KOREAN SOCIETY OF GEOTECHNICAL ENGINEERS

SEOUL 85/11/16 3.00 p.m.

SEMINAR ON

UNDERGROUND WALLS AND PROBLEMS RELATED TO DEEP EXCAVATIONS

1. FUNCTIONS OF UNDERGROUND WALLS

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. Retaining Structure
. Cut-off
. Bearing Structure
. Permanent Structure

1.2. Table of Comparison

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Applied loads
Toe, Types of toe
Internal Loads. Reinforced concrete

2.2. Hydraulical Stability

2.3. Bearing Criteria

2.4. General Stability

3. SOME PROBLEMS RELATED TO DEEP EXCAVATIONS

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. Measurements
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. Dams effect
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3. SOME PROBLEMS RELATED TO DEEP EXCAVATIONS

3.1. Displacements

3.1.1. Forecast: Without any doubts the forecast of the displacements generated by the deep excavations is one of the most difficult tasks an engineer has to cope with.

The displacements depend upon numerous parameters. Among them are =

- mechanical characteristics of the retaining structure
- history of the soil
- parameters of the soil and their evolution in time.
- evolution of hydrogeology
- procedure
- actual process on site
- time factor
- etc.

The theories of Elasticity and Strength of materials so as experimentation give to the engineers the means to forecast the deflection of beams, supports, etc..., according to some simplifications, with a good accuracy.

It is not the case for underground structures which are four dimensions problems with numerous mechanical parameters and time factor.

Computer outputs such as obtained with plastic programs do not give reliable informations. Elastoplastic programs give better accuracy but the result depend upon data which, even though detailed one, are too much schematic ones.

The three dimensions finite elements models bring a considerable improvement of the forecast. However, it shall be also considered it is generally costfull.

The modelization of the soil cannot take into account the complexity of the nature. Generally the finite elements models are not worth their cost.

Therefore, the forecast of the displacements is generally based on individual experiences of specialized engineers. And the best way to get this experience is to experiment and to monitor on site.

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For some reasons, easy to understand and not only related to soil mechanics and cost, the displacements were poorly monitored so far. The designer has a small amount of publication to consult.

Specialized companies understood, however, that site instrumentation is a good way to show off their know-how so as the validity of the modern techniques. This instrumentation opens the way to cost saving thru the design.

3.1.2. Measurements, Site Instrumentation

The site engineer may take profit of a wide range of methods.

* Simple topographical levelling and triangulation enable him to get indications of millimeters.
* More sophisticated topographical instruments provide the engineer with an accuracy ranging one or two length of a millimeter. It has been extensively used for several years in sensible areas of subway construction job lots.
  These techniques need expertise and, of course, good topographical basis.

* Straingauges in D. Wall are much helpful in corelation with other measurements.

* The accuracy of inclinometers has been quite improved in the last few years with small program and highly skilled operators. it enables the engineer to get periodical result of displacement versus time.

* A tensionning procedure has been invented by SOLETANCHE in order to monitor the actual tension in the tiebacks. During this procedure, the displacements can be measured precisely.

* Tassometers piezometers, tiebacks dynamometers... give the means to get a full set of informations.

It is wise and good engineering practice to take profit of the instrumentation in order to monitor the construction and its surrounding, to improve the site procedures thru a better quality control, and to improve further designs.

The cost of site instrumentation is usually a small percentage of the foundation budget, even with sophisticated devices.

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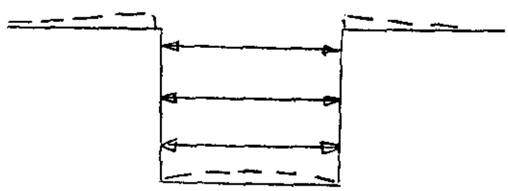
3.1.3. Results

Let it be simple and consider the problem of a dry excavation. The release of stress together with the Poisson's phenomenon will give such a deformations.

The heaving of the bottom of the excavation is not generally noticed by the earth moving contractor even though it actually exist.

This heaving has not to be considered as the swelling of clay with water. It may last 5 to 10 years and has to be taken into consideration in the design.

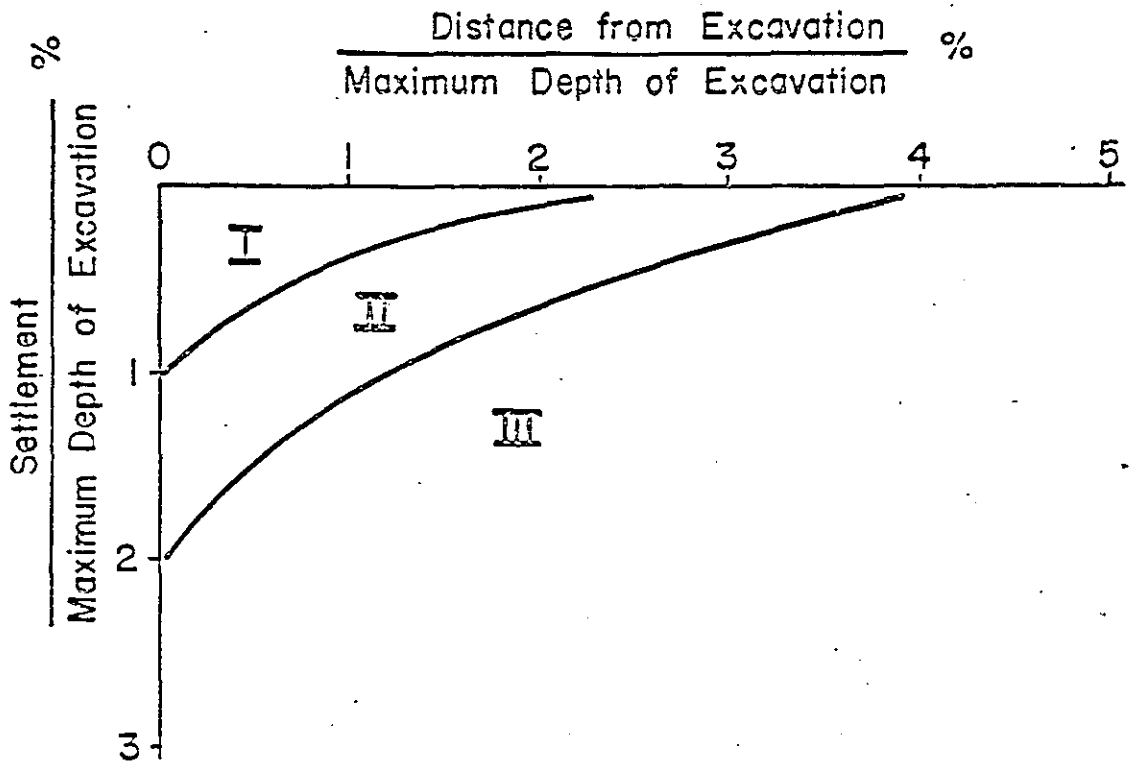
As far as a retaining structure can be prestressed up to a stress equivalent to the one of soil before excavation it can be observed such deformations.



This is the symetrical phenomenon of the settlement under an area loaded with a uniform pressure.

In other words, if one wants to avoid any lateral displacement of a retaining wall one should prestress up to the at rest pressure. It is not always realistic in overconsolidated soils.
(Ko 2.5 in London, for instance).

PECK (1969) gave a global chart of settlement in the surroundings of an excavation with braces.



Zone I – Sand and Soft to Hard Clay – Average Workmanship.

Zone II – Very Soft Clay, Soft Clay – Limited Depth of Clay Below Cut or N < 6.

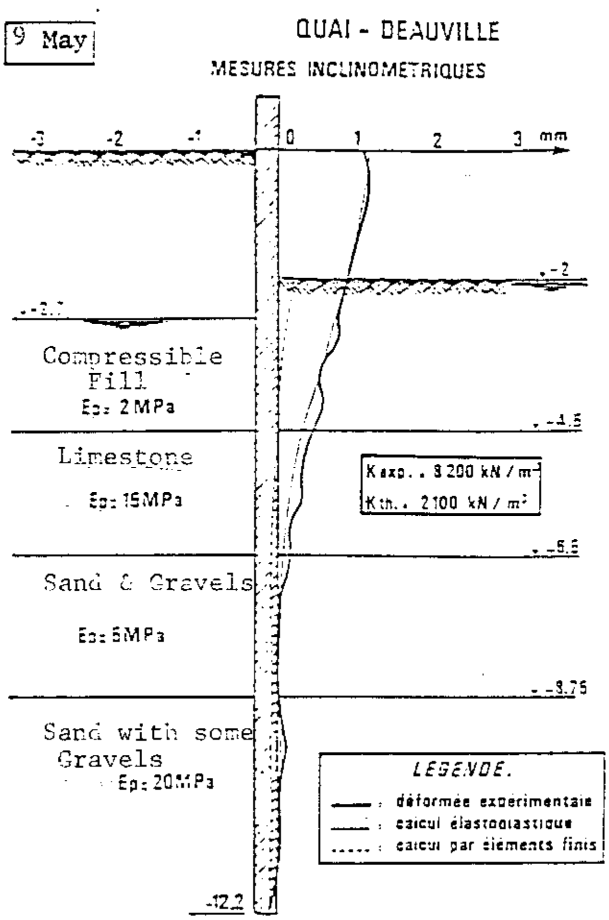
Zone III – Very Soft Clay to a Significant Depth Below Bottom of Cut.

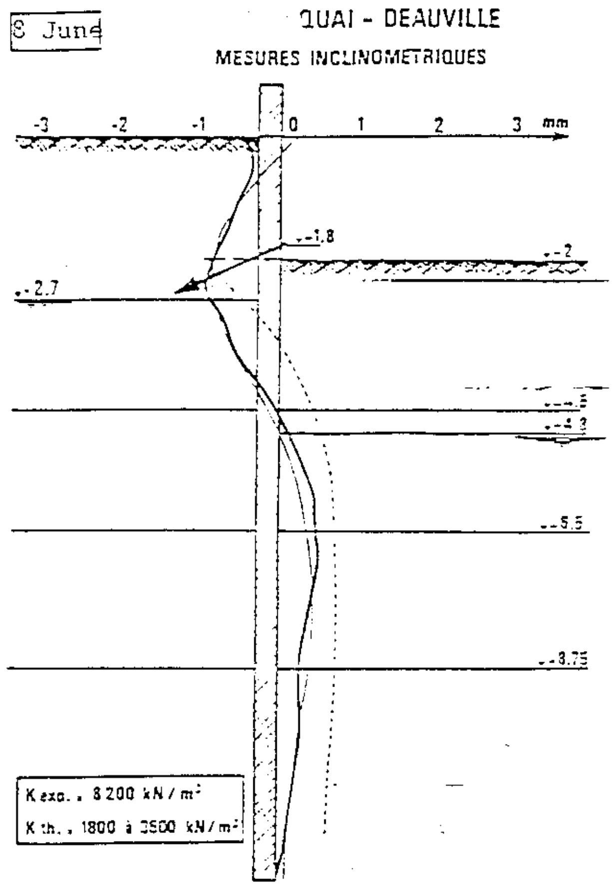
Settlements Behind Braced Cuts — Peck (1969)

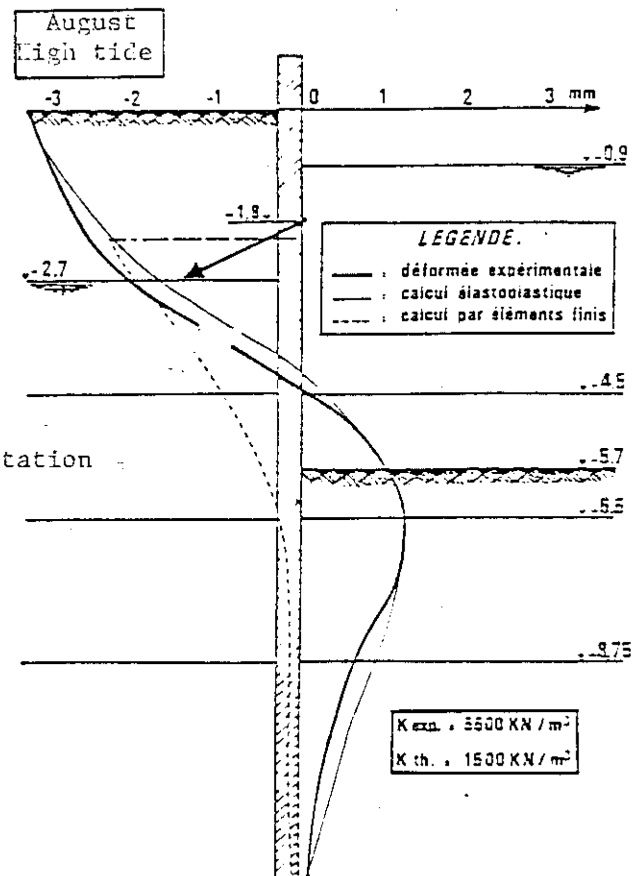
These range of displacement results are not allowed nowadays from an enviromental standpoint.

Cast-in-situ diaphragm wall on ther related techniques with tiebacks and/or preloaded struts enable the constructor to avoid decinetical. displacements such as those which can be expected with modern deep excavation.

The following examples are typical actual result of well instrumented sites.







Legend

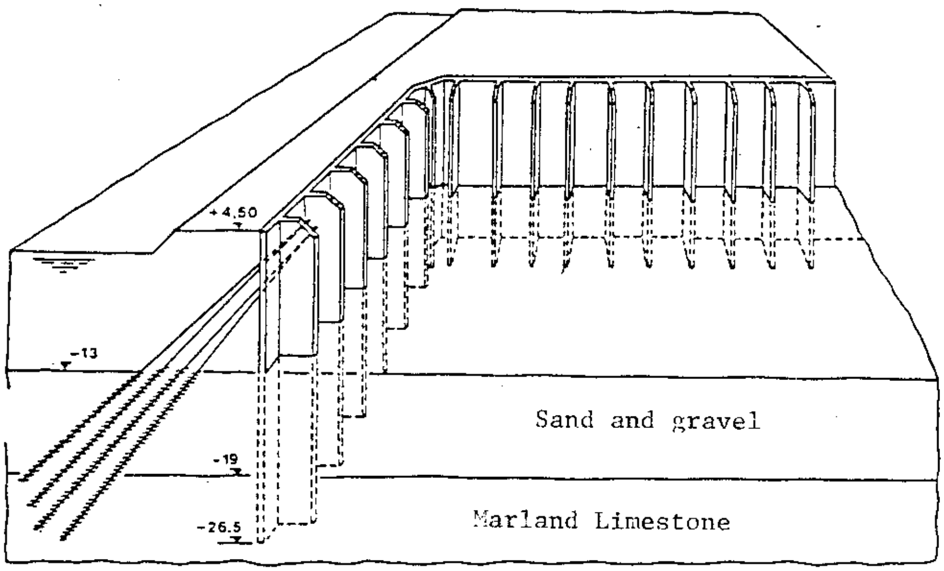
—— Actual results

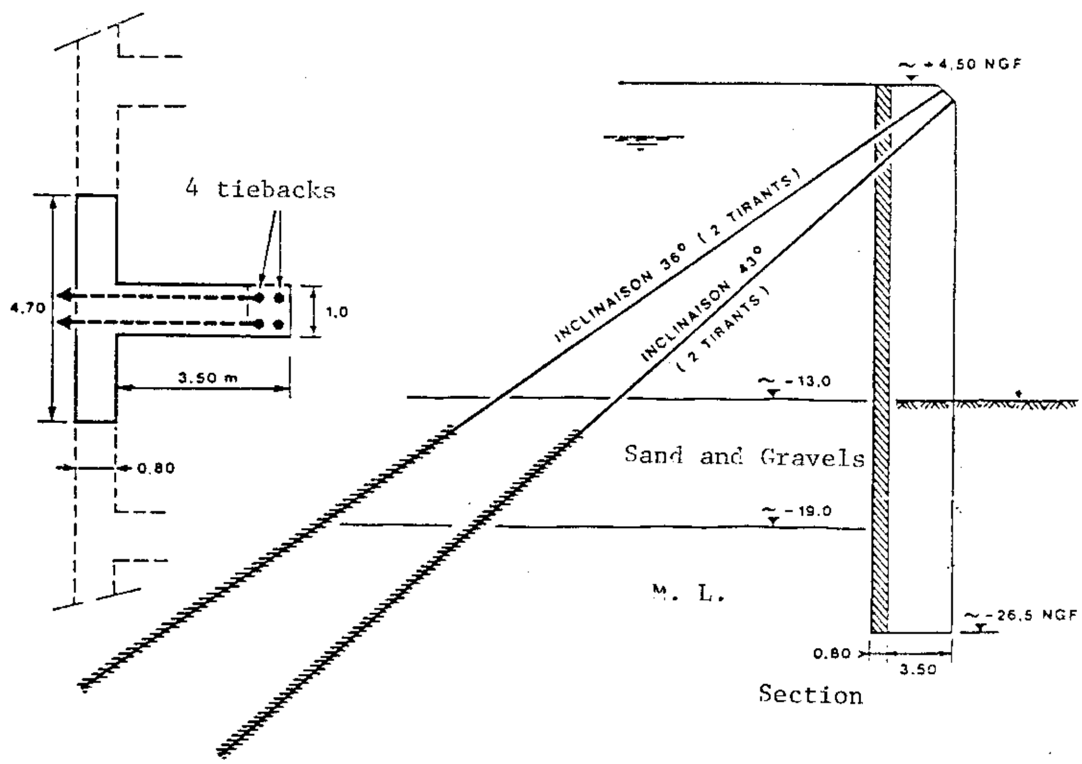
—— Elastoplastic Computation

----- Limite Elements

Courtesy SOLETANCHE

BLAYAIS NUCLEAR POWER PLANT





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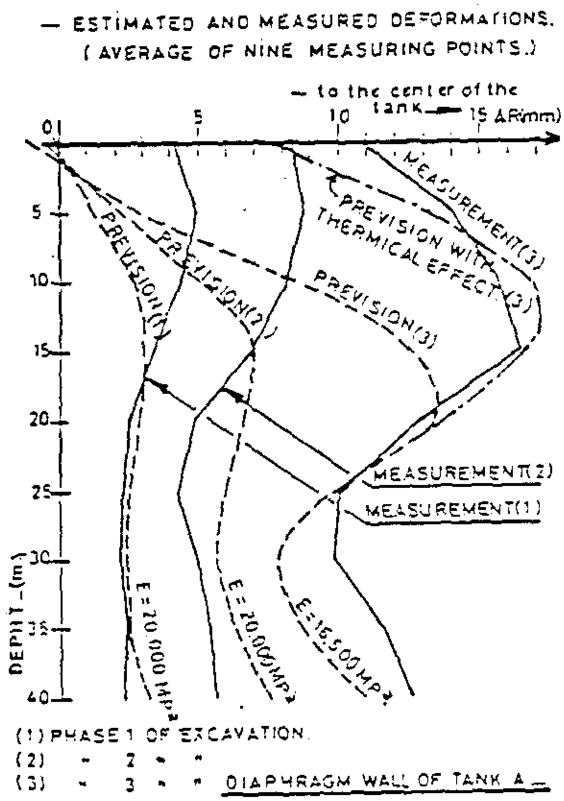
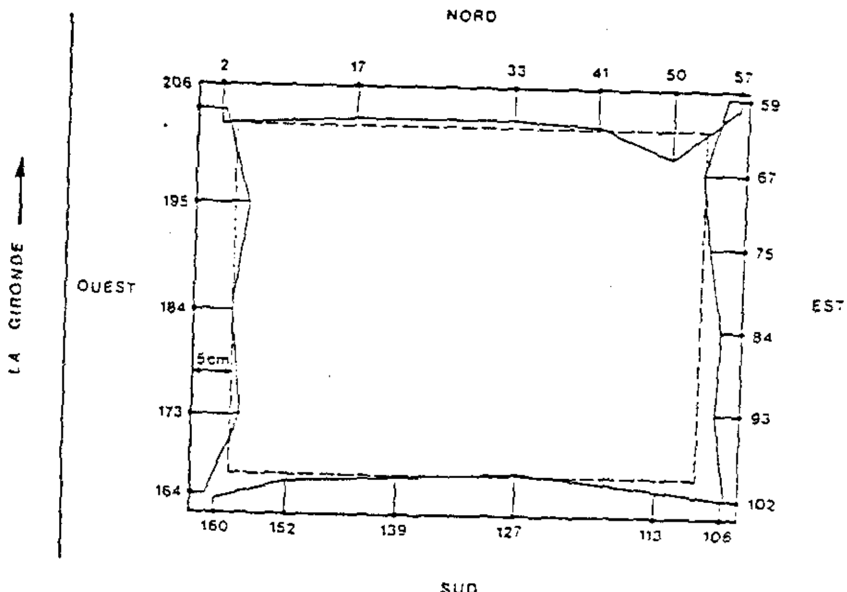


Zeebrugge LNG

Radius 43 m

Depth 20 m

Thickness 1.20 m



D. Wall Horizontal Displacements

3.2. Bottom Heaving

As already mentioned, the heaving of the bottom during the excavation stage is simply a matter of soil levelling.

However, in some swelling clays the bottom will heave continuously during several years. Then, the designer may utilize three solutions:

- rigid mats able to withstanding the pressure, connected to the underground structure, and bearing the load of the building.
- void between the basement and the bottom of the excavation in order to allow a fee heaving of the soil (Paris National Assembly)
- Flexible pavement (e.g. in tunnels) to be adapted as per need.

3.3. Underground water

3.3.1. Dam effect

A tunnel, a subway, an extensive parking lot create an underground obstacle against the natural underground water flow.

The designer shall take into consideration the right piezometric level into his computation.

He shall not only consider one level usually given by the most simplest soil survey but he was to consider:

a. level versus time (rainy season, modification of environmental conditions, tidal effects...)

b. Level versus depth (confined aquifer...)

c. Modification of the level generated by his own design (temporary drawdam, dam effect...)

Some portion of the Brussels Subway were performed in areas with plat layers.

The dam effect endangered the downstream part of the tunnel by depressing the water table in the peat layer with severe consequences for the hight surrounding buildings.

In order to limit the dam effect a constant upstream-downstream communication was made thru water pipes crossing the tunnel.

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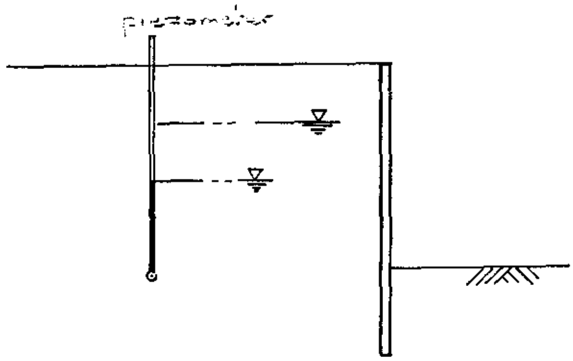
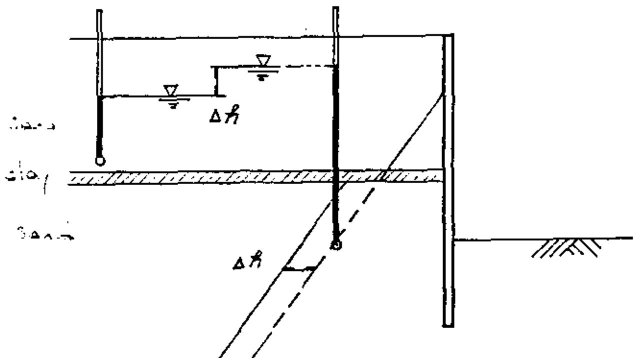
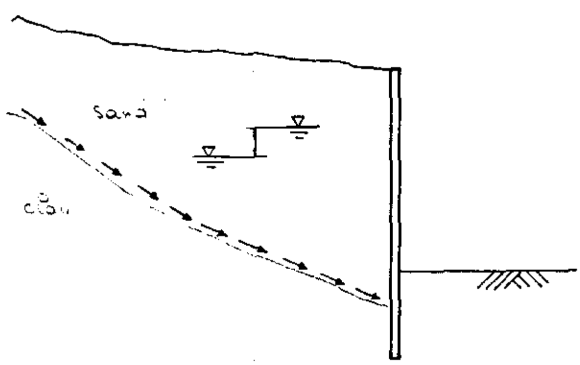
LEVEL OF WATER TABLE TO BE CONSIDERED



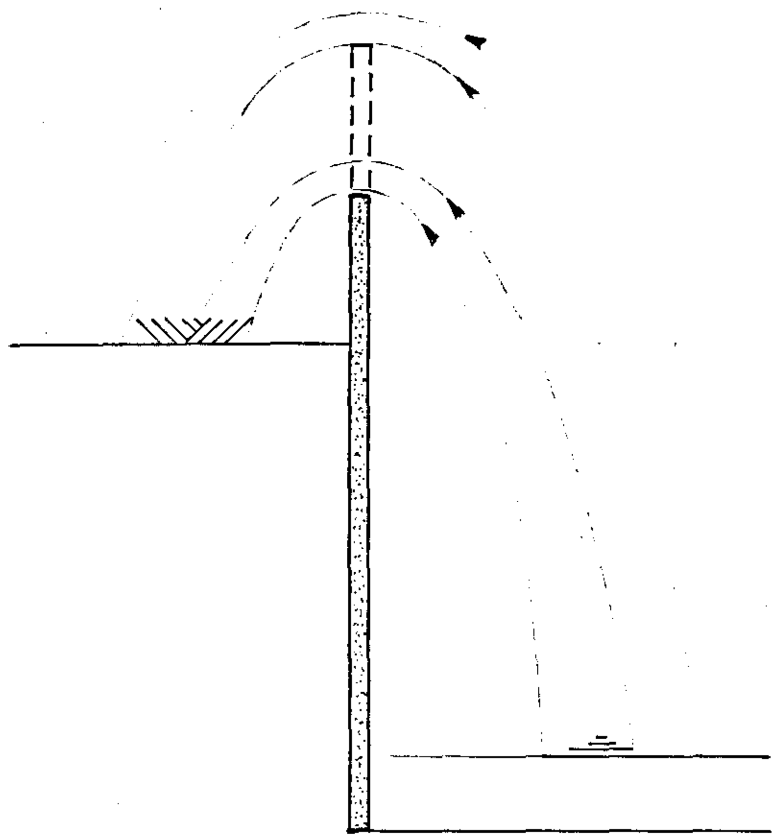
a. Records of piezometric levels over a sufficient period giving basis for comparison with other records in the area.



b. Confined aquifer



c. dam effect.



3.3.2. Piping-Boiling

The stability of the bottom of an excavation has to be deeply considered under two aspects.

- mechanical stability
- hydraulical stability.

The concentration of the streamlines, (hence, of the potential lines) generates a seepage force under the bottom of the excavation.

When the unitary seepage force becomes more important than the buoyant specific weight of the soil, then starts a regressive dangerous erosion (Piping boilings).

Moreover, the seepage force reduces the actual passive pressure in the toe of the retaining wall.

The designer has two main ways to avoid such hazard:

- Deepening of the toe in order to increase the length of the streamlines. This deepening may not be needed from a mechanical point of view.
- Deviation of the streamlines towards wells.

Actually, the execution of well have two other major interests,:

- Enable the site the perform a dry excavation thru drainage
- Avoid the possible hazard of boiling due to an impervious layer.

A very thin expected layer beneath the bottom of the excavation is quite dangerous for its stability.

3.3.3. Rate of Outflow

Well known theories give the means to compute expected outflow of an excavation with mathematical model's ratio either at the temporary stage or at the permanent one.

Everyone knows the limit of these theories based on simplified hypothesis, but one must never forget that the final result depends upon the permeability parameters.

The only valid model is a large scale pumping test. It will enable the designer to define a permeability/transmisivity at the scale

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of the excavation.

A punctual permeability test performed with a good expertise give only... a punctual result.

The challenge of energy saving is often worth some pumping test with observation wells.

3.3.4. Relief wells - Interest

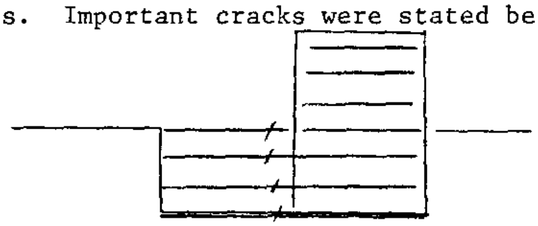
The interest of relief wells or "passive" wells (i.e. without pumping inside) for merely dewatered excavation has to be mentioned for the same reason as expressed in #3.2.2. = automatical definition of the pore pressure under the bottom of the excavation.

3.3.5 Uplift pressure

Purely structural considerations for the building itself at not always sufficient and the structural engineer has to consider deeply the problem of uplift pressure.

It is too often understood that a low permeability of underlaying soil means a low outflow, then the absence of pressure. It is of course a basic mistake. The uplift phenomenon depends only upon the water pressure distribution. An unbalanced water pressure means an uplift pressure with corresponding displacements.

We stated already in several cases that the problem is considered for the main building and not for the high surrounding parking facilities. Important cracks were stated between the two parts.



Two solution can be taken.

- Permanent pumping: then, from an energy saving standpoint, it is often worth designing a "grouted raft"
- vertical anchors.

The design of these types of remedial works is based upon simple consideration of stability. The use of diaphragm wall is always favorable, the toe of it being an anchor. Some D. Wall are submitted to upwards forces at the permanent stage.

4. CONCLUSION

Building higher, deeper, wider and heavier is the engineer in front of biger problems.

A good foundation basic design is the first step of a good construction & entrusting a reliable specialized contractor is the second one.

The cost of the environmental defects so as the defects to the designed building itself are always worth a deep study and the involvements of speciaists at each stage of the construction.

A famous geotechnical teacher of ours used to say "Mother nature is a nice lady for constructors by she does not like to be raped."

As geotechnical engineers, it is our duty to induce good soil engineering practice at various levels: educational level, design level, construction level.

The return on cost of a comprehensive survey (environmental conditions, coring, sampling laboratory test, in situ tests, hydrogeological test, geophysical one as per need....) is always excellent as repect of environmental nuisance, defects and design optimiation.