Dissipation tests in near near-saline and near quick environments

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ABSTRACT: The results of two research projects are presented here. The first is based on soil exploration in Szeged City, Hungary, possibly due to the variation of near-salineand non-near-salinesoils in depth. The geotechnical laboratory and in situ data are treated by some statistical tests. In addition, chemical and some special, new tests (simple local side friction and cone resistance dissipation tests and multistage oedometric relaxation tests) are mentioned to characterize the fabric instability and composition of the near-salinelayers. The results of some geotechnical laboratory and in situ dissipation tests related to a near-salinespot u a depth down to 66 m.

Keywords: saline soil, quick clay, compression test, DMT dissipation test, CPTu dissipation test, simple dissipation test, special soils

1. Introduction

The aim of this paper to show that the effect of the near-salinegroundwater flow on fresh-water clay and the effect of fresh groundwater flow on marine clay are similar, through two sites. The near-salinesite is situated in Hungary, the recently discovered near-quick site is in Australia. Both sites may serve a geotechnical testing site due to the homogeneous soil profile over large areas otherwise.

The chemistry change of the soils is leading to larger void ratio in both cases. Further effects in the near-salineenvironment are the reduction in shear strength, the increase in the compressibility and coefficient of creep, due to the internal structure changes the amount of promary consolidation decreases.

The soils were characterized by borings, samples and in situ tests. From the samples, geotechnical and soil science tests were made. The in situ tests were simple CPT cone resistance and local side friction dissipation tests (near-salinearea) and CPTu pore water pressure dissipation tests (in both sites). The laboratory tests in the near-salinecase entailed some soil science an triaxial tests, also hiv.

The CPTu pore water pressure dissipation tests were evaluated using three methods. Methods I and II (slow and fast methods) were precise Least Squares fittings of a 2D consolidation model. Method I was numerically more expensive than II. Method III – the one of Teh and Houlsby (1988) [].

In addition, a software for the oedometric compression test using the modified Bjerrum model. This is described in the ISC5 paper hiv.

1.1. Near-saline site in Hungary

The geological features of Hungray are summarized as follows. Hungary occupies the central part of the intermontane basin of the Alpine belt of Europe - the Carpathian Basin. Hungary's surface area can be divided into four major geographical units (Fig. 1).

(1) The Hungarian Central Mountains are Mesozoic mountains trending SW-NE. The mountains are flanked by the Little Plain to the northwest and the Great Hungarian Plain to the southeast.

(2) The Little Plain has a basement of Palaeozoic sediments on the west and Mesozoic rocks on the east buried 2000 - 3000 m deep.

(3) The Transdanubian Tableland is composed of Late Tertiary deposits that have not undergone any marked subsidence.

(4) The Great Hungarian Plain is the largest Neogene Deression of the Carpathian Basin filled up with Quaternary deposits. It includes two hilly regions (Danube-Tisza Interfluve and the northeast part of the Great Plain) and an almost perfect plain region (the Tisza-Körös Plain). The former regions are characterized by sandy-silty hills. The Tisza-Körös Plain is covered by fluviatile, lacustrine (mainly) plastic deposits and by infusion loess.

The tested site is situated at the Szeged area, part of the following section. There is a hilly area with a divider between the Duna and the Tisza Rivers in Hungary, where the groundwater moves downwards, in the low areas along the two large rivers the soil water is moving upwards (Figs 1, 2, [1], [2], [14]).

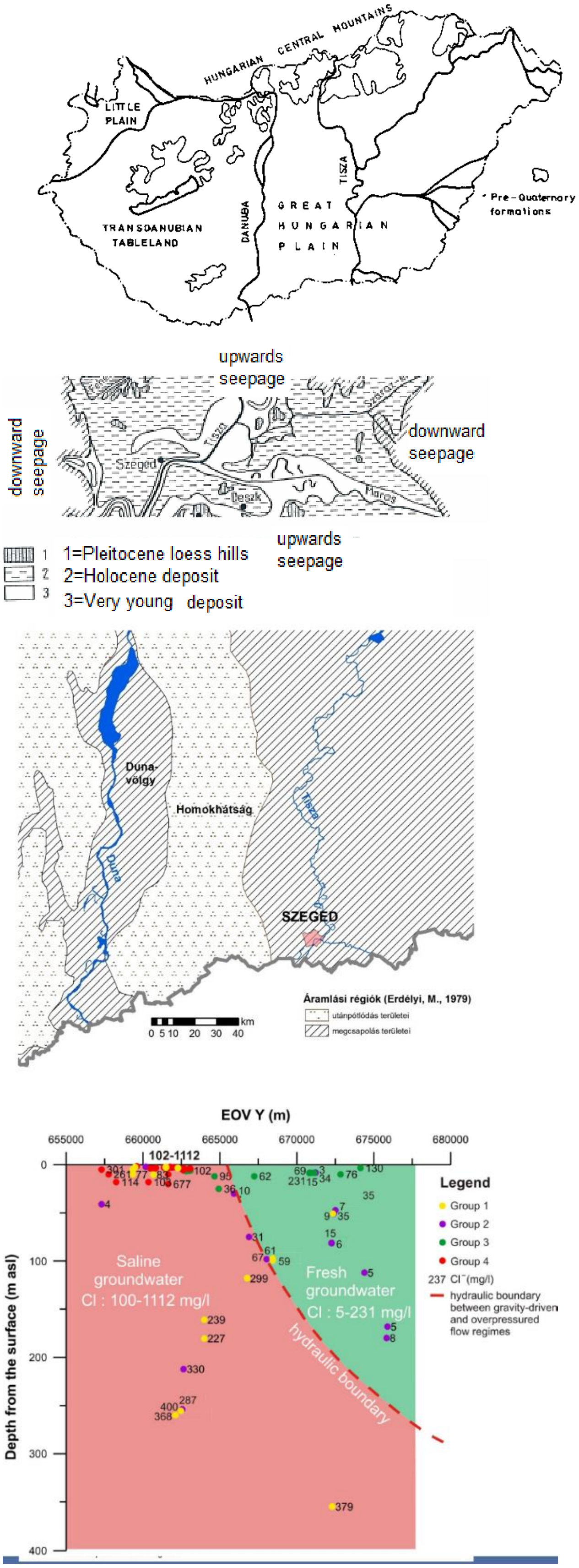

Figure 1. (a) Geological units of Hungary. (b) The Duna river -Tisza river environment, the boundary of upwards and downwards seepage is assumed along the loess hills. (c) Szeged environment of the section. (d) The spot like upwards near-saline groundwater flow from lower marine clay.

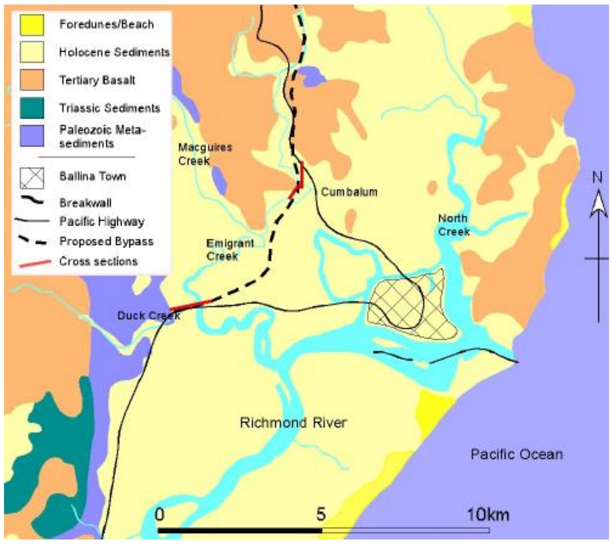

Figure 2. Surface geology and major features in the Ballina study area. Modified from Pogson and Hitchins (1973) by Bishop [3]

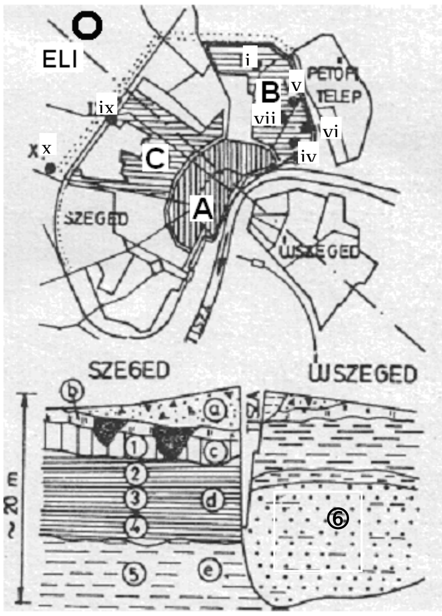

Figure 3. Site plan with around Maximum 20 m deep explorations in Szeged (borings, CPT) in Szeged City (closed symbols), the weaker, near-saline soil part C and the near-saline spot ELI with 66 m deep exploration. Layers 1 to 5 (or a to e) are shown in Table 1 (or [12]).

A statistical study made by Réthári and Ungár ([12]), based on soil physical parameters of 11000 laboratory tests determined from 2600 soil samples taken in the western side of Szeged (Figs 1 to 3) revealed that the layering is the same, however, the soil conditions are worse on part C in comparison with parts A and B. The aim of the research was analyse and to explain this difference, based on existing data.

In this work it is shown that in area C some near-salinegroundwater may move upwards in some spots from a very deep, old clay marine deposit, and, as a result, the soil may be altered in a different degree at various depths and locations. Concerning this, the results of some research projects are summarized. In the first borings, laboratory and CPT data were produced in Szeged down to 20 m depth, which was completed by chemical and special dissipation tests. In the second one, a near-saline–

like site in area C was investigated down to 70 m depth using conventional laboratory tests and CPTu u_2 dissipation tests.

1.2. Near-quick area

The main geological feature of the tested Australian estuary sites is that a sand layer separates the upper Holocene estuarine clays from the lower Pleistocene estuarine and deeper alluvial clays.

An apparent "over consolidated" behavior is encountered for the upper, normally consolidated. near-quick clay which is originated from the post-depositional changes of the bio/chemical characteristics at the particle and/or molecular scale ([3]).

The results of the evaluation of some CPTu, entailing eight *u2* dissipation tests data are presented here showing significant differences in the various layers, in accordance with the foregoing as follows.

Table 1. Maximum 20 m deep explorations in Szeged, OTKA research, Soil Science tests – 1 (Sites are indicated in Fig 2, site X is at part C, site VI is at part B).

Area, sample number, code and depth	ESP exchangeable cations	Salt %	1:5 water suspension Electric conductivity mS/cm
C) X-12,3m	**3.94**	**0.15**	**1.55**
B) VI-12,5m	1.536	0.06	0.75
C) X-10,0m	**5.142**	**0.17**	**1.55**
B) VI-5,0m	3.117	0.06	0.86
B) VI-6,5m	1.93	0.05	0.82

Table 2. Cont.

Area, sample number, code and depth	1:2.5 water suspension pH(H2O)	Electric conductivity mS/cm
C) X-12,3m	8.02	**0.66**
B) VI-12,5m	8.29	0.30
C) X-10,0m	7.96	**0.86**
B) VI-5,0m	8.46	0.36
B) VI-6,5m	8.53	0.34

Table 3. Cont.

Area, sample number, code and depth	Ca++	Mg++	Na+	K+
	Mg-equivalent/100 g soil			
C) X-12,3m	0.596	**0.183**	**0.841**	**0.034**
B) VI-12,5m	0.369	0.133	0.259	0.029
C) X-10,0m	0.641	**0.247**	**1.089**	**0.03**
B) VI-5,0m	2.64	0.088	0.626	0.012
B) VI-6,5m	1.193	0.067	0.546	0.013

Table 4. Maximum 20 m deep explorations in Szeged, OTKA research, soil layers.

Notation	soil
1	Loess
2	Upper yellow lacustrine clay
3	Silty inclusion
4	Lower yellow lacustrine clay
5	Blueish fresh-water deposit
6	Sand

Table 5. Maximum 20 m deep explorations in Szeged, OTKA research, Category limits and notations for soil layers.

Notation	Category limits
a	> 25 I_p [%]
b	15-25 I_p [%]
c	10-15 I_p, [%]
d	5-10 I_p, [%]
e	d_{30}>0.1mm
f	d_{30}<0.1mm

Table 6. Maximum 20 m deep explorations in Szeged, OTKA research, Mean values and standard deviations for the upper 20 meters (after Imre, 1995 [6])

Symbol layer	Plasticity index [%]	Void ratio
1	7.4 ± 2.1	0.68 ± 0.08
2	28.9 ± 3.3	0.76 ± 0.06
3	19.1 ± 10.4	0.76 ± 0.07
4	36.3 ± 6.8	0.85 ± 0.10
5	30.0 ± 9.1	0.80 ± 0.09

Table 7. Maximum 20 m deep explorations in Szeged,OTKA research, mean of relative shear strength parameters.

Layer Group	s_u [%]	q_c [%]	f_s [%]
4AB	100	100	100
4C	88	67	62
2	80	68	71
5AB	79	91	91
3	58	51	53
5C	32	31	51

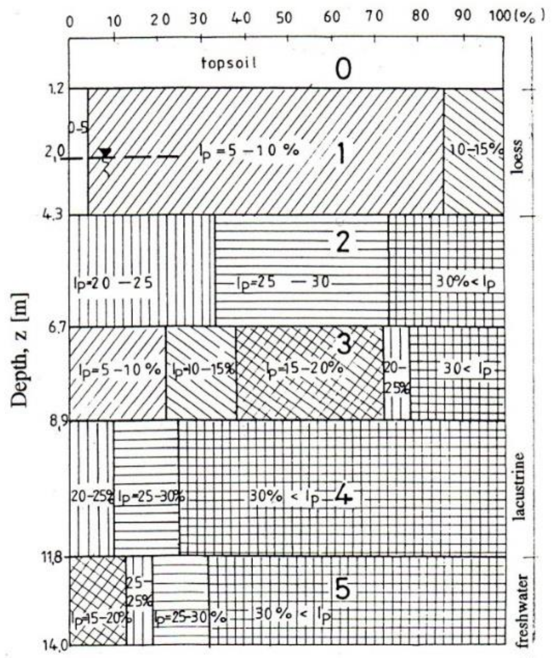

Figure 4. Percentile composition of layers (on the basis of borings shown in Fig 2, after Imre, 1995 [6]).

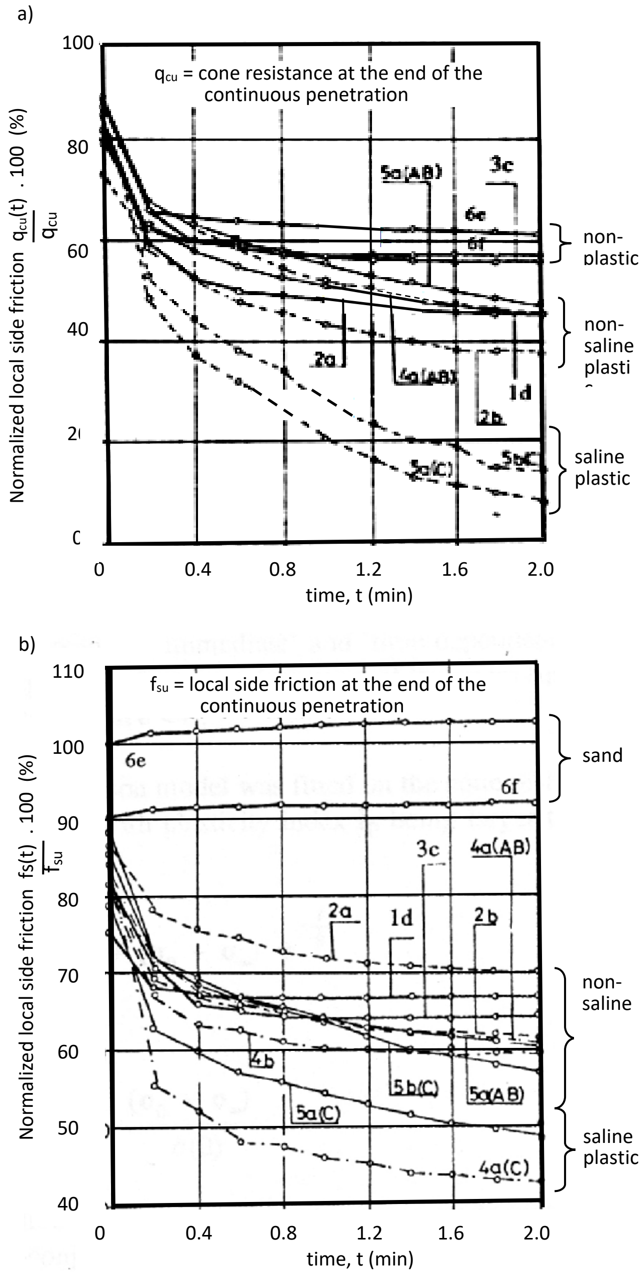

Figure 5. Average dissipation test records (OTKA research) a) cone resistance b) local side friction (on the basis of CPTs I to X shown in Fig 3) Area A, B or C is indicated in bracket. (The sand shows f_s increase, the near-saline soils show the largest stress According to the results, the sandy layers and the lower Pleistocene clay have monotonic dissipation test behavior, the upper organic and high plasticity clays from Holocene have a non-monotonic dissipation test reply, without ever being overloaded/unloaded, just due to the post-depositional bio/chemical changes.

2. Near-near-saline area investigation

2.1. Szeged city down to 20 m

2.1.1. Statistical and soil science tests

In the frame of the OTKA research on in situ test modelling seven, approximately 15 to 20 m deep borings with undisturbed samples and CPT's with simple dissipation tests were made at locations indicated in Figure 1 (Imre, 1995). All geotechnical data (classification tests, chemistry tests, continuous or dissipation type CPT) were separated into horizontal and vertical groups on the basis of soil classification and area (i.e. area A, B and C). The data sets were statistically compared. Chemical tests and double compression tests were made on a few samples.

The bluish-grey deposit has lower plasticity index I_P at *C* than at A and B. The montmorillonite + illite content of the lower yellow clay layer was less on unit C than A and B. According to the results of the chemistry tests (see Table 2) near-salinesoil with high salt content was found at various depths in part C.

The lower yellow clay and the bluish-grey deposit has considerably less undrained shear strength c_u, and ultimate cone resistance q_{cu}, on area *C* than on areas A, B (see Table 3). This result supported the result of the statistical study made by Rétháti and Ungár (1978) [12].

2.1.2. Simple (rheological) dissipation test

The CPT can be used in a logging and a rheological testing mode. In the ''simple rheological test" the time variation of the local side friction and the cone resistance are measured for a few minutes.- 3 135 simple rheological type CPT were made with the CPT Sz832 (with a shaft sensor of 350 cm^2) in Szeged. These were divided into 10 groups on the basis of soil classification and site A, B and C. Tests made in the vicinity of layer boundaries were not included into these groups. Tests made in an eolian sand layer 6 in Debrecen city were used as a reference (Tables 4, 5).

The mean simple CPT dissipation test records shown in Figure 4 generally show an immediate stress drop (or discontinuity) at the stop of the steady penetration, possibly since the loading type changes from basically dynamic to quasi-static.

After the stress drop, the rate of the cone resistance dissipation is larger in sand and is smaller in clay, it can be related to soil plasticity. The sign of the shaft resistance change during dissipation, in the first two minutes (measured with a 350 cm^2 element for the shaft) is strongly dependent on the soil type. For sands, it increases and for clays it decreases with time.

Concerning the horizontal inhomogenity (Fig 4), the stress decrease after 2 minutes was larger in part C than in parts A or B possibly since the normalization unit was less in area C than in area A and B. In addition, a non-zero final tangent was observed in area C which may indicate an unstable fabric. The plasticity dependent results of the mean simple CPT dissipation test records were qualitatively reproduced by some multistage oedometric relaxation test both experimentally and in terms of modelling (Imre, 1995, [8]).

2.2. Near-saline spot down to 66 m

2.2.1. Conventional oedometer tests

The conventional oedometric compression tests was evaluated with the modified Terzaghi and Bjerrum models (a constant term for the immediate compression was added, [9], [10]). The immediate, primary and secondary consolidation settlements were separated.

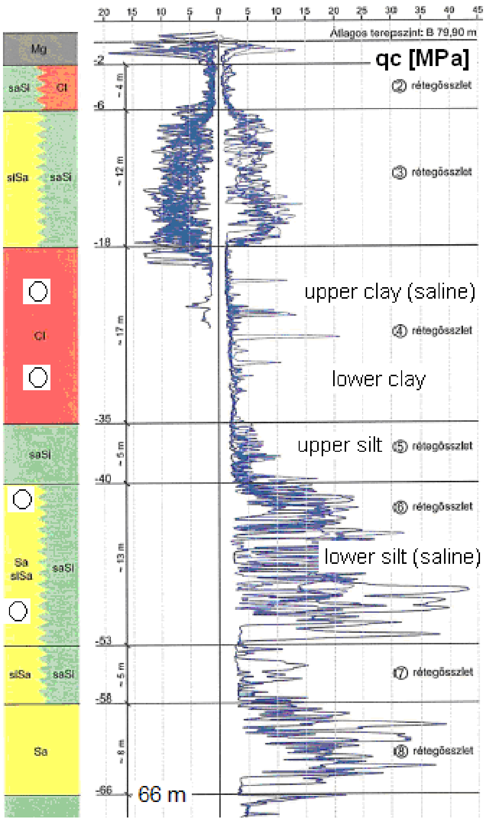

Figure 6. Mean profile indicating location of the dissipation tests.

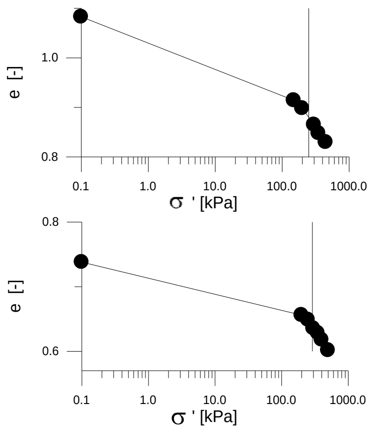

Figure 7. The underconsolidated soils, if the only the weight of the soil layers are considered (indicated by a vertical line), the uplift drag force is neglected.

Table 8. The identified *c* without correction factors (*c* in m^2/s)

Test id	Compression test	Method III	Method I	Method II
4/upper near-salineclay	5E-8	7,0E-05	6,0E-05	6,0E-04
6/lower clay	3E-8	1,0E-06	4,0E-06	7,0E-06

Table 9. The identified parameters for silts– oedoemeter test

	Near-saline silt	Non-near-saline silt
c[cm²/s]	2,00E-04	1,00E-03
mc[.]	1,88E-02	4,92E-02
ho[mm]	3,12E-03	-1,02E-02
CA[-]	5,20E-02	2,05E-02

Table 10. The identified parameters for clays – oedoemeter test

	Near-near-salineclay	Non-near-salineclay
c[cm²/s]	4,00E-04	9,00E-05
mc[.]	3,31E-02	5,73E-02
ho[mm]	2,04E-02	5,07E-03
CA[.]	5,26E-02	1,80E-02

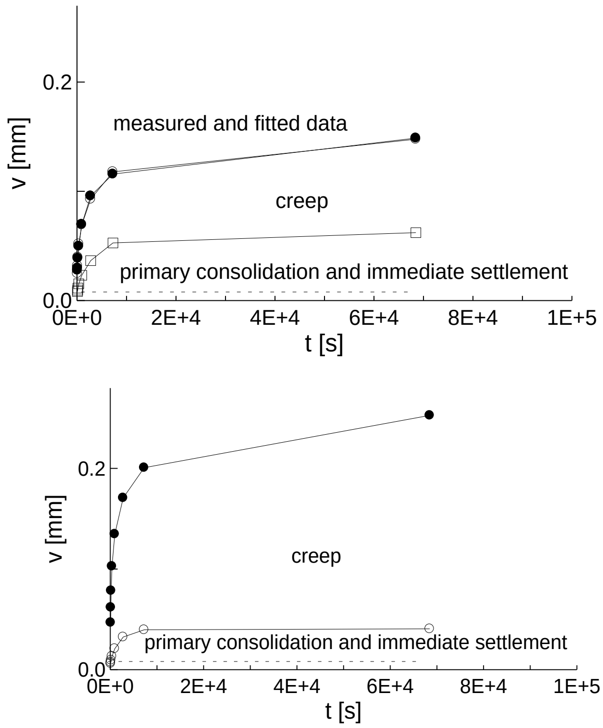

Figure 8. ELI-site, Compression test evaluation for non-near-saline and near-saline Szeged soils, upper: Less or non-near-saline clay e = 0,74, lower: near-saline clay e = 1.06.

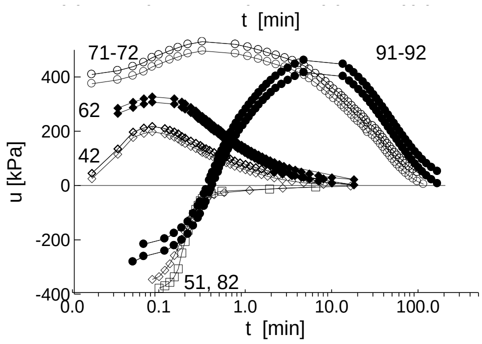

Figure 9. Pore water pressure dissipation curves at ELI-site. 41/42=4, 61/62/=5 upper near-salineclay, 91/92=6, 71/72=7 lower clay, 33=1, 51=2, 82=3 granular.

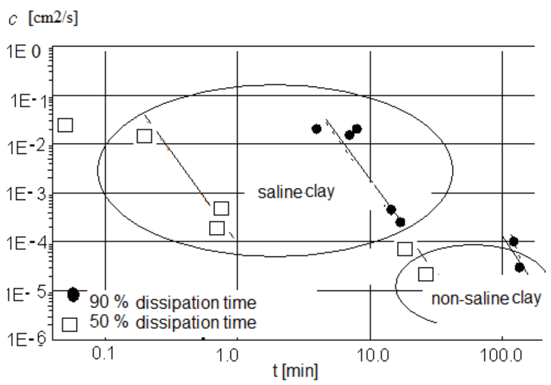

Figure 10. The relation between c and time (with t50 or t90), with correction factors, method I.

The coefficient of consolidation *c* identified from oedometer test data was considerably smaller than the dissipation test values, as expected. It was larger for near-salinesoils. Concerning the coefficient of creep, the Ca alue was above 0,05 for the near-salinesoils, around 0,02 for non-near-salinesoils at the 66 m deep sitze, but in Szeged city the value generally was less than 0.02.

Concerning the coefficient of compressibility of soils with respect to effective stress change, exclusively from consolidation without creep denoted by *mc*, it was less for near-near-salinethan non-near-salinesoils (Tables 12, 13). The immediate compression h_0 was non-negligible for clays and smaller or near zero for silts, being larger for the near-salinesoils.These are reflected in the simulated model response describing the stages of the compression tests with the modified Bjerrum (1967) model [4]. The ratio of the primary consolidation settlement was smaller and the creep settlement was larger for the near-salinesoils than for the non-near-salinesoils at the end of the stages (Fig 7).

2.2.2. Dissipation test

The pore water pressure dissipation tests were evaluated using three methods. Methods I and II (slow and fast methods) were precise Least Squares fittings of a 1D consolidation model. Method I was numerically more expensive than II. Method III – the one of Teh and Houlsby ([15]) - was based on a two-dimensional model and a one-point-fitting at the t_{50} determined according to Sully et al. (**Error! Reference source not found.**).

The dissipation curves were non-monotonic in the NC clays (type III and IV), similarly to the case of near-quick clays in Australia.

The dissipation curves were negative, monotonic in the silty sand (type V). This result can be explained by the small compressibility of the particles and, the nearly drained penetration around the tip. At the shaft the sand layer becomes highly overconsolidated due to the effect of the compression made by the penetrometers tip.

The upward flow was proven by the 100% long, measured dissipation curve data which resulted in various at rest groundwater levels on the same location in different depth. The evaluation of dissipation data was made for both the approximate equilibrium and the actual non-equilibrium groundwater levels.

The u_2 data were evaluated using three methods. The first and second methods (fast and slow) were Least Squares fittings of a coupled consolidation model using two initial conditions. The third method was suggested by Teh and Houlsby ([15]) as a one-point-fitting-method based on the t_{50} determined according to Sully et al, **Error! Reference source not found.** being valid for undrained penetration.

The results are shown in Figs 9 to 10, Tables 4 and 5. The method I gave better fit than method II but the solution was not unique (double, larger the *c*-valued solution was accepted). The solution of the methods I and II needed to be corrected with a factor of 0.49 to 0.86 for the clays and silts due to the *u*2 filter position (see e.g. in Imre and Bates, 2015).

For clays, the c solution of method II was larger than the one of method I. The solution of method I was close to the one of method III if a correction factor of 0.5 was used due to the filter position.

In silts and sands the *c* values determined by method III seemed to be too large (no proper initial condition shape function is available in partly drained case). The *c* values identified from oedometer tests were smaller than the dissipation test values, as expected (Table 4, [4])

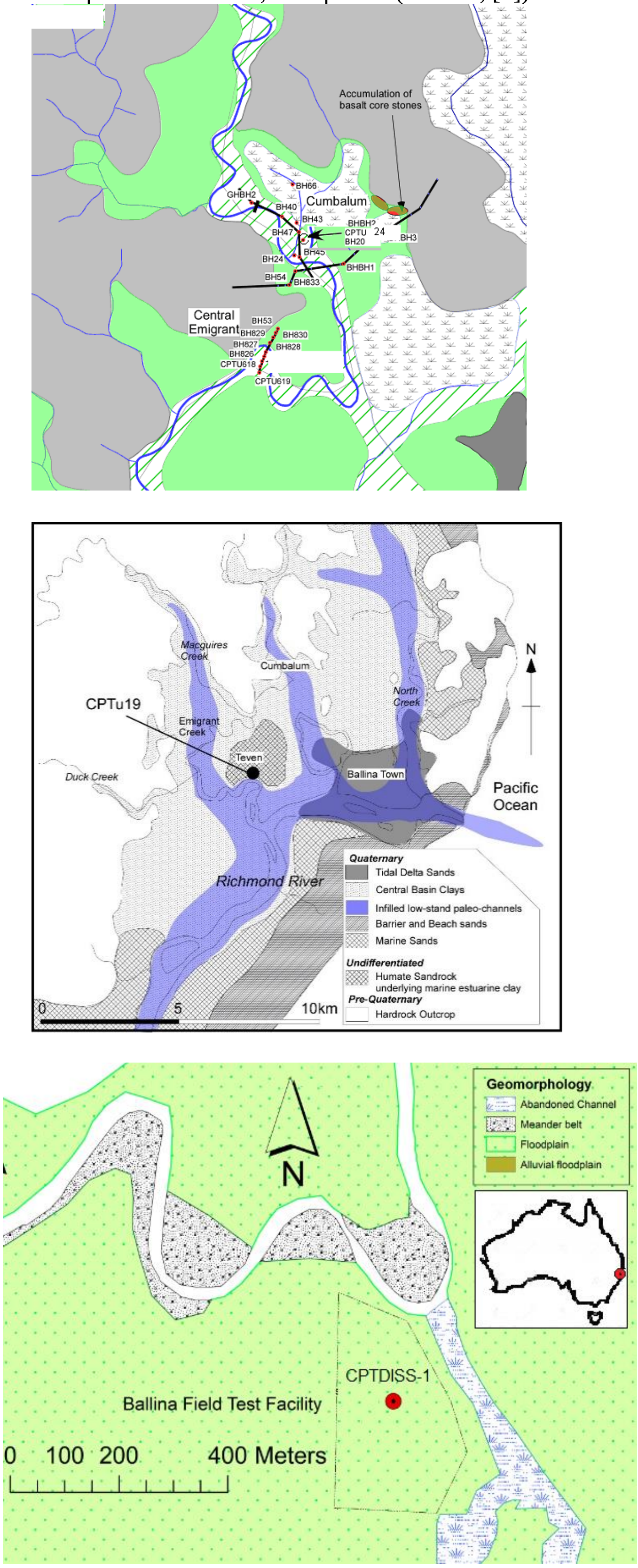

Figure 11. Emigrant Creek site (b) Teven site (c) Ballina soft soils test site.

3. Near-quick area in Australia

3.1. Engineering geology

The distribution and behavior of soft clays associated sediments in the coastal estuaries was, investigated in the Richmond River esurary ([3]).

The microstructure and geotechnical performance of sediment is a function of its deposition environment and in particular the biology, geochemistry and pore water chemistry of the environment at the time of deposition. These are important to subsequent mechanical behavior as a foundation element is the evolution over time of its biogeochemical characteristics.

From a geotechnical perspective a better appreciation of the geological relationships of estuarine clays leads to the elucidation of significant observations of what and why particular behaviors are found in specific locations within the stratigraphy. These include the occurrence of highly sensitive clays in locations where central basin clays have remained saturated and normally consolidated but have been flushed by fresh water.

The soils appear to be “over consolidated” in the classical sense, however, they are actually normally consolidated, but have had the stability of their fabric modified in the post-depositional environment, by changes to the bio/chemical characteristics at the particle and/or molecular scale, without ever being overloaded/unloaded. The organic substances leads to the stabilization in “normally consolidated” clays at high void ratio resulting in slight overconsolidation and anomalies in the correlation between excess pore pressure dissipation and rate of consolidation are sometimes observed beneath fills [3].

3.2. Geotechnical explorations

3.2.1. Borings

The three sites from which the data presented in this paper has been obtained are located on the coastal plain of the Richmond River and Upper Emigrant (Cumbalum) (Fig 14). The sub-tropical Richmond River is located in Northern NSW on the east coast of Australia.

The Teven Rd site lies next to a narrow tidal channel approximately 5 km upstream from the river estuary entrance. The geological profile, geotechnical data and CPTu trace are presented in Figures 15 to 17.

The main feature of the profile is the 3-4 m thick indurated sand layer that separates the upper Holocene estuarine clays from the lower Pleistocene estuarine and deeper alluvial clays.

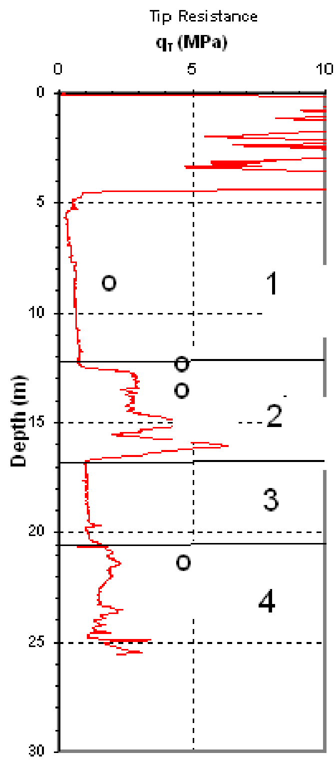

Figure 12. Emigrant Creek site, CPTu 24. 1: high plasticity estuarine clays from the Holocene, 2: silty sand 3: sand, 4: high plasticity estuarine clay from the Pleistocene.

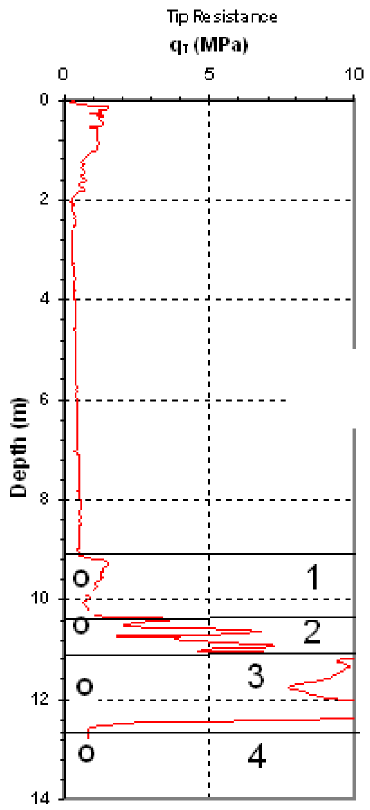

Figure 13. CPTu 19 Teven site. 1: high plasticity estuarine clays from the Holocene, 2: silty sand 3: sand, 4: high plasticity estuarine clay.

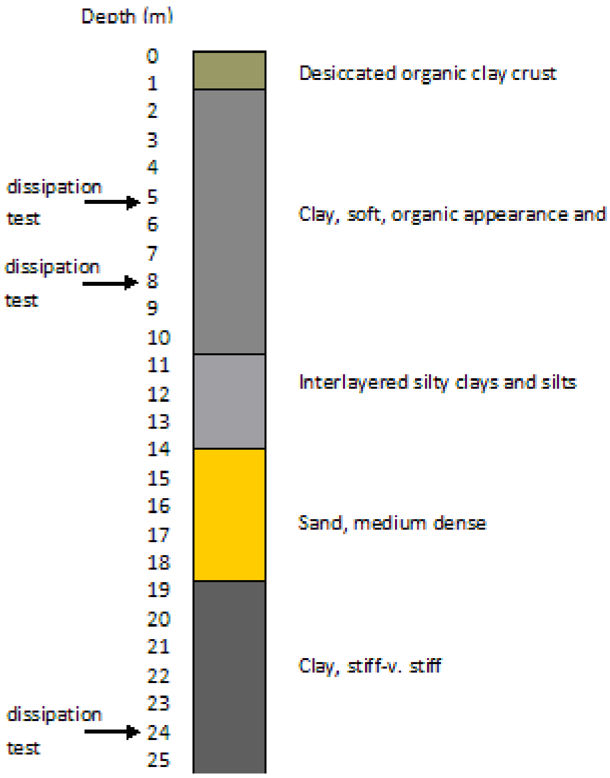

Figure 14. CPTu profile showing dissipation tests: at 5m and 7m in the high plasticity estuarine clays from the Holocene, at 23 m in the high plasticity estuarine clay from the Pleistocene.

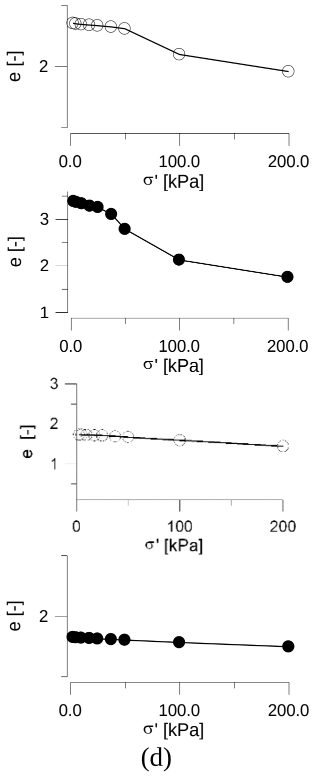

Figure 15. Compression curves. The upper Pimlico Clay in (a) Cumbalum, 7.7 m. and in (b) Teven, 6.7 m. The lower clay in (c) Cumbalum, 16.8 m and in (b) Teven, 14.8 m. Note the slight difference in OCR.

Typically the Upper Clay have a liquid limit of around 100%, a plastic limit of 40% and a natural water content of 80% with a unit weight of around 14.2 kN/m^3. The shear vane strength is low, around 25kPa. The Lower Pleistocen Clay has a liquid limit of around 80%, a plastic limit of 25% and a natural water content of 60% with a unit weight of around 16.4 kN/m^3. The shear vane strengths are higher, around 70kPa.

By evaluating some compression tests in Ballina, results indicated significantly larger void ratio than in less affected soils (Fig 18).

3.2.2. CPTu measurements

The dissipation tests were conducted at both sites in the four important layers (Figs 15 to 17) as follows. 1: high plasticity estuarine clays from the Holocene, 2: silty sand 3: sand, 4: high plasticity estuarine clay from the Pleistocene.

The layer boundaries can be clearly seen if we look the continuous profile together with the dissipation test result since both sites are homogeneous (Figs 15,16).

The tests were undertaken by the "NEWSYD" 200 kN truck-mounted penetrometer facility using a 50 MPa compression cone with the filter in the u2 position.

Measured and fitted data are shown in Figures 19 to 22 and the identified parameters and standard deviations are shown in Tables 9 to 11.

According to the results, the sandy layers and the lower Pleistocene clay have monotonic behavior while the upper organic, high plasticity clays from Holocene has a non-monotonic reply in both cases.

The measured data of the two sites are nearly identical by 'eye' and in terms of parameter values (Figs 8 to 15). The homogeneity is supported by the identified parameter values, also (Tables 3, 4). A good relationship between c and t_{50} using the data of both sites is shown in Fig 16 and Table 4.

The results (Figs 17 to 23, Tables 2, 4) indicate reliable solution for each monotonic and one non-monotonic tests. The solultion is unreliable for one non-monotonic test but can be regularized, due to it having a reliable *c*(*s*) function.

Table 11. Emigrant Creek site – method II, monotonic tests

Layer:Num id:Test id	*c* [m2/s]	relative s. deviation for *c*
2 : 82 : 24/12.4 m	1 E-03	0.47
3: 83 : 24/13.6 m	3 E-03	0.42
4: 84 : 24/20.6 m	5 E-05	0.08

Table 12. Teven site – method II, monotonic tests

Layer:Num id:Test id	*c* [m2/s]	relative standard deviation for *c*
2: 86:19/10.7 m	2 E-03	0.39
3: 87:19/11.9 m	7 E-04	0.15
4: 88: 19/12.9 m	7 E-06	0.27

Table 13. Identified c [m^2/s] (uncorrected values) for the near-quick layer

Test Depth [m]	5
Method II	2E-06
Method I and III	4E-08*

*similar value was found with DMTA

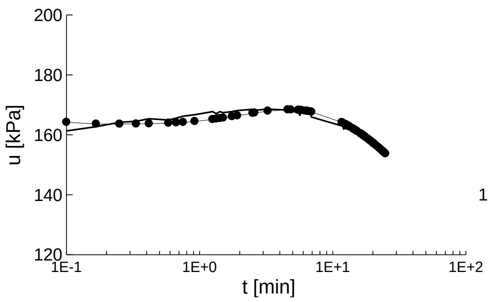

Figure 16. Measured – fitted data, Method I, 24/ 7.66m, near-quick Pimlico Clay

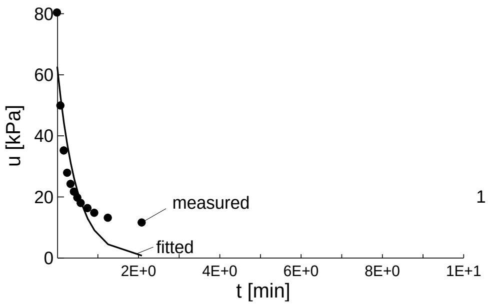

Figure 17. Measured – fitted data, method II, 24/12. 4 m silty soil

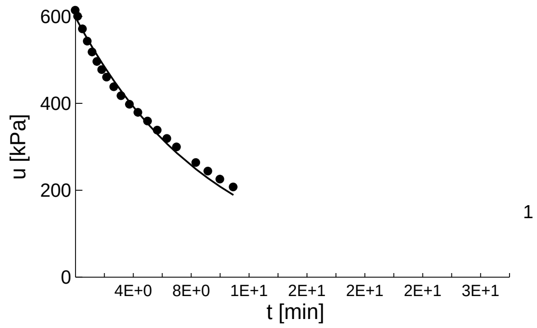

Figure 18. Measured – fitted data, method II, 24/20.6 m, lower clay.

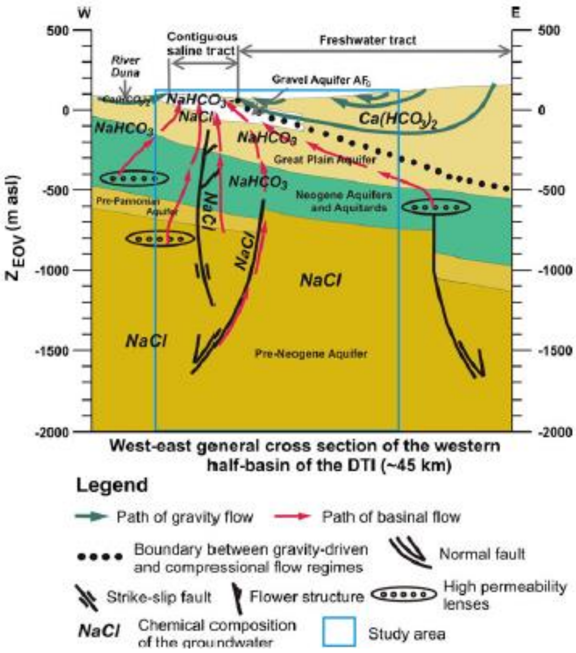

Figure 19. Geology of Szeged site

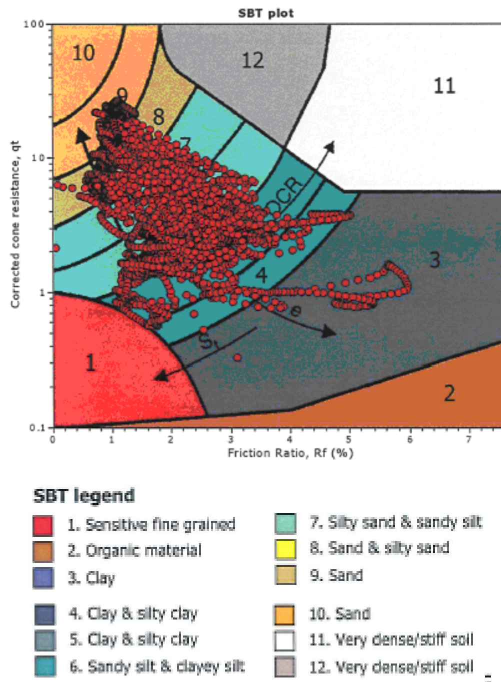

Figure 20. CPTU plots- Szeged

4. Discussion

4.1. Analyses in Szeged area

The Duna-Tisza Interfluve, Hungary, is characterized by patchy surface salinization (Fig. 23). However, in the Duna Valley, salinized wetlands appear in a N–S trending continuous zone. The source of the salts is reported to be the overpressured NaCl-type water of the Pre-Neogene basement and the NaHCO3-type water of the Neogene sediments. This "basement and basin origin of salts" concept is based on the strong correlation between the regional distribution of surface salinization and the basinal flow pattern. A later study, applying integrated methods, presents hydrogeological evidence for this theory and created a conceptual model for the salinization. The model reflects that the basement water rises near to the surface through conductive faults crosscutting an extensive aquitard and aquifer. These faults ensure "shortcut"-type water exchange between the basement and the uppermost aquifer. This hydraulic setting generates chemical anomalies in this aquifer up to the surface, producing Na–HCO3 –Cl-type water. This water causes extensive surface salinization in those discharge areas where the infiltrating freshwater does not superimpose the upwelling near-salinewater. Where a freshwater lens is located above the ascending near-salinewater, this fresh gravity-driven flow controls the surface distribution of salts, which results in near-salinepatches.

The void ratio was larger than 1 for the saline-like soils at the ELI site while for the non-saline-like soils at the ELI site it was less than around 0,8 similarly to the *e* values in areas A, B and C. The presence of upward flow at the ELI site was proven by the long dissipation test data as well, the final values indicated different groundwater surface levels in the same location. The soil in the ELI site was underconsolidated due to the upwards seepage, in the compression test data (Fig 8).

The near-salinesoils seemed to be plotted in area 3 of the Roberston chart, the lower clay in areas 4 to 6 of the Roberston chart (Fig. 24).

Moreover, further analysing the compression test data, smaller primary consolidation, larger creep settlements were encountered for the saline-like than for the non-saline-like soils (Fig. 7).

Concerning the coefficient of creep, the Ca value was above 0.05 for the near-salinesoils, around 0.02 for non-near-salinesoils at the 66 m deep sitze, but in Szeged city the value generally was less than 0.02.

Concerning the coefficient of compressibility of soils with respect to effective stress change, exclusively from consolidation without creep denoted by mc, it was less for near-salinethan non-near-salinesoils (Tables 12, 13). The immediate compression was zero for silts due to the incompressibility of the grains explaining the negative, monotonic dissipation curves (type V, Fig 8).

Analysing the dissipation test data (Fig 11, Tables 12, 13), different c - t_{50} or t_{90} relations were obtained for saline-like and non-saline-like clays, reflecting larger c for the saline-like clays. Opposite tendency was measured in silt. By the changes chemical forces, Generally permeability decrease is resulted by salt addition ([18]). However, if the primary consolidation compression strain decreases, the net effect on c can be an increase. The cementation bonds of the particles may cause a permeability increase.

The soil chemical tests (ESP exchangeable cations, salt content etc.) showed near-salinesoils at various depths, in area C. The simple CPT dissipation tests results revealed some fabric instability tests in area C in all depths. The difference was further increased in the direction of the ELI site where the spot was investigated 66 m depth and the upwards grongwater flow was demonstrated. The results indicated worst soil condition at various depths, significantly larger void ratio than in areas A, B and C (Fig 6).

The soil science tests (ESP exchangeable cations, salt content etc.) indicated spotlike near-salinesoil in area C, however, in the ELI site worst soil science parameters can be expected.

The high void ratio is possibly related to bonds exactly in the location of the high coef. of consolidation. In order to comment full a lot more data on the geology, clay chemistry and regional geography is needed. To many factors are at play to come up with a simple explanation.

4.2. Analyses in Ballina area

The estuarine valleys of the East coast of Australia contain extensive soft clay deposits. In marginal marine environments, uniformly thick sequences of homogenous sediment are uncommon and the extrapolation of soil properties across large areas is enhanced by the use of a geological model (Fig. 25).

Utilizing the principles of sequence stratigraphy and a depositional model, it is possible to correlate packages of sediment and gain an important insight into the areal extent of layers. This is highly significant in the case of interbedded sand layers that may or may not act as drainage pathways during the consolidation of adjacent clay layers. One of the key features of Recent marginal-marine environments is the impact of eustatic fluctuations in sea levels on sediment distribution ([21]). Rising sea levels result in the flooding of coastal valleys and the development of estuarine environments. Coastal sand barriers form adjacent to headlands and interbedded fluvial-estuarine-marine sediments are deposited behind them. Falling sea levels cause coastal rivers and streams to incise, the removal of large volumes of existing sediments and the development of extensive weathering surfaces. With exposure above the water table, sediments can become oxidised and indurated; certainly clays become stiff and fissured, sometimes to great depths. These processes are substantially controlled by the prevailing climatic conditions of the period. The interpretation of the sedimentary sequence within the study area depends heavily on the interpretation of the origin of the alteration layers. The alteration horizons are considered to record weathering that occurred during periods of sea level fall (Kenney 1964), corresponding to periods of global glaciation. Another consequence of a fallen sea level is the exposure of former sediment deposits, making them prone to renewed erosion and channel incision. Although depositional environments can exhibit significant variation both spatially and temporally, major weathering and erosion events associated with sea level changes tend to be ubiquitous and are particularly useful for identifying the demarcation between depositional events.

The understanding of the sedimentary sequence developed in the preceding sections can be used to make a more informed interpretation of geotechnical information gathered from the site A summary of the characteristic geotechnical properties available for each unit are presented as follows (Fig. 25).

Surface crust: This layer is generally found in those areas that have been cleared and drained. The main differences between this layer and the underlying Pimlico clay are likely to result from alteration due to drying and wetting cycles and biogenic activity. ([4]) and because the upper crustal soils are likely to have more of an alluvial nature, as they are formed at about sea level during the current sea level stillstand. The cone tip resistance (*qt*) values are around 700 kPa and Suvane values are between 75-100 kPa. Orangebrown mottling and fissuring is a common feature of this layer.

Pimlico Clay: The clay has extremely high moisture content, up to around 130% at 5 m depth. Undrained shear strength ranges from 16-33 kPa while qt is around 0.2-0.3 MPa.

Woodburn sand (Broadwater sandrock): CPTu test were unable to penetrate this layer in many locations due to the induration, but pumping tests have shown that this unit has a low porosity ([20]).

Gundarimba clay: The natural moisture content of the middle clay unit is considerably lower, around 60%, and the PL and LL are 30 to 100 % respectively. The qt values rise sharply to around 1 MPa in the mottled zone but then fall off again with depth, consistent with the observation that the lower portion of this clay is unaffected by weathering. Suvane data for the mottled zone is over 100 kPa but falls back to around 40-50kPa in the lower region. Similar values are found at depth in the Pimlico Clay.

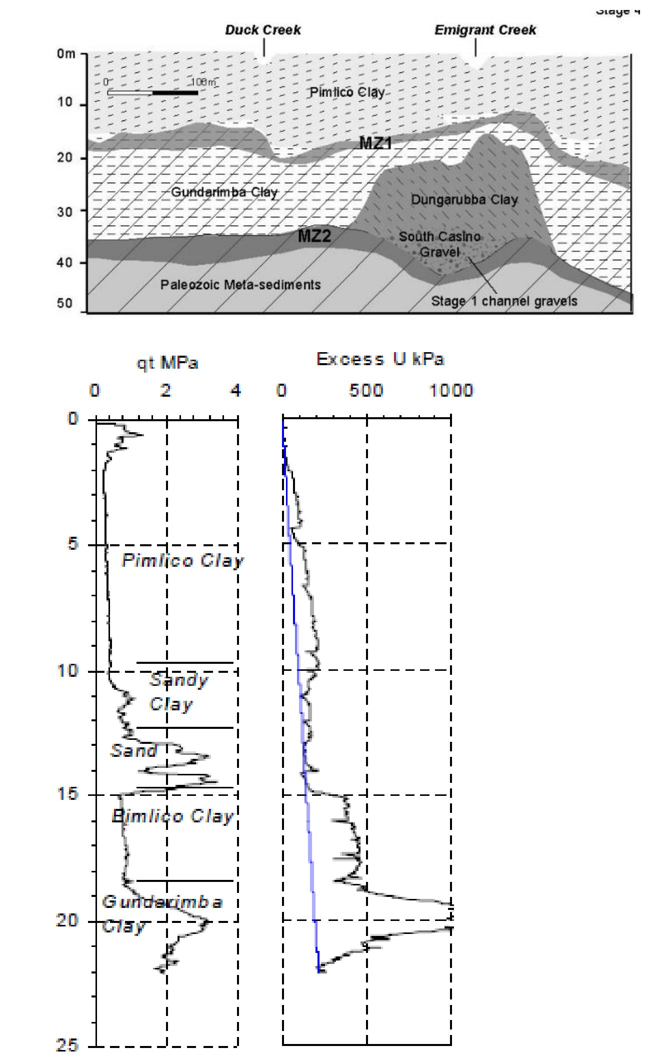

Figure 21. Section and properties of the Quaternary sediments. Data taken from a single Borehole and CPTu at Cumbalum.

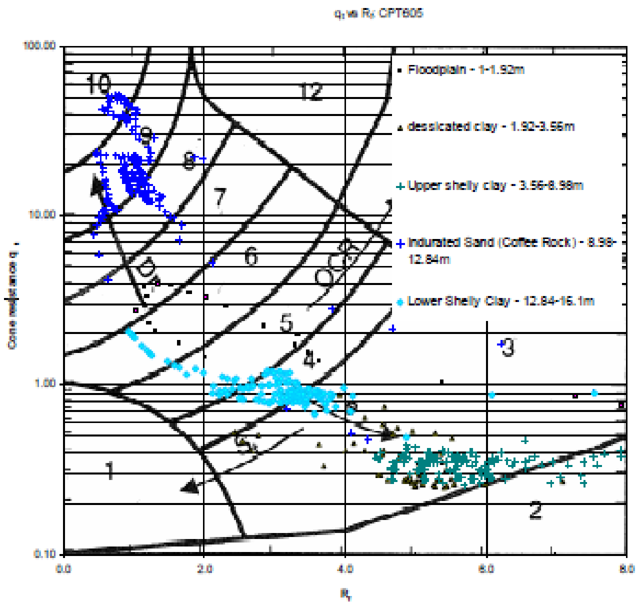

Figure 22. CPTU plots- Ballina

Dungarubba clay: No moisture content data is available for this clay but borehole logs indicate that the clays are hard and moist, suggesting values much lower that the upper clays while the excess pore pressure drops to hydrostatic, probably as a result of open fissures observed in this zone.

4.2.1. Evaluation

There is some evidence of unaltered clay below the coffee rock and bleached horizons from -10 mRL. The bleached horizon has been taken as the boundary between the recent Holocene deposits and the older Pleistocene clay deposited around 115,000.

I should also point out that unless to clay was deposited in near-salinewater and then at some point sea levels change and the clay is flushed with fresh water very sensitive or near-quick clay are unlikely (will not) to form.

If you can look at a local sea level curve in the literature and look at the depth/age relationship to sea level and there is a salt - fresh water transition with in the clay sequence you can expect there to be near-quick clay.

5. Conclusion

The measured data, the identified parameters and the reliability information are homogeneous at the both test sites. Ballina is a testing site at present, Szeged A, B and C areas seem to be acceptable as future potential geotechnical sites since a special series of soil types (nearly NC soils) can be found there in relatively homogeneous position, the geology is known. However, before using for this purpose some further CPTu dissipation tests are suggested to be made in areas A, B and C.

The effect of the too salty or too fresh groundwater flow with respect to the chemistry of a clay is similar on these sites, causing a change in the chemistry, leading to unstable fabric, larger void ratio. The geological reason of the salty groundwater flow is an underlying, compressing marine clay. The near-quick caly formation is related to the fresh-water flowing /seeping in the river deltas of the ocean.

The upper near-salineclay in Szeged and the upper near-quick, organic and high plasticity clays from Holocene in Balline have a non-monotonic dissipation test reply.

The void ratio was larger for the near-quick soils than for the non-quick soils. The void ratio was larger between 2 and 3 for the near-quick soils while for the non- quick soils it was less than around 2 (Fig. 10). In detail, the following features were found.

5.1.1. Soil alteration and compression test

By evaluating some compression tests in Szeged and Ballina, results indicated significantly larger void ratio than in less affected soils (Figs 6, 10).

By evaluating some compression tests in Szeged, the compression test indicated the internal structural changes. In the case of the near-salinesoils the compression was mostly originated from creep, the coefficient of creep increased, the coefficient of compressibility due to primary consolidation decreased due to the alteration.

Analysing the dissipation test data, different *c* vvalues were obtained for saline-like and non-saline-like clays, reflecting larger c for the saline-like clays. Opposite tendency was measured in silt. Generally permeability decrease is resulted by salt addition ([18]), however, if the primary consolidation compression decreases, the net effect on *c* can be an increase. Also, the effect of cementation – which is evident from the non-monotonic nature of the dissipation curves – may cause an increase in c, also.

Similar consequences can be assumed for near-quick clays which assumption can be validated by evaluating some compression tests in future research.

5.1.2. Various dissipation tests, CPTu chart

Concerning the near-salineand quick clays, the CPTu pore water pressure dissipation curves were non-monotonic which is normally related to overconsolidated soils. However, in both for near-salineand near-quick soils although they were normally or even underconsolidated. This phenomenon is attributed to bonding in the case of the Ballina clay, further research is suggested on the reason in the case of the Szeged site.

Concerning sand and silt soils, the very small immediate compression identified from the oedometer tests data indicated the in-compressibility of the grains. The negative, monotonic dissipation curves (type V, Fig 8) which was found in granular can be explained partly by the grain incompressibility partly by the large permeability which may result OC state due to the penetration process itself. Since no precise initial condition shape function is available in partly drained case, the identified c values could be approximate.

Both the near-salineand the near-quick clay seemed to be plotted in area 3 of the Roberston chart, the lower clay in Szeged and Ballina plotted in areas 4 to 6 of the Roberston chart (Figs. 24, 26).

The simple CPT cone resistance and local side friction dissipation tests (near-salinearea) were previously used to elaborate using some empirical formulae for soil profiling. The significant difference between saline-non-near-salinesoil areas was demonstrated. The near-salinesoils had smaller cone resistance and local side friction values.

Analysing the dissipation test data, different c - t_{50} or t_{90} relations were obtained for saline-like and non-saline-like clays, reflecting larger c for the saline-like soils, in accordance to the smaller percentage of primary consolidation.

5.1.3. Comparing dissipation and compression test

The coefficient of consolidation *c* identified from oedometer test data was smaller than the ones of from dissipation tests, as expected. This is the consequence of the different in situ testing condition and is a general picture ([4]). Both tests could be used to demostrate the effect of upwards grounwater flow in Szeged and the existence of the cementation bonds in both sites.

It can be noted that - according to the results of a statistical analysis -, the layering is the same but the spotlikely near-salinegroundwater changed the soil chemistry in Szeged, in area C. Szeged A, B and C areas seem to be acceptable as future potential geotechnical sites since a special series of soil types (nearly NC soils) can be found there in relatively homogeneous position, the geology is known. However, before using for this purpose some further CPTu dissipation tests are suggested to be made in areas A, B and C.

The high void ratio is possibly related to bonds exactly in the location of the high coef. of consolidation. In order to comment full a lot more data on the geology, clay chemistry and regional geography is needed. To many factors are at play to come up with a simple explanation.

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