Problems caused by the presence of hard concretions and lithified beds in the subsoil on the realisation of geotechnical investigations and infrastructure projects

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ABSTRACT

The presence of hard concretions in the subsoil can cause serious problems during the realisation of infrastructure projects. This paper gives an overview of geological features and general characteristics of typical hard soil concretions in Flanders, and their effects on geotechnical investigations and realisation of infrastructure projects, illustrated by 2 case studies.

RÉSUMÉ

La présence de concrétions dures dans le sol peut causer de graves problèmes lors de l'exécution de projets d'infrastructure. Cet article donne un aperçu général des caractéristiques géologiques et mécaniques de quelques concrétions typiques pour le sous-sol Flamand, et leur effet sur les investigations géotechniques et la réalisation de projets d'infrastructure, illustré par 2 cas pratiques.

Keywords: hard concretions, geology, soil investigation, case histories

1 INTRODUCTION

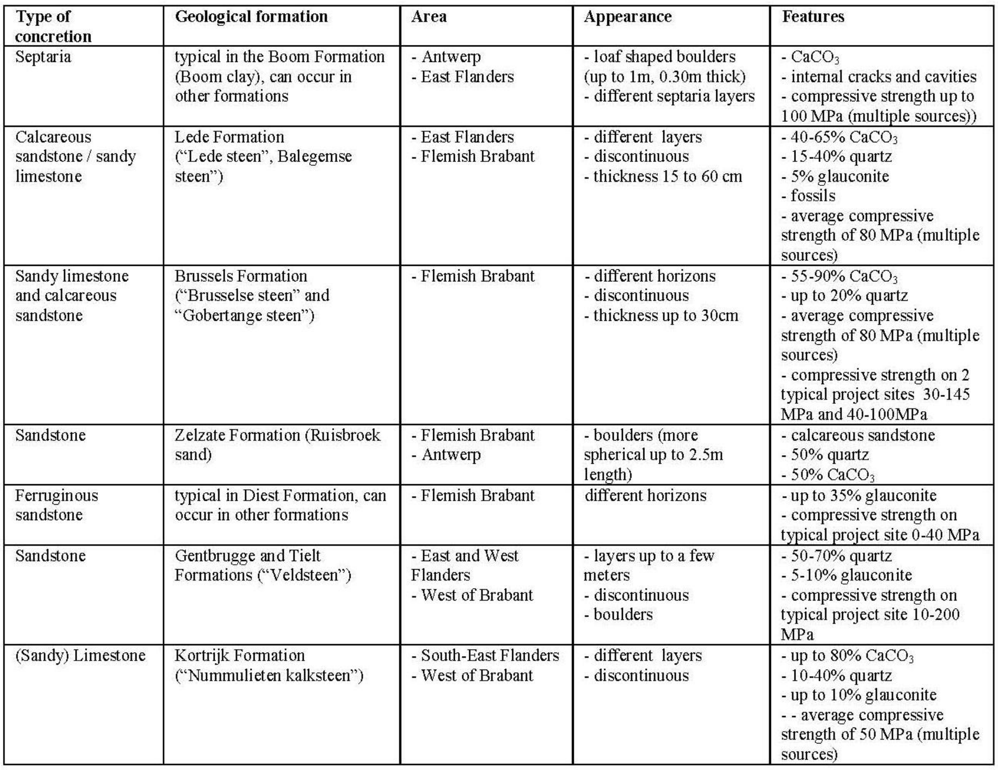
In Flanders outcrops of Primary bedrock are rare, and bedrock is covered by Tertiary clay, sand and gravel sediments with thicknesses up to hundreds of meters. The upper Quaternary formations have been influenced by the glacial periods, resulting in the formation of marine, coastal, river, lake or wind deposits of sand, clay, peat and loam (silt). A typical soil profile in the Antwerp harbour area eg. consists of soft clay and peat, loose Quaternary sands, very dense Tertiary sands and stiff clay.

Within Tertiary sediments hard concretions can occur as continuous/discontinuous layers or as boulders. Their presence in Flemish soils is certainly not predominant, but can have a major impact on geotechnical design.

Some of these hard concretions (sandstone, limestone…) have been quarried over the past centuries for the construction of historical buildings (cathedrals, belfries…). The demand for authentic natural building stones is now growing rapidly for renovation projects.

Table 1 gives a summary of some typical concretions in Tertiary layers in Flanders and their features. The features and compressive strength of the described concretions or rocks can be quite heterogeneous. In many cases only the better quality, meaning the rocks used as building stones, are well described and investigated. Poor quality rocks have not been studied quite extensively.

This table gives a broad overview of these concretions, but is certainly not complete.



Type of concretion	**Geological formation**	**Area**	**Appearance**	**Features**
Septaria	typical in the Boom Formation (Boom clay), can occur in other formations	- Antwerp - East Flanders	- loaf shaped boulders (up to 1m, 0.30m thick) - different septaria layers	- $CaCO_3$ - internal cracks and cavities - compressive strength up to 100 MPa (multiple sources))
Calcareous sandstone / sandy limestone	Lede Formation (“Lede steen”, Balegemse steen”)	- East Flanders - Flemish Brabant	- different layers - discontinuous - thickness 15 to 60 cm	- 40-65% $CaCO_3$ - 15-40% quartz - 5% glauconite - fossils - average compressive strength of 80 MPa (multiple sources)
Sandy limestone and calcareous sandstone	Brussels Formation (“Brusselse steen” and “Gobertange steen”)	- Flemish Brabant	- different horizons - discontinuous - thickness up to 30cm	- 55-90% $CaCO_3$ - up to 20% quartz - average compressive strength of 80 MPa (multiple sources) - compressive strength on 2 typical project sites 30-145 MPa and 40-100MPa
Sandstone	Zelzate Formation (Ruisbroek sand)	- Flemish Brabant - Antwerp	- boulders (more spherical up to 2.5m length)	- calcareous sandstone - 50% quartz - 50% $CaCO_3$
Ferruginous sandstone	typical in Diest Formation, can occur in other formations	- Flemish Brabant	different horizons	- up to 35% glauconite - compressive strength on typical project site 0-40 MPa
Sandstone	Gentbrugge and Tielt Formations (“Veldsteen”)	- East and West Flanders - West of Brabant	- layers up to a few meters - discontinuous - boulders	- 50-70% quartz - 5-10% glauconite - compressive strength on typical project site 10-200 MPa
(Sandy) Limestone	Kortrijk Formation (“Nummulieten kalksteen”)	- South-East Flanders - West of Brabant	- different layers - discontinuous	- up to 80% $CaCO_3$ - 10-40% quartz - up to 10% glauconite - - average compressive strength of 50 MPa (multiple sources)

2. HARD CONCRETIONS A CURSE ?

The presence of hard concretions in the subsoil can cause problems for the realisation of infrastructure projects, because the contractor is faced with:

- Lower production rates than expected
- Inadequate execution techniques that can only be used if adapted

This will definitely lead to discussions where following questions need to be addressed:

- Could the presence, number and hardness of hard concretions be anticipated by the contractor, based on available information
- Were the execution methods proposed by the contractor adapted to the known soil conditions
- Could lower production rates or need for adapted execution techniques be anticipated
- Who is financially responsible for extra costs

The presence of hard concretions can have impact on

- building excavations (groundworks and groundwater lowering)
- deep foundation techniques (piles)
- retraining walls (all types) [1]
- tunnel boring

Due to a limited geotechnical investigation hard concretions can be a curse for a project..

A geotechnical investigation program with a special focus on hard concretions can limit problems and even show opportunities for quarrying building stones.

3. A CHALLENGE FOR SOIL INVESTIGATION

In Flanders nearly all site investigations make use of CPT, with depths ranging between 20m and 40m.

The presence of hard stones is marked by an abrupt increase of cone resistance in the CPT diagram, sometimes up to refusal of the equipment.

Three situations can occur:

- the stone is pushed away, or CPT rods are deflected at the contact point with the stone (fig 1 a and b): the CPT profile doesn't give evidence of the presence of these stones. In the latter case the CPT might deviate significantly from the vertical
- the maximum thrust of the CPT is reached, and further penetration is not possible without use of special techniques (fig 1 c)
- the CPT rods do not touch the stone at all, and there isn't any evidence of the presence of stones in the CPT-profile.

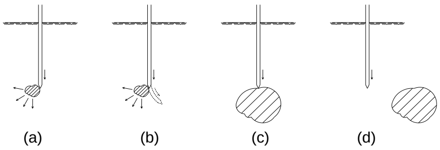


Fig 1 Hard concretions vs CPT

However a laboratory research at the Catholic University of Leuven demonstrated that penetration of sandstone with a thickness up to 20cm might be possible with CPT cones [2].

Anyhow when refusal is met one can recall to different techniques to resume CPT. Depending whether or not intact samples of the stones are needed, destructive or non destructive methods can be used [3].

Destructive methods:

a) pneumatic hammering

In between thrust column and CPT rods a framework with a pneumatic hammer is placed allowing a pulsating downward movement of the rods. By the pulsating force and a limited static thrust the stone can be crushed. The use of this technique is limited to rather thin stone layers.

b) Overburden drilling with eccentric method (ODEX)

At refusal of the CPT, all rods are removed and a drilling rig with ODEX-system takes over. The boring tubes are lowered into the ground by percussion, combined with an eccentric movement of the tophammer. After perforation of the hard concretions the casings and tophammer are withdrawn and CPT is resumed. Extra casings are needed to avoid buckling of the CPT rods.

Non destructive methods

a) After interruption of CPT a core drilling is performed to sample the hard concretions; alternately CPT and core drilling take over about every half a meter.

b) Geophysical methods could be used to detect hard concretions as they are not limited to point locations; There is however little positive experience with this method.

2 CASE HISTORIES

Sandstone concretions in Ruisbroek sands

During construction of the tunnel under the Rupel river and the canal Brussels-Schelde in Boom (1970-1980) the unexpected presence of sandstone boulders caused serious problems.

The tunnel was finished with a delay of 6 years at an extra cost of millions of euros. The in situ test program consisted of 32 CPT and 7 borings. Only 3 CPT had to be stopped prematurely, at a level which later proved to correspond with the presence of the sandstones. The geotechnical report did not make any comment on this fact, as the old geological maps did not draw attention to the hard concretions (only mentioned in 2 borehole logs).

Observations on the project site showed that the concretions consisted of calcareous sandstone with dimensions ranging from 1 to 2.5m. The concretions had a area coverage of about 7%. This means that CPT, borings or any other method representative for discrete test locations had only a probability of 1/14 to detect the concretions (which corresponds with the 3/39 effectiveness of executed CPT and borings on site).

During dredging activities for the diversion of the canal Brussels-Schelde the presence of a “hard layer” was met, which didn’t allow the further use of conventional dredging techniques. CPT and borings revealed the presence of the calcareous sandstones mentioned above. Again the presence of the hard concretion layer was not anticipated.

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Sandstone concretions in Brussels sands

For the Diabolo project in Zaventem TUC RAIL, aware of the impact of sandstone layers in Brussels sands, had the intention to compile a complete soil investigation dossier. Main objective was to have a good estimate of the number, extent and hardness of sandstone layers within the excavation volume. Moreover the efficiency of executing strutted excavation trenches was monitored in a test pit.

From the test pit (3m x 1,5m and 13m deep) detailed geological profiles ware drawn (see fig2). Excavation rates (m³/manhour) were also monitored to have an idea of the efficiency of executing strutted excavation trenches within part of the tunnelling project, and the amount of stones within each excavation phase.

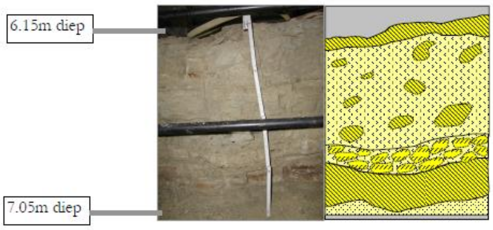

Fig 2 – geotechnical profile of test pit section

On about 20 sandstone samples uniaxial compresssion tests, Brazilian tests and abrasive tests were performed to estimate the impact on tunnelling rates and wear of equipment. Tested samples had a heterogeneous structure with laminations, cavities and porous zones. Compressive strength varied between 30 and 145 MPa, tensile strength between 3 and 9 MPa.

From mineralogy tests heterogeneity was confirmed and stones could be classified as either calcareous sandstone or sandy limestone.

The specifications on the tunnelling project included general information on geology and complete data on the test pit (geological profiles and descriptions, test results, efficiency of executed strutted excavations). Moreover TUC RAIL organised for all interested tenderers a visit to the site, where samples of different excavated sandstones were exhibited.

Thanks to the extensive investigation and the well documented specifications the tunnelling project could be realised without problems related to the presence of sandstones.

CONCLUSION

The presence of hard concretions in subsoil is a challenge to geotechnical engineering. Common in situ testing methods (CPT, borings…) are related to discrete location points and discontinuous stone layers may not be detected. Geophysical methods that can investigate larger areas do not give reliable results or are not workable on a routine basis.

Therefore a well detailed desk study for any infrastructure project is essential; geological and geotechnical maps give evidence of possible hard concretion layers.

The case of the tunnelling project in Zaventem shows that a well documented dossier and geotechnical/geological investigation that is shared with tenderers can reduce significantly uncertainties with respect to the presence of hard concretion and their features.

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