4.0 *FIELD EXPLORATION AND LABORATORY TESTING:*

4.1 *Field Exploration:*

4.1.1 *Drilling:*

During the period between May 9th and 10th, 1999, two boreholes were drilled at the site. The boreholes are numbered 1 & 2. Each borehole was drilled to a depth of 15.0 m, below the existing ground surface. The locations of the boreholes are shown in Figure No. 2. This limited scope of works was specified by the client, as the final design of the project is not defined at this stage.

The drilling was executed with Edico Drill using the rotary air flush drilling method. The logs of the two boreholes are presented in Appendix A attached to this report.

4.1.2 *Sampling:*

Samples were obtained continuously from the boreholes, through out the drilled depth. Double tube core barrel was used to obtain undisturbed samples of bedrock materials, whereas split spoon samples were obtained from alluvial and mixed materials. The samples recovered were examined, described and classified by our geotechnical engineers, placed in proper sequence in wooden boxes and taken to our laboratories for testing. The moist samples were placed in waterproof plastic bags before placing in wooden boxes.

Down the hole hammer was used at intervals of low engineering interest and where the nature of the materials did not allow for coring, in order to advance the boring.

4.1.3 *Field Testing in Boreholes:*

Standard Penetration Tests (S.P.T.) were performed at selected locations in the boreholes, to obtain approximate consistencies and relative densities of the ground materials. The tests were performed in accordance with:

ASTM D 1586-67 (1974), "Penetration Test & Split Barrel Sampling Of Soils".

The test results are shown on the boring logs at depths corresponding to tests locations.

The Standard Penetration Test is defined in the legend to boring logs. attached at the end of this report. Interpretation of the test results is also given in the legend.

4.2 *Laboratory Testing:*

In order to determine the physical and mechanical properties of the ground materials, laboratory tests were performed on selected samples from each borehole. The following tests were performed according to American Society For Testing And Materials (ASTM) Standard, and the British B.S. Standards:

1. ASTM D 2216-92, "Laboratory Determination Of Water (Moisture) Content Of Soil, Rock And Soil Aggregate Mixtures".

2. ASTM D 422-92, standard test method for "Determination of Particle Size Distribution".

3. ASTM D 422-63 (Re-Approved 1990), Standard Test Method For "Particle -- Size Analysis Of Soil". Hydrometer Method .

4. ASTM D4318-93,standard test method for, "Liquid Limit, Plastic Limit, Plasticity Index of Soil"

5. ASTM D 2166-66, "Tests for Unconfined Compressive Strength of Rock".

6. B.S. 1377 : Part 3 : 1990. Test 5, "Determination of The Sulphate Content of Soil & Ground Water". Gravimetric method for acid extracts in which hydrochloric acid was used.

7. B. S. 1377 : Part 3 : 1990, Test 7.3, "Determination of Acid-Soluble Chloride Content". Nitric Acid was used.

4.3 *Laboratory Tests Results:*

The laboratory tests results are summarized in Tables No. 1 & 2.

Table No. 1
Laboratory Tests Results

BN	Depth (m)		M/C (%)	BD (gm/cm³)	Atterberg Limits				Grain Size Distribution				Unconfined Comp. Test	
	From	To			LL (%)	PL (%)	PI (%)	LI	Grav (%)	Sand (%)	Silt (%)	Clay (%)	Q_u (kg/cm2)	F.S. (%)
1	Top	1												
	1	1.5												
	1.5	2	7.7											
	2	3	10.7		27.6	13.7	13.9		0.8	24.6	47.7	26.9		
	3	4.5	10.7											
	4.5	5												
	5	6	10.9											
	6	7												
	7	8												
	8	9												
	9	10	10		23.7	11.2	12.5		16.9	34.4	32.7	16.0		
	10	11												
	11	12												
	12	13.5												
	13.5	15	9.2											
2	Top	1												
	1	2.5	7.7											
	2.5	3												
	3	4	12		22.7	11.3	11.4		1.6	35.7	42.1	20.6		
	4	5.5	10.5											
	5.5	6												
	6	7												
	7	9	10.5		24.4	12.7	11.8		2.6	22.5	45.5	29.4		
	9	10												
	10	11	13.6											
	11	12												
	12	13												
	13	15	10.6											

BN : Boring No
M/C : Moisture Content
BD : Bulk Density
q_u : Unconfined Compressive Strength
L.I : Liquidity Index.

LL : Liquid Limit
PL: Plastic Limit
PI : Plasticity Index
F.S : Failure Strain

Table No. 2
Chemical Tests Results

BN	D (m)		Chemical Tests Results	
	From	To	SO3 (%)	CL (%)
1	3	4.5	0.0779	0.0473
1	5	6	0.0723	0.0411
2	3	4	0.0788	0.0439
2	4	5.5	0.0702	0.0401

BN : Boring Number
D : Depth of Sample
SO3 : Sulphate Content
Cl : Chloride Content

5.0 SURFACE AND SUBSURFACE CONDITIONS:

5.1 *Ground Materials:*

The two boreholes drilled show that there are general similarities and continuities of the subsurface materials, in spite of some local variations.

A generalized subsurface profile (AB) was constructed and is presented in Figure No. 4. The profile was constructed through boreholes No. 1& 2, and its location is shown in Figure No. 2. The profile was constructed by direct interpolation between the materials encountered in the boreholes. The lines connecting the various ground strata are made for illustration purposes only and are not to be considered as actual field conditions.

The geologic description of the ground materials at the site and the approximate average depth at which they were encountered in the boreholes are presented in Table No. 3.

Further information about the materials encountered can be obtained from the logs of borings, Appendix A.

5.2 *Materials Physical and Mechanical Properties:*

The field and laboratory tests results as well as the corresponding material classification were summarized for the various ground materials and are also presented in Table No. 3.

Atterberg limits test results were plotted on Casagrande Plasticity Chart, Figure No. 5 to obtain the plasticity of the soils.

In order to obtain the degree of potential expansiveness, the percentage of clay fraction for the tested samples were plotted against the plasticity index for the same samples on the chart for the degree of potential expansiveness (Williams & Donaldson , 1980), Figure No. 6 .

The results obtained from the particle size analysis tests were used to obtain the textural classification of the soils as shown in Figure No. 7.

The tables given in the legend to boring logs, Appendix A, were used to describe the consistency of the soils, and the strength and quality of the rocks.

Further information about the materials encountered and their physical and mechanical properties can be obtained from Table No. 1.

GENERALIZED SUBSURFACE PROFILE AB

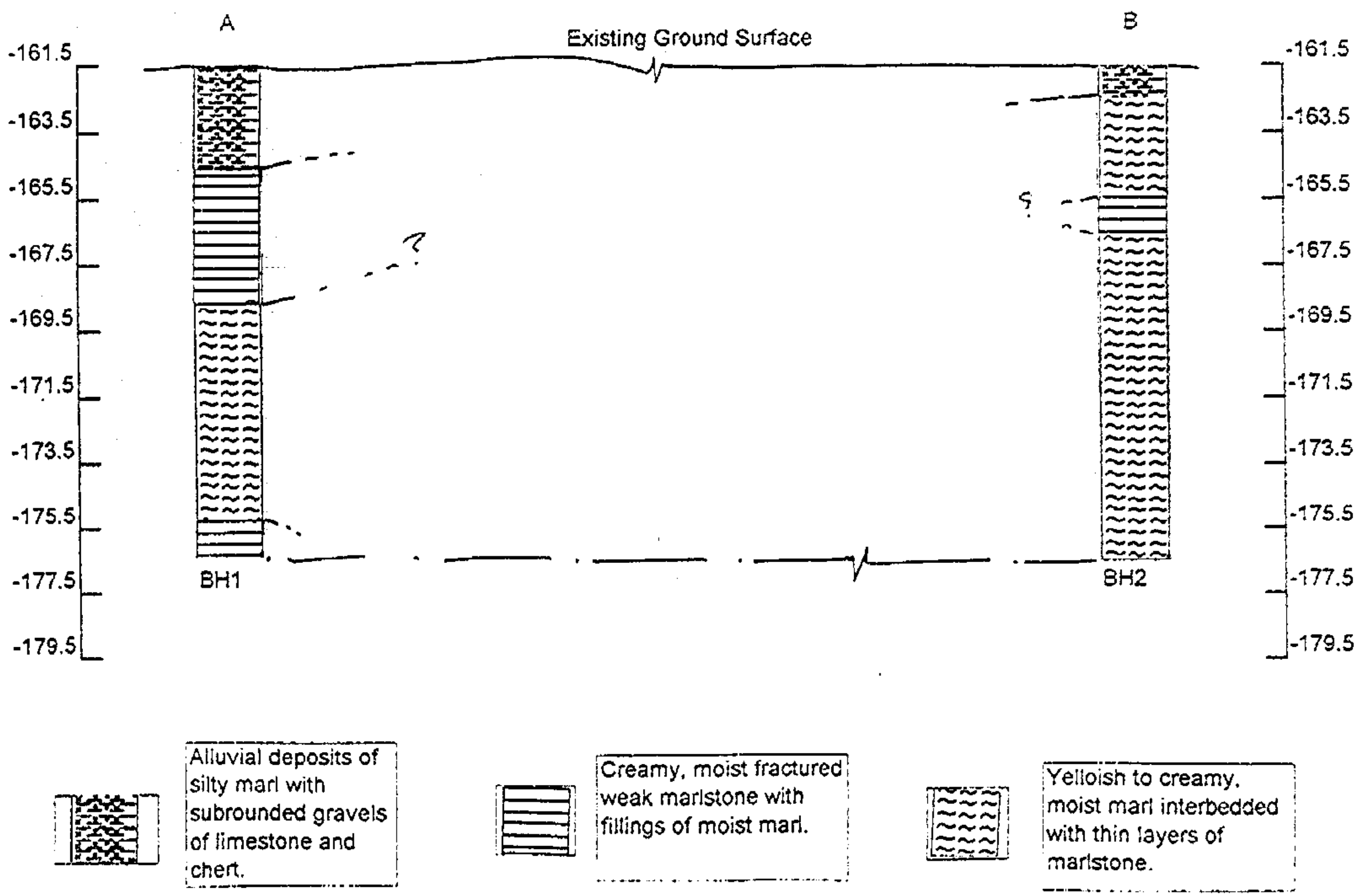


Figure No. 4

Table No. 3
Materials Types and Properties

Approximate Depth				Geologic Description	Summary of Tests Results	Material Classification
	Depth		Bore hole			
	From	To				
	Top Top	3 1	1 2	Alluvial deposits of creamy silty marl with gravels of limestone and chert.	M/C:7.7-10.7% LL:26.7% PL:13.7% PI:13.9% Gravel:0.8% Sand:24.6 Silt : 47.7 Clay : 26.9 N : 68	P : Low PE : Medium TC : Sandy & Silty Clay
& & &	3 13.5 4	7 15 5.5	1 1 2	Creamy, moist, fractured, weak marlstone with fillings of moist marl	M/C : 9.2 – 10.9 RQD : 0 qu : -	D: Very poor. St.: Weak to very weak as assessed by the geologic hammer.
& &	7 1 5.5	13.5 4 15	1 2 2	Yellowish to creamy, moist marl, interbedded with thin layers of marlstone.	M/C 7.7 – 13.6 LL : 22.7 – 24.4 PL : 11.2 – 12.7 PI : 11.4 – 12.5 Gravel : 1.6 – 16.9 Sand : 22.5 – 35.7 Silt : 32.7 – 45.5 Clay : 16 – 29.4 N : 79 - 84	P : Low PE : Low to Medium TC : Clay & Sandy Silt, Sandy & Silty Clay to Clay

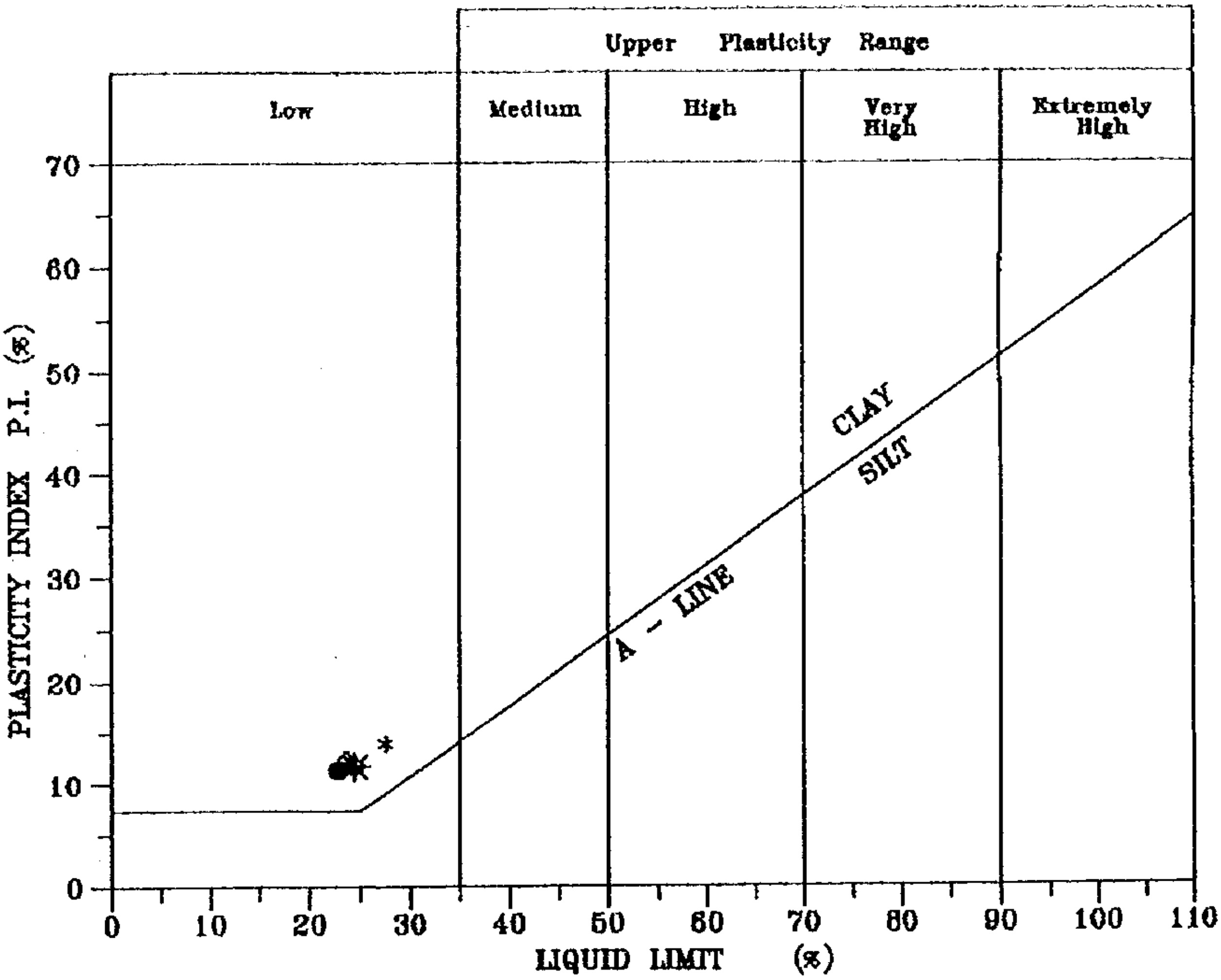
M/C : Moisture Content
PL : Plastic Limit
PI :Plasticity Index
LL : Liquid Limit
P: Plasticity
TC : Textural Classification
PE : Potential & Expansiveness
EOB: End Of Boring

qu: Unconfined Compressive Strength
St: Rock Strength Description
RQD: Rock Quality Designation
D: Rock Quality Description
N : Number & Blows (30 cm)

* NOTE : See Legend to Boring Logs, Appendix A

CASAGRANDE PLASTICITY CHART

(A - LINE)

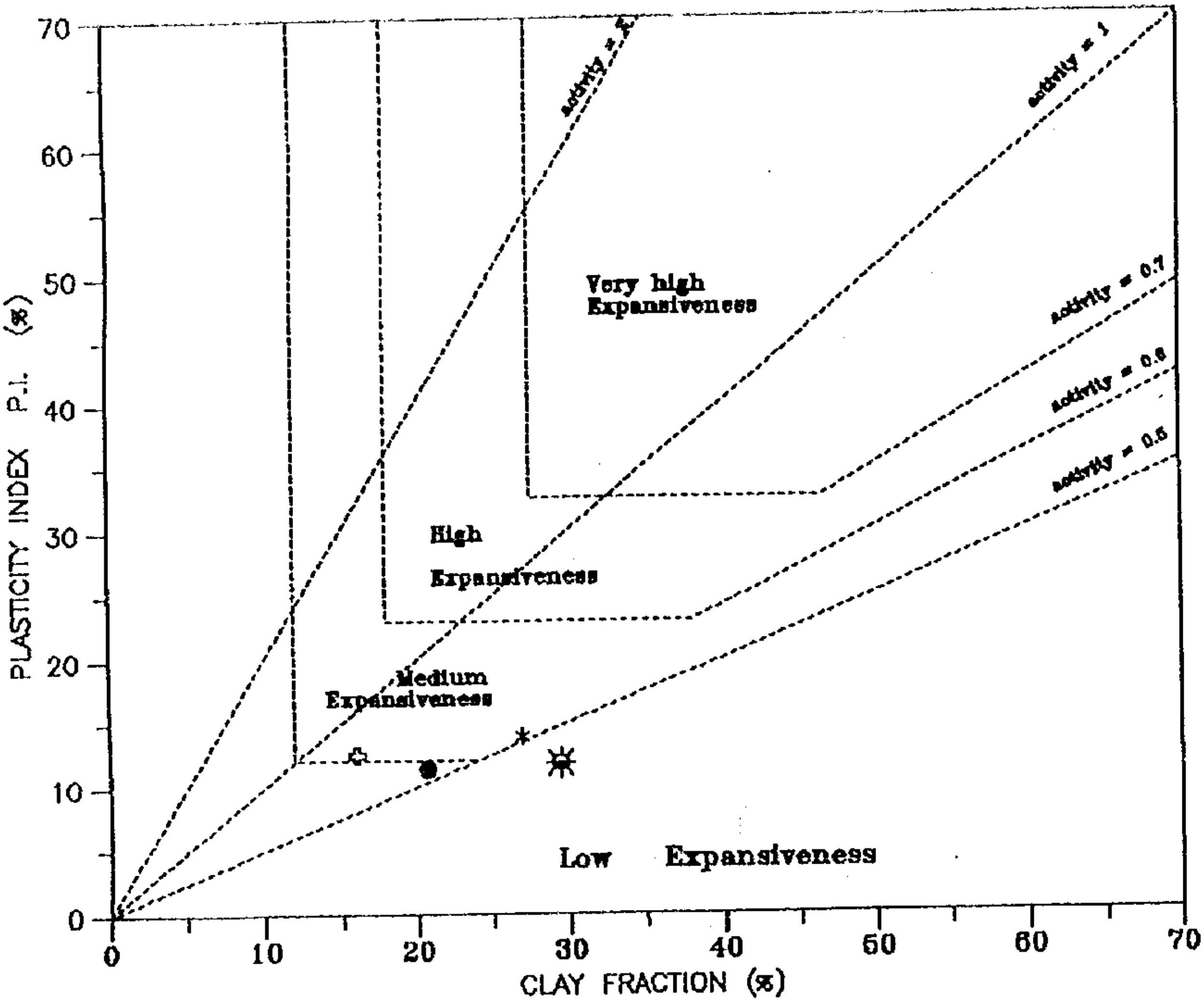


SYM.	BN	SAMPLE No.	DEPTH (m)	L.L. (%)	P.L. (%)	P.I. (%)	CLASSIFICATION	PLASTICITY
+	1	1	2.00 - 3.00	27.67	13.65	13.92	Sandy and silty clay	Low
◆	1	2	9.00 - 10.00	23.71	11.20	12.51	Clayey & sandy silt	Low
●	2	1	3.00 - 4.00	22.73	11.33	11.40	Sandy and silty clay	Low
✳	2	2	7.00 - 9.00	24.45	12.69	11.76	Clay	Low

<u>Figure No. 5:</u> Casagrande Plasticity Chart S99031

MODIFIED CHART OF EXPANSIVENESS

(Williams and Donaldson 1980)

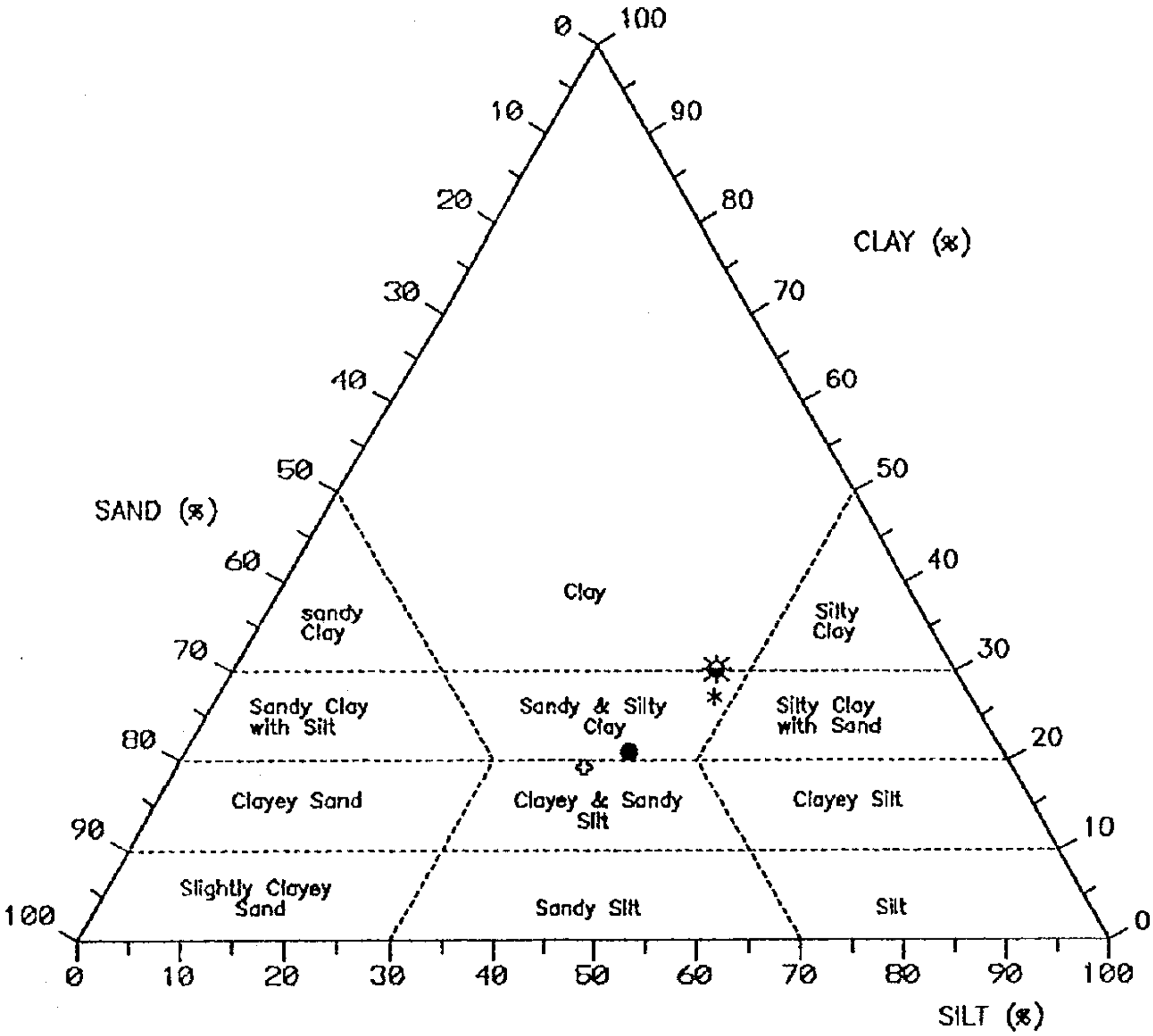


SYM.	BN	SAMPLE No.	DEPTH (m)	CLAY (%)	P.I. (%)	CLASSIFICATION	POTENTIAL OF EXPANSIVENESS
*	1	1	2.00 – 3.00	26.90	13.92	Sandy and silty clay	Medium
◇	1	2	9.00 – 10.00	16.00	12.61	Clayey & sandy silt	Medium
●	2	1	3.00 – 4.00	20.60	11.40	Sandy and silty clay	Low
☀	2	2	7.00 – 9.00	29.40	11.76	Clay	Low

Figure No. 6: Modified Chart Of Expansiveness S99031

ARAB CENTER FOR ENGINEERING STUDIES

TEXTURAL CLASSIFICATION CHART



SYM.	BN	SAMPLE No.	DEPTH (m)	CLAY (%)	SILT (%)	SAND (%)	CLASSIFICATION
*	1	1	2.00 - 3.00	27.12	48.08	24.80	Sandy and silty clay
◇	1	2	9.00 - 10.00	19.25	28.52	41.40	Clayey & sandy silt
●	2	1	3.00 - 4.00	20.93	42.78	38.28	Sandy and silty clay
☀	2	2	7.00 - 9.00	30.16	46.71	23.10	Clay

Figure No. 7: Textural Classification Chart S99031

ARAB CENTER FOR ENGINEERING STUDIES

5.3 *Ground Water And Cavities:*

No ground water was encountered, in any of the boreholes to the depths drilled.

5.4 *Sulphate Content in Ground Materials:*

The sulphate content expressed as sulphur trioxide (SO_3) for the soil samples tested from boreholes, are shown in Table No. 2.

Sulphate attack to concrete, is a well documented phenomenon and is caused by the presence of the high sulphate content either by the ingress from the sulphate of the surrounding environment such as foundations soils, or by the presence of sulphate in the concrete ingredients such as the sand or aggregate, or both. The attack results in a considerable internal expansion which may lead to cracks and disintegration of the concrete.

The British Code of Practice BS 5328 : Part 1 :1990 "Guide to Specifying Concrete" have stated requirements for concrete exposed to sulphate attack, depending on the concentration of the sulphate in the surrounding soil or in water. These requirements state the type of water to cement ratio to be used, the minimum cement content and maximum free water to cement ratio. A copy of BS 5328 : Part 1 requirements is attached to this report in Appendix B.

The British Building Research Establishment (BRE), in UK have published Digest 363 "Sulphate and acid resistance of concrete in the ground", 1991, in which the sites are divided into five categories of increasing severity, based on the sulphate contents of the soil or ground water (Table 1). However, having classified the site on the bases of sulphate level, type of exposure (Table 1a) and type of concrete (Table1b), further recommendations for concrete in acidic conditions are given in Table 2 and Fig. 1.

Changes made to the basic classification given in Table 1 are commutative, Table 1 states for each of the five categories cement type, minimum cement content, and maximum free water/cement ratio. A copy of Tables 1, 1a, 1b, 1c, and 2 and fig 1 (procedure for classification of site) of BRE Digest 363 are attached to this report in Appendix B.

Due to the sulphate content present in the foundations soils and ground water, this site is classified within Class (1) as categorized in BS 5328 : Part 1. The requirements of BS 5328 : Part 1 is to use ordinary portland cement or combination of Portland cements to BS 12, and Pfa to BS 3892: Part 1 containing not less than 25 % Pfa and not more than 40 % Pfa by mass of Pfa plus cement. The requirements for minimum cement content and maximum water cement ratio are given in Table 1, class 1, presented in Appendix B.

The classification of the site on the basis of the sulphate level can be determined according to Table 1 of BRE Digest 363. However, modifications to this classification should be made by the designers once the type of exposure to sulphate (such as types of floors exposures, static ground water and permeability of soils, the location and thickness of the structure and the hydrostatic head), and the types of concrete used (such as precast concrete, cast-in-situ concrete, wall units, piles, etc.) are finally determined.

It should be noted however, that practical experience have indicated that mixes having both the minimum cement content and maximum free water to cement ratio recommended above may result in concrete of low level of workability, such that full compaction to achieve dense concrete of the necessary degree of impermeability to resist, as much as possible chemical attack, cannot be easily achieved. It may be therefore, practical to increase the cement content while maintaining the recommended water to cement ratio in order to obtain the appropriate workability to achieve full compaction of the concrete. Alternatively, workability/compaction can be enhanced by using a plasticizing or superplasticizing admixtures. The admixtures should comply with BS 5075 Parts 1 and 3. Admixtures containing calcium chloride are not recommended for sulphate resisting, or any reinforced concrete.

The CIRIA Guide to Concrete Construction in the Gulf Region, 1983, recommended maximum limit of sulphates as (SO_3), in the coarse or fine aggregate used for concrete as 0.4 % and recommended maximum limits for total sulphate content in concrete from all sources expressed as a percentage by weight of cement as 4% in all cases. It is our opinion that these limits must be adopted and specified for contamination of the concrete and its ingredients in order to achieve durable concrete.

Concrete cast in the ground will cure under the conditions normally favored for strength development and durability provided that the temperature rise due to the heat of hydration is kept low. In the particular case of resistance to sulphate attack, a period of air curing to the structures has been shown to provide a protective layer associated by allowing the access of air to a dry concrete surface for several weeks after the normal curing schedules (BRE Digest 363). It is emphasized however, that since good curing entails keeping the surface wet, the subsequent treatment of dry surface should be regarded as a specific secondary process.

5.5 *Chloride Content in Ground Materials*:

The chloride content for the same soil samples are also shown in Table No. 2.

BS 5328, Part 1 grade soils and ground waters in five steps of sulphate concentration : 0.2 % total sulphate (SO_3), or 1.0g/L in 2:1 soil water extract is considered significant. However, there is no widely accepted view on the concentration which chlorides become significant in soil or ground water, but limited experience in the Gulf Region suggests it may be as low as 0.05 %, particularly in situations where alternate wetting and drying or capillary rise affect the concrete.

Chloride do not react expansively with portland cement as do sulphates. Their effect when present in concrete is to increase the risk of corrosion of embedded metals of which the greatest volume used is steel reinforcement. They can be tolerated in plain concrete, although when present in large amount some surface dampness may result, but widespread and serious damage has been caused by the use of chloride-contaminated aggregates in reinforced concrete.

The corrosion products occupy more than twice the volume of steel. and their formation can be accompanied by very high tensile pressures as great as 32 N/mm2, resulting in cracking of the concrete, frequently followed by spalling of the cover. In severe cases of corrosion there may be a reduction in section of the reinforcing bars, leading to a loss of tensile strength of the reinforced concrete.

Therefore, it is of utmost importance to ensure that the maximum limits for chlorides and sulphates in the aggregate components and in the concrete, are not exceeded. These limits must be clearly stated in the technical specifications of the project.

The CIRIA Guide to Concrete Construction in the Gulf Region, 1983, recommended maximum limit of chlorides, as CL, in the coarse and fine aggregates used for concrete as 0.03 and 0.06, respectively, and recommended maximum limits for total chloride content in concrete from all sources expressed as a percentage by weight of cement as 0.15 % for reinforced concrete made with Portland cements containing less than about 4 % C^3A (e.g. sulphate resisting Portland cement) and 0.03 % for reinforced concrete made with Portland cements containing 4 % or more C^3A (OPC and ASTM Type I and II usually contain more than 4 % C^3A). For un-reinforced concrete the limit is 0.6 %.

Additionally, it is advisable that concrete cover for the steel reinforcement be increased in the members to protect the steel from the ingress of the chlorides present in the surrounding environment. Surface protection and sealing of the concrete and steel may also be considered.

Evidences of concrete cracking and steel corrosion were observed on many of the old concrete elements existing in the area. While corrosion can be initiated at lower chloride level in sulphate resisting portland cement concrete than in ordinary Portland cement, the use of sulphate resisting portland cement blended with pozzolanic materials, can reduce the risk of damage caused by the sulphate contaminated aggregates. If chlorides are also present, the use of sulphate resisting cement may increase the risk of corrosion of reinforcing steel.

Sulphates may be present in the environment to which the concrete is exposed, often in combination with chlorides. Their main effect is on the concrete itself, where their attack leads to internal expansion and disruption. Their effect can be reduced by the use of sulphate-resisting cements, cements containing blast-furnace slag or pozzolanic, or in severe exposure conditions, by protecting the concrete by tanking.

Where sulphates and chlorides occur together, problems are accentuated because sulphate-resisting cements provide less protection to steel against attack in the presence of chlorides. Current research is giving grounds of increasing concern that where sulphates and chlorides occur together, the use of sulphate-resisting cement may be inadvisable, (CIRIA Guide to Concrete Construction in the Gulf Region, 1983). Sulphate-resisting cements do not make concrete immune from sulphate attack but only make it better able to withstand moderate concentrations of sulphate since it contains less tricalcium aluminate (C^3A) than OPC, to reduce the effect of the reaction between the C^3A and sulphate. However, C^3A can also combine with chloride which might otherwise cause reinforcement to rust.

Recommendations

Generally, where resistance is needed against sulphate attack, but there is NO significant risks of chloride-induced corrosion, SULPHATE-RESISTING CEMENT to BS 4027 or ASTM Type V (i.e. cement with a maximum C^3A content of 3.5 or 5.0 %, respectively gives better protection)

Where improved resistance is needed against chloride corrosion of the reinforcement, but there is NO significant to sulphates, Cement with a medium to high C^3A content is preferred. OPC or ASTM Type I usually have high C^3A contents and ASTM Type II usually has a medium C^3A content.

Where resistance is needed against both sulphates and chlorides, concrete may need to be protected form the soil and groundwater with waterproof membrane or tanking, and a compromise has to be made on the type of cement used. Generally, a cement containing at least 3.5 % but not more than 9% C^3A is preferred. Each situation should be considered on its merits.

In this case where both sulphate and chloride existence is very slight, then the minimum considerations stated above shall be satisfied.

However, it is advisable that the designer consult CIRIA Guide to Concrete Construction in the Gulf Region or any other similar reference, once the exposure conditions of the designed structures are finally determined, in order to determine, more accurately, the cement type (Figure 6 and range of specifications limits requirements for minimum cement content, maximum water cement ratio and minimum cover for reinforcement (Table 13). Figure 6 and Table 13 are attached in this report in Appendix B.

6.0 *CONCLUSIONS AND RECOMMENDATIONS:*

According to field and laboratory investigations, subsurface conditions, engineering analysis and practical experience, it can be concluded that the proposed building can be satisfactorily supported by the ground at the site, provided that the following recommendations are followed:

6.1 *Foundation Depth And Type:*

The foundations of the proposed building shall be laid below the top overburden material of alluvial deposits <u>into</u> materials of creamy to yellowish marl and marlstone encountered in all boreholes at depths ranging between 1 to 3m. The foundations shall be laid <u>into</u> coherent materials, and any friable, or soft inclusions of silty clay or any other material, shall be removed before foundations construction.

Moreover, the foundations depth may vary according to architectural considerations, however, it should not be less than 2.0m below the minimum adjacent, finished ground level.

The encountered foundations ground is suitable to support the structural loads using spread footings with tie beams, however strip footings may also be used, if required.

6.2 *Allowable Bearing Pressure:*

The allowable bearing pressure corresponding to the encountered highly fractured, creamy, thinly bedded weak marlstone was estimated using the following equation, recommended by Tomlinson, for strip foundation on rock mass with closed joints:

$$q_u = c\,N_c + 0.5\,\gamma\,B\,N_\gamma + \gamma\,D\,N_q$$

N_c , N_γ & N_q are given as a function of the friction angle φ. Correction for the footing shape may also be applied.

The shear strength parameters were estimated according to Kulhawy and Goodman, as a function of the rock quality designation (RQD), and the unconfined compression strength q_{uc} , as :

RQD (%)	C	φ°
0 - 70	0.1 q_{uc}	30°
70 - 100	0.1 q_{uc}	30° - 60°

The obtained parameters for the highly fractured marlstone were :

RQD : 0 %, therefore φ° was taken as 30 for marlstone, and 20 for the marl.

q_{uc} : Very weak as assessed with the geologic hammer (Unconfined compression test could not be carried out due to the highly fractured nature of the material), taken as 5 kg/cm^2 for marlstone, and 1 kg/cm^2 for the creamy marl.

Therefore, based on the obtained results, and considering the existence of weaker marl materials within the zone of influence of the foundations, and based on our previous experience with similar materials, it is recommended that the allowable net foundation bearing pressure be taken as 2.2 kg/cm^2, for the whole site, provided that the recommendations given in paragraph 6.1 for "Foundation Depth And Type", are satisfied.

Important Note: The above conclusions apply to the areas of the site represented by the drilled boreholes. In case that the plan area of the proposed school building and its layout over the site did not satisfy the above conditions, additional test borings are recommended in other areas of the site to confirm that the above conclusions and recommendations apply.

6.3 *Foundation Settlement:*

With the foundations designed and constructed in accordance with the above recommendations, the settlement is estimated to be within the tolerable limits.

An estimate of the anticipated foundation settlement was carried out using the following relationship :

$$S_i = q_{fn} B' \frac{1 - \mu^2}{E_d} I_f I_s$$

in which,

S_i : Immediate, or elastic foundation settlement.
q_{fn} : Specified maximum net foundation pressure.
B' : Characteristic Dimension of the foundation.
μ : Poisson's Ratio, taken as 0.33
E_d : Deformation Modulus, estimated as 150 kg/cm2
I_s & I_f : Shape & Depth Correction Factors.

The obtained settlement was insignificant, and negligible. Moreover, most of this settlement will take place during the construction period.

6.4 *Excavation Methods:*

It is expected that the excavation will be through top soil of silty clay and marl deposits, and through, highly fractured, weak marlstone and marl. Therefore, conventional excavation equipment such as loaders and dozers, will be sufficient for the excavation works. However, pneumatic equipment such as jack hammers with compression and rock breakers may be required, in some locations for the excavation of marlstone materials.

6.5 *Excavation of Side Slopes:*

To minimize the instability problems, the temporary side excavation during construction should be sloped at a face inclination not steeper than one horizontal to two vertical (1H: 2V).

6.6 *Surface Drainage:*

It is recommended to protect the foundation ground and excavation from surface water both during and after construction by providing proper drainage and protection system. Surface water should be diverted away from the edges of the excavations.

6.7 *Subsurface Drainage System:*

No free ground water was encountered within the proposed zone of foundation depth, therefore, no subsurface drainage system is needed. However, in order to prevent water dampness at the basement walls, and ground floor, if any, all subsurface walls and bottom of foundations should be water insulated with proper insulating materials. Water stops should be used at all construction joints.

6.8 *Protection of Foundation From Soil Environment* :

The chemical tests results indicated that the soil environment is slightly hostile to the foundation concrete. Therefore, no special considerations for foundation protection are required (see paragraphs 5.4 and 5.5). However, all subsurface structures should be totally protected by isolating the structures with appropriate protective coating or sheeting which shall extend up to and a little above the finished ground level. Normal concrete cover (50 - 75 mm) shall also be provided.

6.9 *Backfill Material And Compaction Criteria:*

The top silty clay materials are not suitable for backfilling purposes because of their plasticity. The marlstone crushings and creamy marl materials resulting during excavation works, are probably suitable as backfilling material. However, the final decision shall be taken during construction and after testing.

The materials to be used for backfilling purposes behind underground walls and basement floor slab shall be a soil or soil-rock mixture which is free from organic matter or other deleterious substances. It shall not contain rocks or lumps over 15 cm in greatest dimension, and not more than 15 percent larger than 7 cm. The plasticity index for the backfill material shall not be more than 15 percent.

It shall be spread in lifts not exceeding 25 cm in uncompacted thickness, moisture conditioned to its optimum moisture content, and compacted to a dry density not less than 95 percent of the maximum dry density as obtained by standard proctor compaction test (ASTM D 698).

6.10 *Earth Pressure:*

The underground walls of the building, if any, drained and backfilled as recommended above, shall be designed for an equivalent fluid pressure of 0.8 gm/cm3 (800 kg/m3) plus a uniform lateral pressure which corresponds to the maximum expected surface loads.

In all cases, additional lateral pressures, if any, exerted on the underground walls from footings and loads at higher levels of the adjacent buildings shall be considered in the structural design.

6.11 *Seismisity of Site:*

The study area is very close to the Jordan rift (the area is only few kilometers from the Jordan rift) and is in fact affected by the tectonics of the rift. The Jordan rift represents a focus of earthquake activity. Therefore, any activity in the rift would certainly have a bearing on the naturally or artificially instable earth blocks. According to the seismic photomap published by the Geologic Survey of Israel and which includes a record of the earthquakes measured in the area during the period of 1981 to 1993, there is evidence of the existence of numerous non-major earthquakes of Richter magnitudes of more than 5.

According to Jordan National Building Code for Loads and Forces, the site may be classified as class A according to this code. This region has an earthquake intensity of VII to IX on Mercalli Scale, and of 0.75 intensity factor. This region is generally considered as the highest active seismological zone according to this code. Major hazards shall be expected in the area of this region.

The seismic hazard for any particular site could be assessed by Modified Mercalli intensity (Factor of intensity) or by Peak Ground Acceleration (PGA).

The PGA is very widely used for the assessment of seismic hazards at the sites of engineering projects. Due to the seismicity of the project area and because of its proximity from the Jordan Valley, a PGA value of 0.1g to 0.15g is recommended for structural design purposes. (Richter 1958, has developed a correlation between the Richter Magnitude, Modified Mercalli Intensity, Velocity, and Ground Acceleration. The above recommended ground acceleration corresponds to an earthquake of a Richter Magnitude of 7, and modified Mercalli intensity of VIII).

Modified Mercalli Scale is a measure of the intensity of earthquakes and is correlated with Richter (Magnitude) Scale, as follows (Richter 1958):

Modified Mercalli Scale	Equivalent Richter Magnitude	Ground Acceleration (g)
IV		0.007 – 0.015
	4	
V		0.015 – 0.035
VI		0.035 – 0.07
	5	
VII		0.07 – 0.15
	6	
VIII		0.15 – 0.35
	7	
IX		0.35 – 0.70

6.12 ***Foundation Excavation Inspection:***

The recommendations given in this report are based on the assumption that the subsurface materials and conditions do not deviate appreciably from those disclosed in the borings.

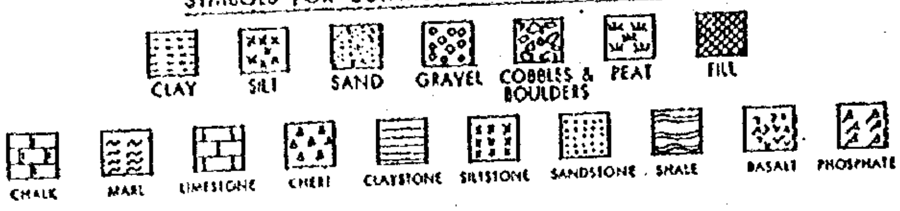
Our office should be notified, in writing, immediately after foundation excavation and before foundation construction to inspect the excavations and confirm that the required ground is reached and all the undesirable and loose materials are removed. Such inspection, and any other routine foundation excavation inspection (if requested), will be carried out at separate fees.

APPENDIX A

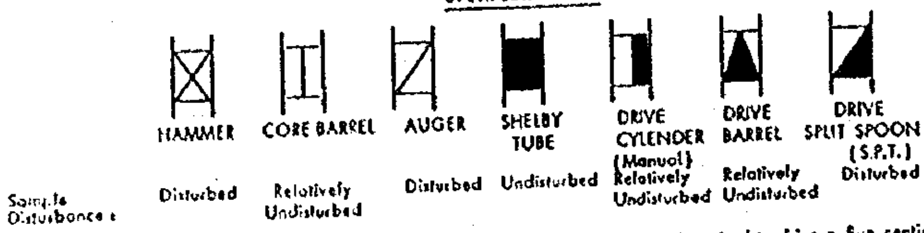
LOGS OF BORING

LEGEND TO BORING LOGS

SYMBOLS FOR COMMON SOIL AND ROCK TYPES



SAMPLER TYPE



S.P.T. (Blows/30 cm): The number of blows, in the Standard Penetration test, required to drive a five centimeter diameter split tube sampler a distance of thirty centimeters using sixty five kilograms weight falling seventy six centimeters.

Fine Grained Soils

S.P.T. (Blows/30 cm)	Consistency	Field Identification	Unconfined compressive strength (kg/cm²)
0-2	Very soft	Easily penetrated several cms with fist.	<0.25
2-4	Soft	Easily penetrated several cms with thumb.	0.25 – 0.5
4-8	Firm	Penetrated several cms by thumb with moderate effort.	0.5 – 1.0
8-15	Stiff	Readily indented by thumb but penetrated only with great effort.	1.0 – 2.0
15-30	Very Stiff	Readily intented by thumb nail.	2.0 – 4.0
≥ 30	Hard	Indented with difficulty by thumb nail.	> 4.0

Coarse Grained Soils

S.P.T. (Blows/30 cm)	Description	Field Identification	Relative Density (%)
0-4	Very loose	Easily indented with finger, thumb, or fist.	0 – 20
4-10	loose	less easily indented with fist but easily shoveled.	20 – 40
10-30	Medium dense	Shoveled with difficulty.	40 – 60
30-50	Dense	Requires pick to loosen for shoveling by hand.	60 – 80
> 50	Very dense	Requires blasting or heavy equipment to loosen.	80 – 100

Recovery: The percentage of length of core recovered in each run to the total length of the core run.

R.Q.D. : The Rock Quality Designation is the percentage of the sum of lengths of intact core pieces ten centimeters or longer to the total length of the core run.

Point Load Strength and Unconfined Compressive Strength

In the point load test, a rock core is loaded between two steel cones and failure occurs by tensile splitting. A point load strenght index, Is, is calculated as the ratio of the applied load ,P, at rupture to the square of the distance ,H, between the loading points: $I_s = P/H^2$

A correlation that is commonly used between the point load index and the unconfined compressive strength, ,qu, of a cylender with a length to diameter ratio of 2 to 1 is : $q_u = 24\, I_{s(50)}$

where $I_{s(50)}$ is the point load strength corrected to a diameter of 50 mm (Brock and Franklin, 1972).

Rock Quality

Rock Quality Designation, RQD (%)	Rock Quality Description
0 – 25	Very Poor
25 – 50	Poor
50 – 70	Fair
70 – 90	Good
90 – 100	Excellent

Rock Strength

Description	Point Load strength (for 50 mm diameter sample) $I_{s(50)}$ (kg/cm²)	Unconfined Compressive strength (kg/cm²)
Very Weak	<0.5	<12.5
Weak	0.5 – 2	12.5 – 50
Moderately Weak	2 – 5	50 – 125
Moderately Strong	5 – 20	125 – 500
strong	20 – 40	500 – 1000
Very strong	> 40	> 1000

LOG OF BORING

PROJECT: Al-Nwaimah School Building
LOCATION: Jericho
DRILLING DATE: 09/05/99
DRILLING METHOD: ROTARY AIR FLUSH

BORING No.: BH1 (S 99031).
ELEVATION: 161.50
GROUND WATER DEPTH: N.E.
TOTAL BORING DEPTH: 15.00

DEPTH (m)	ST	REC (%)	RQD (%)	S.P.T (N) 15 cm	S.P.T (N) 15 cm	S.P.T (N) 15 cm	SYMBOL	DESCRIPTION	qu (kg/cm²)	Dd (gm/cm³)
0 – 3				7	18	50		Alluvial deposits of silty marl with subrounded gravels of limestone and chert.		
3 – 4.5		95.0	0.0					Creamy, moist, fractured, weak marlstone with traces of shells and fillings of moist marl.		
4.5 – 7										
7 – 8.5		95.0	0.0					Yellowish to creamy, moist marl interbedded with thin layers of marlstone.		
8.5 – 10									1	2

ST : Sampler Type
REC : Core Recovery
qu : Compressive Strength
Dd : Dry Density
RQD : Rock Quality Designation
SPT : Standard Penetration Test

LOG OF BORING

PROJECT: Al-Nwaimah School Building

LOCATION: Jericho

DRILLING DATE: 09/05/99

DRILLING METHOD: ROTARY AIR FLUSH

BORING No.: BH1 (S 99031).

ELEVATION: 161.50

GROUND WATER DEPTH: N.E.

TOTAL BORING DEPTH: 15.00

DEPTH (m)	ST	REC (%)	RQD (%)	S.P.T (N) 15 cm	15 cm	15 cm	SYMBOL	DESCRIPTION	qu (kg/cm²)	Dd (gm/cm³)
10–13.5				9	22	57				
13.5–15		95.0	0.0					Creamy, moist, fractured, weak marlstone with traces of shells and fillings of moist marl.		
15								END OF BORING		
20									2	2

ST : Sampler Type
REC : Core Recovery
qu : Compressive Strength
Dd : Dry Density
RQD : Rock Quality Designation
SPT : Standard Penetration Test

LOG OF BORING

PROJECT: Al-Nnaimah School Building
LOCATION: Jericho
DRILLING DATE: 10/05/99
DRILLING METHOD: ROTARY AIR FLUSH

BORING No.: BH2 (S 99031).
ELEVATION: 161.60
GROUND WATER DEPTH: N.E.
TOTAL BORING DEPTH: 15.00

DEPTH (m)	S T	REC (%)	RQD (%)	S.P.T (N) 15 cm	15 cm	15 cm	SYMBOL	DESCRIPTION	qu (kg/cm²)	Dd (gm/cm³)
0–1								Alluvial deposits of silty marl with subrounded gravels of limestone and chert.		
1–4		90.0	0.0					Yellowish to creamy, moist marl interbedded with thin layers of marlstone.		
4–5.5		95.0	0.0					Creamy, moist, fractured, weak marlstone with traces of shells and fillings of moist marl.		
5.5–10				11	23	61		Yellowish to creamy, moist marl interbedded with thin layers of marlstone.		
									1	2

ST : Sampler Type
REC : Core Recovery
qu : Compressive Strength
Dd : Dry Density
RQD : Rock Quality Designation
SPT : Standard Penetration Test

LOG OF BORING

PROJECT: Al-Nwaimah School Building
LOCATION: Jericho
DRILLING DATE: 10/05/99
DRILLING METHOD: ROTARY AIR FLUSH

BORING No.: BH2 (S 99031).
ELEVATION: 161.50
GROUND WATER DEPTH: N.E.
TOTAL BORING DEPTH: 15.00

DEPTH (m)	ST	REC (%)	RQD (%)	S.P.T (N) 15 cm	15 cm	15 cm	SYMBOL	DESCRIPTION	qu (kg/cm²)	Dd (gm/cm³)
10.0 – 11.5	X						~~~	Yellowish to creamy, moist marl interbedded by thin layers of marlstone.		
11.5 – 13.0		98.0	0.0				~~~			
13.0 – 15.0	X						~~~			
15								END OF BORING		
20									?	?

ST : Sampler Type
REC : Core Recovery
qu : Compressive Strength
Dd : Dry Density
RQD : Rock Quality Designation
SPT : Standard Penetration Test

APPENDIX B

SULPHATE & CHLORIDE

Table 7. Concrete exposed to sulphate attack

Class	Concentration of sulphates expressed as SO_3: In soil[2]: Total SO_3	Concentration of sulphates expressed as SO_3: In soil[2]: SO_3 in 2:1 water:soil extract	Concentration of sulphates expressed as SO_3: In ground-water	Cement complying with	Dense, fully compacted concrete made with 20 mm nominal maximum size aggregates[1] complying with BS 882 or BS 1047: Cement content not less than	Dense, fully compacted concrete made with 20 mm nominal maximum size aggregates[1] complying with BS 882 or BS 1047: Free water/cement ratio not more than
	%	g/L	g/L		kg/m³	
1	Less than 0.2	Less than 1.0	Less than 0.3	Table 1	—	—
2	0.2 to 0.5	1.0 to 1.0	0.3 to 1.2	BS 12, BS 146, BS 6588 BS 12 combined with less than 25 % pfa BS 12 combined with less than 70 % ggbs	330	0.50
				BS 12 combined with 25 % to 40 % pfa BS 12 combined with 70 % to 90 % ggbs BS 4246 with at least 70 % ggbs BS 6588 with at least 25 % pfa BS 6610 with not more than 40 % pfa	310	0.55
				BS 4027 (SRPC) BS 4248 (SSC)	280	0.55
				BS 12 combined with 25 % to 40 % pfa BS 12 combined with 70 % to 90 % ggbs BS 4246 with at least 70 % ggbs BS 6588 with at least 25 % pfa BS 6610 with not more than 40 % pfa	380	0.45
3	0.5 to 1.0	1.0 to 3.1	1.2 to 2.5	BS 4027 (SRPC) BS 4248 (SSC)	330	0.50
4	1.0 to 2.0	3.1 to 5.6	2.5 to 5.0	BS 4027 (SRPC) BS 4248 (SSC)	370	0.45
5	Over 2	Over 5.6	Over 5.0	BS 4027 and BS 4248 (SSC) both with adequate protective coating (see BS 8110)	370	0.45

[1] Adjustments to minimum cement content should be made for aggregates of nominal maximum size other than 20 mm in accordance with table 8.

[2] If much of the sulphate is present as low solubility calcium sulphate, analysis on the basis of a 2 : 1 water extract may permit a lower site classification than that obtained from the extraction of total SO_3. Reference should be made to BRE Current Paper 2/79 for methods of analysis, and to BRE Digests 250 and 276 for interpretation in relation to natural soils and fills, respectively.

NOTE 1. Within the limits specified in this table, the sulphate resistance of combinations of ggbs and pfa with SRPC will be at least equivalent to combinations with cement complying with BS 12.

NOTE 2. It is recommended that the alumina content of ggbs does not exceed 15 %.

Table 1 : Classification of sites and recommendations for concrete BRE Digest 363, 1991

Well - compacted cast-in-situ concrete between 14.0m to 4.50mm thickness and exposed on all faces to sulphate soil or fill. Aggregates to BS 882 or BS 1047. For other exposures or types of concrete see Tables 1a and 1b.

Class	Concentration of sulphate and magnesium					Cement type see table 1c	Minimum cement content kg/m^3 Notes 1 & 2	Maximum free water/cement ratio Note 1
	In soil or fill			In ground water g/l				
	By acid extraction %	By 2:1 water/soil extract - g/l						
	SO_4	So_4	Mg	SO_4	Mg			
1	<0.24	<1.2		<0.4		A-L	Note 3	0.65
2		1.2-2.3		0.4-1.4		A-G H I-L	330 280 300	0.50 0.55 0.55
3	If >0.24	2.3-3.7		1.4-3.0		H I-L	320 340	0.50 0.50
4	Classify of	3.7-6.7	<1.2	3.0-6.0	<1.0	H I-L	360 380	0.45 0.45
	2:1	3.7-6.7	>1.2	3.0-6.0	>1.0	H	360	0.45
5	extract	>6.7	<1.2	>6.0	<1.0	As for Class 4 plus surface protection see CP 102		
		>6.7	>1.2	>6.0	>1.0			

Note 1 Cement content includes pfa and slag.

Note 2 Cement contents relate to 20mm nominal maximum size aggregate. In order to maintain the cement cont of the mortar fraction at similar values, the minimum cement contents given should be increased by 40kg for 10mm nominal maximum size aggregate and may be decreased by 30 kg/m3 for 40mm nom maximum size aggregate as described in Table 8 of BS 5328 : Part 1.

Note 3 The minimum value required in BS 8110 : 1985 and BS 5328 : Part 1 : 1990 is 275kg/m^3 for unreinfor structural concrete in contact with non-aggressive soil. A minimum cement content of 300kg/m^3 (BS 81 and maximum free water/cement ration of 0.60 is required for reinforced concrete. A minimum cem content of 220kg/m^3 and maximum free water/cement ration of 0.80 is permissible for C20 grade conc when using unreinforced strip foundations and trench fill for low-rise buildings in Class 1.

Table 1a Modification to Table 1 for other types of exposure to sulphates BRE Digest 363, 1991

Exposure	General recommendations
Floors On fill or hard-core containing sulphate in:	
Class 1	Provide membrane between the fill or hard-core and floor finish.
Class 2	Provide membrane between the fill or hard-core and any concrete.
Class 3, 4 and 5	Not recommended for use as a base for concrete floors.
Static groundwater Table 1 refers to permeable soils (i.e >10^{-5}m/s in Figure 6 of BS 8004) which give rise to mobile groundwater and would include exposure to free water. In less permeable soils, the amount of water movement will depend on the topography of the site and a judgment or a site measurement must be made to decide whether the groundwater is static or mobile.	For normally dry sites or soils with permeability less than 10^{-5}m/s. (e.g. unfissured clay) where it is decided that the groundwater is essentially static, the classification in Table 1 for Classes 2, 3 and 4 may be reduced by one less.
Basement, embankment or retaining walls	If a hydrostatic head greater than five times the thickness of the concrete is created by the groundwater, the classification in Table 1 should be increased by one class. This required can be waived if a barrier to prevent moisture transfer through the wall is provided or, if after completion of normal curing, the concrete face that is to be exposed to sulphate has been exposed to air but protected from rain for several weeks.

Table 1b Modifications to table 1 for other types of concrete

BRE Digest 363, 1991

Concrete Type	General recommendations
Poorly compacted concrete designed for full compaction	Not acceptable for sulphate resistance
Cast-in-situ concrete over 450mm thick. Precast ground beams, wall units or piles with smooth surfaces which, after normal curing, have been exposed to air but protected from rain for several weeks.	For classes 2, 3 and 4 the requirements for type of cement, cement content and water/cement ratio given in Table 1 may be reduced by one class if other durability and structural considerations permit.
Cast-in-situ concrete (other than ground floor slabs) less than 140mm thick or having many edges and corners	Increase classification in Table 1 by one class
Precast concrete blocks	Blocks should comply with BS 6073 and with BS 5628 : Part 3 relating to use below ground for classes 2 and 3 pf Table 1. As an alternative to compliance with the minimum cement content and water/cement ratio given in Table 1 for Classes 1 to 3, autoclaved blocks (including aerated blocks - Aircrete - with a minimum density of 600kg/m^3) or pressed blocks with more than 50% of their least cross-sectional area carbonated* may be used.
Concrete bricks	Compliance with BS 6073 and with Table 1
Concrete Pipes	Classification with respect to type of cement may be reduced by one class for pipes complying with Part 100 and 120 of BS 5911. Cement contents and water/cement ratios in Table 1 are not relevant.
Porous concrete pipes	Compliance with BS 1194, Porous concrete pipes are not suitable for use in Class 3, 4 and 5 soils.

* Estimated by breaking block and applying phenolphthalein - see BRE information Paper 6/81

Table 1c Types of Cement

BRE Digest 363, 1991

Code	Type or Combination	Code	Type or Combination
A	Portland cement to BS 12	H	Sulphate resisting Portland cement to BS 4027.
B	Portland blastfurnace cements to BS 146	I	High-slag blastfurnace cement to BS 4246 containing not less than 74% slag by mass of nucleus.
C	High slag blastfurnace cement to BS 4246	J	Combinations of Portland cements to BS 12 and blastfurnace slag to BS 6699 containing not less than 70% slag and not more than 90% slag by mass of slag plus cement.
D	Combinations of Portland cements to BS 12 and blastfurnace slag to BS 6699	K	Portland pfa cement to BS 6588 containing not less than 26% pfa by mass of nucleus.
E	Portland pfa cements to BS 6588	L	Combinations of Portland cements to BS 12 and pfa to BS 3892 : Part 1 containing not less than 25% pfa and not more than 40% pfa by mass of pfa plus cement.
F	Combinations of Portland cement to BS 812 and pfa to BS 3892 : Part 1		
G	Pozzolanic pfa-cement to BS 6610 - 1991		

In codes I and J, slag with alumina (Al_2O_3) content over 14% should be used only with Portland cement having low to moderate C_3A content (typically less than 10%).

Use	Concrete in Contact with:	pH	Mobility of Water (Table 1a) M = Mobile S = Static	Aggressive CO_2 (Table 3) H = High L = Low	Change in Classification with respect to minimum cement content and maximum water/cement ratio for the type of cement recommended on the basis of sulphate in Tables 1, 1a and 1b. *When advancing classes for cements A - G into Classes 3-5, choose the higher cement content option*
Foundations including poured cast-in-situ piles. For piles made by special techniques using low water/cement ratio, slightly stringent requirements may be applicable	Natural ground	>5.5	S or M	-	No Change
		3.5 to 5.5	S	-	No Change
			M	-	Advance by one less
		<3.5	S	-	Advance by one less
			M	-	Advance by one less
	Ground Containing wastes or made-up ground	>5.5	S	-	No Change
			M	-	Advance by one less
		4.5 to 5.5	S	-	Advance by one less
			M	-	Advance by two less
		<4.5	S	-	Advance by one less
			M	-	Advance by three less
	External Surface: Natural Ground	>3.5	M	-	No Change
		<3.5	M	-	Provide surface protection if SO_4 is above Class 3
	External Surface: Ground Containing wastes or made-up ground	>4.5	M	-	No Change
		<4.5	M	-	Provide surface protection if SO_4 is above Class 2
Pipes to BS 5911 : Parts 100 & 120	Natural water effluent doemstic sewage	>5.0	M	-	No Change
			M	-	No Change
			M	-	No Change
		<5.0	M	-	Provide surface protection lining if SO_4 is above Class 3
			M	-	Provide surface protection lining if SO_4 is above Class 2
		>5.0	M	-	Provide surface protection lining irrespective of SO_4 Classification
Porous pipes to BS 1194	Land Drainage	>3.5	M	H or L	No Change
		<3.5	M	H or L	Concrete not suitable
Culverts cast-in-situ or precast	Natural water effluent	>5.5	M	L	No Change
			M	H	Advance by one class
		<5.5	M	L	Advance by one classes
			M	H	Advance by two class
	Industrial effluent	>5.5	M	-	Advance by two classes
		<5.5	M	-	Advance to Class 5
Agricultural and Industrial	Milk (lactic acid)	See diary Floors : Ministry of Ag Fish and Food 1967 and Concrete in Milking Parlours, Cements and Concrete Association. Farm Not. 8 : 1980			
	Silage (principally lactic acid)	Contact Ministry of Ag Fish and Food for current recommendations			
	Acid spillage in industrial processes	Refer to specialist producers of acid resistance finishes and CP 204			

Fig 1 Procedure for classification of site

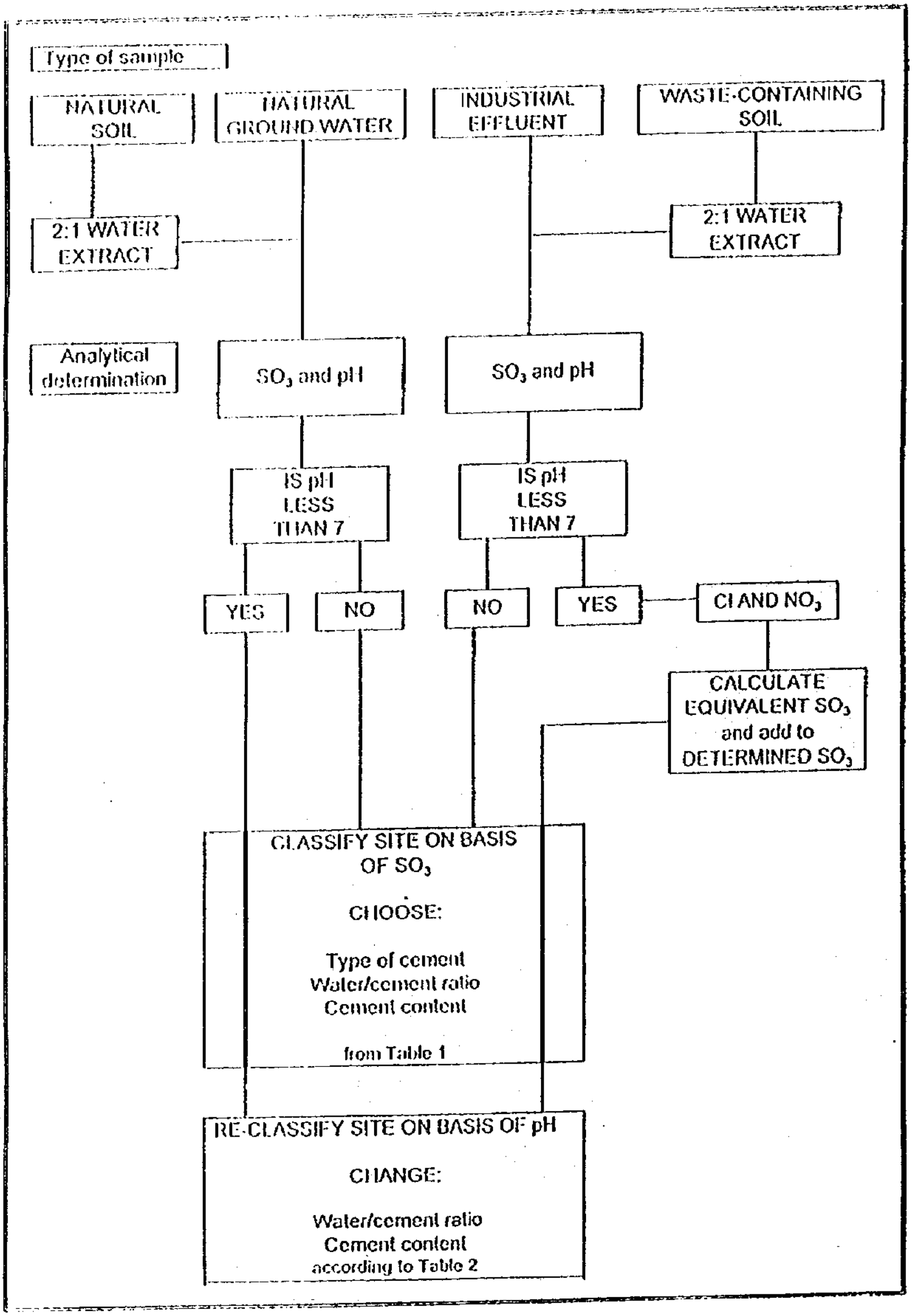
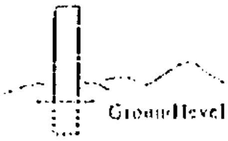


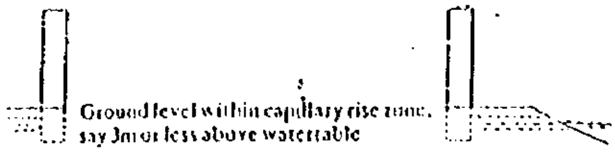
Figure 6 *Typical exposure conditions*

Note: These exposure conditions cover natural environments only. In industrial environments, concrete can be exposed to a range of more aggressive conditions, for example corrosive effluents, and may need to be specially protected.



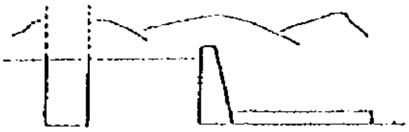
Recommended cement type (1) or (2)
For concrete criteria, see Table 13

(a) Superstructures, inland with NO risk of windborne salts



Recommended cement type (1) or (2)
For concrete criteria, see Table 13

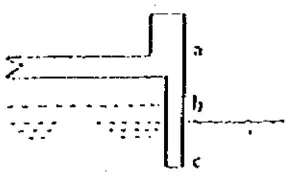
(b) Superstructures, in areas of saltflats, inland or near the coast, exposed to windborne salts



Recommended cement type (1) or (2)
For concrete criteria, see Table 13

Note: The recommendations for this exposure condition make NO PROVISION for protection from potentially aggressive soil conditions. Exposure conditions shown in Figure 6(d) should be assumed if it is believed that such protection might be needed

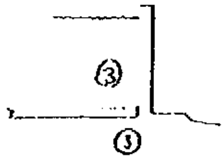
(c) Parts of structures in contact with the soil, well above capillary rise zone, and with NO risk of water introduced at the surface by irrigation or faulty wastes, washing down, etc.



For superstructure: recommended cement types (1) or (2)
For concrete criteria, see Table 13

Recommended cement types	Exposure condition	For concrete criteria see Table 13
(1) or (2)	Splash zone	c(i)
(1) or (2)	Intertidal zone	c(ii)
(1) or (2) or (3)	Submerged zone	c(iii)

(e) Marine structures



For substructure: use recommendations given in Figure 6 (d)

(f) Water-retaining structures

CEMENT TYPE

Where resistance is needed against sulphate attack, but there is NO significant risks of chloride-induced corrosion: SULPHATE-RESISTING CEMENT to BS 4027 or ASTM Type V (i.e. cement with a maximum C_3A content of 3.5 or 5.0%, respectively gives better protection.
Colour key: (3)

Where improved resistance is needed against chloride induced corrosion of the reinforcement, but there is NO significant exposure to sulphates. Cement with a medium to high C_3A content is preferred. OPC or ASTM Type I usually have high C_3A contents and ASTM Type II usually has a medium C_3A content (but those specifications do not specify minimum C_3A contents. See Section 8.2.8).
Colour key: (1)

Where resistance is needed against both sulphates and chlorides, concrete may need to be protected from the soil and groundwater with a waterproof membrane or tanking, and a compromise has to be made on the type of cement used. Generally, a cement containing at least 3.5% but not more than 9% C_3A is preferred. Each situation should be considered on its merits. See also Section 8, which gives more information on different types of cement. Colour key: (2)

THE IMPERMEABILITY OF THE CONCRETE HAS MUCH MORE INFLUENCE THAN THE CEMENT TYPE, UNDER ALL CONDITIONS OF EXPOSURE

JICA