ENGINEERING GEOLOGICAL MAPS AS A TOOL FOR SOLVING GEOTECHNICAL PROBLEMS IN THE ANTWERP AGGLOMERATION

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ABSTRACT

Since 1976 engineering geological maps of the Antwerp agglomeration are being compiled. In 1982 nine atlases covering the centre of the city, the built-up area of the left bank and the southern part of the harbour area have been completed. Each atlas contains a series of maps and an explanatory notice. One map shows the topography and the location of the observation points (boreholes, cone penetration tests, geophysical tests, piezometers). Other maps provide information about the presence and the thickness of the successive layers to a depth of approximately 50 meters, the relief of a substratum, the groundwater level, and the engineering geological zoning.

The presence in the top layers of fill and disturbed soils former military and castle moats, whirl pool deposits, alluvial sediments and peat, and the top of the Tertiary layers, may have a considerable influence on the design of harbour works. This is demonstrated by some case histories, one relating the construction of a quay wall at the spot of a whirl pool deposit, one concerning the construction of an oil tank on alluvial deposits of varying thickness, and one concerning the construction of retaining walls in fill and disturbed soils.

INTRODUCTION

Ever since 1971 engineering geological maps are being compiled of the agglomerations of Antwerp, Brussels, Charleroi, Ghent, Liege, and Mons. At first geotechnical data are assembled, confronted and transferred to filing cards. This data bank can be consulted by the public. In order to make this information more accessible an engineering geological atlas is made.

An engineering geological atlas comprises a series of maps, which form a clearly arranged documentation concerning the geology, the geotechnical and hydrogeological properties of the subsoil in a particular area.

The engineering geological mapping is performed by the Centres for engineering Geological Mapping of the Universities of Brussels, Ghent, Liege, and Louvain-la-Neuve. They operate under the general direction of the National Committee for Engineering Geological Mapping, founded by the State Geotechnical Institute. The geotechnical atlases are published by this Institute with the financial support of the Ministry of Public Works (E. De Beer et al., 1980).

The geotechnical mapping of the Antwerp agglomeration started in 1976. In the initial stage twelve atlases will be compiled. Each of them covers an area of 10 km² (4 km by 2,5 km) at the scale of 1/5000. On December 1st, 1982 three atlases have been edited and the draft of the ninth atlas was ready for printing. By the end of 1985 the initial program will be completed and the extension of the mapping to the entire harbour area on both banks of the Scheldt may be considered.

GEOLOGY OF THE ANTWERP AREA

A section between the borings at Kallo and Beerzel (Fig.1) gives a schematic view of the geology of the Antwerp area. The Paleozoic substratum consists of fractured consolidated sedimentary rocks. In Antwerp its top lies between -500 and -575 m. The Mesozoic deposits contain marly chalk at the bottom and chalk and tuffeau at the top. The surface of the Mesozoic is found between -400 and -450 m.

The overlying Tertiary deposits comprises sand and clay layers of unequal thickness, dipping monoclinally in a north-easterly direction. From bottom to top one encounters successively :

- Lower-Landenian of marine origin, consisting of marl (Heersian), covered

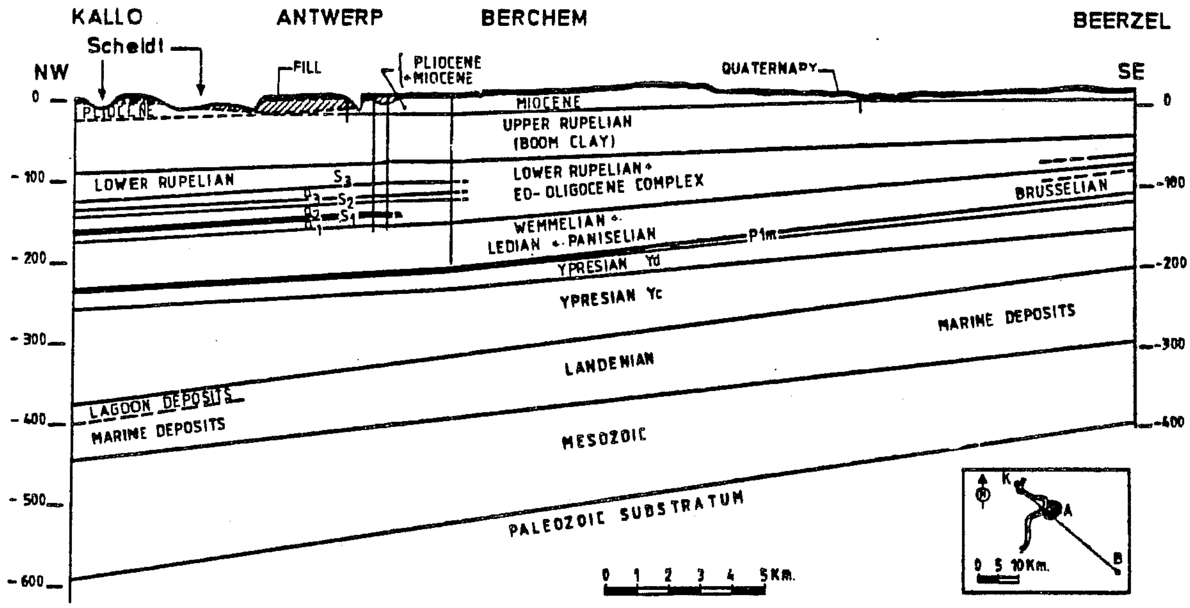


Fig. 1 - Schematic cross-section Kallo-Beerzel

by solid clay gradually passing into silty sandstone and fine sands;
- Upper-Landenian, consisting of sands, clays and lignite of lagoonal origin; this unit has been encountered in the boring at Kallo but not in the one at Beerzel;
- Ypresian, composed of clay and silty clay (Yc) at the bottom and very fine glauconiferous sand with local clay lenses and hardened horizons (Yd);
- Paniselian, consisting of a schistose compact clay (P1m) overlain by a complex of sand, clayey sand and sandy clay, with sandstone layers;
- Brusselian, composed of fine, sometimes calcareous sand and limy sandstones; Brusselian has been encountered at Beerzel but not at Kallo; it is unlikely to occur in the mapped area;
- Ledian, composed of fine calcareous sand and limy sandstone layers;
- Wemmelian, consisting of fine, sometimes clayey sand;
- Eo-oligocene transition complex composed of alternating sandy and clayey layers; the boring of Beersel has only struck a part of it;
- Lower-Rupelian composed of clayey sand;
- Upper-Rupelian formed by a clay complex (Boom Clay);
- Miocene and Pliocene deposits consisting mostly of glauconiferous sand;

The Quaternary deposits on top of the Tertiary are composed of

- Pleistocene deposits, consisting of sand and loam;
- Holocene alluvial deposits consisting of clay, loam and peat.

THE ENGINEERING GEOLOGICAL ATLASES OF THE ANTWERP AGGLOMERATION

The geotechnical atlases of the Antwerp agglomeration comprises a number of maps, one or two geological cross sections and an explanatory notice.

Documentation map

The documentation map shows the location and the kind of the main observation points. It informs the user on the density of the data and the kind of information which were available for the compilation of the map. Hence it also givers an insight into the degree of interpolation.

This map also shows the contour lines of the present ground level. These are partly derived from the existing topographical maps. A larger part of the contour lines has to be adapted by means of data from sewer plans, or levelling by the Technical Department of the City of Antwerp or by the Centre for Engineering Geological Mapping itself. All levels are expressed in meter versus the datum plane of the National Geographical Institute (Second General Levelling).

Map of the thickness of fill and disturbed soils

In general foundation conditions are greatly influenced by the presence of fill and disturbed soils. Former ditches and water courses having a width of at least 5 m are located by consulting historical maps and plans (W. De Breuck & P. Van Burm, 1980). These zones usually contain a considerable amount of fill. In general their location but not their thickness is indicated.

Besides other important fill deposits on polder lands, embankments of railways and motorways, and levees along the Scheldt are indicated.

Furthermore mapping is based on local data from in situ tests and borings. For some areas older maps showing the situation before the filling may provide additional information.

Maps of the thickness of the units considered in the area

Units are given successively from top to bottom. The thickness is shown by lines of equal thickness or isopachs. Depending on the density and the accuracy of the data available the Holocene and the Pleistocene deposits are mapped either separately or as together a single unit. Sometimes the composition of the Holocene deposits is shown in a single point by appropriate symbols. The Pliocene deposits in the area are subdivided in Merksemian, Scaldisian b, and Scaldisian a. The Miocene comprises the Diestian and the Antwerpian.

The position of the units mapped in the area are shown in two geologic cross sections (fig. 2a and 2b).

Map of the top of a substratum

Besides the isopach maps a contour map of the top of a substratum is made. In the Antwerp area the Rupelian clay (Boom Clay) has been considered as the substratum.

From the documentation map, the contour map of the substratum and the maps of the different units one may construct an engineering geological section on every spot.

Hydrogeological map

The hydrogeological map shows the data concerning the water table point by point. The kind of test and the date of measurement is given.

Map of engineering geological zoning

The map of engineering geological zoning is a synthesis of all previous maps. Within a zone the overall geotechnical conditions remain largely constant. An engineering geological zone is characterized by a well defined sequence of layers. Sometimes the thickness of a mapped formation is considered as a parameter indefining a zone. In some cases additional data are given on the map such as the presence of former ditches, watercourses, whirl pools ....

Geological cross sections

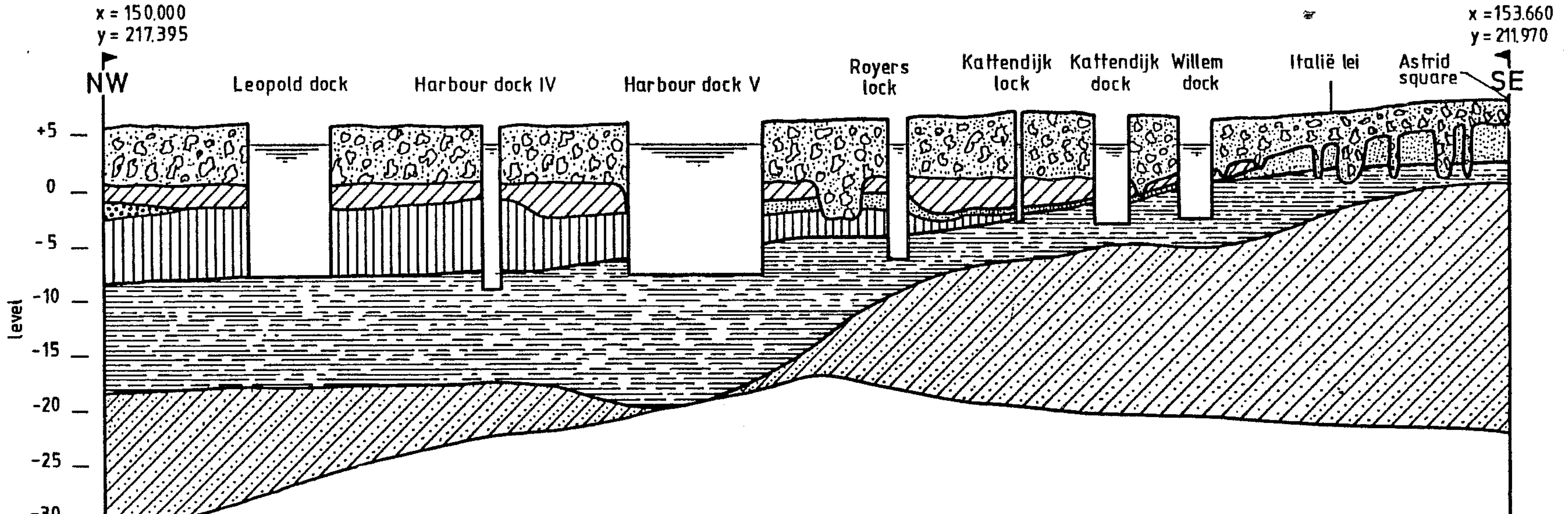
The general geological conditions of the area are illustrated by one or more cross sections (fig. 2a and 2b).

The explanatory notice

The explanatory notice contains geographical information, the general geology, the investigations which have been carried out, the explanation of the documents, the geotechnical properties of the mapped formations, and references and bibliography.

POSSIBILITIES OF USE OF THE ENGINEERING GEOLOGICAL ATLASES

The information contained in an engineering geological atlas may contribute to the selection of an adequate building site, to the preparation of the preliminary design and the planning of a detailed soil investigation program as a basis for the final project. Although the information usually cannot be quantified the attention of the user is drawn to the possible interference of certain geological, geotechnical and hydrological anomalies with the project.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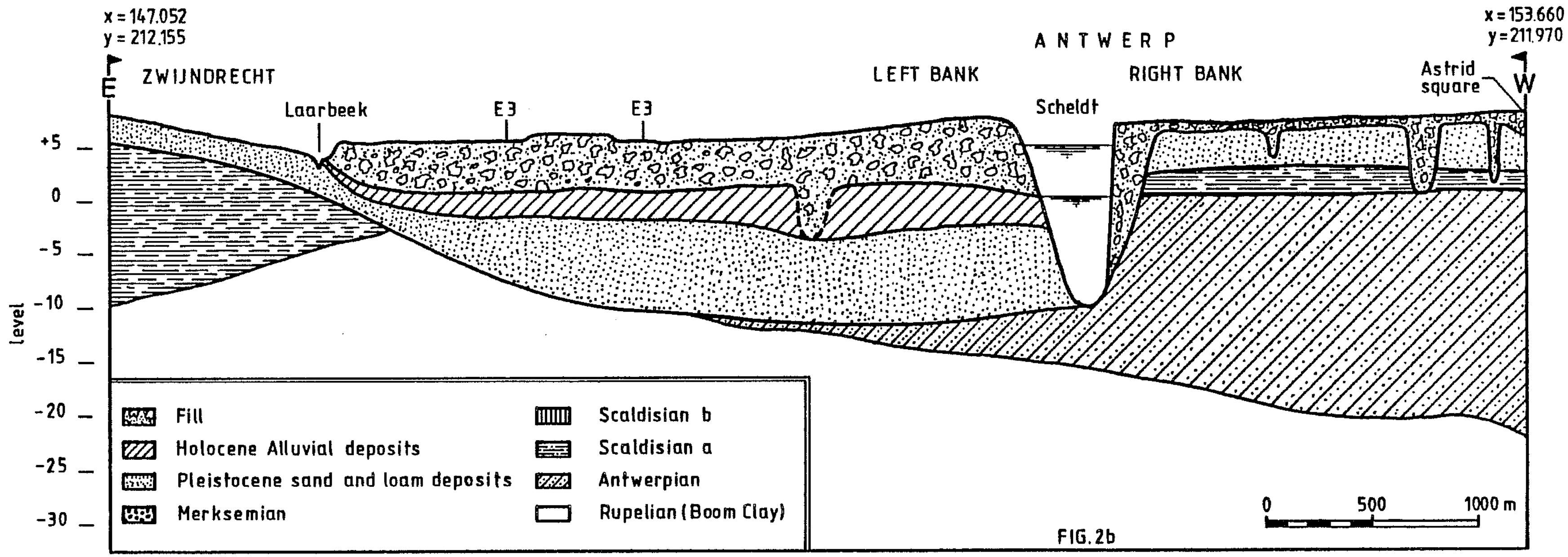
NW
Leopold dock
Harbour dock IV
Harbour dock V
Royers lock
Kattendijk lock
Kattendijk dock
Willem dock
Italië lei
Astrid square
x = 153.660
y = 211.970
SE
level
+5
0
-5
-10
-15
-20
-25
-30

FIG. 2a


x = 147.052
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E
ZWIJNDRECHT
Laarbeek
E3
E3
ANTWERP
LEFT BANK
Scheldt
RIGHT BANK
Astrid square
x = 153.660
y = 211.970
W
level
+5
0
-5
-10
-15
-20
-25
-30
Fill
Holocene Alluvial deposits
Pleistocene sand and loam deposits
Merksemian
Scaldisian b
Scaldisian a
Antwerpian
Rupelian (Boom Clay)
0
500
1000 m

FIG. 2b

The engineer may then take the necessary precautions to prevent mishaps during the construction. Some examples will illustrate this.

Shallow foundation of large constructions such as petroleum tanks

Shallow foundation of large constructions requires a good knowledge of the composition of the top layers. The value of the settlements, especially the differential settlements and the necessity of an eventual soil improvement, depend on it. It is very important to know to which degree the thickness and the composition of the fill and disturbed soils and of soft layers may change.

Such sudden changes occur especially in filled ditches, creeks and whirl pools. They always are a source of additional problems for the engineer.

As an example one can refer to the accident with a petroleum tank of an Antwerp oil refinery.

On the site originally planned for the tank a soil investigation was carried out. Just before the construction it was decided to build it on a nearby spot without additional soil investigation to be performed. During the first replenishment of the tank large differential settlements occured and heavy damage was inflicted. An additional soil investigation has revealed the presence of important layers of very compressible alluvial deposits under a small part of the tank. These deposits were not encountered at the first site and the available data did not allow to predict their presence at the second site.

The zones where alluvial deposits occur in old creeks or whirl pools are indicated on the engineering geological maps. They allow the engineer to predict whether a shallow foundation can be made with or without soil improvement such as accelerated consolidation, stone columns or soil replacement.

Considerable variations in composition and thickness of fill and disturbed soils and of the alluvial top layers also occur in areas where peat has been extracted. From the middle ages till the beginning of this century peat has been excavated as a fuel in many places of the polders. The excavation pits thus created have been filled with materials of different origin, often material covering peat in nearby excavations. A recent investigation in the inner harbour area of Zeebrugge (M. Depret, 1981) has revealed that often peat walls, that were left behind (Fig. 3), are causing considerable changes in peat thickness. A surcharge on these cannot be tolerated by the construction, a pile foundation or soil improvement is required. Even when the remaining peat is covered by a considerable thickness of fill, important differential settlements may still occur.

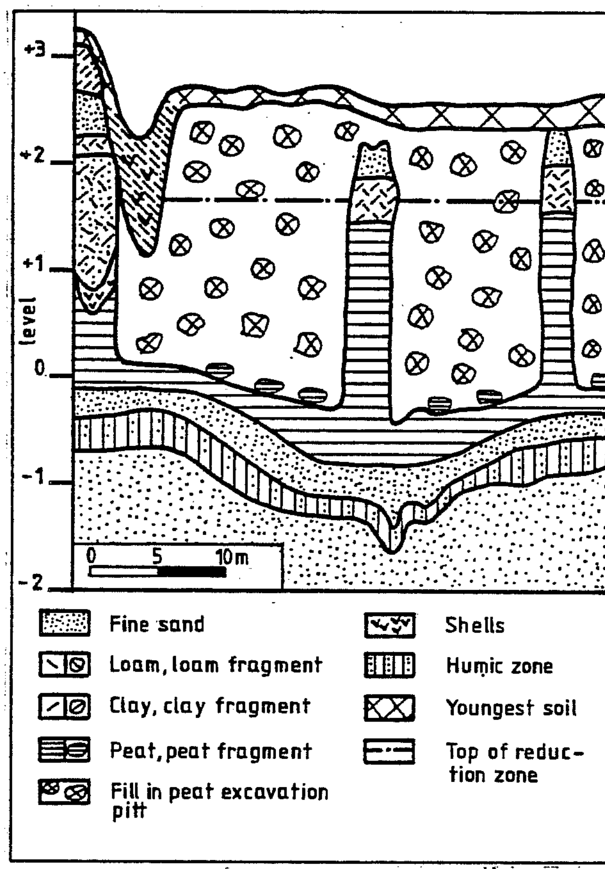


Fig. 3 - Old peat excavation pitt at Zeebrugge

In Antwerp peat has been extracted in the Melsele Polder (Left Bank) and the Hoboken Polder (Right Bank). These zones are indicated on the engineering geological maps (Fig. 4).

The laying-out of slopes in case of excavation including slope protection

The construction of slopes meets with many difficulties in areas, where thick layers of soft soil occur, more specifically in filled ditches, creeks or whirl pools. In these cases special techniques have to be applied. Gentle slopes may sometimes provide an answer but very often they are uneconomical and require a large surface.

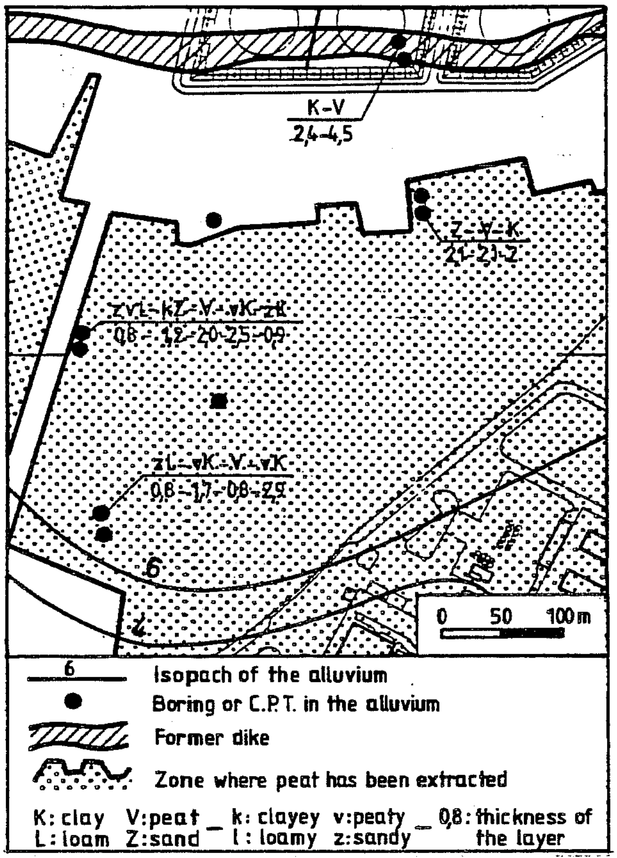


Fig. 4 - Map giving the thickness of the alluvial layers (Engineering geological map 15.3.3. Antwerpen-Zwijndrecht)

In the Antwerp area a 7 m thick mud layer was located at the site of a quay wall which had to be installed in a shallow foundation. The walls of the building pit had a slope of 5 %. By a combined system of Kjellman drains and electro osmosis slopes were reduced to a normal (E. De Beer and M. Wallays, 1964).

Foundation on piles

When a foundation on piles is considered one has to reckon with

- the eventual presence of hard inclusions which may hinder the penetration of the pile;
- negative friction;
- horizontal loads.

The information contained in the engineering geological maps allow to predict in many cases these phenomena and to adapt the geotechnical investigation in such a way that their influence may be evaluated.

This can be illustrated by a recent investigation for the planned Scheldt Surge Barrier at Oosterweel. A quay wall has to be constructed on a filled whirl pool. A cone penetration test in the whirl pool deposit shows a diagram completely different from the one performed outside (Fig. 5). The best method for the foundation of the quay wall seems to replace the mud layer in the whirl pool by sand.

The laying-out of a crane way along a storage yard for ores, coal or other bulk goods and on soft soil also causes problems. Pile foundation is required. A considerable horizontal load and negative friction must be expected. Hence a thorough site investigation will be necessary. Although the location of these yards usually is decided on nautical and economical grounds, it may be useful to take the composition of the soil into consideration. In that case the available surface may be put to a better use and construction costs may be reduced (E. De Beer and M. Wallays, 1968).

Earth retaining structures

Hard inclusions may considerably hinder the construction of sheet pillings and slurry walls. Hard inclusions occur in different forms. Their presence is indicated on the engineering geological maps. Filled ditches may contain large amounts of rubble from nearby demolished buildings. During the construction of the subway tunnel at the Rooseveltplaats in Antwerp such a ditch was met. The excavation could only be continued after the material had been injected.

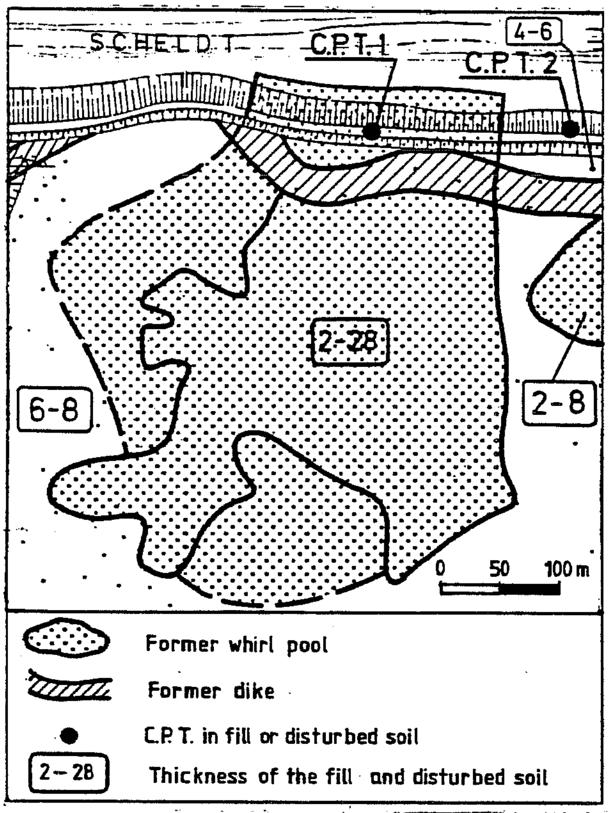
Tertiary layers often comprise petrified horizons. They sometimes form an insurmontable barrier for the driving of sheet piles. In the Rupelian clay complex (Boom Clay) layers of septaria occur. These are hard loaflike concretions composed of calcite, kaolinite, illite and quartz.

For the design of earth retaining structures the presence of soft soil layers has to be taken into account since they influence the distribution of forces in the structure.

The diagrams of two cone penetration tests, one in a filled ditch and one outside of it (Fig. 6), clearly show that the differences in soil composition will influence the design of earth retaining structures.

Groundwater lowering

Groundwater lowering may often cause damage, especially when soft clay layers



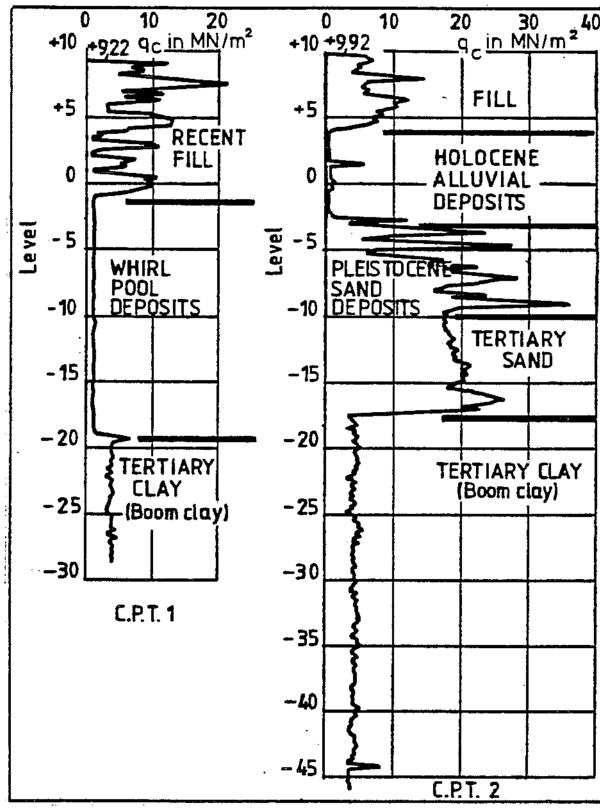
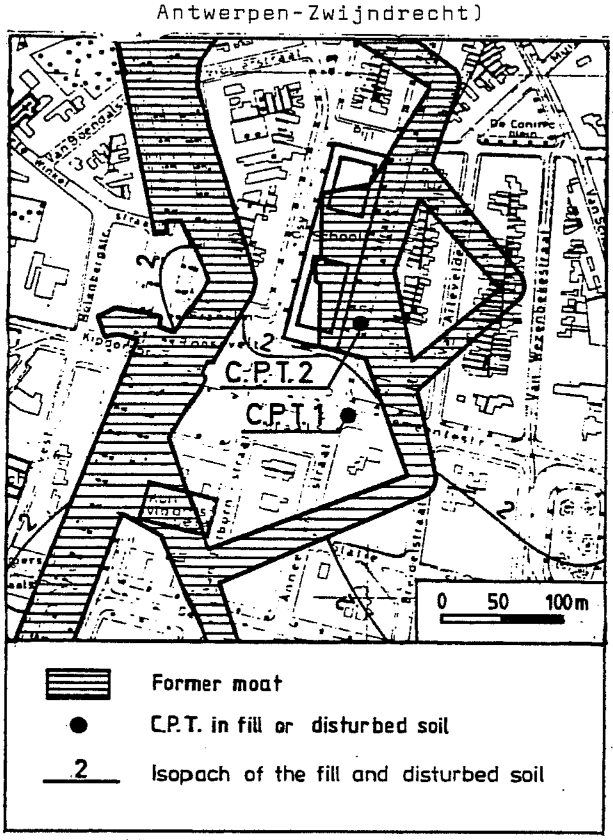


Fig. 5 - Map giving the thickness of the fill (Engineering geological map 15.3.3. Antwerpen-Zwijndrecht)



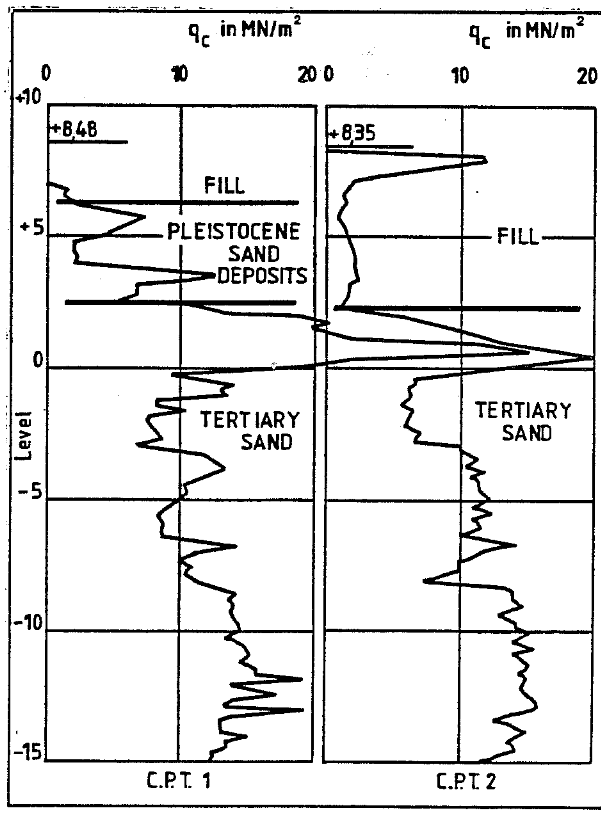


Fig. 6 - Map giving the thickness of the fill and disturbed soils (Engineering geological map 15.3.6. Antwerpen-Centrum)

and peat occur within the zone of influence. The damage to buildings in Zeebrugge during the works for the construction of the sea-lock can be cited as an example.

As much as possible the composition and the thickness of the soft alluvial layer is given on the engineering geological maps (Fig. 4). In the explanatory notice one finds a summary of the data available on permeability. These data have been obtained from pumping tests and laboratory measurements.

The important clay layers being mentioned on the maps, the engineer may have an idea where and how deep a watertight screen whill have to be put to minimize the influence of the pumpings.

The information contained in the atlas may help to plan the hydrological investigations prior to the pumping. An important aspect of this information is the fact that the user may be able to decide whether the site investigation should be restricted to the construction area or should be extendend beyond it.

CONCLUSIONS

Engineering geological atlases provide the information needed to draw a reliable geological section at a single point or along a line. The geotechnical properties, as contained in the explanatory notice, and the different maps may assist the engineer in the choice of infrastructure works, in the making of a project and in planning a detailed site investigation (geological, hydrogeological, geotechnical).

In the Antwerp area a large amount of information is given which allows to predict the problems in the harbour area. This information is related to the anomalies, in thickness and in composition, such as fills, peat layers, hard inclusions and hardened layers. Although this information is more qualitative than quantitative, the attention is drawn to the presence of the anomalies. Hence the engineer will have to take them into account when planning his site investigation.

The engineering geological maps furthermore offer the possibility to test the results of a site investigation against a broader background. Discrepancies in the results may incite the engineer to perform an additional investigation.

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