Regional Report for East European Countries

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ABSTRACT: The paper presents information concerning CPT use and application in the assessment of geotechnical parameters, stratigraphy of subsoil and equipment used in countries of Eastern Europe, i.e. Belarus, Bulgaria, The Czech Republic, Estonia, Lithuania, Latvia, Poland, Russia, Romania, Slovakia, Ukraine and Hungary. The application of CPTU to determine mechanical parameters of industrial wastes used in the construction of man-made reservoirs is also discussed. The use of statistical methods to isolate homogenous subsoil layers based on CPTU parameters is also presented in this paper.

1 INTRODUCTION

The last CPT-95 Conference organized in 1995 by the Swedish Geotechnics Society in Linköping may constitute as a point of reference for the evaluation of the development of static penetration in the analyses of subsoil in East European countries. The status of knowledge and the scope of application of this method were presented during that conference in the "national reports". These reports were prepared by Poland, Hungary, Romania, Lithuania and Russia. The present regional report has been extended to include Bulgaria, Latvia and Estonia (Table 1). No data were received from Ukraine and Belarus and thus these countries were not included in this report. The development of in-situ testing with the application of static penetration in the period since the last CPT-95 conference in East European countries up to the present has been affected by several significant factors:

- These countries are characterized by huge research potential, due to the number of academic centers, research institutes, private and state companies working in the field of geotechnics,
- These countries have huge human resources potential and highly varied economic potential (Table 2). The economic potential has resulted in the development of their own designs of static penetrometers in several of these countries, e.g. Russia, Hungary and Poland. Penetrometers of this type successfully supplemented, particularly in the initial period, the pool of equipment composed of penetrometers of leading European CPT manufacturing companies such as, A.P. van den Berg, Geomil, Pagani.

Table 1. Number of published papers at international conferences.

Country	Conferences A	B	C	D	E	F	G	H
Belarus	-	-	-	-	-	-	-	-
Bulgaria	-	-	-	-	-	-	-	-
Czech Rep.	-	-	-	-	-	-	1	-
Estonia	-	-	-	-	-	-	-	1
Hungary	-	3	-	2	-	3	3	2 (Imre & Kralik)
Latvia	-	-	-	-	-	-	-	-
Lithuania	-	-	-	-	1	-	-	1 (Furmonavicius & Dagys)
Poland	1	3	1	1	5	3	-	4 (Młynarek, Tschuschke & Wierzbicki)
Romania	-	-	-	-	-	-	-	1 (Marcu & Culita)
Russia	-	1	1	-	-	-	-	6 (Trofimienkov, Kulachkin, Mariupolsky & Ryzhkov)
Slovakia	-	-	-	-	-	-	1	-
Ukraine	-	-	-	-	-	-	-	-

Note:
A – XIII European Conference on Soil Mechanics and Geotechnical Engineering, Prague 2004.
B - XIV European Conference on Soil Mechanics and Geotechnical Engineering, Madrid 2007.
C – XVI International Conference on Soil Mechanics and Geotechnical Engineering, Osaka 2005.
D – XIII Danube-European Conference on Geotechnial Engineering, Ljubljana 2006.
E – XI Baltic Sea Geotechnical Conference, Gdańsk 2008.
F – II International Conference on Site Characterization, Porto 2004.
G – III International Conference on Site Characterization, Tajwan 2008.
H – International Symposium on Cone Penetration Testing CPT'95, Linkoping 1995 (Including authors of the National Reports).

• Changes in the political situation after the year 1990 had a decisive influence on the possibility to purchase new generation penetrometers. These changes contributed to the development of free market economy and made it possible to purchase modern equipment. This situation is documented very well by the data presented in Table 5,

• Geographical location of East European countries has resulted in highly diversified geological, hydrogeological, hypsometric and climatic conditions. Even in relatively small countries, e.g. the Czech Republic, the structure of subsoil does not make it possible to conduct static penetration, since subsoil is mostly composed of solid rock. An excellent example of a country in which all geological formations are found is Russia. In that country there is also a deep zone of permafrost. In relation to the other countries, e.g. Poland, the maximum ground freezing depth is 2.2 m.

Table 2. Summary of topography, weather, land area and population

Country	Topography	Weather/Climate	Area [thousands of km^2]	Population [million]
Bulgaria	The relief is varied. There are extensive lowlands and plains (e.g. Danubian Plain), hills, low and high mountains (over 2,5 km of height), many valleys and deep gorges. Almost 1/3 of the territory is located over 600 m a.s.l. Over 350 km of rocky and sandy coastline.	The climate in Northern Bulgaria is moderate continental, while the climate in Southern Bulgaria is intermediate continental tending to Mediterranean.	110.9	7.6
Czech	Mountain ranges surround the country on almost all sides. Most of the territory is highlands with few river valleys and many artificial lakes.	Mild but variable locally among the various regions, depending on the height above sea level. Cold winter, spring, followed by a warm summer and chilly autumn.	78.9	10.5
Estonia	Uplands and plateau-like areas alternate with lowlands, depressions and valleys, alongside with the coastal cliffs in northern and western.	Mild because of proximity of North Atlantic Ocean and Baltic Sea. January and February with temperatures below 0°C. Summers tend to be short and cool with cloud cover.	45.2	1.3
Hungary	Fifty percent of territory consists of flatlands. The highlands stretch diagonally across Hungary. In the central part the Central Europe's warmest lake, (Balaton) is located.	Temperate climate, similar to the rest of the continental zone. January is the coldest month (-1 C average) and August the warmest (21,3 C average).	93.0	10.2
Latvia	The topography consists mainly of a lowland plain with a few areas of uplands consisting of moderate-sized hills.	Climate is influenced by proximity of Baltic Sea. January and February with temperatures below 0°C. Precipitation is common throughout the year with the heaviest rainfall in August.	64.6	2.2

Lithuania	Over 90 km of sandy coast line. The highest areas are the moraines in the western uplands and eastern highlands, (up to 300 metres above sea level) The terrain features numerous lakes, and wetlands.	Climate ranges between maritime and continental and is relatively mild. The near cost winters are slightly warmer (about 0°C) than in the interior (to -6°C).	65.2	3.6
Poland	Over 500km costal line in north with deltas, cliffs and sandy beaches . All north and middle part are lowlands. Uplands and mountains (also the Alpine type - Tatry mountains) are located in south part.	Transitional climate between the maritime and continental. Winters are sometimes mild and sometimes cold (-20°C), similarly the summers are cool and rainy or hot and dry (30°C).	312.7	38.1
Romania	Natural landscape is almost evenly divided among mountains (31 % - Carpathian Mountains, which reach elevations of more than 2,4 km), hills (33 %), and plains (36 % - Danube Delta, which is just a few meters above sea level).	Transitional climate between temperate and continental. Climatic conditions are somewhat modified by the country's varied relief. In the extreme southeast, Mediterranean influences offer a milder, maritime climate.	238.4	21.5
Russia	The topography of Russia features a broad plain with low hills west of the Ural Mountains with vast coniferous forests and tundra in Siberia. There are uplands and mountains along the southern border region. Despite its size, only a small percentage of Russia's land is arable, with much of it too far north for cultivation.	Most of the country has a continental climate, with long, cold winters and brief summers. There is a wide range of summer and winter temperatures and relatively low precipitation. January temperatures are in the range of 6° C (45 ° F) on the southeastern shore of the Black Sea and -71° C (-96 ° F), recorded in 1974 at the northeast Siberian village of Oymyakon.	17075.2	142.0
Slovakia	Mountains in the central and northern part of the country (the Carpathian Range with the high Tatry), and lowlands in the south (plains, with the Danube River valley).	Climate relatively continental with almost no extremes below minimal -20°C or above maximal +37°C. Winters are more severe in mountains, where the snow lasts the whole winter until March or even April.	48.8	5.4

On the basis of information from the national websites and www.nationsencyclopedia.com.

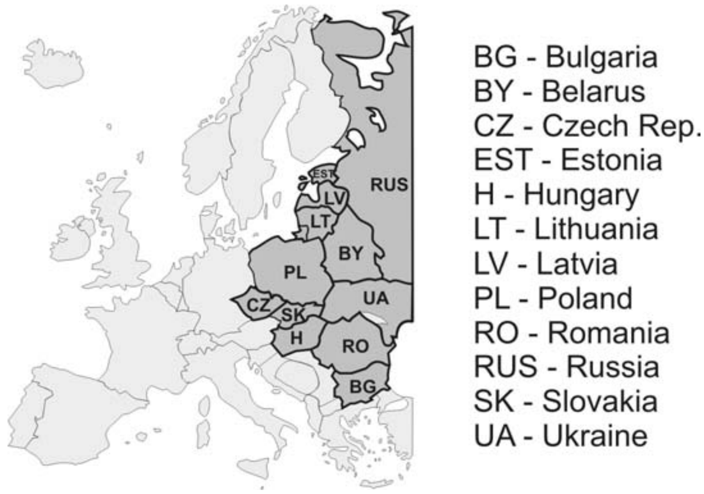


Fig. 1. East European countries under consideration in the report.

2 GEOLOGY OF EAST EUROPEAN REGION

Dominant areas of geotechnical exploration include zones of subsoil composed of postglacial deposits from the last glaciations. These zones are filled with fluvial and lacustrine accumulation deposits. Testing areas are also found in coastal zones of the Baltic and Black Seas, including marine exploration (e.g. the construction of oil rigs on the Baltic Sea). Some countries are located within the zones of seismic activity, e.g. Bulgaria, Romania and Russia. Countries of Eastern Europe occupy an extensive area, which geological structure was formed by numerous geological processes (Table 3). It needs to be stressed that in many countries digital geological-engineering, magnetic, chemical (subsoil contamination potential) or seismic maps are being prepared. These maps are available to the general public e.g. in Poland at the State Institute of Geology in Warszawa and in Bulgaria in the Geoarchive DB system. In several countries, such as Bulgaria, the Czech Republic, Slovakia and Poland, these maps cover 100% their area. Examples of such maps are given in Figs. 2, 3 and 4.

Table 3. Summary of prevailing geology and topography and implications for CPT.

Country	Summary of geological conditions	Implications for CPT
Bulgaria	The Balkan mountain divides into halves the territory from West to East. The slopes are covered by diluvium. The North part of Bulgaria is covered by loess and loam with high thickness. In the south part the large Tracia lowland is created by alluvium sands, sandy clays etc. The South border of Bulgaria is dominated of the Rodopy Mountain made of gneiss and bentonite tuff. The East part of Bulgaria is on the Black Sea Coast made of limestone, volcanic rocks and very many lagoons, lakes and sand beaches. Between the - Balkan and the Rodopy mountains there is a large kettle, fulfilled by Quaternary and Pleiocene deposits at around 400m of the depth. Bulgarian territory has a high seismity.	Suitability for CPT limited to lowlands. CPT used for investigation of loess and loam, the slight soil near the Black See, the high thickness of silt clay in Sofia, evaluation of soil liquefaction risk in Plovdiv City, near Maritza River.

Czech	The whole area is covered by highlands, structured by several big rivers. Those highlands are the remains of old mountain ridges, the rocks are folded and altered by a long orogenetic history. The sedimentary rocks are not in their original state of horizontal layering, but torn into pieces, folded and slanted. All the limestone karst areas of the Czech Republic are small and have a complex structure. The whole country is dotted with caves, all of them located in small, not to say tiny, karst areas.	Usage of CPT is restricted due to large area of shallow rock basement. Young, non-lithified deposits are also difficult for testing due to high amount of gravel in fluvial sediments.
Hungary	Hungary's surface area can be divided into four major units: ▪ The Mesozoic Hungarian Central Mountains are trending SW-NE. ▪ The Little Plain has a basement of Palaeozoic sediments on the west and Mesozoic rocks on the east. The surface is covered by Holocene and Pleistocene fluviatile sediments: *gravel and coarse sand* are exposed over vast areas. ▪ The Transdanubian Tableland, composed of Late Tertiary deposits. It is covered by thin sheets of Quaternary (mainly) *loess* deposits. ▪ The Great Hungarian Plain, the largest Neogene Depression of the Carpathian Basin filled up with Quaternary deposits. The former regions are characterized by sandy-silty hills and fluviatile, lacustrine (mainly) *plastic* deposits and partly by *infusion loess* up to the depth of interest.	The quaternary deposits are found on the major part of Hungary's surface area can generally be tested in situ by CPT.
Estonia Latvia Lithuania	The uppermost part of the Earth crust in Estonia, Latvia and Lithuania has been formed during the youngest geological period – Quaternary. The biggest part of thickness of Quaternary deposits has been formed by Scandinavian glaciers which covered territory of these countries a few times during the Pleistocene. The typical sediments of this period are loams, boulder clays and coarse non-cohesive moraine deposits. The warmer period spans, named as interglacial, existed between glaciations, when sedimentation generally took part in the lakes, rivers and bogs. The thickness of Quaternary deposits is very irregular, but in the largest part of country predominate thickness of Quaternary is about 80-120 meters.	Some problems with deep CPTs due to gravel and boulders in glacial tills. In opposition to this the CPT can be a useful tool for evaluation of geotechnical parameters of near shore and offshore areas and organic fills within the interior.
Poland	The territory of Poland lies at the contact of the main tectonic units of Europe. Therefore, the following three major tectonic units can be identified: East European Precambrian Platform, Palaeozoic foldbelt, Alpine foldbelt of southern Poland. Independent of deep rock basement, most of the area of Poland is covered by non-lithified Quaternary and Neogen deposits to the depth of at least 50m. The young deposits dominate the North and Central part of country, formed by Pleistocene glaciations and interglacial processes. In this part loams, outwash plain sands and moraine deposits dominating. Valleys are fulfilled by fluvial and aeolian deposits with significant share of organic soils. Southern part of Poland is covered mainly by weathered rocks, loess and	Most of area can be tested by CPT, even to the depth of 30 m. Some problems can occur in Pleistocene overconsolidated glacial tills and sands and Neogene clays which can lie also at the depth of a few meters.

	fluvial deposits.	
Romania	The geology of Romania is strongly dominated by the alpine Carpathian Folded Belt. The Carpathian Mountains consist of ancient crystalline rocks, Paleozoic and Mesozoic sediments and recent volcanic material, and are a very complex area of irregular depressions and stranded massifs with meadow platforms or suspended plains. There was erosion but no glaciation in the Quaternary, producing peri-glacial forms. The fluvial Quaternary deposits are located mostly along the Danube River and its delta. The loess and loess-like deposits cover large areas (17% of the country) in Eastern and Southern parts of Romania, around the Carpathian Belt.	The CPT can be very suitable on the large areas of loess-like deposits. It can be use for deep penetration of fluvial deposits, especially within the area of Danube River delta.
Russia	Soil conditions of the Russian Federation (RF) are diverse and include practically all soil types. They are similar to soils of the Western Europe and North America. Quaternary (alluvial, lacustrine, etc.) deposits, often reaching 10…15 m depths: these are mainly clay soils, less frequently sands and gravel. Most occurring are quaternary soils of low plasticity and stiff alluvial clays and clay loams, less frequently deluvial and moraine ones. The north-west area of RF European part features prevailing glacial soils: morainic clay loams (dense, with inclusions of boulders) or deluvial clay and sand loams (similar to alluvial). RF southern parts are characterized by loess and loess like clay loams occurred. Hard or stiff and mostly collapsible. In the northern and partly in the middle latitudes of RF there are many waterlogged areas, featuring peats and sapropels. In mountainous areas, in the Urals especially, there occur many eluvial deposits ("weathering crust") clayey, less frequently sandy, which are highly heterogeneous with inclusions of maternal rock fragments. The freezing depth varies from 0.6 m (northern Caucausus) to 2.5 m (north of the European part, Eastern Siberia, where seasonally frozen soil connects with permafrost). Primary deposits "older" than paleogene are represented by rock or by intercalated rock and hard clay soils. The rock top usually occurs at 10…30 m depth, but at the north-east of the European part of Russia and in many mountainous areas they could occur right below the surface.	Wide range of the CPT use; from organic and soft soils to multistage permafrost soils. Some interesting possibilities of the CPT use related to seismicity and liquefaction potential.
Slovakia	On almost half of the territory the Mesozoic and Paleozoic rocks occur at the surface. Their built the Carpatian Range, an alpine orogenesis age mountains and divide the Slovakia into two major parts. North-eastern is covered mainly by slope and eluvial - deluvial deposits with some fluvial sediments. South-western is built of fluvial and aeolian deposits: sands and silts (almost 10% of Slovakia territory is covered by loess). Only about 1% consists of glacial and glacifluvial sediments.	The use of CPT is possible mainly in South-western part of Slovakia, with large areas of loess and fluvial deposits.

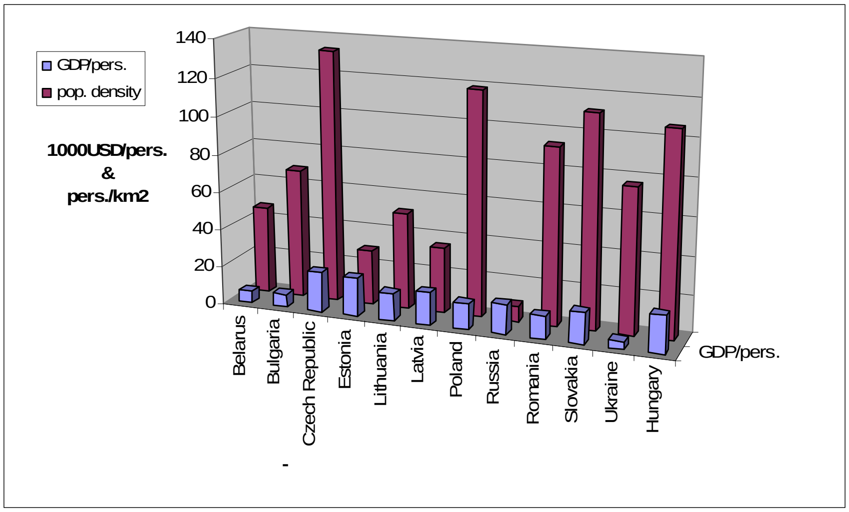


Fig. 2. Comparison of GDP value per capita and the population density of analysed countries.

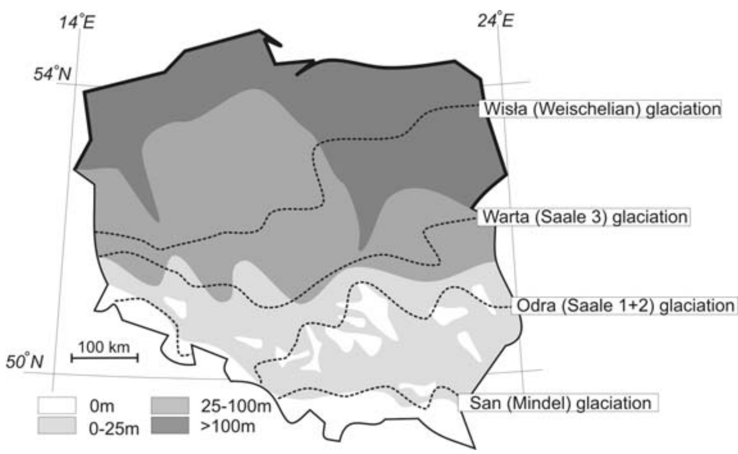


Fig. 3. Thickness of Quaternary deposits on Poland area with indicated the main glaciations range.

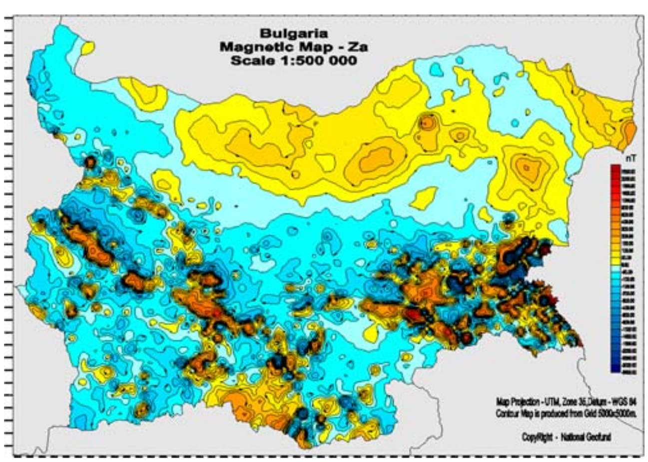


Fig. 4. Magnetic Map of Bulgaria.

Fig. 5. The major geographical units of Hungary's surface area.

3 GEOTECHNICAL CHALLENGES

At present three factors have an effect on the challenges faced by geotechnics and the application of CPT:

a) Investment programs, which are highly varied throughout the region, in the last 10 years exhibit huge dynamics. The primary investment directions in individual countries, based on collected materials and websites are given in Table 4. In individual groups of investments, apart from standard tests, e.g. drillings, a wide testing program, e.g. CPTU, SCPTU, CCPTU, is applied,

b) The complex structure of subsoil, in which there are soils, in which a routine interpretation of penetration characteristics is impossible, e.g. loess soils, non textbook soils, soils in the cyclical freezing zone (Table 4),

c) Identification and forecasting of random incidents influencing the design or operation of an object, e.g. seismic activity zones, regularly flooded areas (Table 4).

Factors of groups (b) and (c) require regular research and the use of statistical methods in finding local correlations.

Summing up the challenges faced by individual countries, connected with the application of CPT, we may stress two elements. One is the occurrence of deposits of specific properties, genesis and macrostructure in individual countries. For these deposits it is necessary to determine local correlations between CPT parameters and parameters describing strength, compressibility and other properties, e.g. liquefaction potential. The other problem is connected with the design of new equipment which could supplement testing under complicated soil conditions, where subsoil is interbedded with soils of very high cone resistance values. A good example in this respect may be the design of a probe, which is a compilation of a dynamic probe with a static probe e.g. by Adina – Sanglerat (1995) or an AMAP – SOLS static-dynamic probe as well as a CPTU probe with a Rotap drill rig by A.P. van den Berg (Fig. 6). A supplementary, but at the same time important element is also the implementation of the Eurocodes, which in many countries have completely eliminated existing standards.

Table 4. Main investment targets in East European Countries.

Country	Road construction and investments in urban areas	Environmental Investments	Deep foundation	Deep excavations	Harbour and sea investments
Bulgaria	Liquefaction potential evaluation of soils in seismic areas, construction of housing estates and road network, Sofia, Plovdiv		Pile foundation design on soft soils near Black Sea	Program of slope protection in the areas of loess and silty clays	Constructions of hotels on coastal and lagoon areas.
Czech and Slovak Republic	Construction of highways and tunnels network	Construction of reservoir for tailings. Identification of polluted areas		Landslide protection	
Hungary	Construction of highways and shopping centers on areas with difficult soil conditions (soft clays loess)	Governmental program of environmental reservoirs	New technologies used in piles foundation design for bridges and high objects		
Estonia Latvia Lithuania	Construction of housing estates and bridges		Tunnels on urban area		Reconstruction of harbor area, construction of terminals, oil and gas platforms in Baltic Sea, open sea wind farms
Poland	Construction of very high buildings in Warsaw, Poznań, Gdańsk, Wrocław Development of highways and high speed train project, EURO 2012 football stadiums	Geothermal projects, program for wind farm construction, identification of polluted areas for chemical maps preparation, new construction and development of existing tailings reservoirs (Żelazny Most	Piles foundation of bridges in construction program of highways	Open pit mines of brown coal (Konin, Bełchatów, Turów), construction of subway lines, Warsaw	Construction of gas terminal (Szczecin), drilling platforms for oil and gas on Baltic Sea

		and Trzebinia)			
Romania	Site investigations of loess soils and seismic activity areas.	Power wind turbines project (over 500 testing points)	Piles on alluvial deposits.	Swelling-shrinkage processes in unsaturated soils.	
Russia	Intensive program of building of housing estates, hotels and offices in main cities	Construction of gas piping on Baltic Sea	Pile foundation with most advanced method on areas consisting swelling soils, soft clay, deep organic layers	Open pits of different minerals, deep excavations in urban areas for many high objects	Renovation of constructions in harbor in Baltic, Black, North Seas

Fig. 6. A.P. v.d. Berg Static-Dynamic penetrometer.

4 CPT EQUIPMENT AND PROCEDURES

4.1. Equipment

4.1.1 *Pushing equipment*

Equipment used in East European countries is technologically highly diverse. Due to economic conditions in many countries, locally designed CPT pushing units are used (e.g. Russia, Poland). CPT pushing units made by leading European companies, e.g. A.P. van den Berg or Geomil, are purchased increasingly more often. Generally 4 groups of CPT pushing units equipped with original drive are used. The first group comprises units of a total dead weight of 200 kN or 250 kN mounted on a truck (Russia, Poland, Hungary) or on truck–track (Poland) or track systems. The second group consists of units of 100 kN, which are designed for anchor systems (A.P. van den Berg, Geotech, Envi, Pagani). The third group comprises light units of less than 100 kN using anchor systems. These are units mounted on a trailer or a crawler (e.g. A.P. van den Berg, Geotech, Pagani). Russia has its own classification system of CPT units. These are 3 groups, depending on cone resistance and sleeve friction. A light penetrometer of thrust force of up to 50 kN may perform tests if:

$0.5 < q_c < 10$ MPa, $2 < f_s < 100$ kPa,

Medium penetrometer of 50 - 100kN

$1 < q_c < 30$MPa, $5 < f_s < 200$kPa

Heavy penetrometer >100kN
$1 < q_c < 50$ MPa, $10 < f_s < 500$ kPa

Technologically advanced penetrometers are equipped with inclinometers. Special purpose designs include penetrometers for the exploration of the sea bed with original drive designs. Penetrometers of this type by A.P. van den Berg are used in Poland (Fig. 7). The last group of CPT pushing units is composed of light portable equipment with no anchorage, which are used for the on-going control of compaction in embankment layers (e.g. a penetrometer by A.P. van den Berg used at the construction of the Żelazny Most waste dump in Poland).

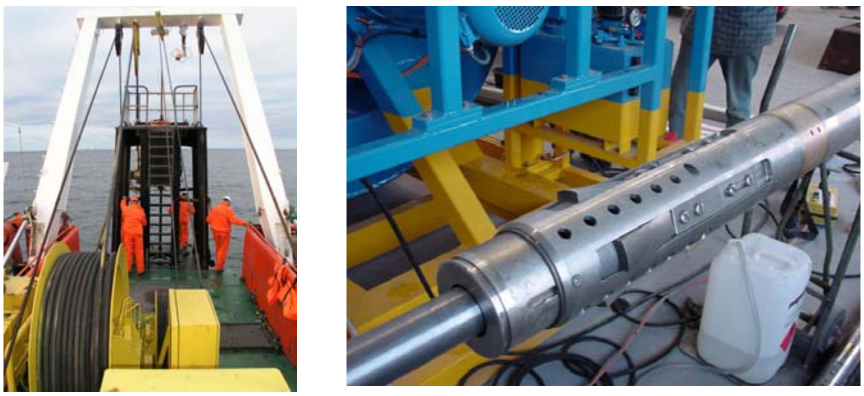


Fig. 7. The Wison by A.P. vd. Berg.

In all the above CPT pushing units the cone is pushed by manual addition of a rod, most commonly of 1.0 m in length. In the analyzed countries the fully automated cone thrust system, e.g. Robot by A.P. van den Berg, is not used. Information on the application of the miniature cone technology is not available. The average scope of subsoil exploration in individual countries is varied, but it may be assessed to be a depth of 20 – 25 m. In special cases, where appropriate technology with casing tubes was used, CPT penetration has been performed to a depth of 60 m (Młynarek and Tschuschke, 2001).

4.1.2 *Cones, measuring systems and data acquisition system*

The high variation of CPT equipment available has resulted in situations when, in individual countries, cones produced by leading companies, such as A.P. van den Berg, Geomil, Geotech, Pagani, Envi or Borros, and original, domestic designs are used. In the classical division, both mechanical (Begmann) and electrical cones are in use. In the transmission of measured CPT values, cable, wireless or acoustic systems are applied. There is no documented information on the use of the optocone system (A.P. van den Berg). The most commonly applied cones are the standard cone of 10 cm^2 apex angle of 60º with the u_2 type filter location. Very interesting, original probe designs are used in several countries, which significantly enrich measurement values, or cones of leading manufacturers are in use, equipped with additional sensors. In Poland, HEBO Poznań, use cones with two filters u_2 and u_3, CPTU and RCPTU cones (Młynarek et al. 1995), a dilatocone (Młynarek et al. 1995), and a SCPTU seismic cone (Młynarek, 2007). Cones of this type are manufactured by A.P. van den Berg.

Testing with the use of a conductivity cone is performed in Poland also by the Warsaw University of Life Sciences (Bajda and Markowska, 2003). Cones used in Hungary also need to be considered original designs developed in that country (Imre and Kralik, 1995). They are EGS (Engineering Geophysical Sounding) cones (Fig. 8) as well as a hydrosounding cone (Fig. 9). The ESG cone makes it possible to measure natural gamma intensity (Irj), gamma intensity (Ij), neutron intensity (In) and pore pressure u_2. A hydrocone makes it possible not only to measure cone resistance, but also collect a sample of water.

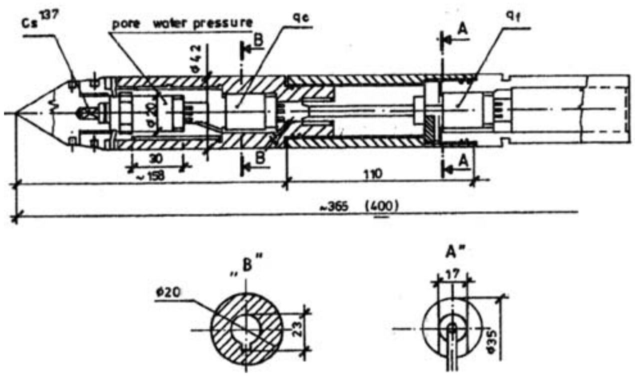


Fig. 8. The EGS cone. (after Imre and Kralik, 1995).

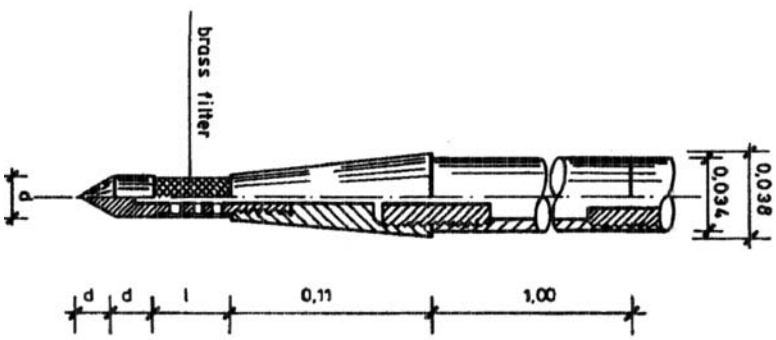


Fig. 9. The hydrosounding cone. (after Imre and Kralik, 1995).

The following types of cones and data acquisition systems are in use in individual countries:

- Bulgaria – Begmann mechanical cones of 10 cm^2, and an electrical cone by Pagani, data acquisition system GMESOOIP 65 – Geomil,
- Estonia – electrical cones, Geotech CPT-Log, Geo Mash (Finland), mechanical cones, also acoustic systems by Pagani, Geotech,
- Latvia and Lithuania – electrical cones, Geotech, Pagani with the TGSWO1 acquisition system, mechanical cones with their own design of data logging system (PIKA-9 penetrometer),
- The Czech Republic and Slovakia – electrical cones by A.P. van den Berg and Pagani, mechanical cones by Maihak Borros, Gouda, data acquisition system: A.P. van den Berg Geolog, Pagani TGSWO1,

- Hungary - electrical cones, Pagani, Geomil, Geotech, Envi - memocone, acquisition systems D-MONE, Cordless Geotech,
- Poland – electrical cones: A.P. van den Berg - Golog touch screen, Geotech AB - wireless, memocone, Geotech - acquisition system CPT, Geotech classic, Pagani, Boftware TGA505, mechanical cones – Begmann, Geomil C10CFIIP, Envi, C-MON registration system,
- Romania – GEOMIL and LANKELMA CPTU equipment and one own construction mounted on truck,
- Russia – touch screen acquisition system by A.P. van den Berg, electrical and mechanical cones, their own design of electrical cones.

In conclusion, we may formulate an opinion that in recent years a massive shift has been observed in the use of CPT cone to the advantage of those manufactured by leading companies. In such countries as Russia or the Baltic states cones of their own original designs are still produced. It needs to be considered a very advantageous element in the interpretation of penetration results, since for these cones and measurement systems correlations have been developed, which are included in locally existing standards.

4.2 *CPT equipment and system in use*

Historical, economic and geological conditions have contributed to the fact that in East European countries the CPT equipment used varies considerably. Estimated numbers of CPT equipment are given in Table 5.

Table 5. Type and number of CPT equipment used in geotechnical practice

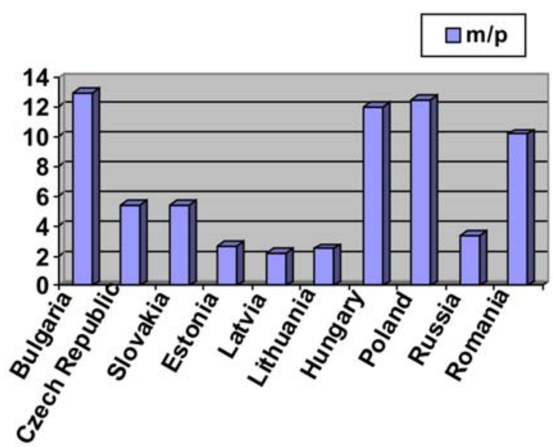
Producer		**Country**								
	Type	BG	EST	CZ/ SK	HU	LV	LT	PL	RO	RUS
A.P. vd Berg	Roson							1		
	Wison							1		
	Truck-Track							1		
	Track, Trailer 200kN			1				7		2
	Hand							1		
Geomil (Gouda)	Track	1		3(?)	+			2	1	
	100kN Trailer	2							+	
Geotech	Trailer		3		2	2	2	6		
Borros					2			1		
Pagani	Truck			2(?)	2(?)		4	1		
	Trailer	1								
Geomash			3							
Own constructions			5		1 *	2**	10	2 ***	1	50-70 ****

Note: BL(Belarus), BG(Bulgaria), EST(Estonia), CZ/SK(Czech and Slovakia), HU(Hungary), LV(Latvia), LT(Lithuania), PL(Poland), RO(Romania), RUS(Russia), UA(Ukraine); - no information received; + unknown number of devices; (?) estimated data; *mini cone; **(Pika-9); ***(Geomor Szczecin 150 kN; Geoteko 50kN); ****(S-832 115 kN; S-979; USZ 100 kN; SP-59 tractor)

Similarly as in case of CPT pushing units, there are two groups of CPT equipment, i.e. penetrometers of original design and penetrometers manufactured by leading companies. In such countries as Russia and the Baltic states penetrometers produced on the basis of original designs developed in those countries predominate. Russia has a long-time tradition of penetrometer construction (Trofimenkow et al, 1964). There are penetrometers mounted on trucks and other self-propelled vehicles or on trailers (Fig. 10). In Poland and in Hungary penetrometers made by Gouda and Borros, produced in the 1950's, are still in use. In view of such an extensive diversity of equipment it is difficult to assess what number of penetrometers may qualify to the categories given in the International Reference Test Procedure for the Cone Penetration Test (CPT) and the Cone Penetration Test with pore pressure (CPTU) (ISSMGE. TC 16, 1999). Penetrometer structures have many advantages, since they are prepared to operate under difficult field conditions, e.g. in Russia. Collected data concerning the number of penetrometers are only rough estimates, as e.g. in Russia it is assessed that at present from 50 to 70 penetrometers are in use (Table. 6). An interesting indicator may be the index informing on the number of members of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) per 1 penetrometer in a given country (m/p; Table 6). This index, to a certain degree, informs on the application of CPT by geotechnicians in their professional practice. This index has most favorable values in the Baltic states and in Russia.

Table 6 Number of ISSMGE Members vs. number of CPT penetrometers.

Country	Number of Members of ISSMGE	Number of penetrometers
Bulgaria	52	4
Czech Republic	43	app. 8
Slovakia	43	app. 8
Estonia	30	11
Latvia	31	14
Lithuania	40	16
Hungary	84	7
Poland	288	23
Russia	235	50-70
Romania	51	5



The proportion of CPT and CPTU in relation to the other in-situ tests varies considerably. Exploratory drilling predominates in the group of other tests, followed by Dynamic Probing Heavy (DPH) and shear vane tests (SVT). At present a significant role in Poland is played by flat dilatometeter testing (DMT, SDMT), which in some countries is not used at all. The proportion of CPT and CPTU in comparison to the other tests may be analyzed in two groups. The first group comprises data from companies, while the other - those from research institutions. In Poland the proportion of CPT in in-situ testing in companies ranges from 20 to 90%, while in Russia it is from 30 to 70%. Mean percentages of CPT as a proportion of in-situ tests are presented in Fig. 11. A similar analysis was conducted concerning the proportion of CPTU and SCPTU in relation to CPT. Only in Poland the share of technologically advanced tests exceeded 60% (Fig. 11 & 12). This index is very low in Russia and the Baltic countries. It results from obtained analyses that only in Poland and Romania testing is conducted using a seismic cone (SCPTU), conductivity or envirocone (CPTU). However, the proportion of these tests does not exceed 20%.

Fig. 10. Truck mounted Russian CPT penetrometer S-832.

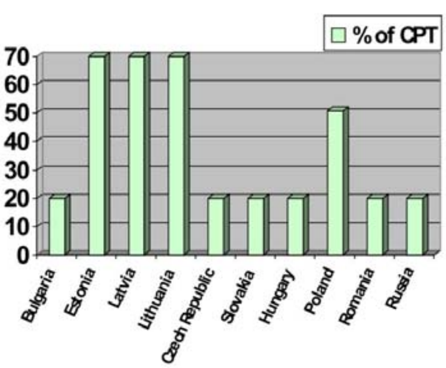


Fig. 11. Percentage of CPT in field investigations.

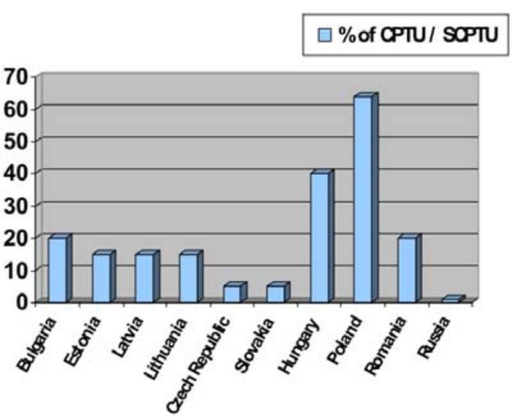


Fig.12. Percentage of either SCPTU or CPTU in static penetration tests.

4.3. *Challenges with equipment*

Expectations connected with the development of CPT penetrometers, similarly as it is throughout Europe, may be grouped as follows:

- Adaptation of penetrometers to testing in soft subsoil, which comprises organic and alluvial or glacialacustrine soils,
- Testing of subsoil composed of layers of gravels, sand-gravels and stones,
- Evaluation of quality of individual penetrometers used under different geotechnical conditions.

These three groups of factors are closely connected with the interpretation of results. In the first group an important element is the movement of the CPT pushing unit over soft organic subsoil. This problem has been partly solved by mounting a penetrometer on a light crawler. This type of solution is preferred by many companies, e.g. A.P. van den Berg, Geotech and Pagani. The second important issue is the accuracy of recording of cone resistance and sleeve friction, as numerical values of these parameters are much lower in soft organic soils than in mineral soils.

Very good prospects for the application of CPT in subsoil, in which very hard layers composed of gravel stones and cemented sands are found, are offered by CPT units equipped with boring heads, e.g. designs by A.P. van den Berg with the Rotap drilling system or the AMAP-SOLS penetrometer. It does not result from received questionnaires that the so-called "dummy" cone testing technique was applied.

Quality of results obtained with the use of different penetrometers has not been thoroughly investigated. This problem seems to be very important, since in countries of East Europe penetrometers of all manufacturers are in use together with original, local designs. Studies on that subject have been conducted only by the Norwegian Geotechnics Institute (NGI) and the Department of Geotechnics, Poznań University of Life Sciences, Poznań, Poland. Figure 13 presents regression lines for q_c, f_r, u_2, while Fig. 14 penetrometers are grouped using the Ward method (Hartingan, 1975). Analyses were conducted on 8 penetrometers by leading European manufacturers.
The main conclusions from these analyses were as follows:

- the values of cone resistance and sleeve friction registered by each penetrometr differ statically significantly at the significance level $\alpha = 0.05$, where α - significance level (Winter et al, 1991).
- in the predominating number of observations no statistically significant differences were found in the mean values of pore pressure measured by each penetrometer,
- no general regularity was found which would answer the question whether the significance of differences between mean parameters changes with depth. The significance of these differences is rather of random character.

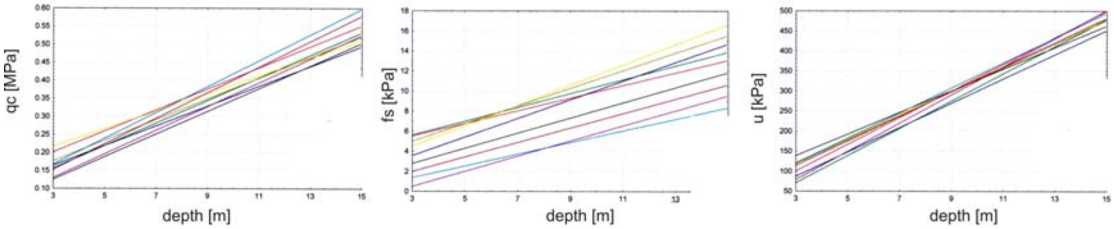


Fig. 13. Regression lines for q_c, f_s and u_c for different penetrometers.

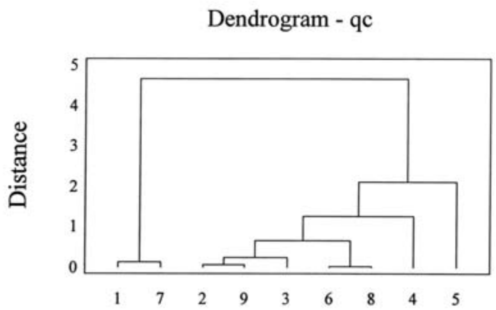


Fig. 14. Grouping of penetrometers registering most similar values of q_c after Ward method (Kaufman and Rousseeuw, 1990).

5 CPT INTERPRETATION

5.1 *CPT Standards*

Three groups of standards are applied in standardization of equipment and interpretation (Table 7).

Table 7. National or International Standards used for CPT interpretation.

Country	Description
Bulgaria	Bulgarian Standards: "Soils. Specification for Static Penetrometer. Technical Requirements."; "Instruction for Determination of Strength Characteristic of Soils with CPT and Dynamic Penetrometer." International Standards: DIN 4094-90.
Czech / Slovakia	Domestic Standards: STN 721033 / CSN 721033 (Cone Penetration Test). ISSMGE Technical Committee TC-16 Report: Test Procedures for Cone Penetration (CPT) and Cone Penetration with Pore Pressure (CPTU).
Estonia/Latvia/ Lithuania	Domestic Standards: LBN 207-01 (Geotechnique. Foundations); LVS 437 (Construction Normative); LBN 005-99 (Civil Engineering Investigations). Eurocodes: LVS EN 1997-1: 2005 (General Rules); LVS EN 1997-1 2007 (Ground Investigations and Testing).
Hungary	Domestic Standards: MI 15005/2 – 1989 "Design of foundations. Calculation methods of mechanic design of pile foundations". Eurocode 7 (Geotechnical design. Part 2). International Standards: DIN 4014 – for piles.
Poland	Polish Standards: PN-B-04452-2002 „Geotechnics. Field test"; PN-83-B-02482 "Piles foundations"; PN-81/B03020 "Shallow foundations". Eurocode: PN-EN 1997-2:2009. Eurocode 7. Geotechnical Design. Part 2. ISSMGE Technical Committee TC-16 Report: Test Procedures for Cone Penetration (CPT) and Cone Penetration with Pore Pressure (CPTU).
Romania	Romanian Standards: NP 074-2007 for geotechnical categories, sands and cohesion soils of low and high consistency. Eurocodes – SREN ISO 22476-2:2006; SREN ISO 22476-3:2006
Russia	Russian Standards: GOST 19912-2001 "Soils. Field static and dinamic penetration tests"; Code SP 11-105-97 "Site survey for buildings construction. Part 1"; SNiP 2.02.03-85 "Engineering of pile footings"; SP 50-102-2003 "Engineering of pile footings". Eurocode 7 EN 1997-3: 2000 (Geotechnical design. Part 3).

The first group comprises national standards, while the second standards originating from other countries, e.g. the German DIN 4094-90, which is used in Bulgaria. These standards are supplemented by the International Reference Test Procedure developed by the TC 16 (ISSMGE). The third group of standards comprises Eurocodes. A characteristic feature of national standards is the fact that they focus on guidelines concerning applied equipment, while interpretations are limited to the determination of density index and liquidity index based on cone resistance. An exception in this respect is found for standards used in Russia and the Baltic countries, which give dependencies for the determination of parameters of shear strength and constrained modulus.

5.2 *Interpretation*

5.2.1 *Subsoil stratigraphy of mineral and organic subsoil*

Classification systems for CPT are used in Poland and Hungary. They are either original or modified systems formulated by Robertson (1990). In Poland the classification system is considered to be the first step in an algorithm for the determination of stratigraphy and drainage conditions in subsoil.

Studies conducted in Poland over a period of many years showed that for the identification of organic subsoil only the Robertson (1995) system is suitable (Młynarek et al., 2008), which applies modulus G_0 (Fig. 15).

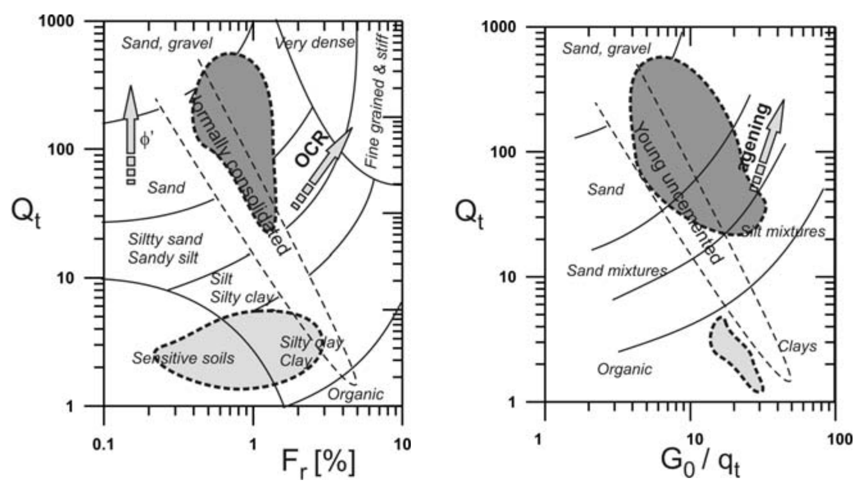


Fig. 15. An example good agreement of non-cohesive soils with the both Robertson classification charts (1990 & 1995) and necessity of use the G_0/q_t chart for the proper classification of organic soils by CPTU.

5.2.2 *Classification chart for CPT in tailings and non-text book soils*

Earthen structures (e.g. embankments of reservoirs) composed of tailings are characterized by interbedded deposits of highly varied grain size distribution. It is anisotropic material, thus the classification system is a very useful tool in the identification of embankment structure and drainage conditions. Figure 16 presents an original CPT classification system for post-floatation tailings of copper ores, which are interbedded in the embankments of the Żelazny Most dump in Poland (Młynarek et al., 1993).

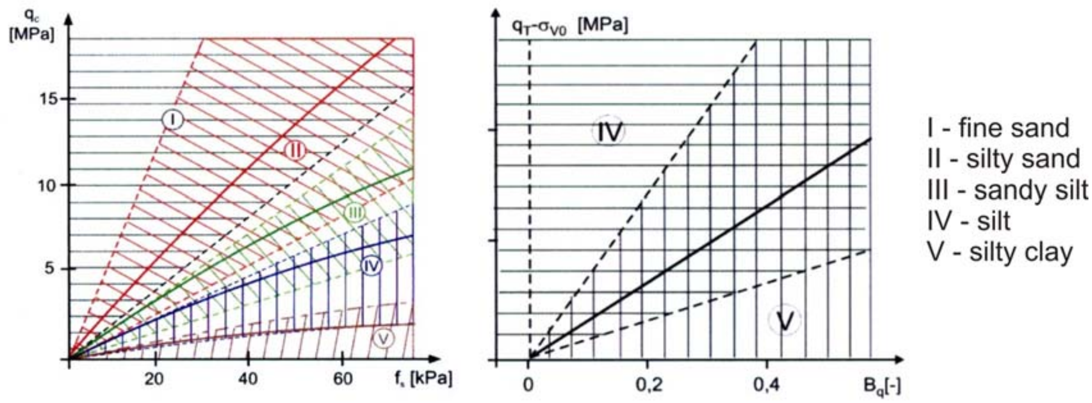


Fig. 16. Recommended and auxiliary classification system for postflotation tailings sediments from CPTU.

5.2.3 *Statistical treatment of CPT data for subsoil profiling.*

Geotechnical profiles, documenting stratigraphy and lithology of subsoil, in East European countries are the primary element in the preparation of an engineering design of a building. Profiles are constructed mainly on the basis of drilling results and are supplemented with data from other in-situ tests.

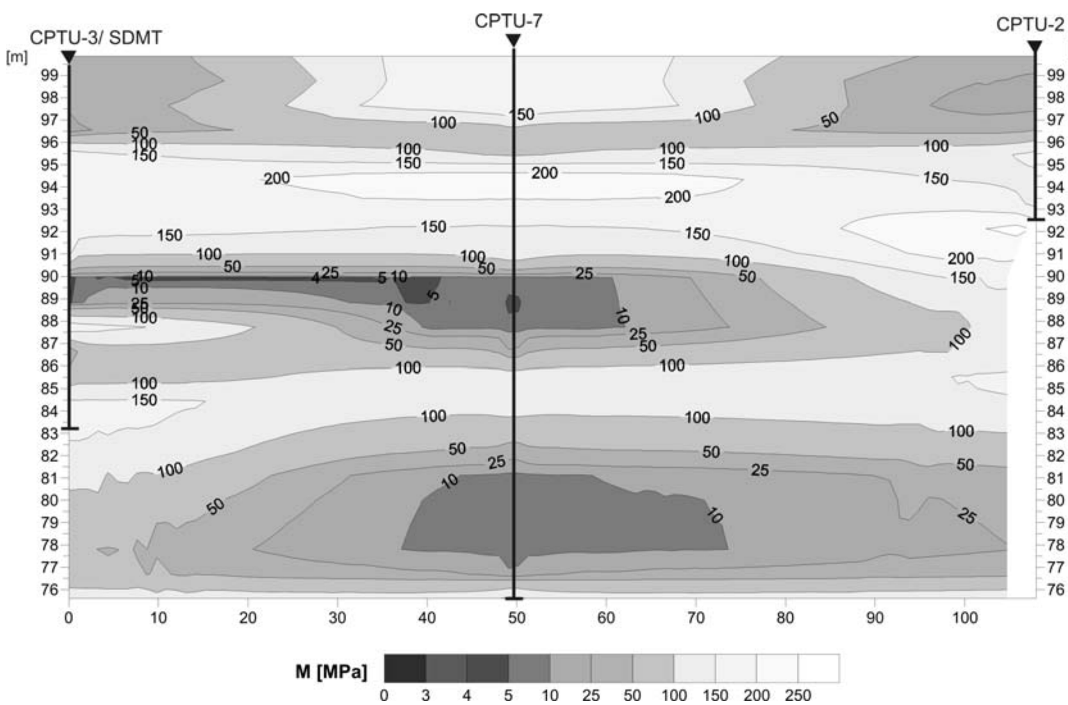


Fig. 17. The rigidity model of test site in Poland obtained on the basis of CPTU.

In Poland for several years now the basic data used to isolate the so-called geotechnically homogenous subsoil layers are CPTU data, i.e. q_c, R_f and u_2. The task of constructing a geotechnical profile starts from the 1-D model, which corresponds to the profile at the site of a single CPTU (Młynarek, 2007). Three methods are applied to isolate these layers, i.e. according to Harder and Bloh (1998), Mayne (2002) and Tschuschke et al,(1993). The next step is to construct the 2-D model, for which cluster theory methods are applied (Młynarek et al, 1993). The last stage comprises the construction of a 3-D model, in which modified Euclidean distance is used (Młynarek et al., 2005). An example of a geotechnical profile and a subsoil rigidity model based on the oedometric constrained modulus from CPTU is given in Fig. 17.

5.2.4 *Shear strength parameters, deformation modulus*

- In the estimation of values of shear strength parameters, effective friction angle Φ' (sands), undrained shear strength S_u (clay) and "Coulomb parameters" in effective stresses Φ', c' three methods are used:
- Based on correlation (local) dependencies $Dr = f(q_c)$, $LI = f(q_c)$ relative density index, Dr or liquidity index, LI are established, and next using standards, Φ' (sands) and c' (clay) are determined. This type of procedure is in use in Bulgaria, Estonia, Lithuania, Latvia, Russia, Hungary, Romania, Slovakia and partly in Poland. For this purpose original programs are applied (Slovakia, Romania, partly Poland) or professional software (Bulgaria – Geostar Software s.a.s., Hungary - Fugro Software, Poland – Geosoft, HEBO CPTU Interpretation pro),
- Based on cone resistance – q_c from tables, depending on the type of soil, values of Φ' (sands), Φ'& c' (clay) are read. Tables are found in local standards (Estonia, Lithuania, Latvia, Russia – Instruction standards 50-11-105.37, Hungary),
- parameters Φ' (sands), Φ'& c', S_u (clay) are determined using advanced methods, taking into consideration subsoil overconsolidation ratio (OCR), geostatic stress σ'_{vo}, σ_{vo}, σ_{ho} and the mineral type of grain (e.g. Jamiołkowski et al, 2001, Lunne et al. 1997, Senneset et al, 1982). The first step in interpretation is to determine dependencies $Dr = f(q_{c,t}, \sigma_{vo}, OCR)$ or $LI = f(q_{c,t})$, which take the general form, e.g. Geoteko Ltd. Warszawa, Poland:

$$LI = A - 0.5 \bullet \log (q_c - \sigma'_{vo}) \quad (1)$$

A - empirical coefficient depended on the type of soil, recommended value 0.3.

Or take into consideration soil genesis (Młynarek 2007):

- solifluction tills

$$LI = 0.271 - 0.147 \ln(q_n) \qquad \text{where } q_n = q_t - \sigma_{vo} \quad (2)$$

- last glaciation tills

$$LI = 0.310 - 0.216 \ln(q_n) \quad (3)$$

- earlier glaciation tills

$$LI = 0.375 - 0.254 \ln(q_n) \quad (4)$$

$$Dr = 0.42 \bullet \ln(q_c) (248 \bullet \sigma'_{vo})^{0.55} \text{ (Baldi et al, 1986)} \quad (5)$$

$$Dr = f(q_c, OCR, \sigma_{vo}, \sigma'_{vo}) \quad (6)$$

Relationship (6) takes into consideration the mineral type of soil. Such a method, for which HEBO Poznań Ltd. applies CPTU Interpretation Pro software, is used in Poland.

- Deformation characteristics

Two groups of methods are used to determine deformation characteristics, which generally take the form of a soil modulus. Soil modulus is a function of stress history, stress and strain levels, drainage conditions, stress path direction and the type of soil.

- The first group is an extremely simple estimate of the 1-D constrained modulus M, as measured in the oedometer test. In this method based on cone resistance and a specific type of soil (e.g. from drillings or laboratory testing) M is established from a table. Such a method is used in Estonia, Lithuania, Latvia and Russia.
- The other method of determination of the 1-D constrained M (defined in several countries by E_s) from a direct dependence (Lunne et al. 1997)

$$M = \alpha_m \bullet q_c \tag{7}$$

Examples of relationships applied in individual countries are as follows:

Bulgaria $E_s = 1.6\ C_{kd} - 8$ (8)

C_{kd} – corresponds to mean value of cone resistance in the layer

Hungary $E_s = 144\ q_c + 3$ [MPa] (9)

$M = 8.25 \bullet (q_t - \sigma_{vo})$ (Kulhawy and Mayne, 1990) (10)

A dependence given by Biuro – FundamentProjekt (Imre and Králik, 1995)

$$E_s = 5q_c + 12 \text{ (clays)} \tag{11}$$

$$E_s = 3.3q_c + 12 \text{ (sands)} \tag{12}$$

Poland formulas by Sanglerat (1972) adopted for clays and organic soils (Młynarek et al. or after Kulhawy and Mayne, 1990)

$$M = 8.25\ (q_t - \sigma_{vo}) \tag{13}$$

or Senneset et al. (1989).

Romania

$$E_s = 3.4q_c + 13 \text{ (sands)} \tag{14}$$

$$E_s = 3.8q_c - 0.55n + 26 \text{ (clays)} \tag{15}$$

n - porosity

$E_n = 1295q_c + 1.33$ (16)

E_n – modulus from the plate test

5.2.5 *Other parameters*

Application of SCPTU, CPTU (RCPTU) makes it possible to determine additional parameters describing subsoil properties. This type of testing is conducted mainly in Poland. The first group of parameters comprises porosity – n or density, while the second group – modulus G_0. Examples of dependencies are as follows:
for Warsaw clays (Lech and Garbulewski, 2009)

$$n = 0.39(\rho_d^{SAT}/\rho_f)^{-0.27} \quad (17)$$

ρ_d^{SAT} - soil resistivity
ρ_f - resistivity of liquid = 8.3 Ω m

Młynarek et al. (1995) defined a dependence between friction factor R_f and formation factor F for preconsolidated clays and sands. Testing conducted using a conductivity cone made it possible to propose a procedure for the determination of formation factor on the basis of q_c and evaluation of subsoil density. Bajda et al. (2007) established relationships for varved clays from SCPTU

$$M = 154 + 1000\,\sigma'_{vo} - 1.2\,V_s \quad (18)$$

V_s – shear wave velocity [m/s]

5.3 *Interrelationships between CPT and other tests*

The most frequently demanded correlation is the relationship between cone resistance q_c and dynamic resistance from testing with the use of dynamic probes (DP). Relationships are constructed by the application of simple linear regression models or on the basis of the principle of work. These dependencies are dependent on the type of probe (light, heavy) and measured penetration (N_{10}, N_{20}). Most commonly this relationship is described by regression lines in the following form

Hungary: $q_c = 1.095 + 0.476\,N_{20}$ (19)

Romania: $q_c = 0.2\,N_{10}$ (20)

Poland: $q_c = 0.897\,q_d$ (Giżycki, 2000) (21)

q_d – dynamic resistance

The second group of dependencies comprises relationships between parameters obtained from CPT and DMT. These type of relationships are used in testing conducted in Poland, e.g. Młynarek et al. (2003) for overconsolidated clays:

$M_{CPT} = 0.976\,M_{DMT}$ M_{CPT} after equation (7) (22)

5.4 *Tailings*

Waste dumps where CPT is used to assess geotechnical parameters and to identify a filtration curve in embankments are located e.g. in Poland and the Czech Republic. Intensive tests with CPTU, SCPTU, SDMT and DMT have been conducted for several decades at the Żelazny Most tailings pond in Poland. Post-floatation tailings of copper ores are deposited at this tailings pond. CPTU, SCPTU and SDMT turned out to be highly efficient methods to evaluate parameters which identify the state of tailings, shear strength parameters and constrained modulus. Several relationships used when designing embankments of the Żelazny Most dump are presented below (Młynarek et al. 1994, 1998, Tschuschke 2008).

$$Dr = a_3\ \sigma_{vo}\ b_3 \ln(q_t) - c_3 \ln(\sigma_{vo}) - d_3 \qquad (23)$$

a,b,c,d, - coefficients dependent on the type of deposits according to the system given in Fig. 16

$$LI_n = a_2 + b_2 \ln(q_{n\ min}) \text{ – normalized liquidity index} \qquad (24)$$

where $LI_n = A\ (W_n/I_c) - B$
A, B- empirical coefficients (Tschuschke, 2008),
I_c – consistency index, W_n – water content after polish standards (PN-88/B-04481)

$$\Phi' = \rho_d + 9.8 \log(q_{c1}) \qquad (25)$$

$$S_u/\sigma'_{vo} = a_5 + b_5\ LI_n \qquad (26)$$

$$M = 2\ q_t,\ \ q_t < 2.5 \qquad (27)$$

$$M = 4\ q_t - 5,\ \ 2.5 < q_t < 5 \qquad (28)$$

$$M_{SDMT} = 24.37\ M_{SCPTU} \qquad (29)$$

6 CPT APPLICATIONS

The application of CPT results is connected mainly with the calculations of load bearing capacity of piles and dimensioning of shallow foundations. Identification of subsoil contamination using CPTU and RCPTU cones, and an environcone has been documented in printed publications only in Poland. CPT is extensively used to control fills and embankments. Relationships or procedures given in point 5.2.4 are used to evaluate Dr in these structures.

6.1 *Shallow foundation*

Two procedures are used in dimensioning of shallow foundations and calculation of settlement:

- CPTU is used in the determination of Φ', c', S_u and M, followed by calculations of bearing capacity of subsoil according to formulas given in standards (Table 7). This type of procedures is used in Russia, Estonia, Lithuania, Latvia, Poland, Hungary and Romania,
- Bearing capacity of subsoil is calculated directly on the basis of q_c values. Such a procedure is applied in Poland (Młynarek and Waliński 2004). Formulas by Meyerhof, Tand or Schmertmann are used in this procedure (1978).

6.2 *Deep foundation design*

The application of CPT for deep foundation design is limited in all countries to dimensioning of piles. Identical procedures are used in this respect as those for shallow foundations. Depending on the pile type, empirical coefficients are used and shear strength parameters or Dr, LI are determined from CPT. In the other method bearing capacity of piles (mainly bored) from CPT is determined from formulas in which q_c is included (e.g. Karlik 1984, Imre 1989)

$$P_{CPT} = q_c \cdot F + u \, \Sigma \, f_s \cdot l_i \qquad (30)$$

where
F – cross section of pile, u – periphery of pile, l_i – length of pile, A method of this type is also used in Poland (Gwizdała and Stęczniewski 1998) and Romania (Marcu and Culita 1995).

7 RESEARCH AND FUTURE TRENDS

Contribution of research centers and other institutions from East European countries in the development of CPT may be considered significant. Research achievements originating from this part of Europe have been repeatedly stressed, since geotechnicians working in this field have served functions of panelists, general reporters, or delivered key-note lectures at international congresses. International workshops concerning CPT and DMT have been organized in that region as well (e.g. in Poland in 2003, 2005 and 2007). Papers presented by researchers from East European countries have been published at each of the important international conferences held worldwide (Table 1). Doctoral dissertations, post-doctoral degree dissertations (Poland, Slovakia and Czech Republic, Hungary) and M.Sc. theses have also been prepared on the CPT. An estimated number of these dissertations is given in Table 9. The tradition of studies on CPT dates back to the times after Second World War. Up to 1990 systematic studies on CPT, financed by the state budget, were conducted in some countries (e.g. Russia, Poland). A good example of considerable achievements resulting from these studies is Russia, where several textbooks were published on CPT, and where original penetrometers were used and standards were prepared. However, the year 1990, which was politically significant for East European countries, marked the beginning of an ambiguous situation. On the one hand, the number of modern penetrometers used in practice has increased considerably (e.g. in Poland), while on the other hand financing of such studies from the state budget was drastically reduced (e.g. in Russia). In some countries research shifted from research centers to specialist companies. The subject matter of these studies as well as centers involved in studies on that field are presented in Table 8. Table 8 shows that mainly investigations concerning important local problems are conducted, e.g. interpretation of CPT in soils of anisotropic structure (varved clay, loess), soils subjected to cyclical freezing processes or industrial wastes. These are problems having a considerable effect on further development of CPT.

Table 8. Research on CPT in East Europe.

Country	Topic	Institution	Hab.	PhD	MSc
Czech / Slovakia	Geo-environmental applications. Local correlations for evaluation strength and deformations characteristics.	Zilina University, Civil Engineering Faulty, Department of Geotechnics	1	1	2
Estonia/ Latvia/ Lithuania	Geo-environmental applications. Onshore tests (Baltic Sea investigations)	Unicone Riga	x	x	x
Hungary	Piles, local correlations. Interrelationships between CPT, DMT, DPH tests. Development related to dissipation tests. Soil profiling from rheological CPT	▪ Szent Istvan University, Miklos Civil Engineering Faculty, Budapest. ▪ Budapest University, Geotechnical Department. ▪ Szechenyi Istvan University, Gyor. ▪ University of Pecs Pollack Mihaly Faculty of Engineering Department of Materials and Geotechnology. ▪ Elgoscar-2000 Ecotechnology and water management Ltd. ▪ Geovil Kft Ady Endre Street H-2000 Szentendre. ▪ Geo-Engineering Kft, Budapest.	-	5	>10
Poland	▪ Local interelations between laboratory and in-situ tests. ▪ Interrelationship between CPT, DMT, SDMT results for mineral and organic soils, tailings. Classification systems for organic soils. Interpretation of CPT in strongly laminated soils (varved clays). Interpretation in post flotation sediments. Applications of statistical methods in site characterization (1D, 2D &	▪ Geoteko-Warszawa ▪ Hebo-Poznań & University of Life Sciences in Poznań, Department of Geotechnics.	x 3	x 4	x >10

	3D models). ▪ Local interrelations between CPT and laboratory tests.	▪ ITB (Building Research Institute),Warszawa.	x	x	x
	▪ Interrelationships between CPT, SCPTU, RCPTU and laboratory tests. Local correlations.	▪ Warsaw University of Life Sciences, Department of Geoengineering	-	3	x
	▪ CPT applications for evaluation of bearing capacity of piles.	▪ Technical University Gliwice	-	-	-
	▪ Calibration chamber tests and local correlations.	▪ Gdańsk University of Technology, Department of Geotechnics, Geology & Maritime Engineering	1	2	x
	▪ Local correlations.	▪ Koszalin University of Technology, Department of Civil and Environmental Engineering	-	1	x
Romania	CPT – Dynamic Penetration Test correlations	Gheorghe Asachi Technical University of Iasi, Faculty of Civil Engineering, Road and Foundations Dep.	x	x	x
Russia	Investigations in difficult soil conditions (permafrost, collapsible etc.) Application for 2D & 3D models of soil massive. Deep penetration tests (>40 m). Development of new probe with non-bearing sensors for determination extra soil parameters.	▪ Geotechnical Engineering Gersevanov Foundation Research Institute, Moscow ▪ Building Construction Research Institute, Ufa	x	x	x

Note: x – no information received

8 SUMARRY

Evaluation of the status of CPT application to forecast geotechnical parameters and stratigraphy of subsoil makes it possible to formulate several generalizations.

- Countries of East Europe have a considerable research, professional and equipment potential for the application of CPT in geotechnical design.
- Geological conditions on the one hand facilitate extensive application of CPT in in-situ testing, while on the other hand there are numerous and serious limitations for the CPT type penetration due to subsoil structure. Considerable potential is found for the method combining CPT with the dynamic tests or drilling.

- Deposits of specific macrostructure (e.g. loess, alluvial deposits) and specific genesis found in many countries result in the necessity to develop and apply local correlations in the interpretation of CPT characteristics. Such correlations have already been developed or studies are being conducted on that subject in some countries.
- Considerable prospects in several countries are found for the application of more advanced methods, i.e. SCPTU and RCPTU. The implementation of Eurocodes, which in many cases eliminate existing national standards, also constitutes a serious challenge.

9 ACKNOWLEDGEMENTS

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