988	62,5	
09/06/2015	01:39:14	13,4	40	0,2937	61,4	
09/06/2015	01:39:20	13,4	41	0,2934	61,4	
09/06/2015	01:39:27	13,4	42	0,3001	62,8	
09/06/2015	01:39:35	13,4	43	0,2906	60,8	
09/06/2015	01:39:44	13,4	44	0,2918	61,0	
09/06/2015	01:39:53	13,4	45	0,3069	64,2	
09/06/2015	01:40:00	13,4	46	0,2810	58,8	
09/06/2015	03:11:37	14,9	47	0,2824	59,1	
09/06/2015	03:11:48	14,9	48	0,2834	59,3	
09/06/2015	03:12:02	14,9	49	0,3082	64,4	
09/06/2015	03:12:21	14,9	50	0,3074	64,3	
09/06/2015	03:12:34	14,9	51	0,3082	64,4	
09/06/2015	03:13:01	14,9	52	0,3037	63,5	
09/06/2015	03:13:20	14,9	53	0,2857	59,7	
09/06/2015	03:13:34	14,9	54	0,2980	62,3	
09/06/2015	03:13:42	14,9	55	0,2901	60,7	
09/06/2015	03:36:14	14,9	56	0,3048	63,7	
09/06/2015	03:36:23	14,9	57	0,3008	62,9	
09/06/2015	03:36:33	14,9	58	0,3024	63,2	
09/06/2015	03:36:42	14,9	59	0,3034	63,4	
09/06/2015	03:36:52	14,9	60	0,2997	62,7	
09/06/2015	03:37:04	14,9	61	0,3012	63,0	
09/06/2015	03:37:13	14,9	62	0,2984	62,4	
09/06/2015	03:37:25	14,9	63	0,2975	62,2	
09/06/2015	03:37:36	14,9	64	0,3030	63,4	
09/06/2015	03:37:45	14,9	65	0,3007	62,9	
09/06/2015	03:37:56	14,9	66	0,3063	64,0	
09/06/2015	03:38:05	14,9	67	0,3064	64,1	
09/06/2015	03:38:21	14,9	68	0,2911	60,9	
09/06/2015	03:38:31	14,9	69	0,3102	64,9	
09/06/2015	03:38:39	14,9	70	0,3083	64,5	
09/06/2015	03:38:45	14,9	71	0,3005	62,8	
09/06/2015	03:38:56	14,9	72	0,3082	64,4	
09/06/2015	03:39:04	14,9	73	0,3076	64,3	
09/06/2015	03:39:16	14,9	74	0,3020	63,1	

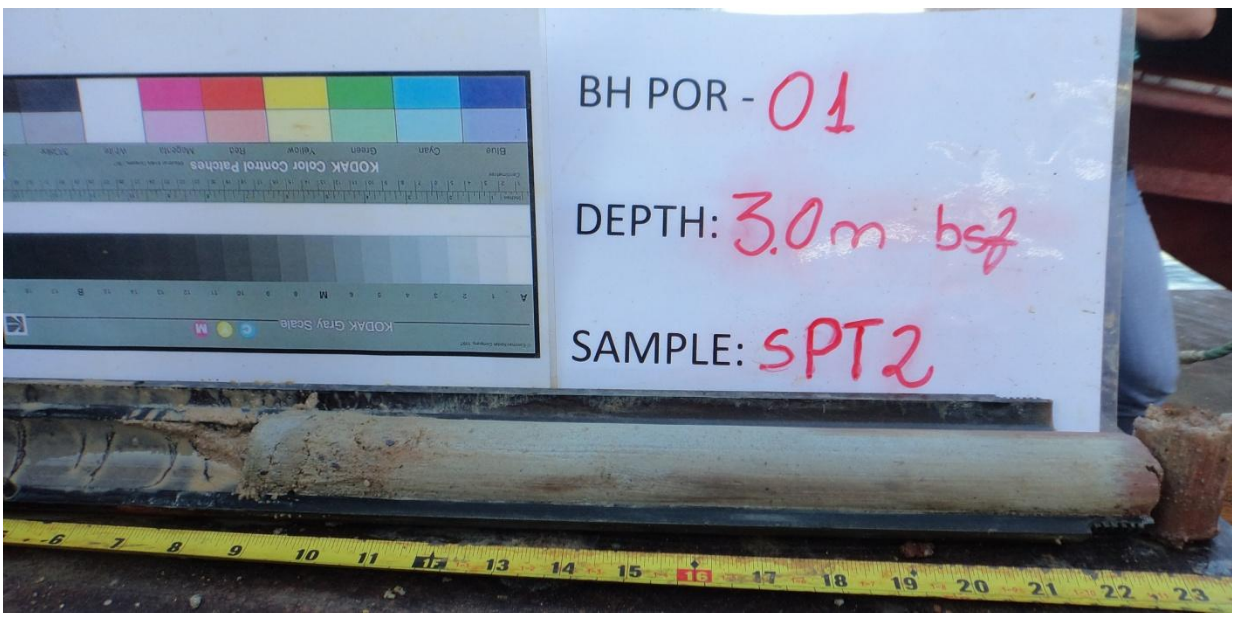
ANEXO I
PROGRAMA DE INSTRUMENTAÇÃO – RESUMO DOS RESULTADOS

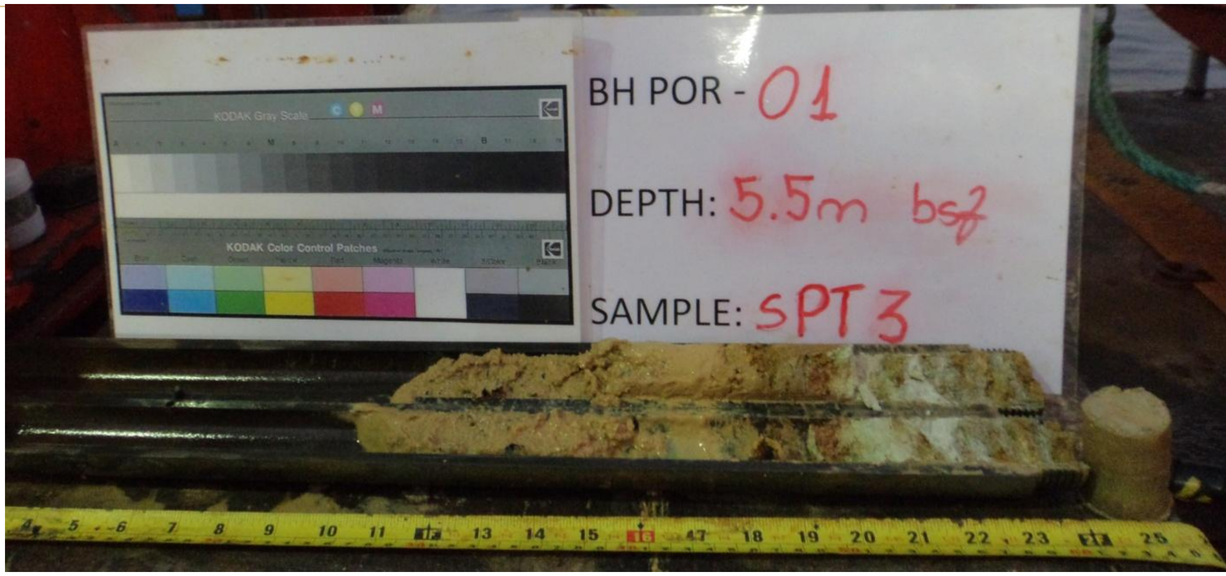
Obra:	ALARGAMENTO DO CANAL DRAGADO
Área/Setor:	BAIA DE GUANABARA
Furo:	POR-10
Tipo de Sondagem:	SPT
Perfuratriz:	COMMACHIO 1200
Martelo:	AUTOMATIC TRIP HAMMER

Date	Time	LP meters	BN	ENERGIA MÁX kN-meters	EFICIÊNCIA (%)	Local
09/06/2015	04:57:19	15,9	75	0,2915	61,0	POR-10
09/06/2015	04:57:28	15,9	76	0,3021	63,2	
09/06/2015	04:57:37	15,9	77	0,3112	65,1	
09/06/2015	04:57:47	15,9	78	0,3130	65,4	
09/06/2015	04:58:03	15,9	79	0,3078	64,4	
09/06/2015	04:58:14	15,9	80	0,3087	64,5	
09/06/2015	04:58:24	15,9	81	0,3083	64,5	
09/06/2015	04:58:34	15,9	82	0,3106	64,9	
09/06/2015	04:58:46	15,9	83	0,2980	62,3	
09/06/2015	04:59:01	15,9	84	0,3168	66,2	
09/06/2015	04:59:10	15,9	85	0,3051	63,8	
09/06/2015	04:59:49	15,9	86	0,2998	62,7	
09/06/2015	05:00:02	15,9	87	0,3103	64,9	
09/06/2015	05:00:29	15,9	88	0,3099	64,8	
09/06/2015	05:00:46	15,9	89	0,3149	65,8	
09/06/2015	05:01:00	15,9	90	0,3131	65,5	
09/06/2015	05:01:11	15,9	91	0,2933	61,3	
09/06/2015	05:01:24	15,9	92	0,3139	65,6	
09/06/2015	05:01:35	15,9	93	0,3180	66,5	
09/06/2015	05:01:45	15,9	94	0,3149	65,8	
09/06/2015	05:01:56	15,9	95	0,3120	65,2	
09/06/2015	05:02:22	15,9	96	0,3131	65,5	
09/06/2015	05:02:41	15,9	97	0,3089	64,6	
09/06/2015	05:02:51	15,9	98	0,3116	65,2	
09/06/2015	05:53:12	17,9	99	0,3066	64,1	
09/06/2015	05:53:37	17,9	100	0,2945	61,6	
09/06/2015	05:53:45	17,9	101	0,2949	61,7	
09/06/2015	05:53:57	17,9	102	0,3010	62,9	
09/06/2015	05:54:08	17,9	103	0,3002	62,8	
09/06/2015	05:54:20	17,9	104	0,3166	66,2	
09/06/2015	05:54:31	17,9	105	0,3030	63,4	
09/06/2015	05:54:44	17,9	106	0,3045	63,7	
09/06/2015	05:54:55	17,9	107	0,3045	63,7	
09/06/2015	05:55:07	17,9	108	0,3044	63,7	
09/06/2015	05:55:19	17,9	109	0,3115	65,1	
09/06/2015	05:55:30	17,9	110	0,3135	65,6	
09/06/2015	05:55:40	17,9	111	0,3158	66,0	
09/06/2015	05:55:52	17,9	112	0,2979	62,3	
09/06/2015	05:56:03	17,9	113	0,3001	62,8	
09/06/2015	05:56:15	17,9	114	0,3041	63,6	
09/06/2015	05:56:27	17,9	115	0,3064	64,1	
09/06/2015	05:56:38	17,9	116	0,3047	63,7	
09/06/2015	05:56:49	17,9	117	0,3046	63,7	
09/06/2015	05:57:01	17,9	118	0,3080	64,4	
09/06/2015	05:57:20	17,9	119	0,3071	64,2	
09/06/2015	05:57:33	17,9	120	0,3025	63,3	
			Média	0,3014	63,0	
			Desvio padrão	0,0092	1,9	

APÊNDICE 3: FOTOGRAFIAS DE AMOSTRAS

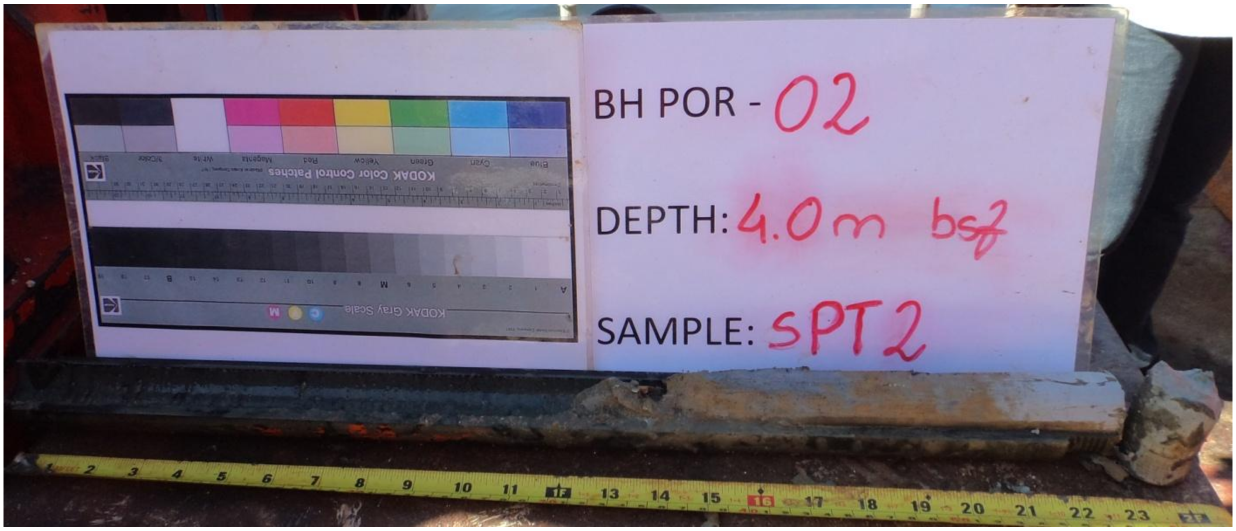

KODAK Gray Scale
KODAK Color Control Patches
BH POR - 01
DEPTH: 1.5m bsf
SAMPLE: SPT1


BH POR - 01
DEPTH: 3.0m bsf
SAMPLE: SPT2



KODAK Gray Scale
KODAK Color Control Patches
BH POR - 01
DEPTH: 5.5m bsf
SAMPLE: SPT 3

POR-02


BH POR - 02
DEPTH: 4.0m bsf
SAMPLE: SPT2
KODAK Color Control Patches
KODAK Gray Scale

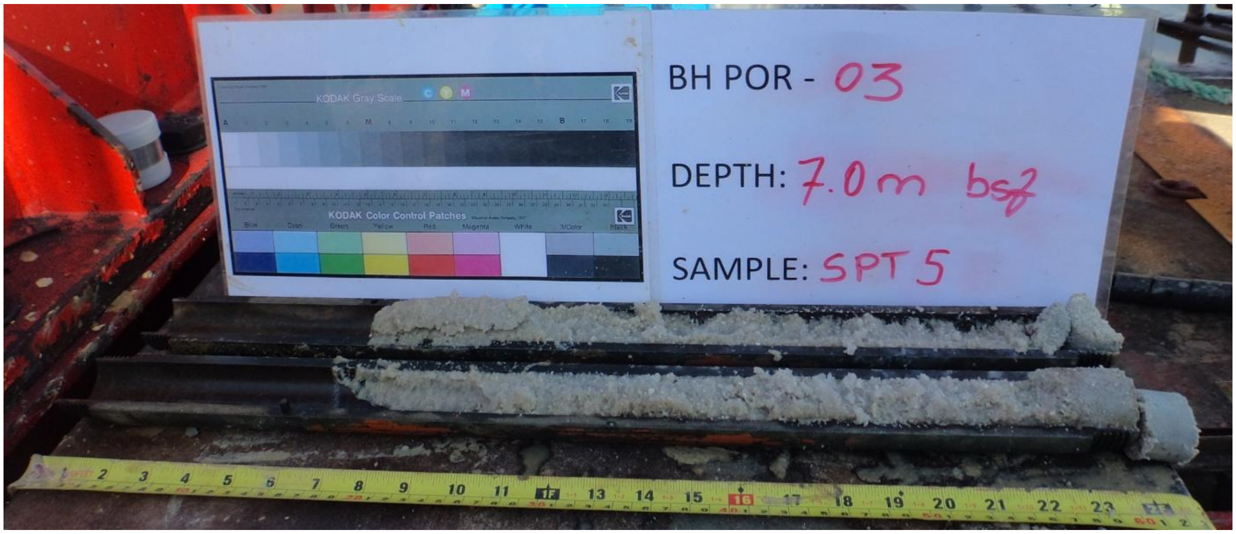
POR-03

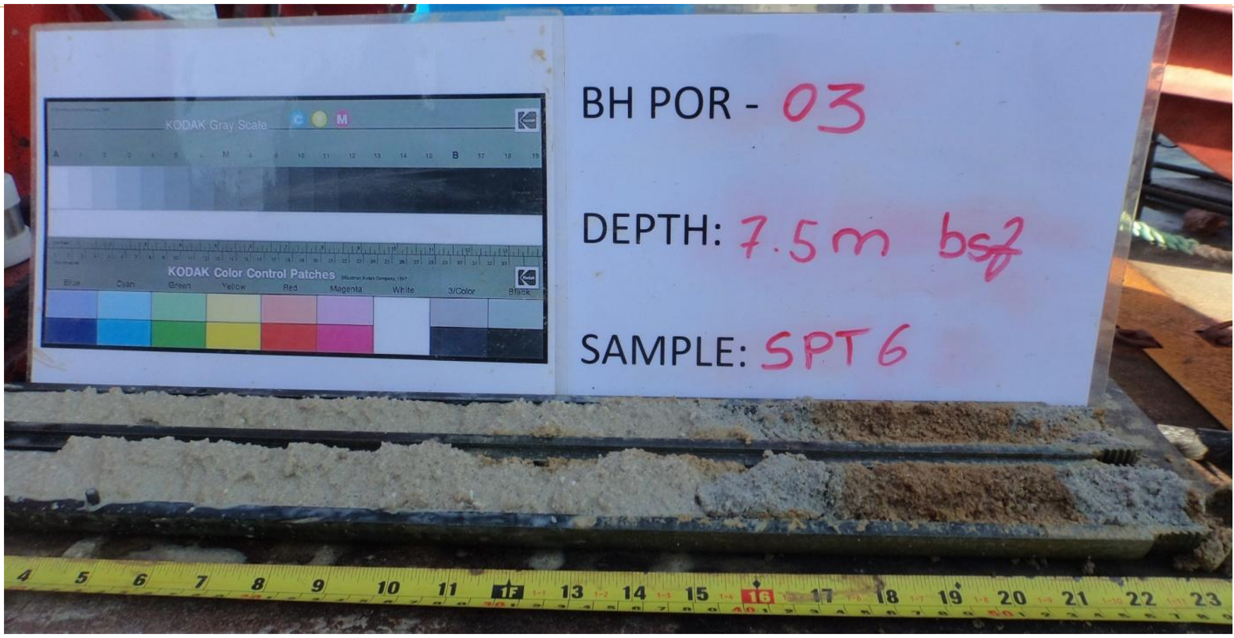

BH POR - 03
DEPTH: 1.5m bsf
SAMPLE: SPT1
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 03
DEPTH: 2.5m bsf
SAMPLE: SPT2
KODAK Gray Scale
KODAK Color Control Patches

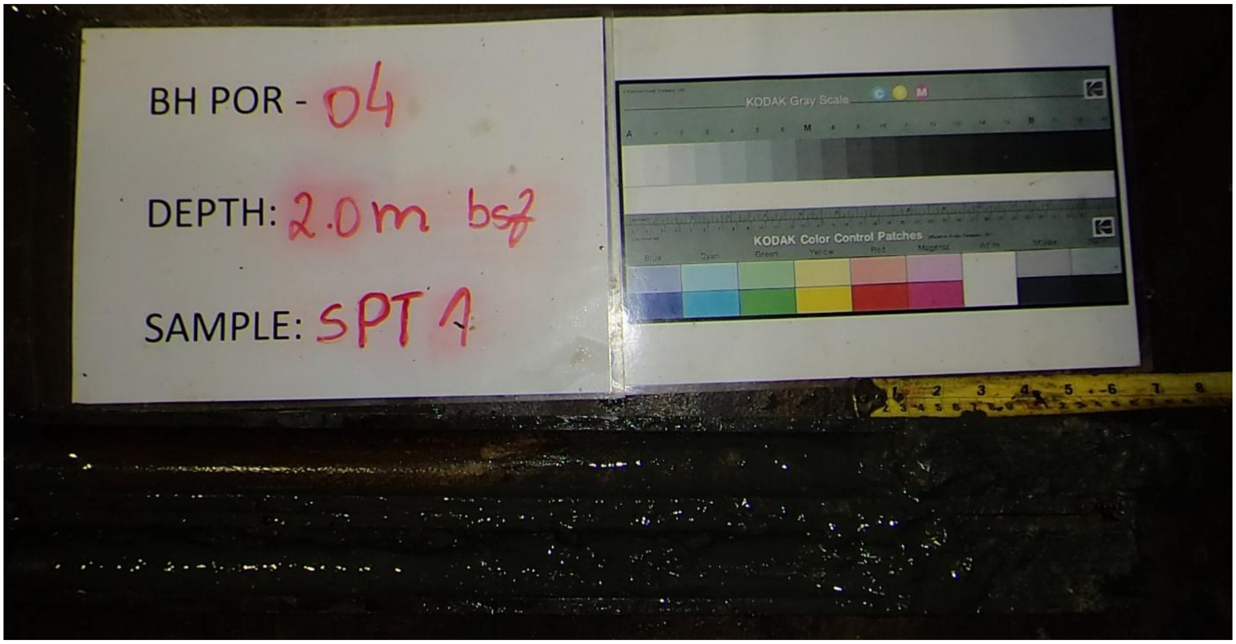

KODAK Gray Scale
KODAK Color Control Patches
BH POR - 03
DEPTH: 3.5m bsf
SAMPLE: SPT3

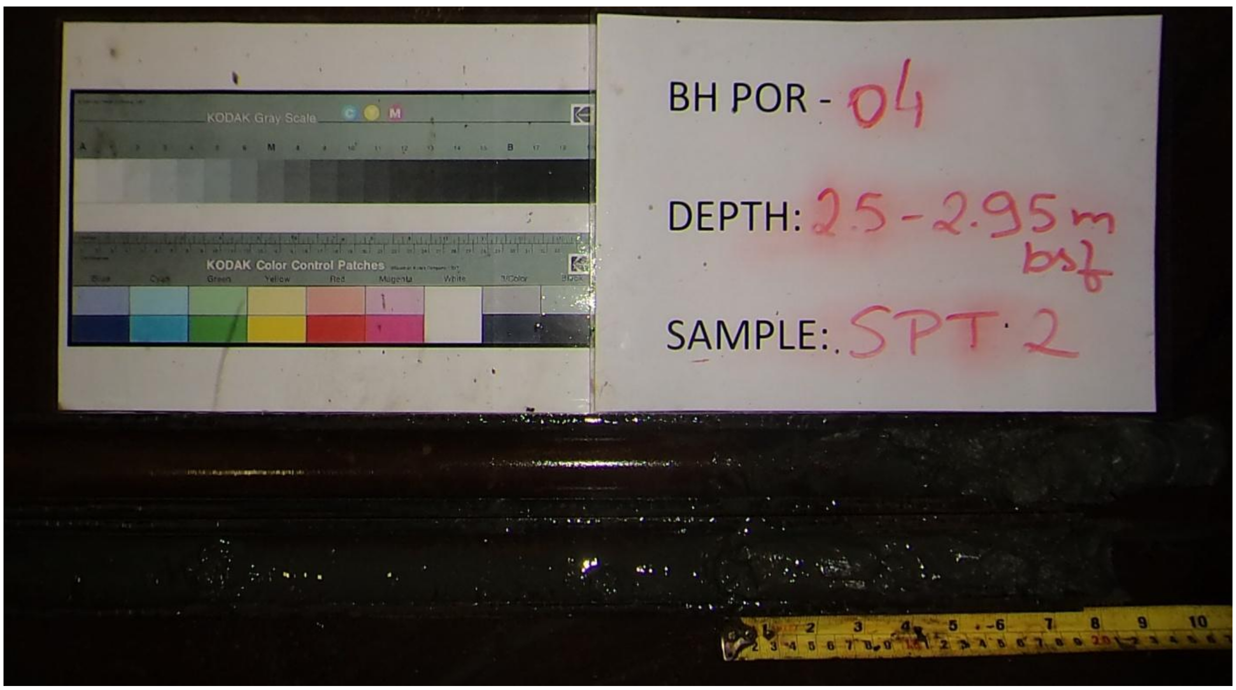

KODAK Gray Scale
KODAK Color Control Patches
BH POR - 03
DEPTH: 6.0m bsf
SAMPLE: SPT4

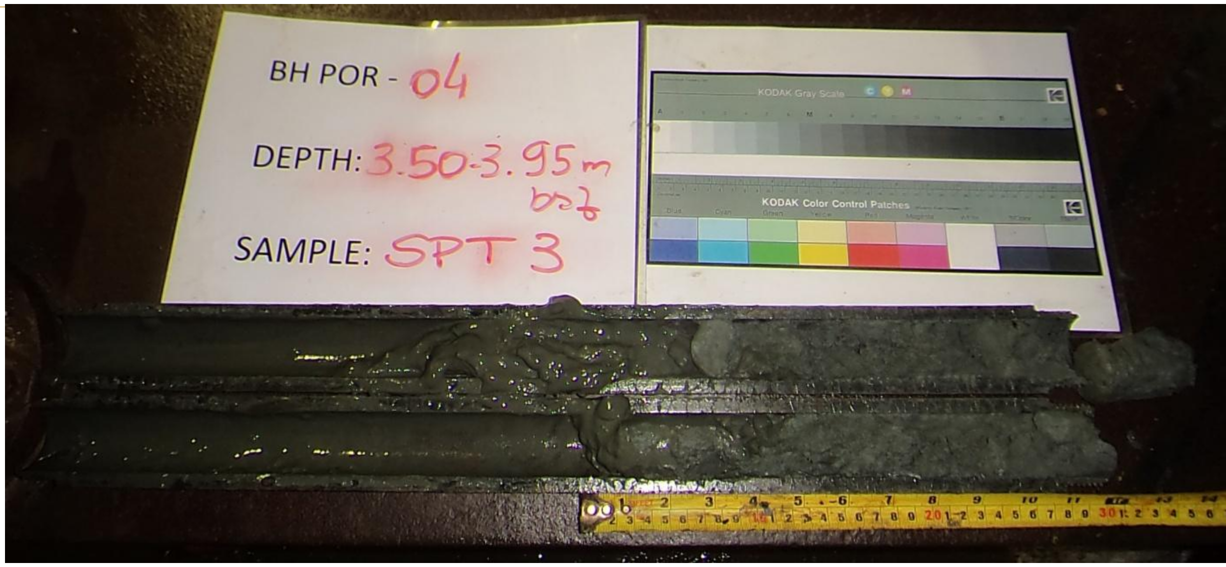

KODAK Gray Scale
KODAK Color Control Patches
BH POR - 03
DEPTH: 7.0m bsf
SAMPLE: SPT5


BH POR - 03
DEPTH: 7.5m bsf
SAMPLE: SPT 6
KODAK Gray Scale
KODAK Color Control Patches

POR-04

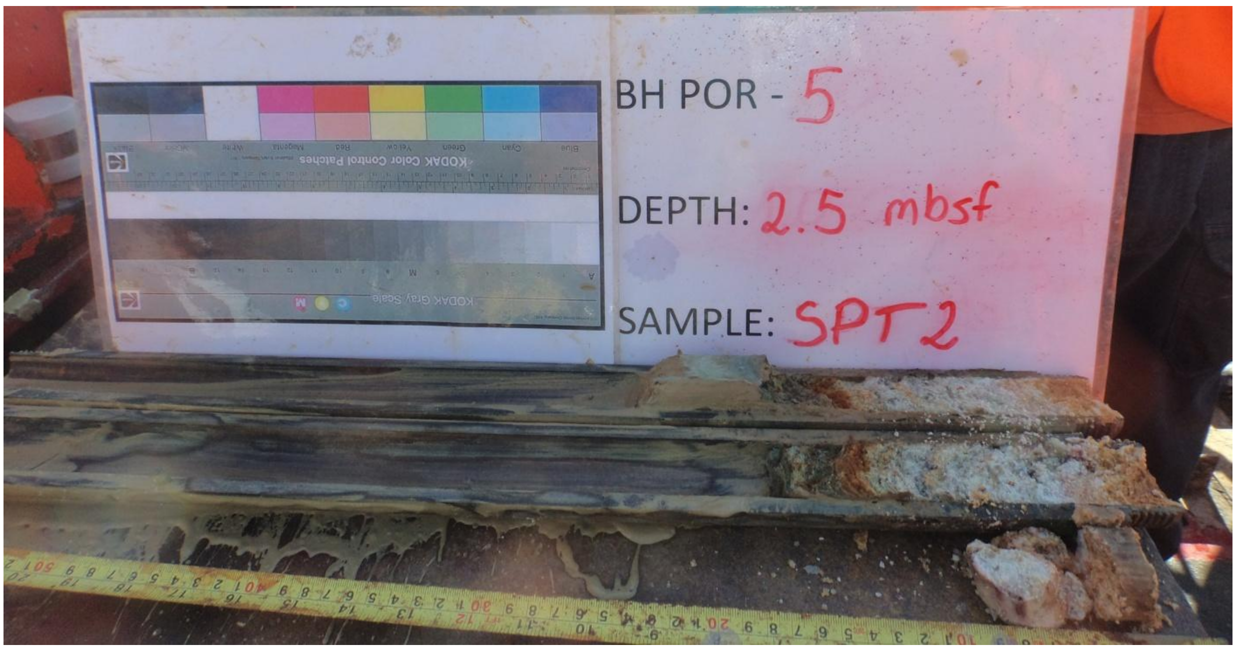

BH POR - 04
DEPTH: 2.0m bsf
SAMPLE: SPT 1
KODAK Gray Scale
KODAK Color Control Patches

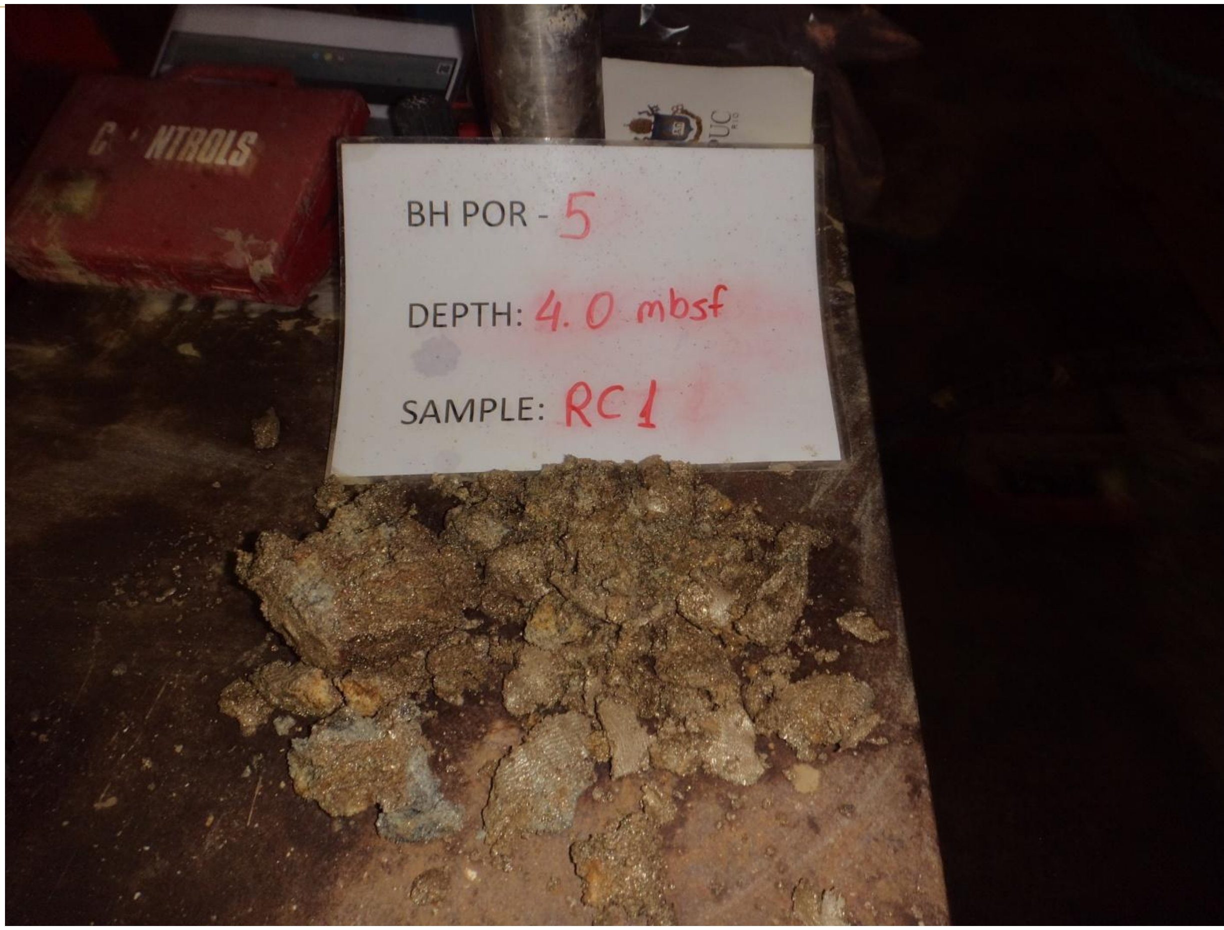

KODAK Gray Scale
KODAK Color Control Patches
BH POR - 04
DEPTH: 2.5-2.95m bsf
SAMPLE: SPT 2

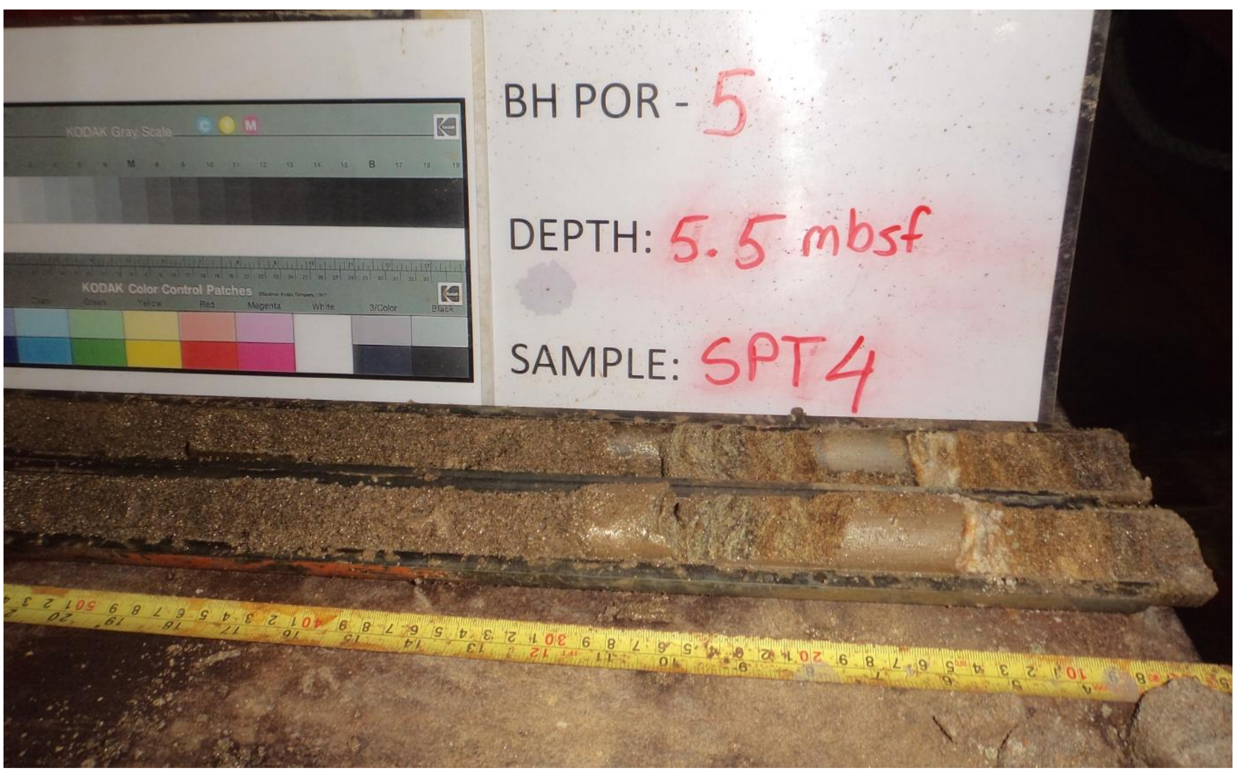

BH POR - 04
DEPTH: 3.50-3.95 m bsf
SAMPLE: SPT 3
KODAK Gray Scale
KODAK Color Control Patches

POR-05


BH POR - 5
DEPTH: 1.0 mbsf
SAMPLE: SPT1
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 5
DEPTH: 2.5 mbsf
SAMPLE: SPT2


BH POR - 5
DEPTH: 4.0 mbsf
SAMPLE: RC 1

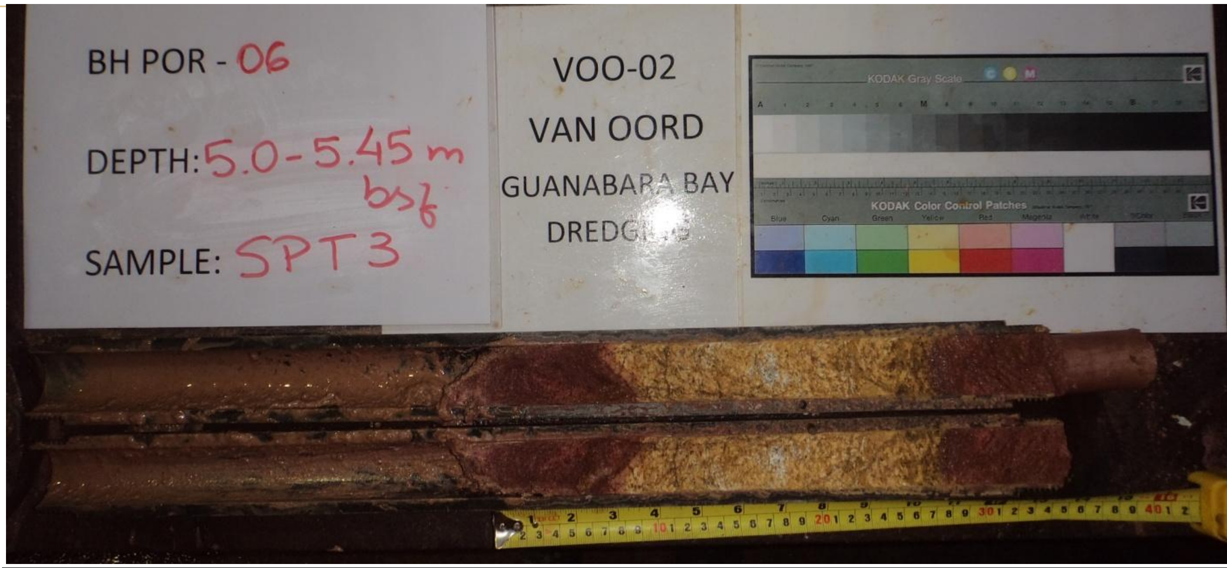

KODAK Gray Scale
KODAK Color Control Patches
BH POR - 5
DEPTH: 5.5 mbsf
SAMPLE: SPT 4

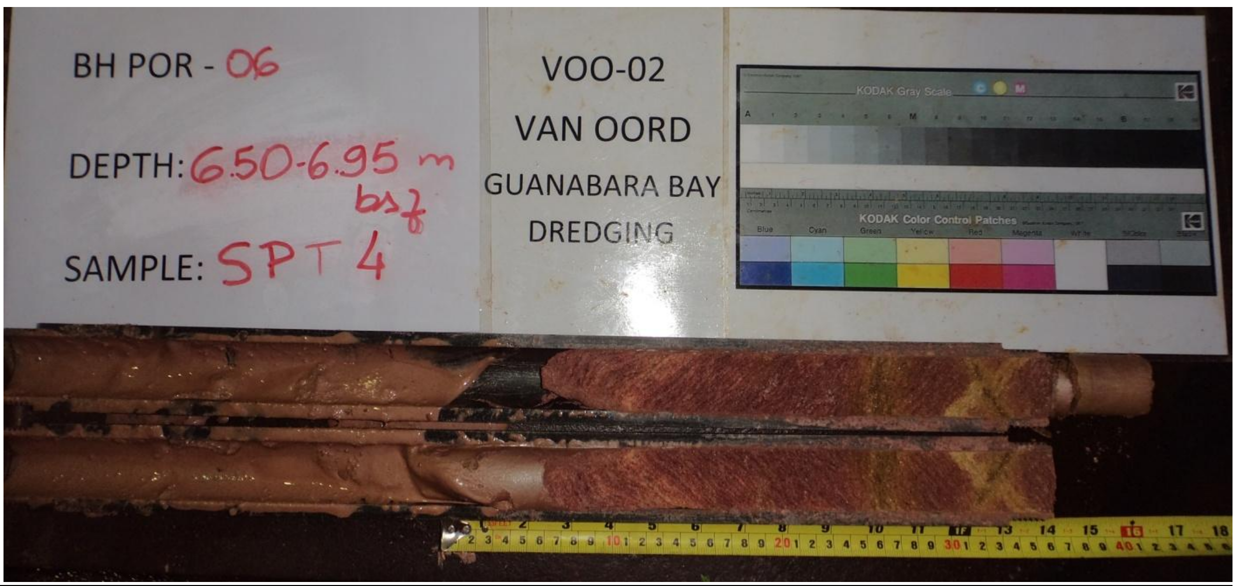

FUGRO GEOTECNIA MARINHA
Project:
Borehole:
Sample:
Depth:
Blowcount:

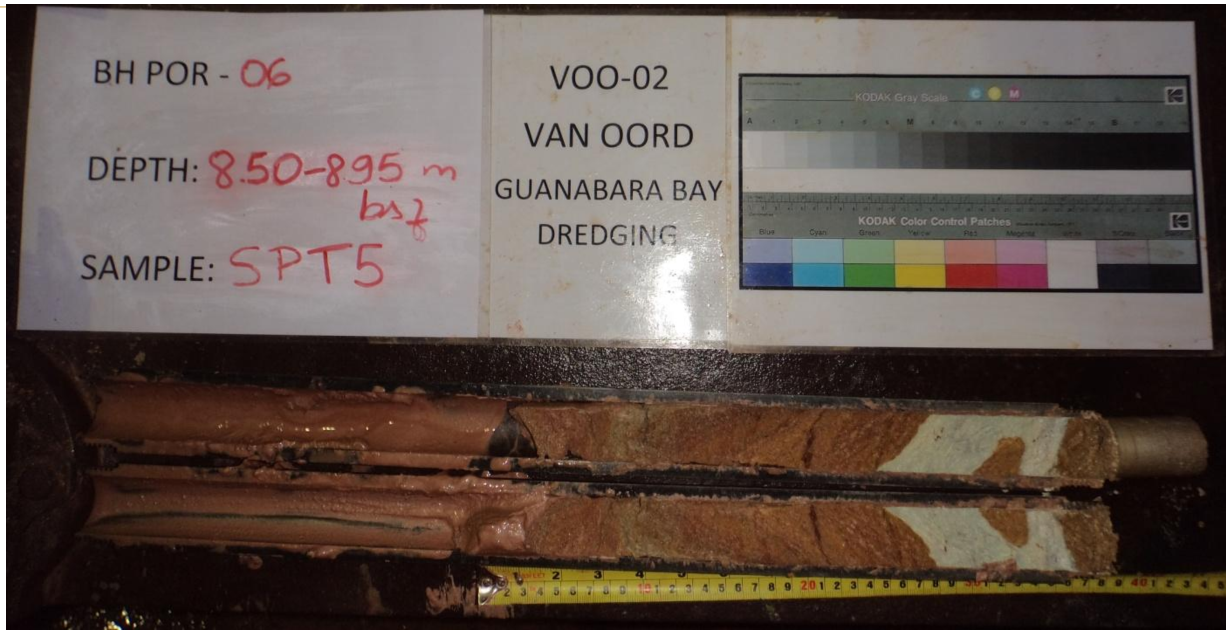
POR-06


BH POR - 6
DEPT 2.0-2.45m bsf
SAMPLE: SPT 1
VOO-02
VAN OORD
GUANABARA BA
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 06
DEPTH: 3.50-3.95 m bsf
SAMPLE: SPT 2
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 06
DEPTH: 5.0-5.45 m bsf
SAMPLE: SPT3
VOO-02
VAN OORD
GUANABARA BAY
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 06
DEPTH: 6.50-6.95 m bsf
SAMPLE: SPT 4
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 06
DEPTH: 8.50-8.95 m bsf
SAMPLE: SPT5
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

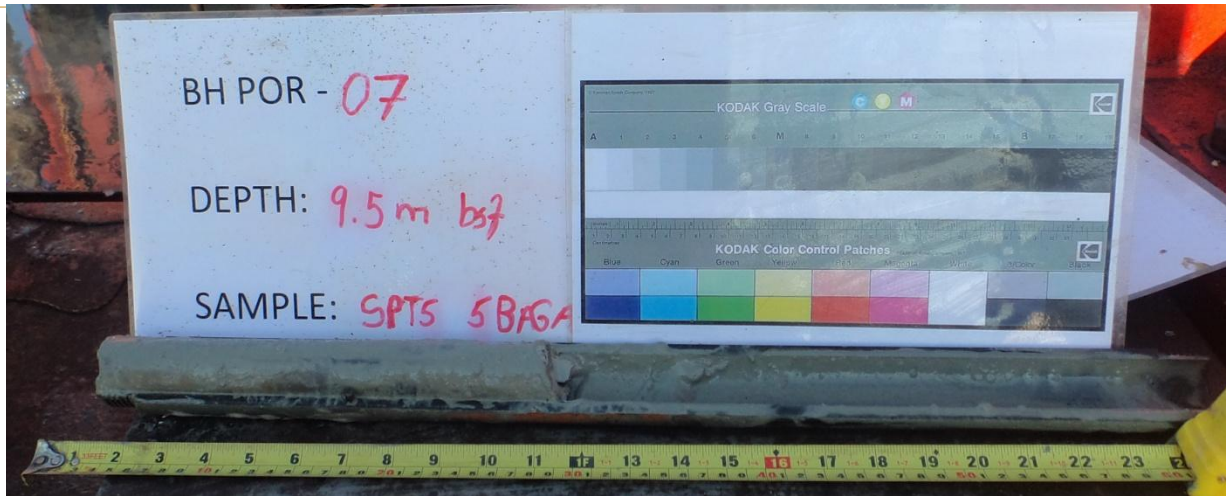
<u>POR-07</u>


BH POR - 07
DEPTH: 1.5 m bgl
SAMPLE: SPT1 1BAGA
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 07
DEPTH: 3.0 m bgl
SAMPLE: SPT2 2BAGA
KODAK Gray Scale
KODAK Color Control Patches
,

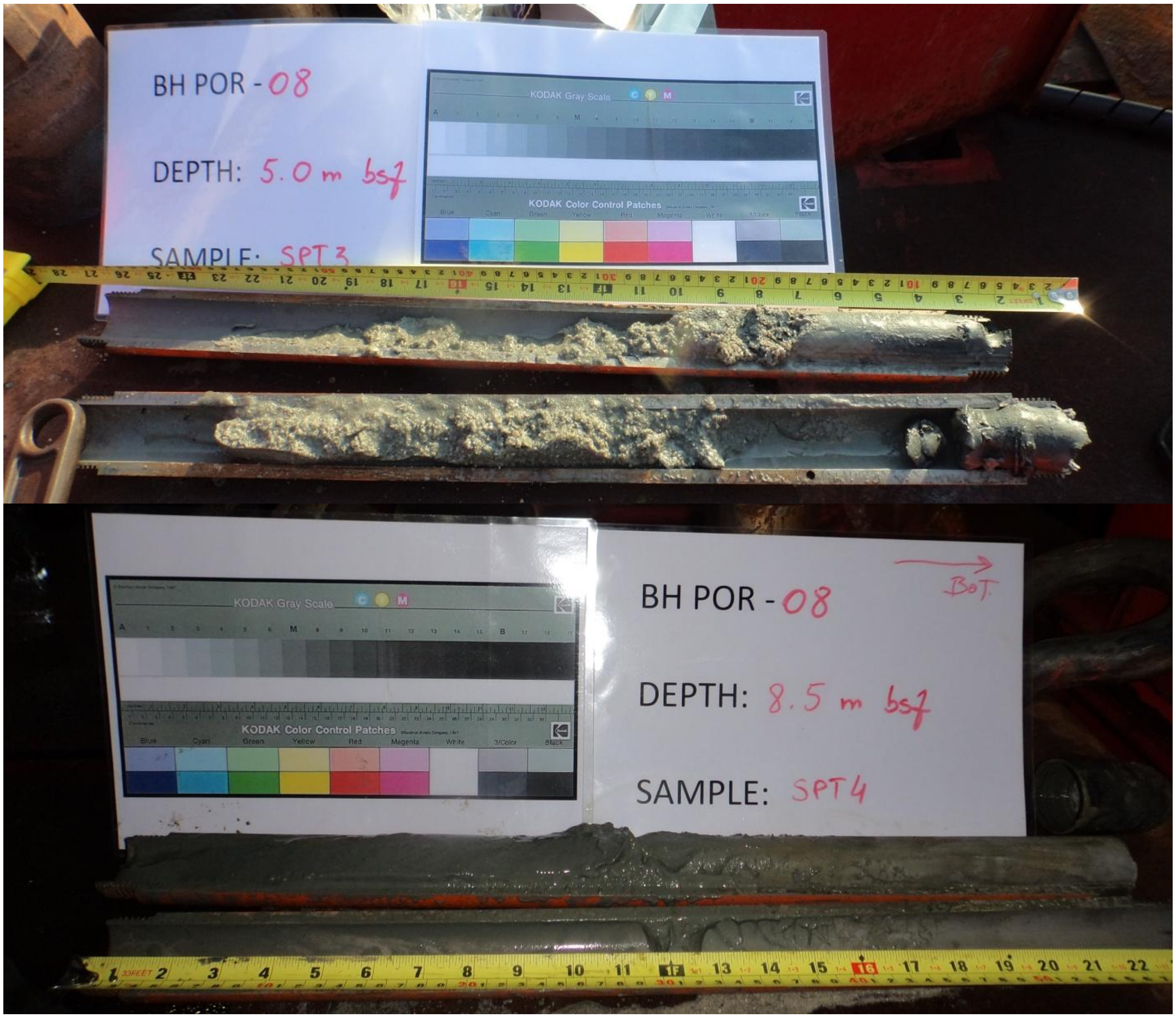

BH POR - 07
DEPTH: 4.5 m bsf
SAMPLE: SPT3 3BAGA
KODAK Gray Scale
KODAK Color Control Patches

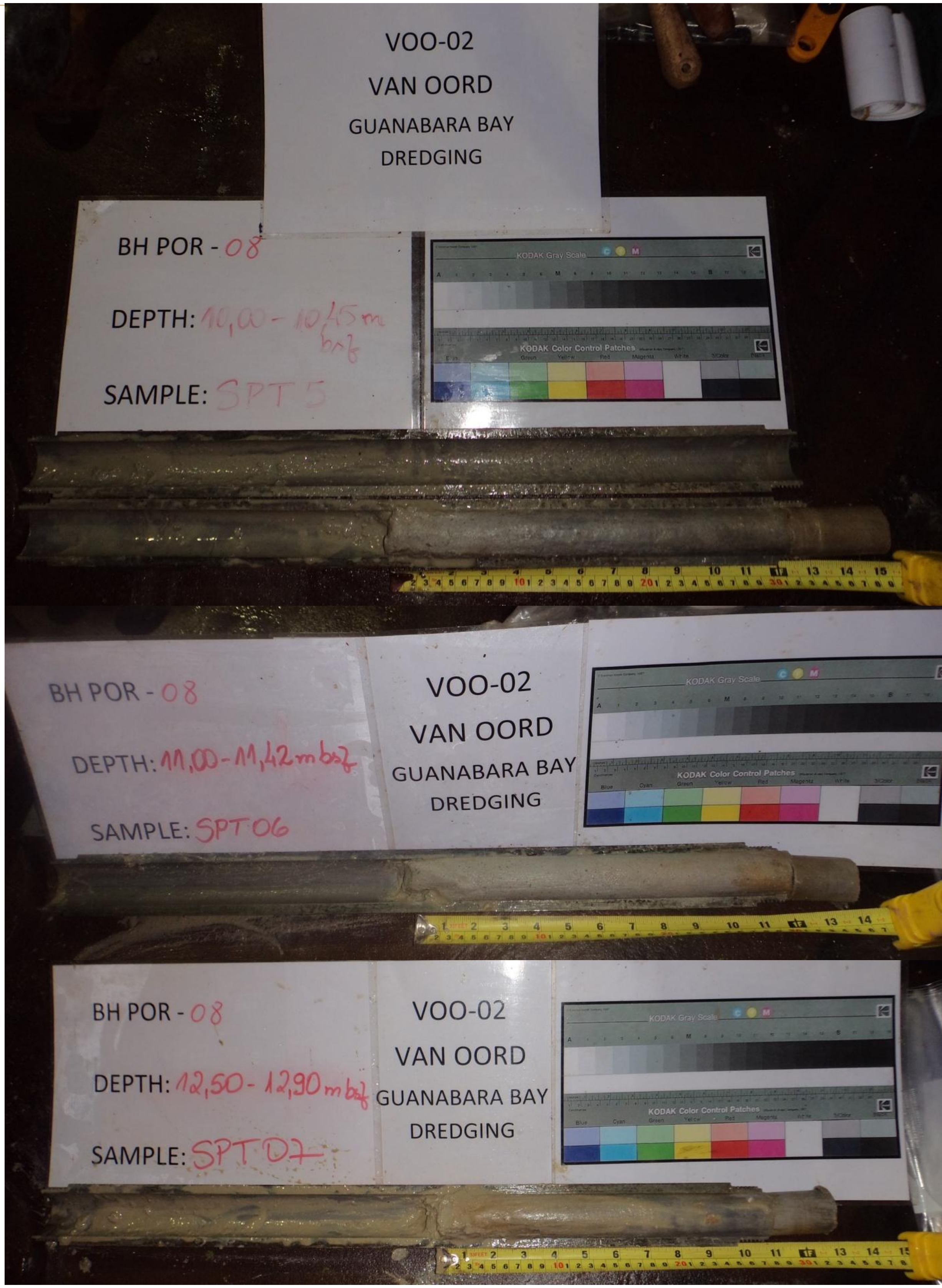

BH POR - 07
DEPTH: 8.0m bsf
SAMPLE: SPT4 4BAGA
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 07
DEPTH: 9.5 m bsf
SAMPLE: SPT5 5BAGA
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 07
DEPTH: 10.5 m bsf
SAMPLE: SPT6 6BAGA
KODAK Gray Scale
KODAK Color Control Patches

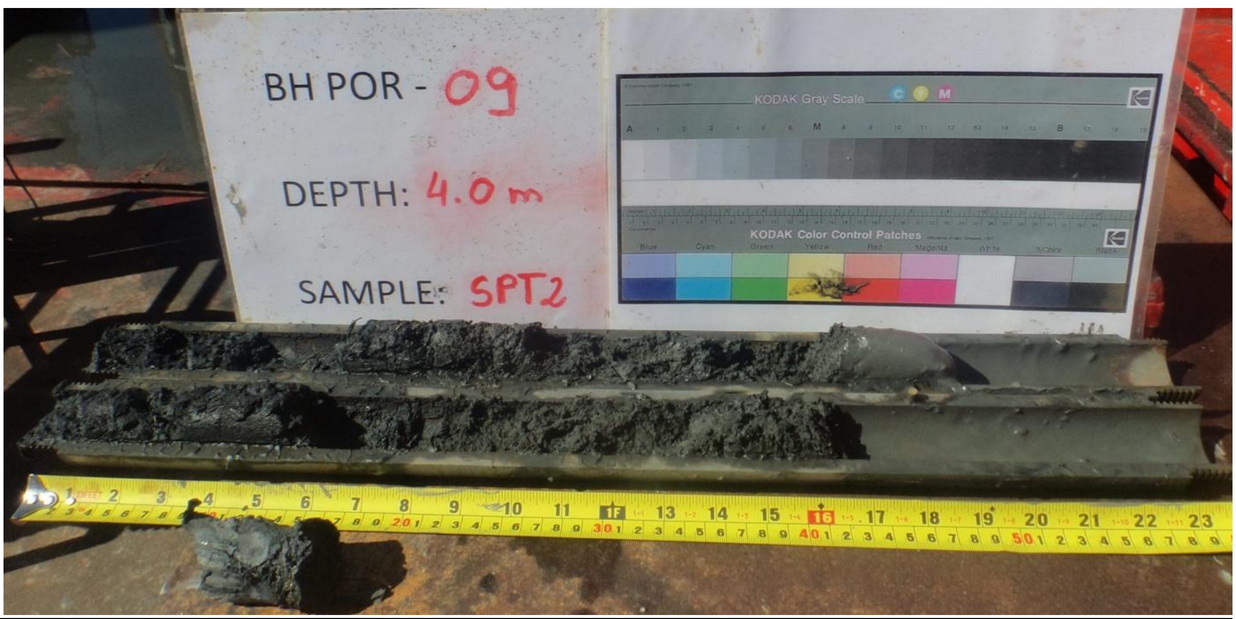
<u>POR-08</u>

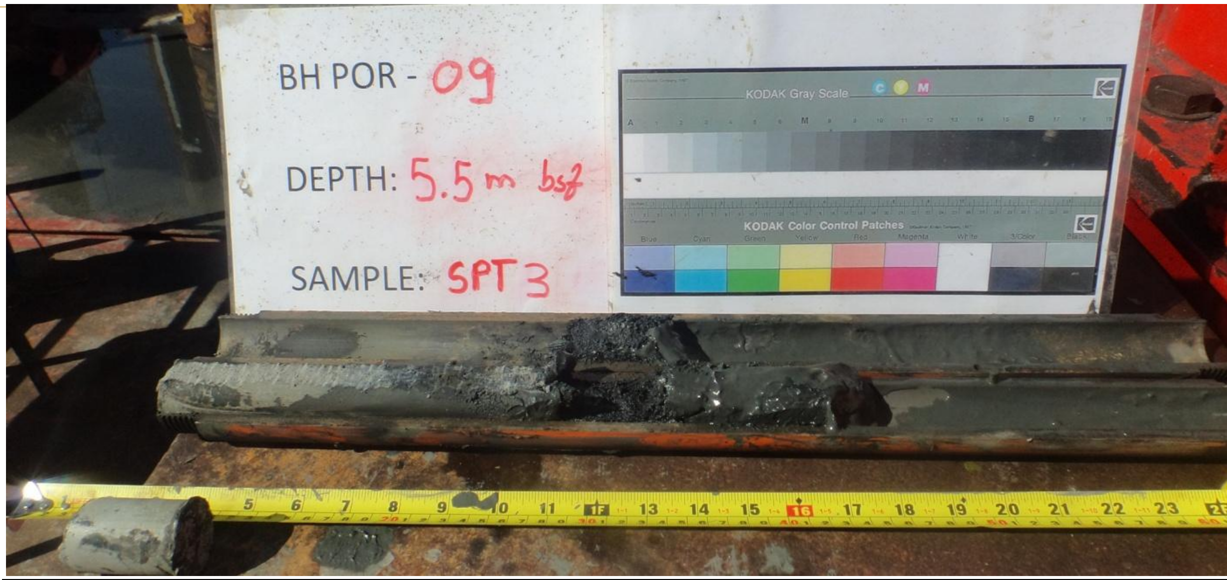

BH POR - 08
DEPTH: 5.0 m bsf
SAMPLE: SPT 3
KODAK Gray Scale
KODAK Color Control Patches
KODAK Gray Scale
KODAK Color Control Patches
BoT
BH POR - 08
DEPTH: 8.5 m bsf
SAMPLE: SPT4


VOO-02
VAN OORD
GUANABARA BAY
DREDGING
BH POR - 08
DEPTH: 10,00 - 10,45 m bsf
SAMPLE: SPT 5
KODAK Gray Scale
KODAK Color Control Patches
BH POR - 08
DEPTH: 11,00-11,42 m bsf
SAMPLE: SPT 06
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches
BH POR - 08
DEPTH: 12,50-12,90 m bsf
SAMPLE: SPT 07
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

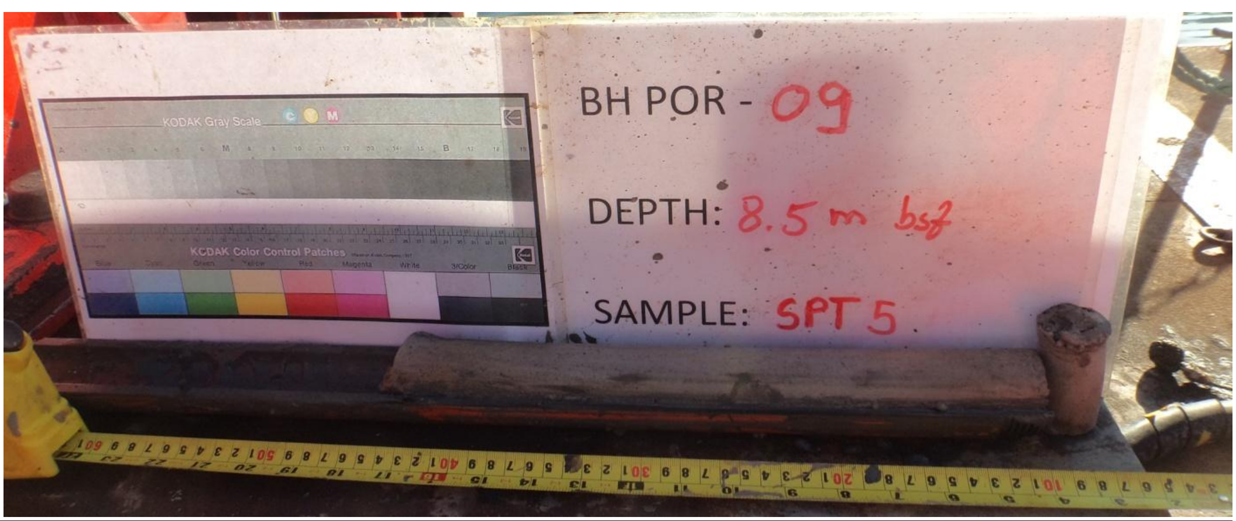
POR-09


BH POR - 09
DEPTH: 1.0 m
SAMPLE: SPT1
KODAK Gray Scale
KODAK Color Control Patches

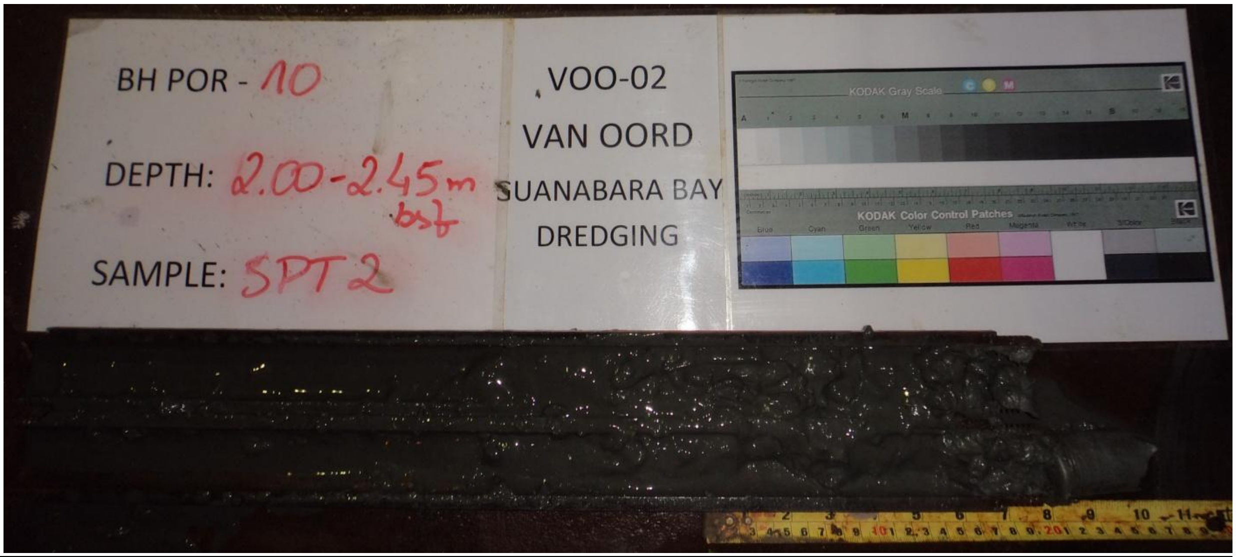

BH POR - 09
DEPTH: 4.0 m
SAMPLE: SPT2
KODAK Gray Scale
KODAK Color Control Patches

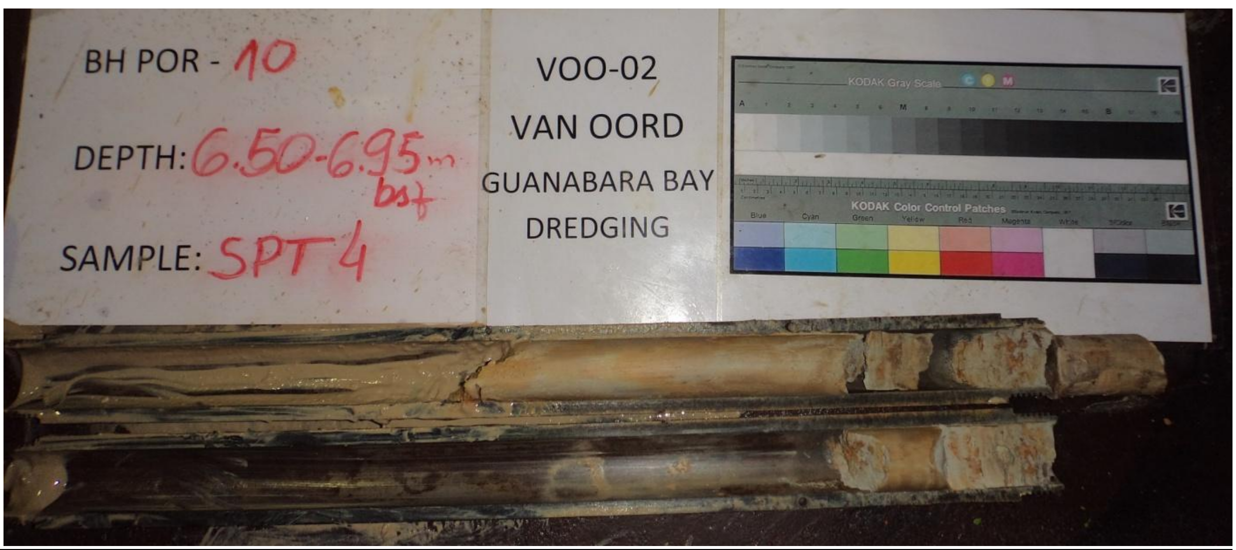

BH POR - 09
DEPTH: 5.5 m bsf
SAMPLE: SPT 3
KODAK Gray Scale
KODAK Color Control Patches

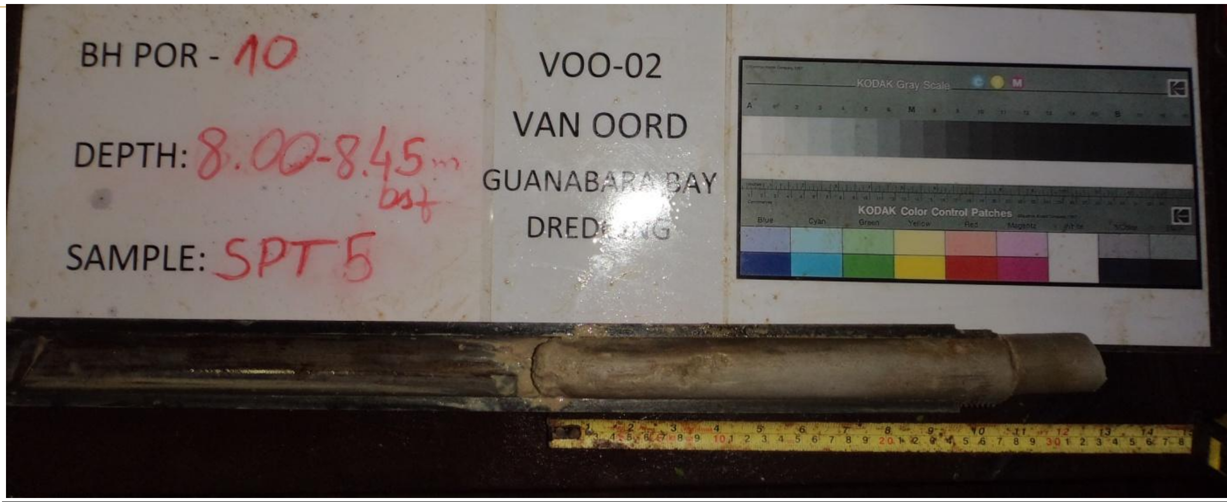

BH POR - 09
DEPTH: 7.0 m bsf
SAMPLE: SPT 4
KODAK Gray Scale
KODAK Color Control Patches

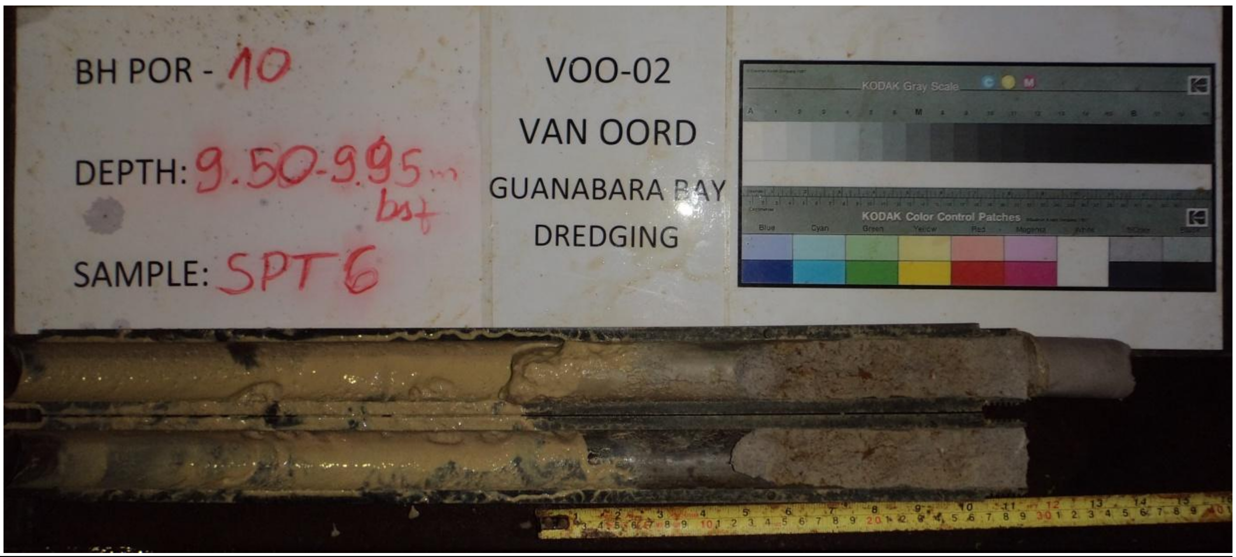

BH POR - 09
DEPTH: 8.5 m bsf
SAMPLE: SPT 5
KODAK Gray Scale
KODAK Color Control Patches

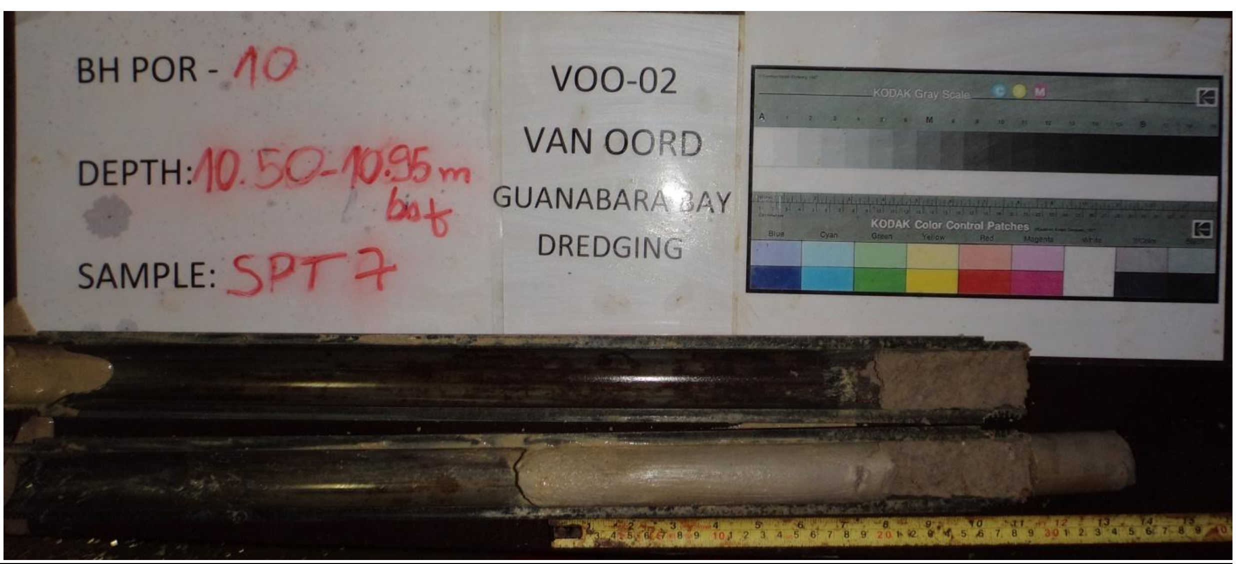
<u>POR-10</u>

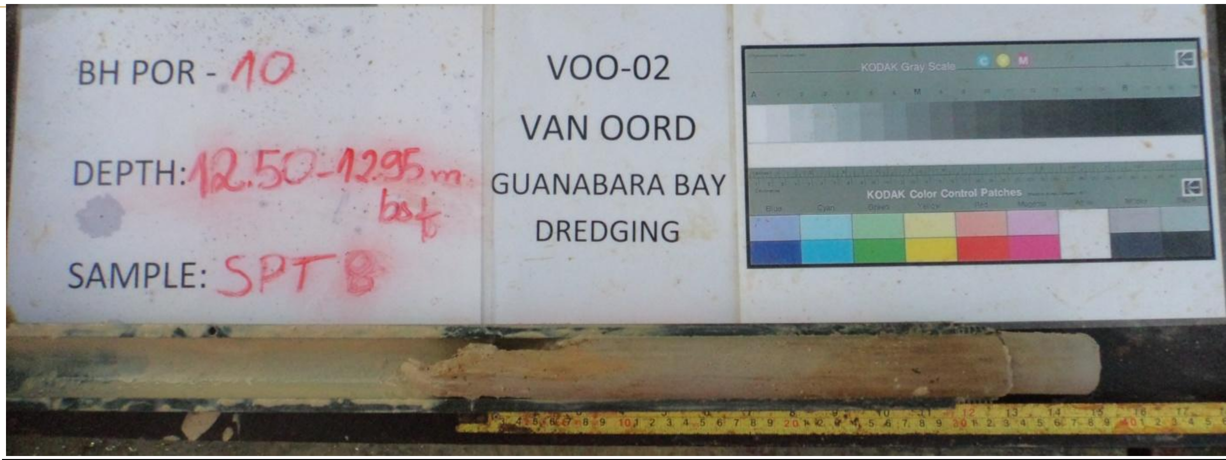

BH POR - 10
DEPTH: 2.00-2.45m bsf
SAMPLE: SPT 2
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 10
DEPTH: 6.50-6.95m bsf
SAMPLE: SPT 4
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 10
DEPTH: 8.00-8.45 m bst
SAMPLE: SPT 5
VOO-02
VAN OORD
GUANABARA BAY
KODAK Gray Scale
KODAK Color Control Patches

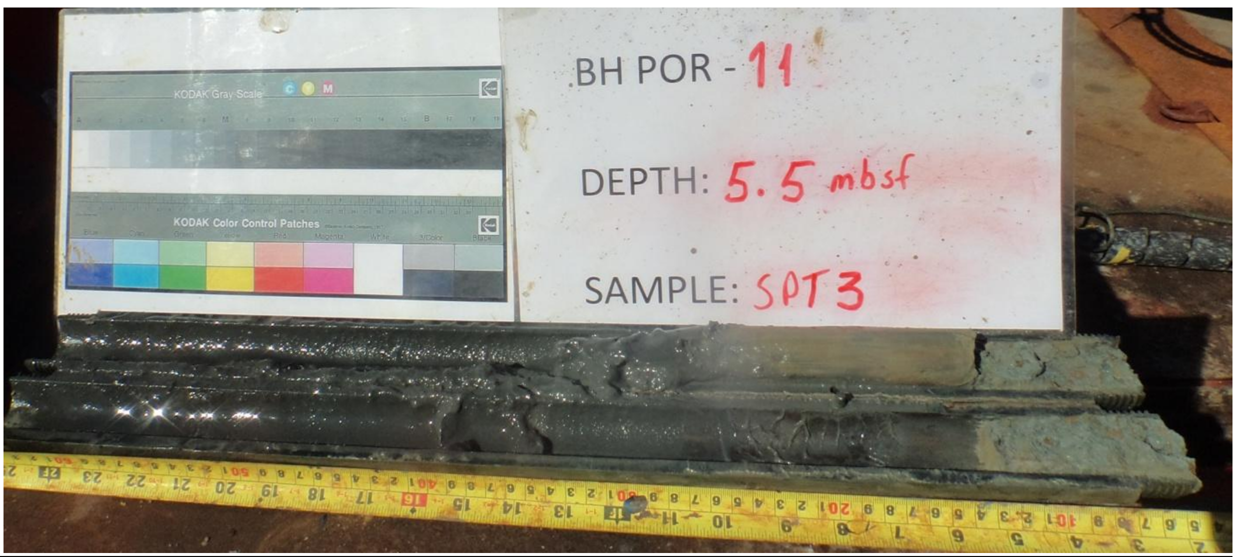

BH POR - 10
DEPTH: 9.50-9.95 m bst
SAMPLE: SPT 6
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 10
DEPTH: 10.50-10.95 m bst
SAMPLE: SPT 7
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

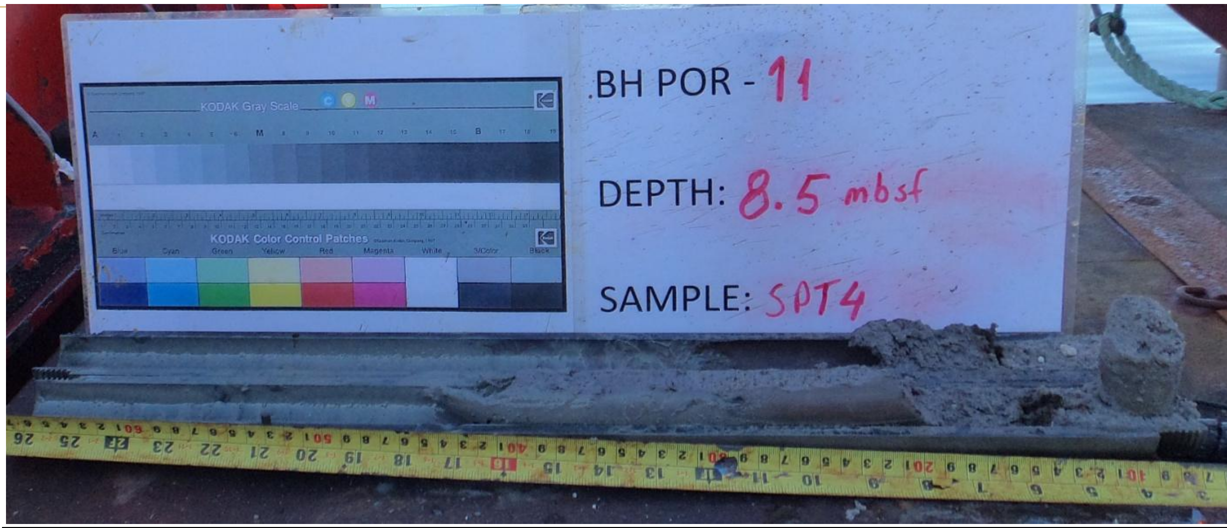

BH POR - 10
DEPTH: 12.50-12.95 m bsf
SAMPLE: SPT 8
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

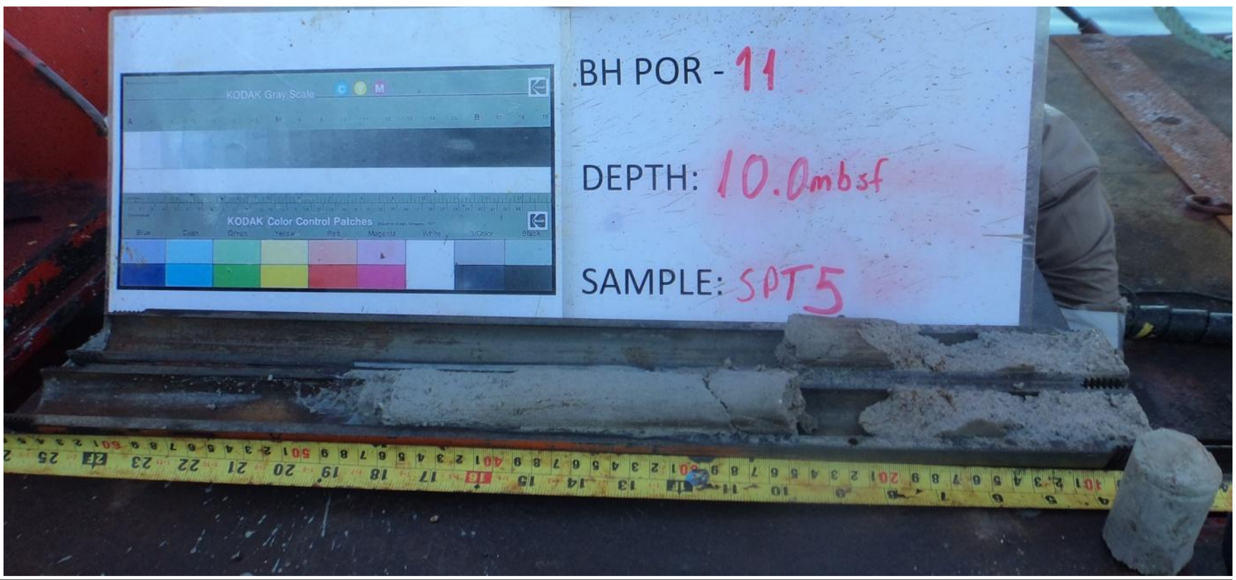
<u>POR-11</u>

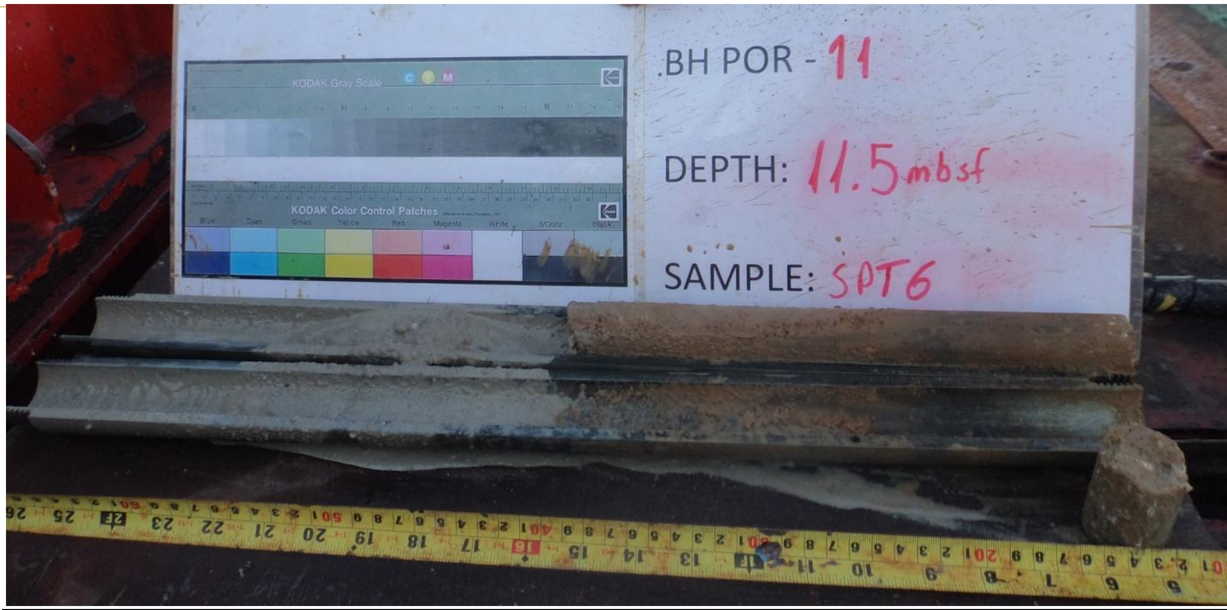
KODAK Gray Scale
KODAK Color Control Patches
BH POR - 11
DEPTH: 4. 0 mbsf
SAMPLE: SPT 2



KODAK Gray Scale
KODAK Color Control Patches
BH POR - 11
DEPTH: 5. 5 mbsf
SAMPLE: SPT 3


KODAK Gray Scale
KODAK Color Control Patches
BH POR - 11
DEPTH: 8.5 mbsf
SAMPLE: SPT4


KODAK Gray Scale
KODAK Color Control Patches
BH POR - 11
DEPTH: 10.0mbsf
SAMPLE: SPT5

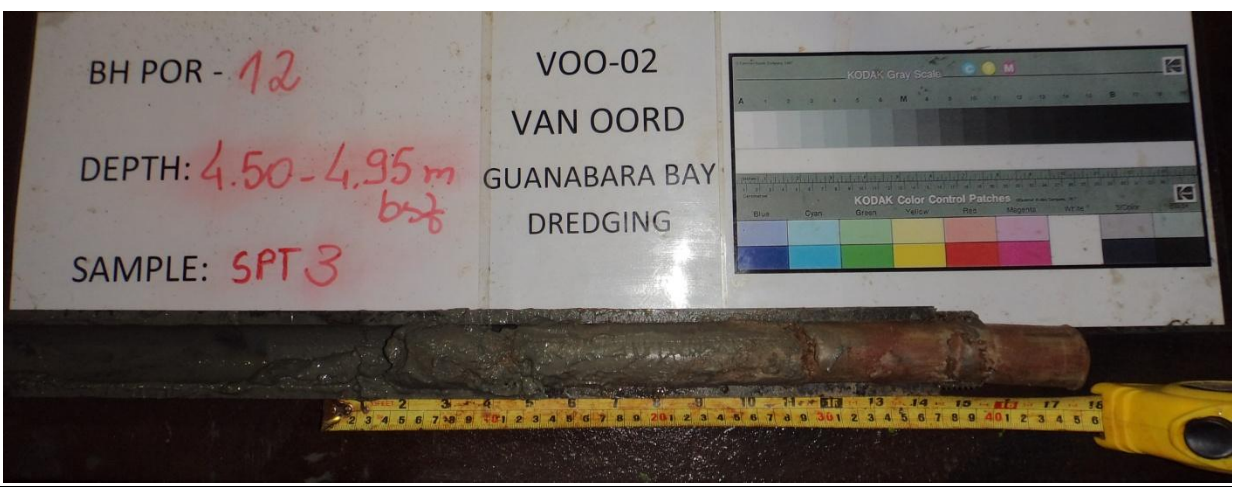

BH POR - 11
DEPTH: 11.5 mbsf
SAMPLE: SPT6
KODAK Gray Scale
KODAK Color Control Patches

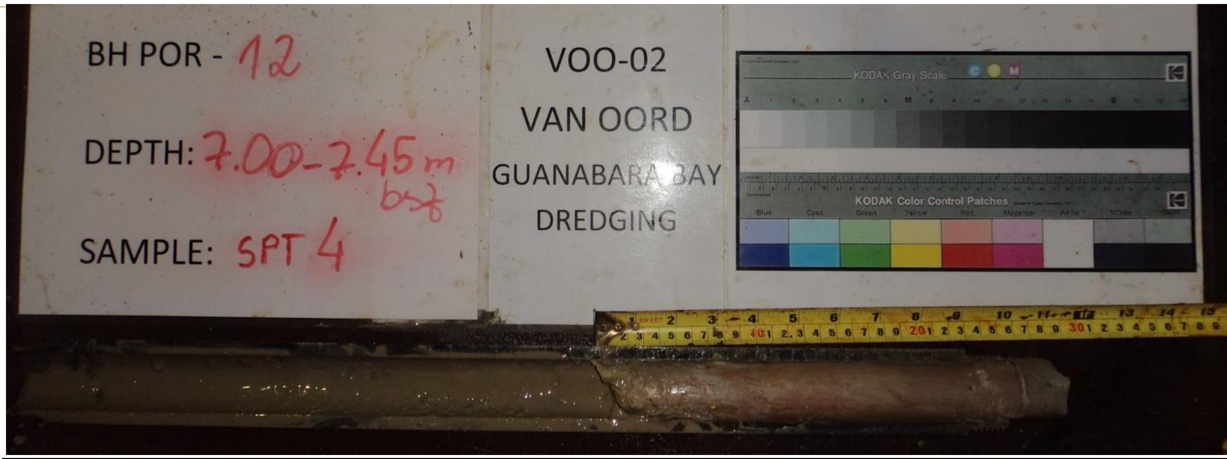

BH POR - 11
DEPTH: 13.5 mbsf
SAMPLE: SPT7
KODAK Gray Scale
KODAK Color Control Patches

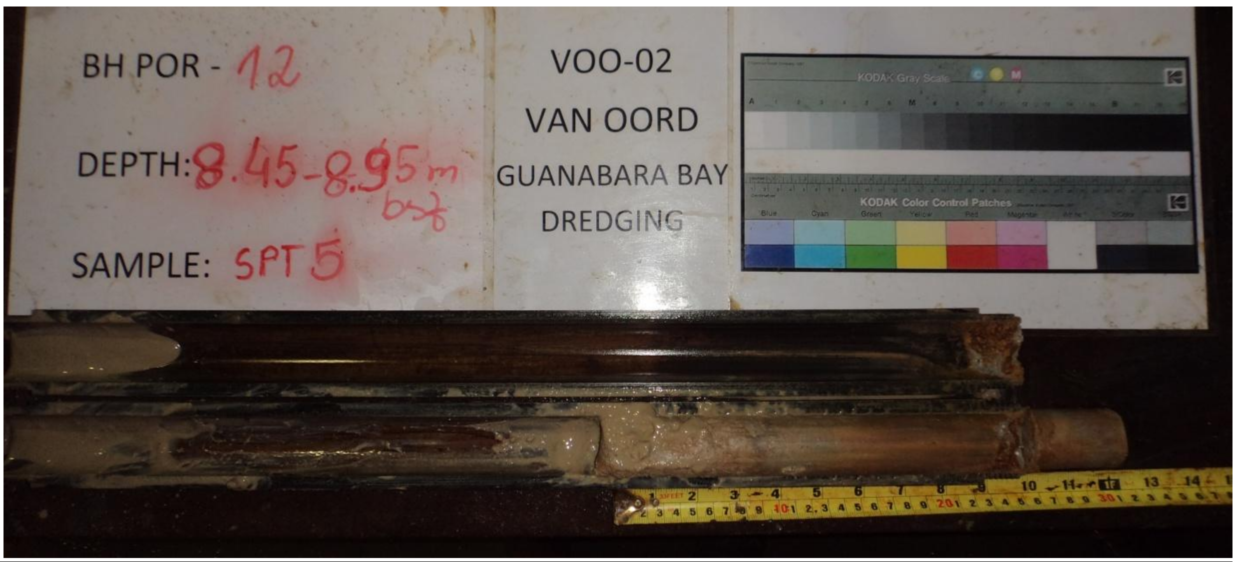
POR-12

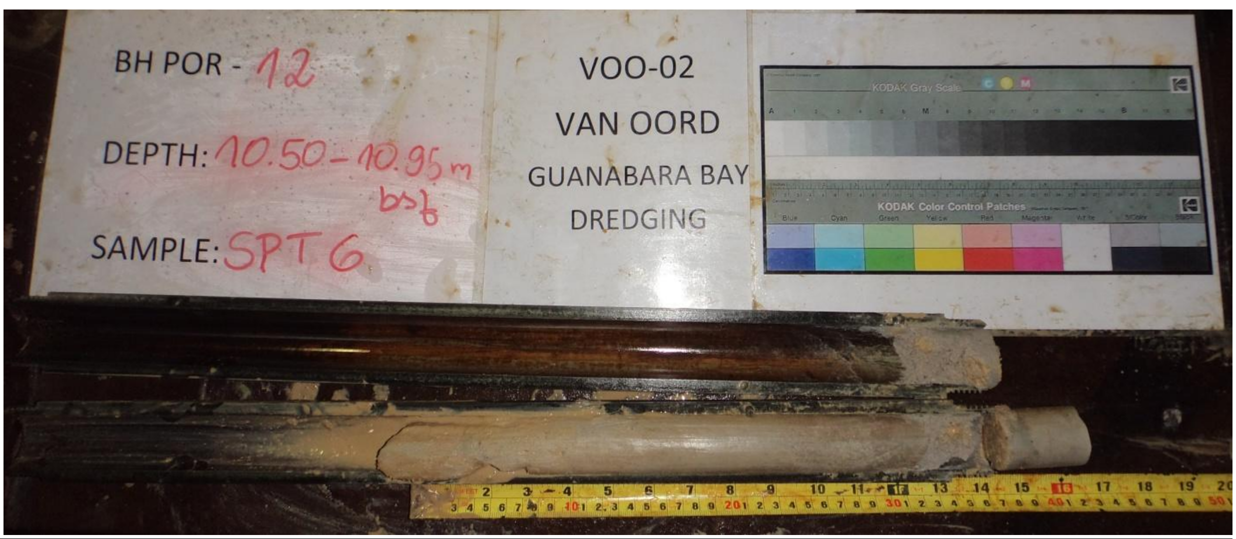

BH POR - 12
DEPTH: 1.50-1.95 mbsf
SAMPLE: SPT 1
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

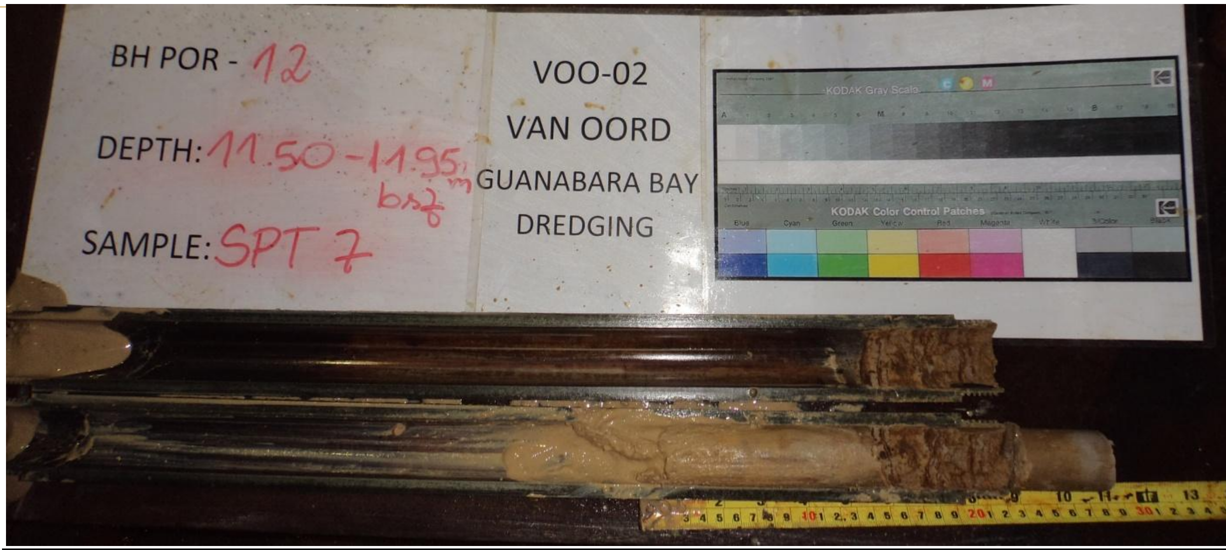

BH POR - 12
DEPTH: 3.00-3.45mbsf
SAMPLE: SPT 2
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 12
DEPTH: 4.50-4.95 m bsf
SAMPLE: SPT 3
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

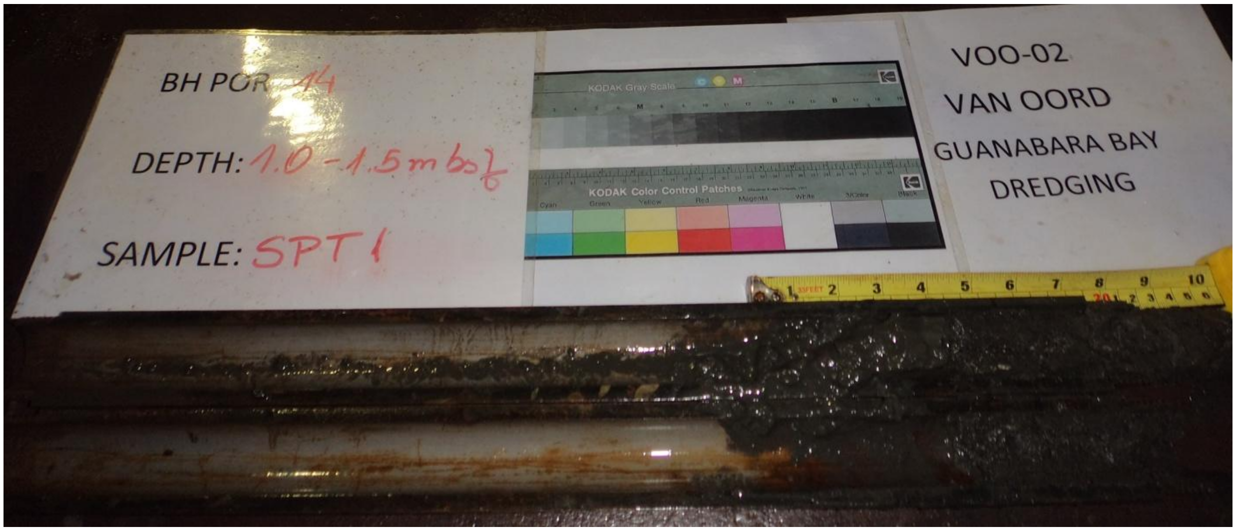

BH POR - 12
DEPTH: 7.00-7.45 m bsf
SAMPLE: SPT 4
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

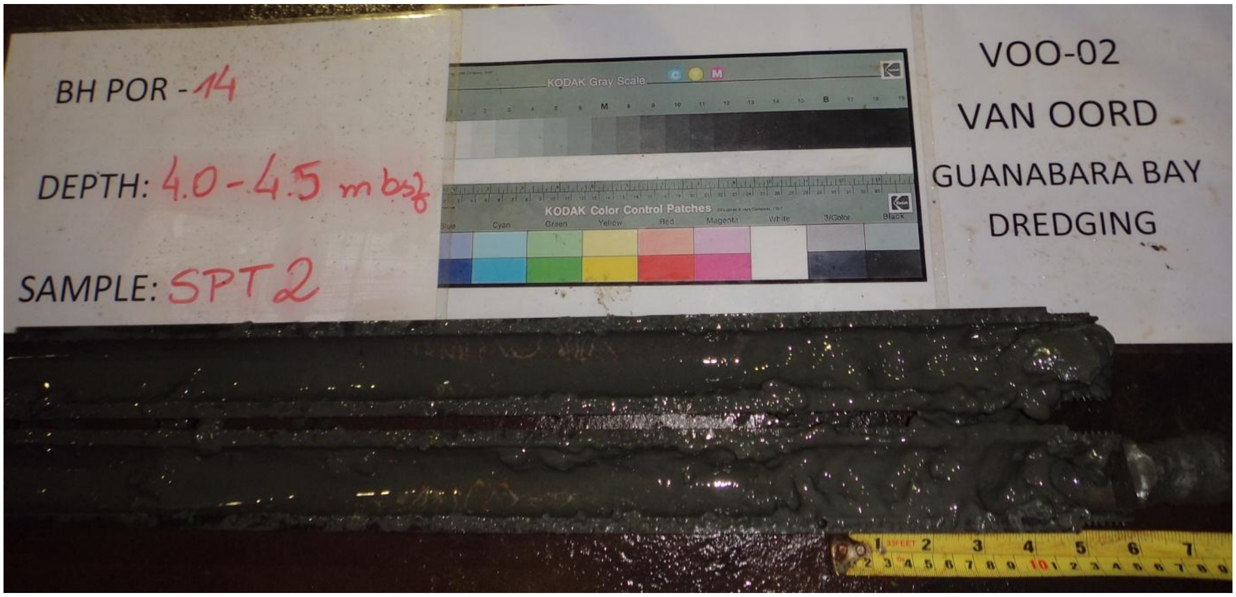

BH POR - 12
DEPTH: 8.45-8.95 m bsf
SAMPLE: SPT 5
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

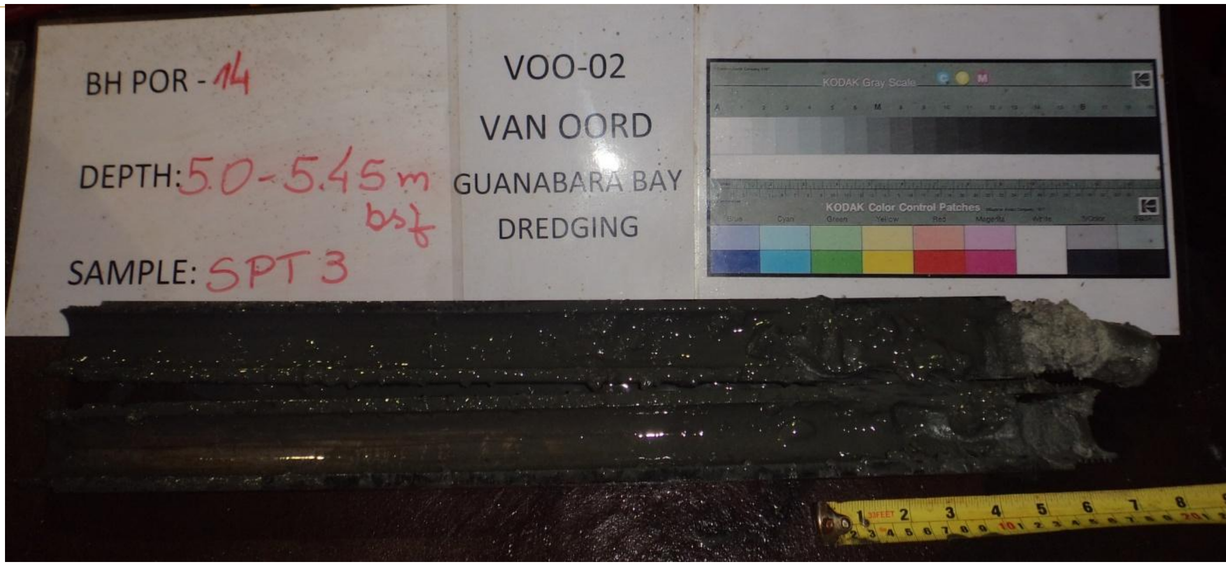

BH POR - 12
DEPTH: 10.50-10.95 m bsf
SAMPLE: SPT 6
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

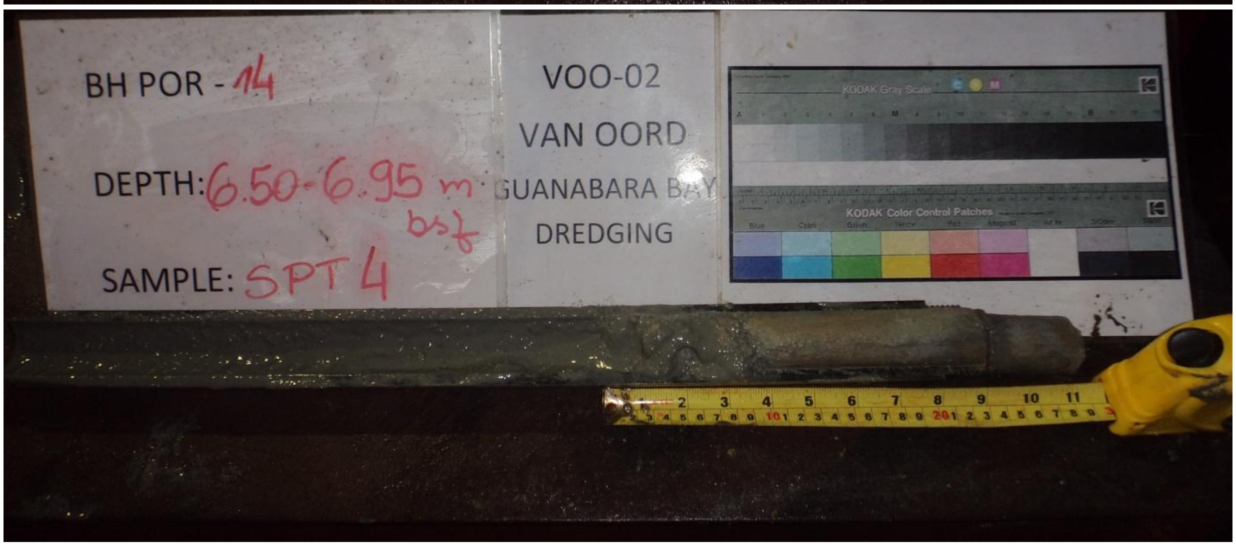

BH POR - 12
DEPTH: 11.50 - 11.95 m bsf
SAMPLE: SPT 7
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

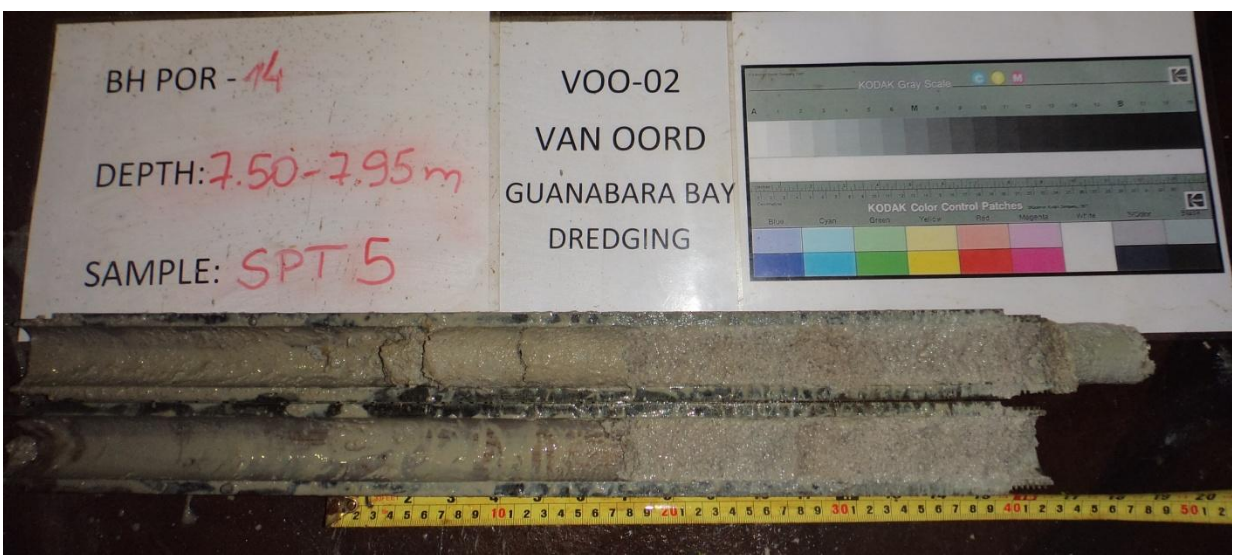
POR-14


BH POR - 14
DEPTH: 1.0 - 1.5 m bsf
SAMPLE: SPT 1
KODAK Gray Scale
KODAK Color Control Patches
VOO-02
VAN OORD
GUANABARA BAY
DREDGING

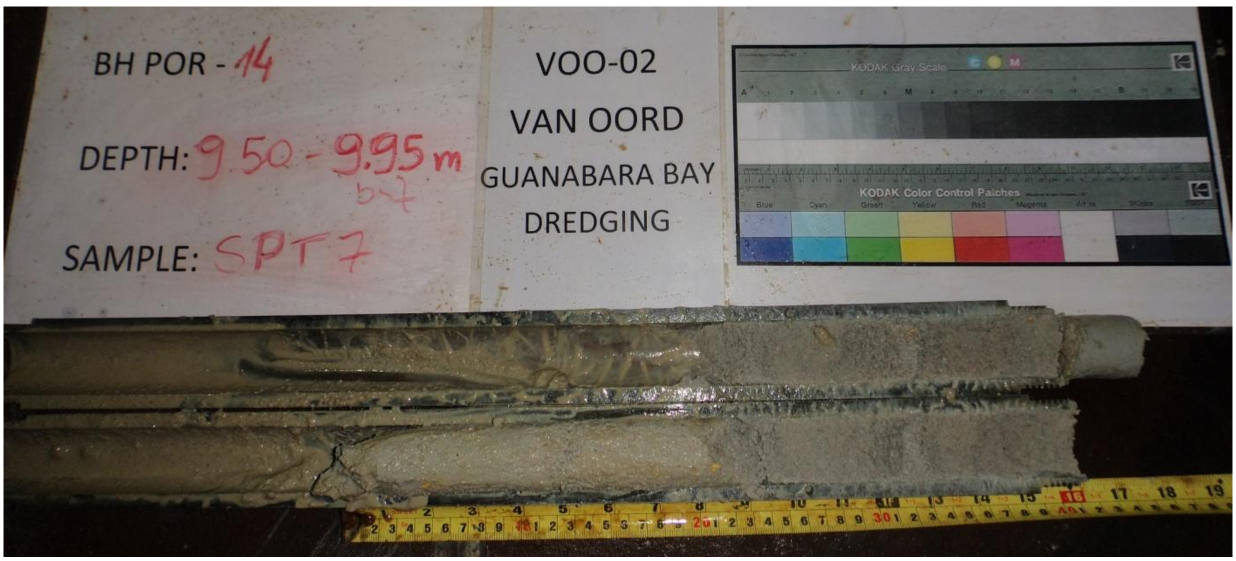

BH POR - 14
DEPTH: 4.0 - 4.5 m bsf
SAMPLE: SPT 2
KODAK Gray Scale
KODAK Color Control Patches
VOO-02
VAN OORD
GUANABARA BAY
DREDGING


BH POR - 14
DEPTH: 5.0-5.45 m bsf
SAMPLE: SPT 3
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 14
DEPTH: 6.50-6.95 m bsf
SAMPLE: SPT 4
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 14
DEPTH: 7.50-7.95 m
SAMPLE: SPT 5
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

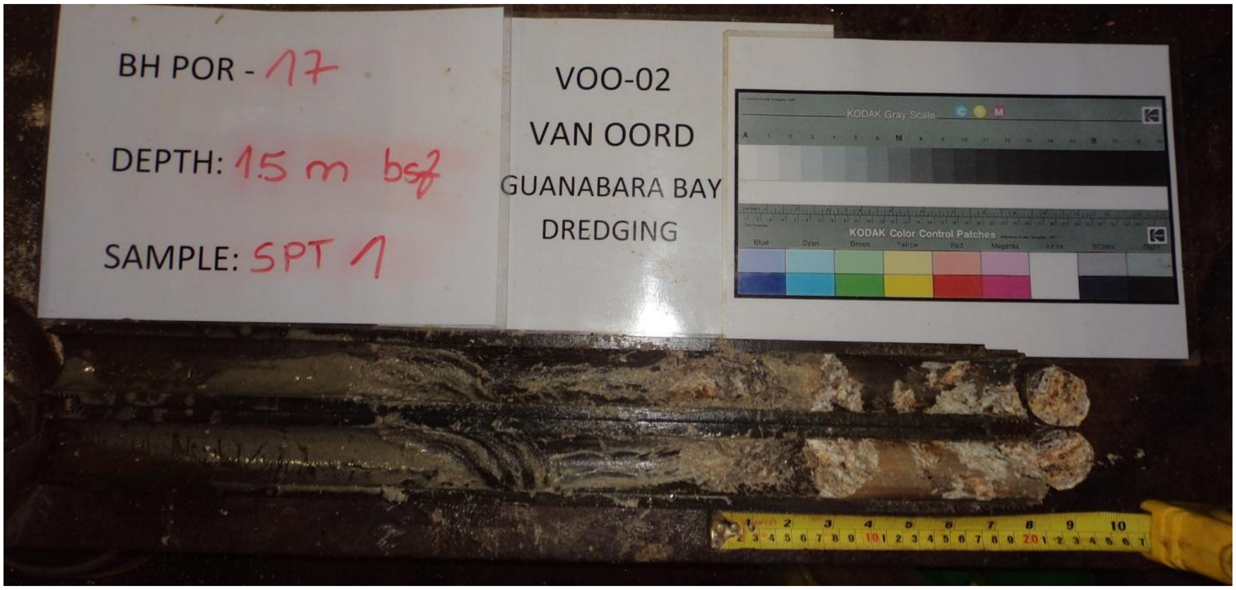

BH POR - 14
DEPTH: 8.50 - 8.95 m
SAMPLE: SPT 6
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


BH POR - 14
DEPTH: 9.50 - 9.95 m
SAMPLE: SPT 7
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches

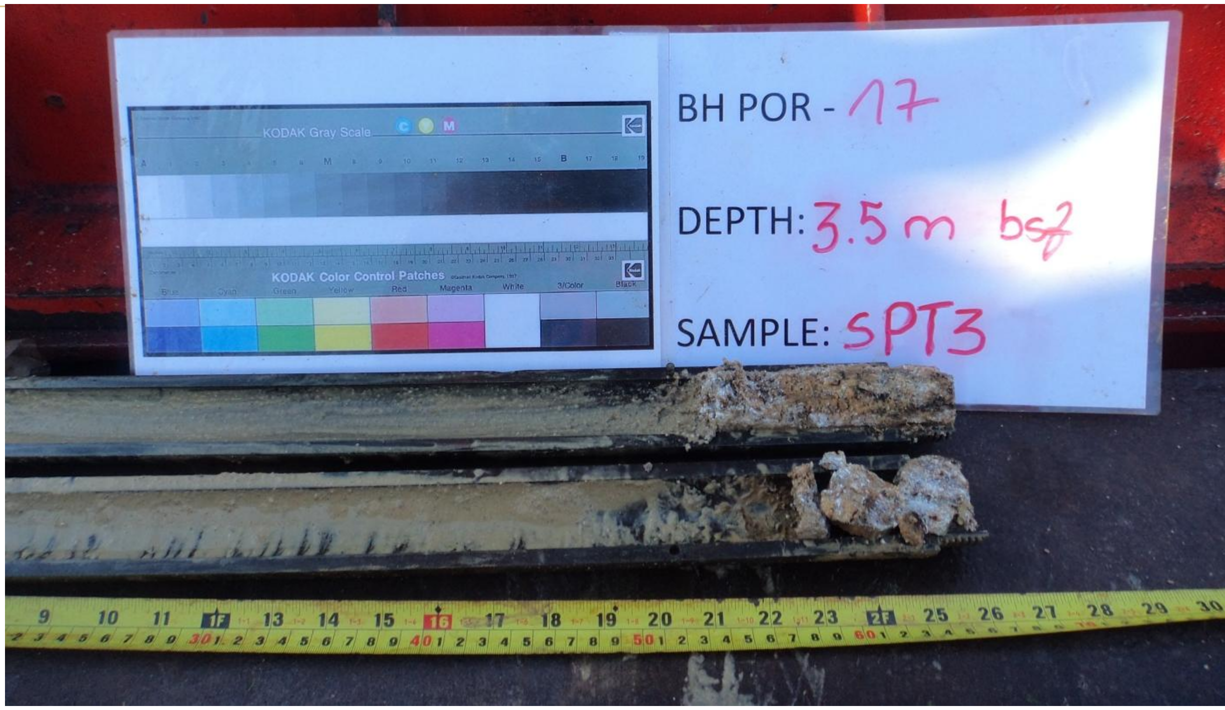
POR-15


BH POR - 15
DEPTH: 2.0 mbsf
SAMPLE: SPT 1
KODAK Gray Scale
KODAK Color Control Patches

POR-17


BH POR - 17
DEPTH: 1.5 m bsf
SAMPLE: SPT 1
VOO-02
VAN OORD
GUANABARA BAY
DREDGING
KODAK Gray Scale
KODAK Color Control Patches


KODAK Gray Scale
KODAK Color Control Patches
BH POR - 17
DEPTH: 2.5 m bsf
SAMPLE: SPT2


BH POR - 17
DEPTH: 3.5 m bsf
SAMPLE: SPT3
KODAK Gray Scale
KODAK Color Control Patches

POR-19

RC2 (1.5 – 3.0 m)

RC3 (3.0 – 4.5 m)