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The Netherlands

11.1 Introduction

By the urban use of soil we mean making the soil suitable as living, working and recreational area, including the infrastructure.

In this article successively will be dealt with the following aspects of the urban use of peat soils in The Netherlands:

- historical development of the settlement and reclamation of peat soils;
- characteristics of peat concerning the urban use;
- requirements that soil will have to meet for various urban forms of use;
- the means to make the peat soils that are unsuited for urban use suitable;
- future developments in peat areas.

11.2 Historical development of the settlement and reclamation of peat soils

11.2.1 Reclamation

The peat in The Netherlands, now lying below sea-level, has been able to grow during phases of regression in the rising of the sea-level after the last ice-age. In those days raised bogs developed with a natural drainage on the big rivers. The surface of the area was then situated above sea-level.

The peat is situated on the sediments of Calais (old marine clay in the west) or right on the pleistocene subsoil. Large parts of peat have been covered with clay from the Dunkirk transgression (cf. Chapter 1).

In the period 900-1300 A.D. the population in Europe grew constantly. Caused by this growth of the population all over Europe waste soils were being put into use. In The Netherlands these were for an important part peat soils.

The reclamation took place starting from the banks of rivers. The first settlement happened on the levees, consisting of clay.

The levees were overgrown with woods. The names of old towns and villages still end in 'woude' (wood) i.e. Zoeterwoude, Rijnsaterwoude, Spaarnwoude, Hazerswoude. Old names of towns and villages ending in 'berg' (mount) have a pleistocene background.

From the 11th century onwards parcels of land were handed out by the landowner for cultivation. The transfer of the land and also the land itself was called 'coop' or 'cope' (cf. Chapter 3).

The pattern of parcelling of this 'cope' cultivation is very regular. The colonists settled along the river or canal on the parcel allotted to them.

Thus a long-drawn village came into being, with behind the houses parcels running parallel, divided by ditches. Towns emerging from such a cultivation often have names ending in 'coop' or 'koop' (Boskoop, Oldeberkoop).

11.2.2 Land use

On the newly cultivated land cereals were grown for the increasing population. From this can be deduced, that the drainage must have been reasonably well.

The fertilization consisted of mud from the ditches, manure mixed with dunesand and perhaps waste from the towns. The soil was probably also improved with calcareous clay and sandy clay that was taken from underneath the peat.

Besides the oxidation of peat has always attributed to the fertilization of the crop. This may be one of the reasons for the almost completely being absent of lost villages, or *Wüstungen*, that do occur in the rest.

of Europe.

Caused by the agricultural use subsidence occurred, whereas the surface of the sea kept rising. Around the year 1200 the situation became troublesome. Count Floris III of Holland had Zeeland dammed in. His son, Count Willem I of Holland, had dykes built in the Southwestern area of Friesland, and he also provided a closed dam around Zuid-Holland. These dykes made further cultivation on a larger scale possible.

The ongoing subsidence caused a rising in the watertable and an increasing unfitness for arable land use.

Around 1500 cattle-breeding must have been the most important source of living. In the 15th and 16th century people passed into poldering and draining by means of windmills.

In the course of time much of the peat has been dug away for heating purposes and for the gaining of kitchen salt as well.

The last has taken a great shape in Zeeland and also in Friesland. Peat digging for household fuel however has been much more extensive. For this the centres of peat areas with moss peat were most suitable, whereas the clayey wood peat alongside the rivers was not dug away.

The result of this was that extensive lakes came into being.

Later on a part of these lakes was reclaimed. Most of the time the sediments of Calais (the old marine clay) are exposed (cf. Chapter 5).

In the polder Giethoorn in Northwestern Overijssel and a number of polders in Friesland this is the pleistocene sand.

11.2.3 Urban development

Towns developed alongside canals, rivers and dug waterways and on the edges of the peat area on the sandy subsoil of the coastal barriers.

At some of these places the Romans already had settlements, i.e.

Utrecht, Zwammerdam and Katwijk, all situated alongside the river Rhine.

In the Middle Ages it was the custom that for building the site was raised and the walls of the houses were founded on double rows of piles, that formed the division of the plot of land at the same time.

In Amsterdam for instance sites were raised with waste from the city moats. In the course of time soil in the towns was further raised with

clay, refuse from the town and sometimes with manure. The thickness of the raisings can eventually amount to several metres.

In the 17th century the towns reached a limit that would not extend much farther for two more centuries.

Initially there was still much open space within the city-walls.

In the 19th century the towns extended in an important way, moving farther away from the rivers and coastal barriers. These extensions of the towns are situated in areas where building was accompanied by greater problems and thus was more expensive as in the original hearts of the cities.

Important parts of Amsterdam, Rotterdam, Gouda and Gorkum have been built on peat soils.

One may wonder why exactly in such an area towns have developed.

The development of the towns is a combination of natural and economical factors.

In the early Middle Ages the soil (clay and mineralizing peat soils) could maintain, together with fishery, a growing population. Most of the interior transportation had to take place by boat. The population was therefore fixed on the water to a large extent and a merchant fleet could easily come into being. A merchant fleet needs harbour facilities, therefore towns.

Besides, the situation of the west of The Netherlands with regard to other countries is thus, that cities had to develop. Initially on the less unsuited soils and as a town grew, the extensions of the town came to be situated, from a civil-technical point of view, in more and more unsuitable areas.

The small settlements in the peat-area, originally fully agricultural, also extended. Caterers, non-residents and the tourist-industry required extension of these places as well.

11.3 Characteristics of peat soils in relation to urban use

11.3.1 Introduction

Naturally the groundwater-level of peat soils is high and they have little bearing capacity. With urban use the draining of the works to be

constructed is important.

the necessary requirements are also made for the accessibility of the site.

The peat has come into being under wet circumstances. If a peat soil is being drained, air enters and the peat-mass irreversibly starts to loose water and the water-binding power decreases. The entering air also causes oxidation of the organic matter (cf. also Chapter 9). In cultivated peat soil a further draining takes place by the roots of the plants, through which the density increases with the maturation. To avoid strong settlement, agricultural soils situated on peat therefore were not drained too deeply.

The fact, that peat soils are liable to settlement, plays an important part if measures are taken for the sake of drainage and accessibility. Most of the time these consist of a raising of the ground level or a decreasing of the level of the groundwater or both.

To be able to judge the effect of certain measures to make the soil fit for building, here follows a brief soil mechanical explanation.

11.3.2 Soil mechanical aspects

Peat has a fibroid structure with little strength and it consists for a great deal of water.

The specific gravity of peat comes close to that of water.

In Figure 1 a profile has been drawn of a layer of peat on sand.

With line σ_w the water pressure has been indicated on a certain level, and with σ_g the weight of the whole column of ground above a certain level. The difference between ground stress and water stress is grain stress.

In Figure 2 an upper-loading has been applied because of which the ground pressure increases.

In a sandy soil the grain frame takes up the extra loading. The water pressure remains hydrostatic and the increase of the grain stress is equal to the extra loading.

In peat soils the increase of loading can be taken up by peat fibres if the structure has grown compact. Therefore water must flow off first. Since peat is badly permeable, this takes place in a slow way so in the

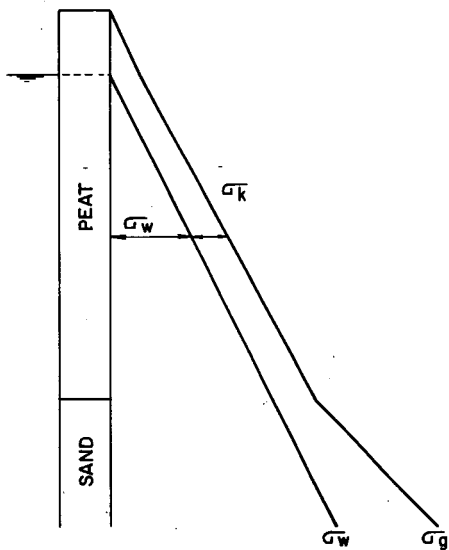


Figure 1

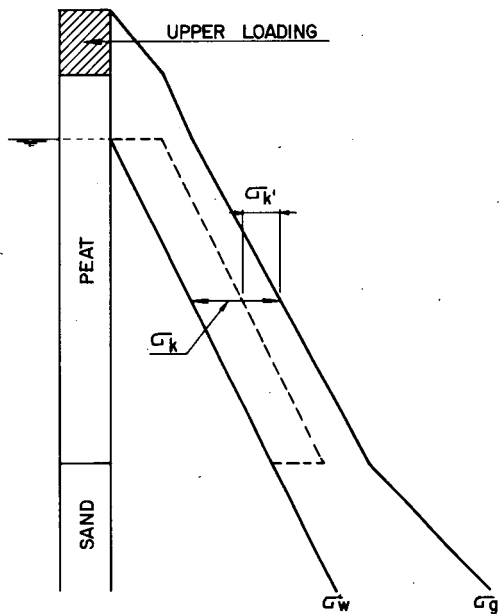


Figure 2

first instance the water takes up the applied loading and the term confined water is used.

If the distribution of the pressure of the water is hydrostatic again, because water has flowed off, the loading has been carried over to the peat. The grain stress then has increased and the volume of the peat has decreased.

In Figure 3 is indicated that a decrease of the level of the groundwater also causes an increase of the grain stress. This can only be caused when water has flowed off and the volume of the ground has decreased. The relation between settlement and increase of grain stress is indicated in the formula of Koppejan, a combination of the formulas of Terzaghi and Keverling Buisman.

The relation has been indicated in Figure 4. The size of settlement depends, among others, on the thickness of the compressible layer and the increase of the grain stress with regard to the present grain stress. The values C_s and C_p depend on the type of soil and are being calculated directly from compression tests.

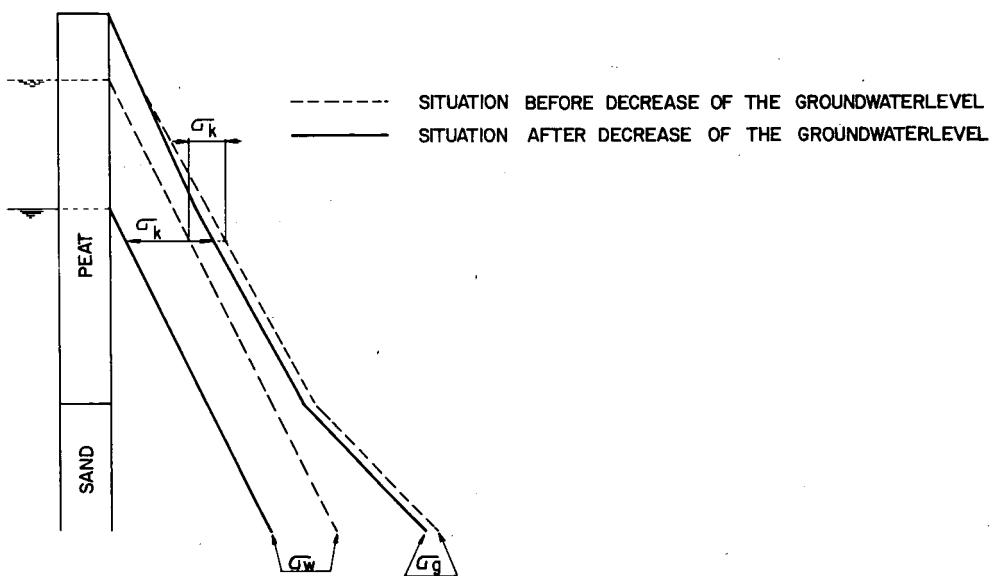
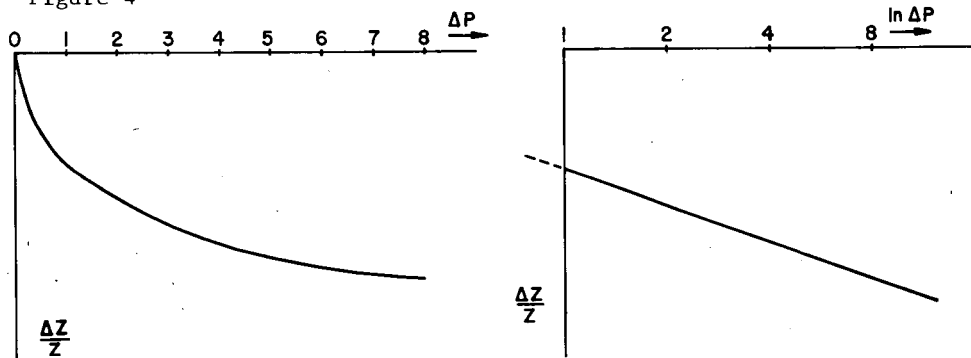


Figure 3

Figure 4



KOPPEJAN:
$$\Delta Z = Z \left(\frac{1}{C_p} + \frac{\log t/t_0}{C_s} \right) \ln \frac{P+\Delta P}{P}$$

ΔZ = settlement

Z = thickness of the compressible layer

P = present grain stress

ΔP = increase of the grain stress

t_0 = 1 day

t = time counted in days

C_p = primary constant of settlement

C_s = secular constant of settlement

Figure 4

The effect of time on the course of settlement is twofold (Figure 5)

- consolidation
- secular effect

The consolidation theory of Terzaghi is connected with the delay that the compression experiences, caused by the pore water in the soil. First the water must flow off from the compressible layer before settlement occurs. The consolidation therefore will have ended when the water pressure is equal to the hydrostatic pressure.

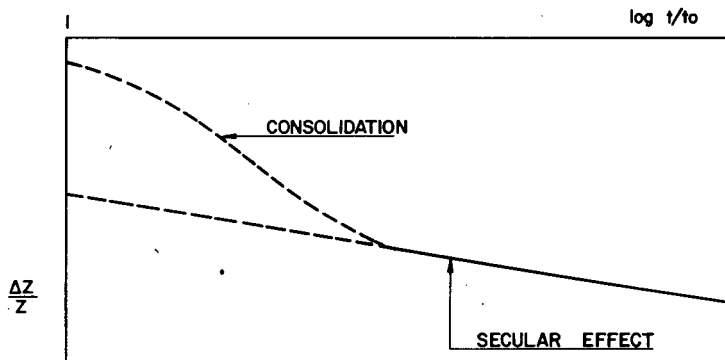


Figure 5

The duration of this period is related with the permeability of the soil, the size of the increase of loading and is proportional with the square of the distance that the extracted water has to cover.

The secular effect of Keverling Buisman has no theoretical end value. It is ascribed to the water fixed to the parts of the soil themselves, and/or connection between the parts of soil.

In peat soils sometimes very low grain stresses can be found. In the calculation $\frac{P + \Delta P}{P}$ then becomes very large, so that non-real settlements are calculated.

By a combination of the 'Elastic law' of Terzaghi from soil mechanics and the 'Law of soil ripening' from soil science Fokkens has been able to meet this. Compression is described by him as a function of:

- the water content of the peat
- the organic matter content of the peat
- the increase of the grain stress

The approach then agrees with reality better.

Till now border effects have not been considered. These effects may consist of:

- the pressing away sideways of sagging layers, caused by which the settlement is bigger than was expected;
- the sticking to elements that do not settle, caused by which settlements are reduced.

Raise and decrease of the groundwater-level cause a process of settlement in a peat area that may be considerable and may stretch out over a long period of time.

Measures, to decrease the damage caused by settlements, are:

- the pressing away or excavating of layers of peat;
- timely applying increases of loading so that settlements have occurred for the greater part before the execution of the actual work gets started;

- the speeding-up of the process of settlement by:

- a) the applying of an extra loading and removal of this when the calculated settlements have occurred (Figure 6).

This may take place by the application of an extra height as well as by a temporary decrease of the level of the groundwater.

The effect on the surroundings should, however, be considered.

- b) The speeding-up of the drainage of confined water. This can be done by using vertical drainage (Figure 7).

The shortening of the distance that the confined water has to cover has a square effect on the decrease of the length of the consolidation time.

With the application of vertical drainage with peat, use is also being made of the better permeability of this soil in a horizontal direction, with regard to that in a vertical direction.

Another negative quality of peat is the small shear resistance.

The shear resistance of soil is characterized by the angle of internal friction, that is the relation between the vertical grain stress and the available shearing stress (Figure 8).

The shear resistance is used for the stability of soil retaining construction.

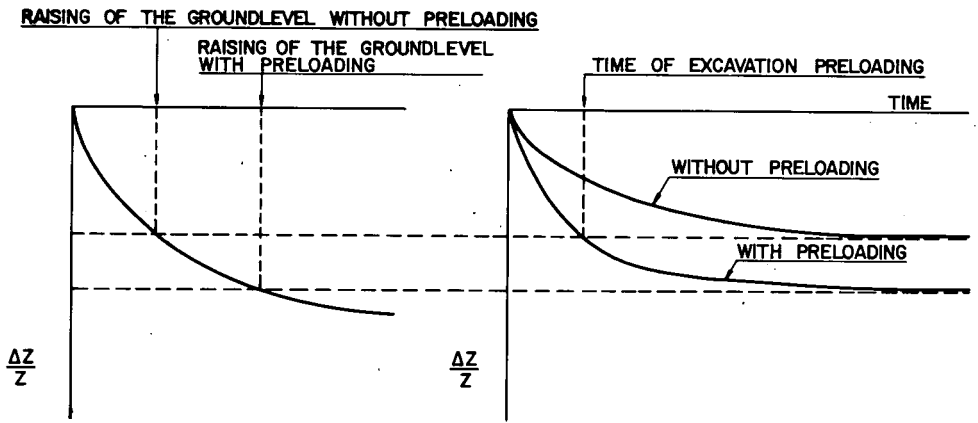


Figure 6

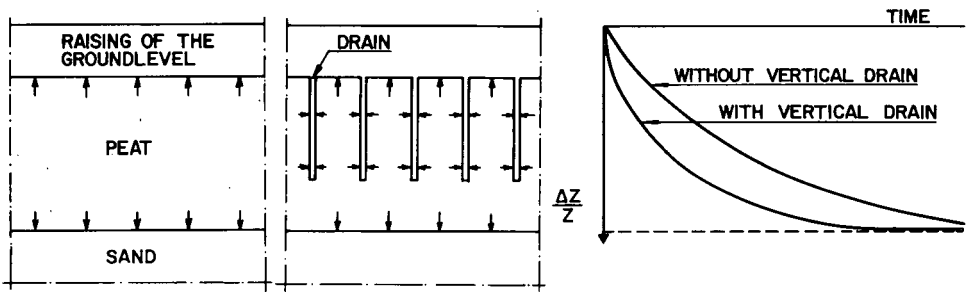


Figure 7

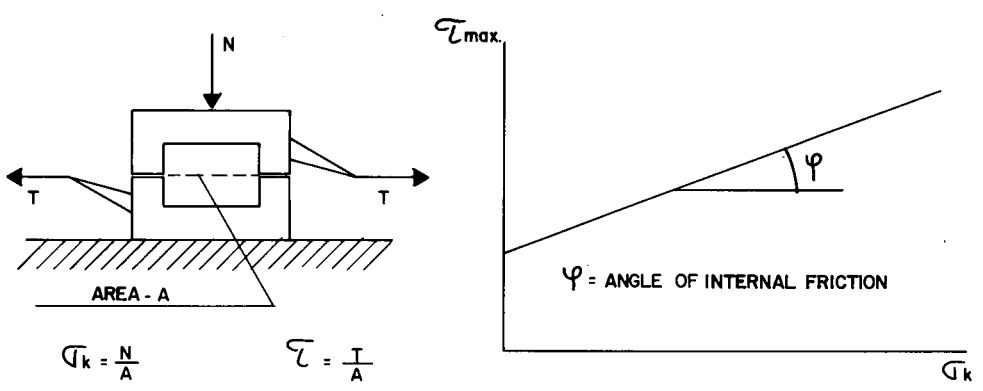


Figure 8

11.3.3 Aggressive groundwater in peat areas

Building materials as concrete and steel may be very strongly attacked by aggressive groundwater in peat soils.

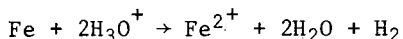
The aggressiveness of groundwater is influenced by a number of factors that are partly interdependent:

- the salt content; a higher ionic strength quickens the attack of building materials;
- acidity;
- the appearance of sulphates and sulphides combined with certain bacteria;
- the presence of complexing organic substances;
- microbiological activity.

I would like to say something more about the microbiological aspect.

This is namely the most spectacular aspect.

Microbiological activity can cause a rapid infection of building materials under aerobic as well as under anaerobic circumstances. Under humid circumstances iron reacts, as most metals do, with (acid) water. With this hydrogen gas is released.



The hydrogen gas protects the iron from a rapid further infection unless the hydrogen is oxidized by bacteria.

With oxidation of the hydrogen the reaction is strongly accelerated.

A large number of bacteria, in the past belonging to the *Hydrogenomonas* genus, is able to oxidize hydrogen. This is an aerobic process. Under anaerobic circumstances a similar reaction can occur as well. The hydrogen is then removed by bacteria from the *Desulfovibrio* and *Desulfotomaculum* genera. These bacteria are able to reduce sulphate to sulphides, with the aid of hydrogen.

These bacteria are responsible for the so-called anaerobic corrosion.

The created sulphide can react, with the Fe^{2+} -ions, to FeS .

Under aerobic circumstances the presence of sulphides has a devastating effect.

The sulphides are oxidized to sulphates by bacteria of the *Thiobacillus* genus; with this reaction considerable numbers of H_3O^+ -ions are released

(acid). *Thiobacillus thio-oxydans*, in the past also known as *Thiobacillus concretivorans*, is resistant to, and still biologically active with an acidity pH = 2.

A production of acid like that is strongly destructive to iron and steel.

Alternating aerobic and anaerobic conditions and the presence of sulphates and sulphides thus may cause a continuous breakdown of iron and concrete. Under aerobic circumstances oxidation of sulphides to sulphates and the production of acid takes place.

Under anaerobic circumstances the sulphates are reduced to sulphides again.

11.4 Means to make peat soils suitable
for use

11.4.1 Building sites

People will realize development of a town by preference on soils that have sufficient bearing capacity and possibilities for drainage. Thus on a building site it must be possible to transport and store materials. Cables and pipes must preferably be placed above the level of the groundwater. For the destination of 'building' of a site the following criteria may be used:

- the average highest level of the groundwater should be situated below 0.8 m minus the level of the surface;
- the soil should be rather well permeable till 1.20 m below the surface of the soil;
- to 2.00 m below the surface of the soil the soil profile should be rather homogeneous and contain no layers that are liable to settlement.

In peat areas measures will be taken to improve the natural bad qualities for building. These measures can be:

1) *Decrease of groundwater level*

With this the level of the groundwater is decreased by a decrease of the polder water-level, possibly combined with drainage.

2) *Raising of the ground level*

With this sand or soil is applied.

Both measures can also be taken in a combined way. As has already been stated, the measures will cause a subsidence that may last for years. Decreases of groundwater level may cause unfavourable side effects, like the increase of (saline) seepage and the bringing to the watertable of wooden foundations of surrounding buildings. Also the vegetation will certainly be impoverished. A site that is filled up with sand, will lose all natural characteristics.



Photo 1. Nederhorst den Berg. The large hillocks of sand that are to be seen, are meant as extra raisings to speed up the settlements on those spots where the total settlements will be largest

The costs of making the soil suitable for building will - not taking into consideration the larger costs of maintenance - be higher in a peat area than those in a sandy area. Thus making a site suitable for building in an area will consist of limited levelling, digging of shallow road trenches, placing of sewer systems and pavements, while keeping the excavation pits dry.

The costs will amount to between Dfl 15.- and Dfl 20.- per m^2 . In a peat area, where 1.5 m of sand is provided, an intensive drainage is applied (including discharge) sewer systems are placed, pavements are applied (including partial overlays) these costs may rise from Dfl 50.- to Dfl 70.- per m^2 .

Yet it is possible to adjust more to the given basis.

This does mean however, that the water-levels as well as the level of the surface should remain unchanged as much as possible.

Since the floor level should be 1 m higher than the water-level, stairs are being used. The level of the surface connected with the houses will be made thus, that settlements will be no problem.

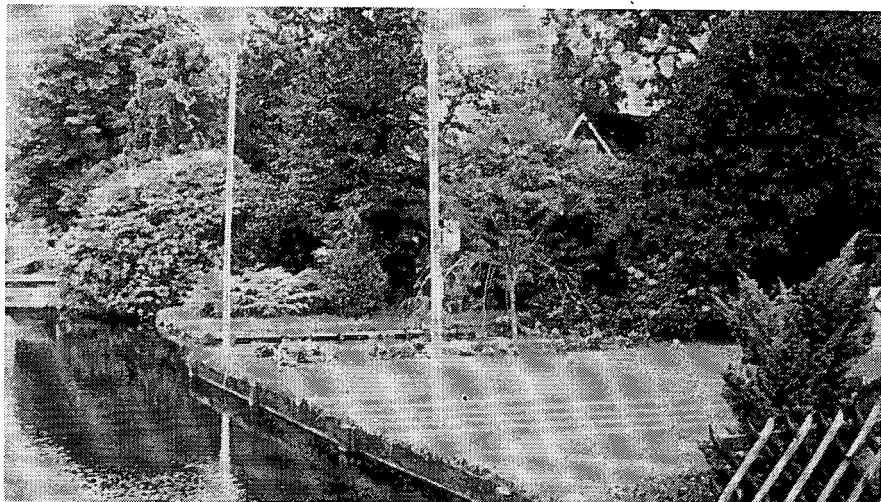


Photo 2. Houses in the extension Boskoop. A house should not be situated against the ditch or road. Space has to be provided, so that plantation can supply a changeover



Photo 3. House at Zuidwijk (Boskoop). If it is impossible to maintain existing ditches, the water-levels will have to be maintained in a different way

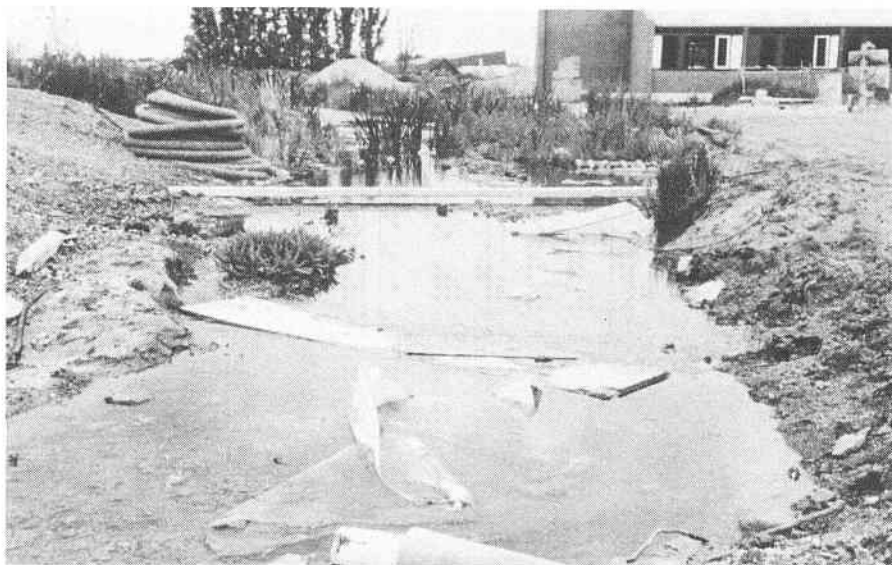


Photo 4. Maria-Oord. By an infiltration system and a group of ponds within the buildings it may be achieved, that despite the filling up of ditches, the original level of the groundwater is maintained as much as possible

11.4.2 Roads

For the building of roads the subsoil is a definite datum. In a peat area measures are necessary from the point of view of stability.

A number of possibilities present themselves.

1) *Fixed system*

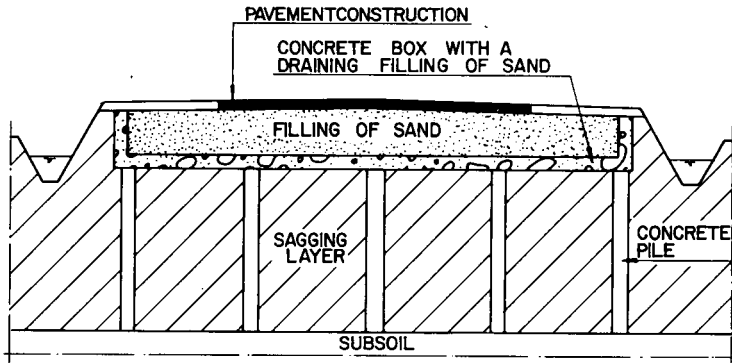
With this the road is founded on piles. It is a concrete box with a draining filling of sand.

It is a very expensive solution, with which connections and widening of the lanes are very hard to construct (Figure 9).

2) *Floating system*

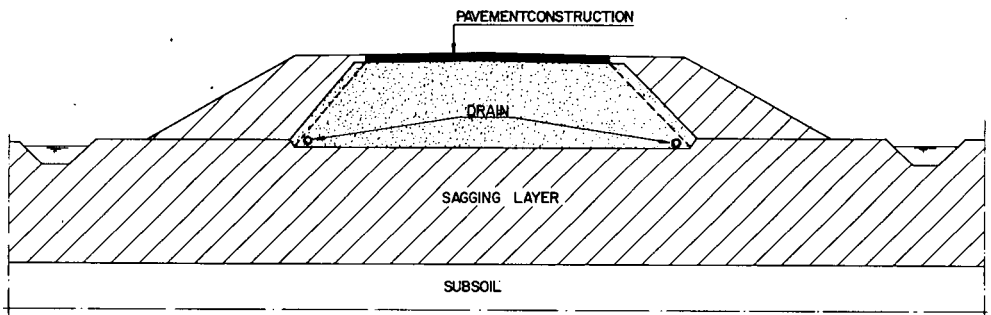
This system will always be combined with sediments.

The hydrodynamical period will last for 3 to 5 years and may possibly be shortened. The secular effect however will continue (Figure 10).



FIXED SYSTEM

Figure 9



FLOATING SYSTEM

Figure 10

To decrease settlements it is possible to:

- 1) limit the height of the road-bed;
- 2) apply light materials;
- 3) remove saggy layers completely or partially by pressing away, excavating or dredging.

To accelerate settlements it is possible to:

- 1) temporarily apply an overloading;
- 2) apply vertical drainage.

Especially concerning the application of light materials a lot of experiments have taken place. Materials to be considered in this respect are:

- expanded clay
- bales of peat dust
- flugsand
- scum slags

Flugsand and scum slags are applied often. The dry volume weight of these materials is about 1.2 g/cm^3 and the wet volume weight about 1.4 g/cm^3 . Scum slags have a little hydraulic action, which means that by water a compound is being brought about, with the characteristics of a plate. Flugsand is not hydraulic and excavating activities in this in connection with cables and pipes can be carried out well.

Expanded clay has a dry volume weight of about 0.4 g/cm^3 and a wet volume weight of about 1.1 g/cm^3 . The application is still in an experimental stage.

Especially the resistance to heavy traffic will yet have to be displayed.

To give an impression of the various costs of the building of roads in peat areas with regard to those in sand, the following:

In a sandy area a road with an asphalt pavement, 4.5 m wide, will amount to a little over Dfl 300/m'. With this we start from an unfounded sewer \emptyset 300 mm, the digging of an excavation and the application of 0.6 m of sand.

The costs of building of this road in a peat area are estimated to be about Dfl 570/m'. With this we start from a founded sewer, a separation cloth and 0.6 m of scum slags.

11.4.3 Sewerages

To limit the size of the sewers the divided system is suitable in a peat area. With this rainwater is carried off paved surfaces, directly to the surface water.

Because of the low weight P.V.C. sewerage is suitable. These pipes are placed without foundation. The sewerage can go along with the subsidence of the whole site. Special provisions will have to be made with the connection of the founded sewage pumping station and the buildings (Figure 11). These provisions consist of the application of loops in the connecting pipes. The connections are carried out in a flexible way.

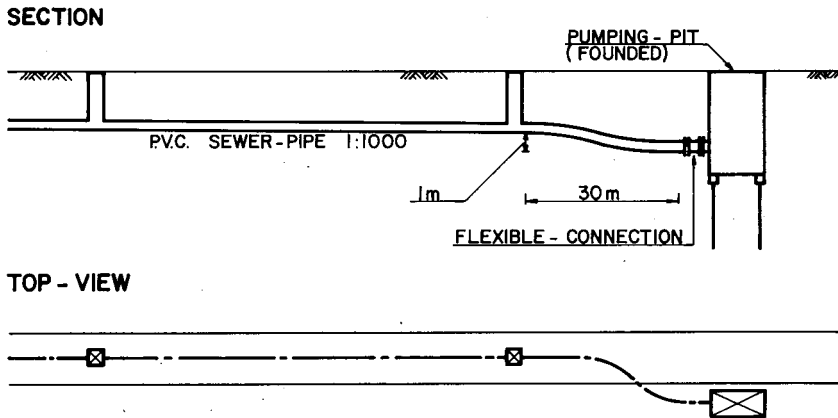


Figure 11

Pipes of asbestos-cement are indeed light, but will break off, because of the rigidity of the material.

In certain cases concrete sewerage can be applied on an improvement of the soil with scum slags. Founded sewers will be very heavily loaded as the surroundings settle. If strong settlements can be expected it is desirable to apply unfounded sewers.

11.4.4 Pipes

For the transportation of gas and drinking water in peat areas also many pipes have been placed.

Problems occurring with this concern the following aspects:

1) *The transportation of the pipes*

The slight bearing capacity of the top soil requires the following provisions:

- construction of a flugsand track
- construction of a narrow track
- transportation by helicopter
- transportation by hovercraft
- vehicles with a low wheel pressure

2) *Loss of soil*

The peat from the excavation, that is stored, oxidizes to the air.

At the same time an irreversible decrease of volume is caused by drying out. The lacking material will have to be supplemented by another, often heavier material. Besides, by increase of the loading on the storage of the soil, water can flow out of the existing profile in the trench and cause settlement.

3) *Stability of the trench*

In order to maintain the counter-pressure on the wall of the trench in a very saggy subsoil a canal is dug, in which water is admitted. The pipe is floated into this and sunk down.

4) *The lifting of pipes*

The weight of a gas pipe is in general smaller than that of the excavated soil. With a high groundwater-level an empty or gas-filled pipe is inclined to lifting, when light supplementary materials are used. The pipe can then be anchored by drilling anchors in cohesive layers. If this is not possible the pipe can be weighted with concrete blocks, thus that the weight of the pipe with blocks is equal to the upward water pressure. The pipe is therefore placed in a suspended way.

5) *The filling up of the trench*

Because of loss of soil and settlement of the transportation road and the level of the groundwater, extra filling materials will always be required in peat areas.

The weight of these should be thus, that no extra loadings are applied, because of which settlement occurs by groundwater flowing off and compression of the ground mass is caused.

Tests with bales of straw and hay have passed off unsatisfactory.

After the event unequal settlements occur.

Flugsand is used very often. This material can be compressed very well, by which little settlement of the supplement itself takes place. By the low volume weight the loading of the underlying peat is hardly increased and therefore the settlement is limited.

11.4.5 Recreation grounds

Sport fields, playgrounds and park areas have a practical function as well as a function with regard to physical planning. This means that the

grounds will have to stand intensive trodding and playing on, while favourable conditions for the vegetation are preserved. The programme of requirements concerning recreative factors of use of peat areas is concerned with the following factors:

- firmness of the top layer
- bearing capacity of the total profile
- drainage
- smooth situation of the level of the surface
- suitability of the soil for plantation.

In order to be well played on, the top layer of grass sport fields, play- and sungrounds must be able to meet the effects that are exercised on it with use and maintenance, while no damage to the vegetation occurs. This means that this top layer should have a resistance to penetration of at least 1.4 MN/m^2 (= 1.4 MPa).

This requirement of firmness concerning the top layer of grassfields for various recreative practical functions implies measures for the improvement of peat soils.

The elevation of peat soils influences the firmness of the top layer. The bearing capacity research on peat grassland also supplies information about the desired elevation above the groundwater-level, of 0.30 m minus ground level, permitted for the firmness, must not take place. A sufficiently smooth situation of the ground level is a condition for sport fields to be well playable.

The requirements that have to be made for the composition of the top layer are:

- a top layer with an organic-matter content < 5%
- a clay content < 5%
- a silt content of < 10%

The suitability of peat soils, with regard to plantations to be provided on recreational objects, is also limited. Only a limited choice, with regard to wood species to be applied, is possible. This limitation is also caused by the lack of a sufficiently firm topsoil for the plantations.

Laying-out of recreation grounds on peat soils

Of most Dutch peat soils the ground level is situated too low with regard to the level of the open water in order to reach the desired draining for the new purposes.

Because of the high groundwater-level they are insufficiently firm for intensive treading and playing on. To be able to create grass sport fields, play- and sungrounds there, suitable sand should be applied after levelling. If the underlying peat layer is poor in clay, as much of that layer can be cultivated, that a mixture with about 5% of organic matter comes into being on the parts of the ground that will be trodden and played on intensively.

For the parts that will be trodden on less intensively a sandy top layer with about 3% of humus will be sufficient.

On peaty soils it is of great importance that the sand covering is poor in clay and silt and that only organic matter is used in combination with the sand in order to provide the soil with the necessary cohesion, firmness, ability for the development of roots and water retention capacity.

For a good, firm top layer on peaty soils a moderate sand covering of about 15 cm, which is poor in humus, is needed.

For peat soils with a slight bearing capacity this will however be a loading that is too heavy on account of which settlement of the soil occurs. By the deeper drainage also a decrease of the ground level is brought about, caused by oxidation of organic matter.

If filled up waterways or clayey or sandy strips are found in the ground then the ground level will settle unevenly. By an uneven settlement the drainage system will function in an insufficient way.

In grass sport fields hollows have to be filled up periodically which is very expensive. In peat soils with a slight bearing capacity and a high level of the groundwater sometimes one or more coatings of polystyrene plates are applied 30 or 50 cm below the ground level. Another measure that is often applied is the use of flugsand in ditches to be filled up. By using these materials, with a specific weight near that of peat, uneven settlement is partly avoided and a higher ground level can be obtained. Thus the bearing capacity increases and root development is improved.

Because of these measures the costs of establishing sport fields on peat soils are approximately 60% higher than when established on sandy soils. The difference is mainly caused by the extra costs of drainage, filling up of ditches with flugsand, working of the top layer and pavements.

11.4.6 Foundation in peat areas

In Section 3 attention has already been drawn to the slight bearing capacity of peat soils. For the foundation of buildings it is therefore almost impossible to have the loads taken up by peat soil.

In the past light buildings were situated on a shallow foundation in peat areas. As far as these buildings still exist they are liable to subsidence, caused by increased loading and decrease of the groundwater level. Often the consequences of slight changes of the groundwater-level can be observed in the jamming of windows and doors or continuous cracking of the walls. For heavier buildings pile foundations had to be employed. In the past wooden piles with slatted floors were used, on which the walls were built.

Caused by the increasing urbanization loads increased and besides people were inclined to increase drainage of the soil. One and another often has as a consequence that in urban areas the groundwater level will be decreased, because of which danger arises that the wooden foundation will decay. Nowadays more and more concrete piles are used, or wooden piles provided with concrete tops.

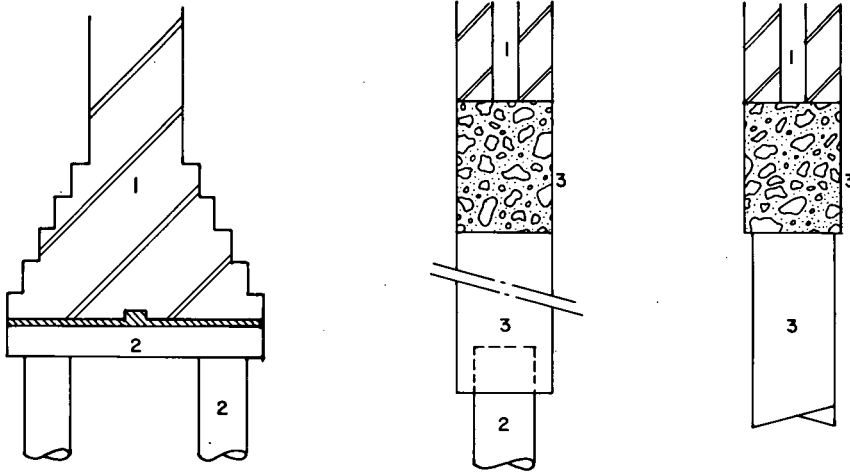
In Figure 12 some principle cross sections are given of past and modern ways of foundation on piles.

With a pile foundation in most cases the total loading is passed on through the point of the pile to the underlying bearing layer.

Besides this point bearing capacity in general, forces of friction between pile and soil will arise along the shaft of the pile.

The extent of frictional resistance depends on the composition of the soil. In clay and peat layers the resistance is mostly slight but in sandy layers the resistance can be considerable (Figure 13).

To be able to realize building sites in areas with peat layers of a thickness of several metres, nowadays it will be necessary to raise the ground with sand, till the required definite situation of the level of



1= BRICKWORK

2= WOOD

3= CONCRETE

Figure 12

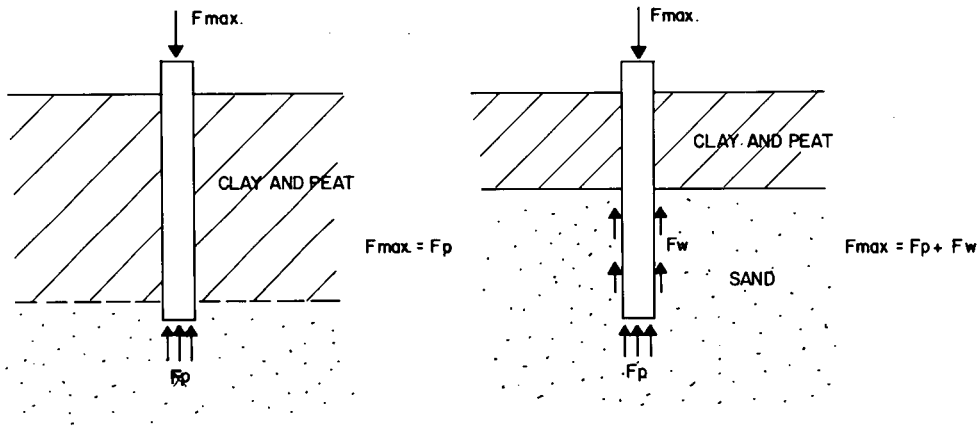


Figure 13

the surface has been reached. The thickness of this layer of sand often amounts to several metres, mainly by the settling of the peat. It has already been mentioned that after a few years the larger part of the

settling will already have taken place, but settlements up to some centimetres can still be expected afterwards. For the grounds and roads this mostly presents no problems. For pile foundations however this is important. With subsidence of the layer of sand with regard to the pile the frictional forces between the supplied sand and the pile are directed downwards.

This is called negative skin friction (Figure 14).

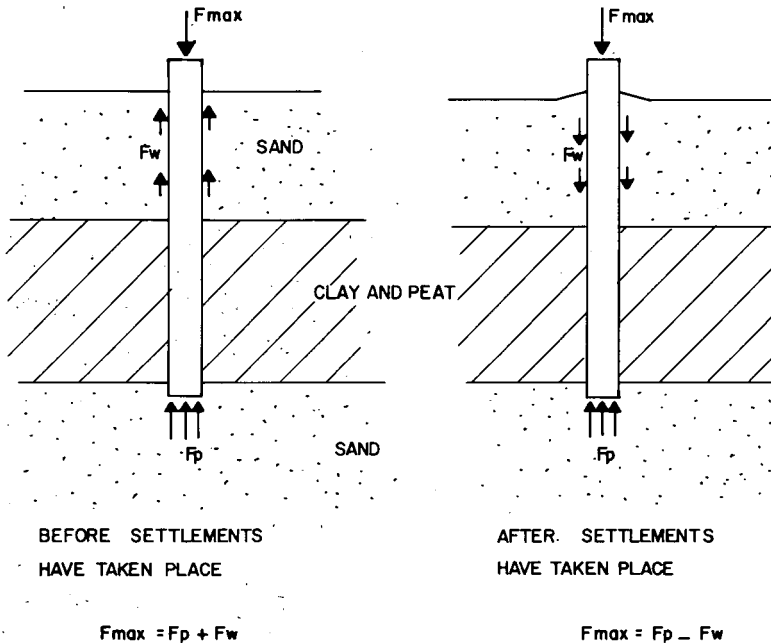


Figure 14

This negative skin friction can diminish the useful bearing capacity considerably. The number of piles for a similar building will therefore be larger than when no negative skin friction is to be expected. When the settlements are small, nowadays piles are sometimes coated with bitumen of such a composition, that the resistance to shearing forces is slight. In this case friction between the soil and the coating will arise, but this friction is not passed on to the pile (Figure 15). In the preceding part it has been pointed out that for foundations quite a number of measures are necessary to eliminate the negative influences of peat soil.

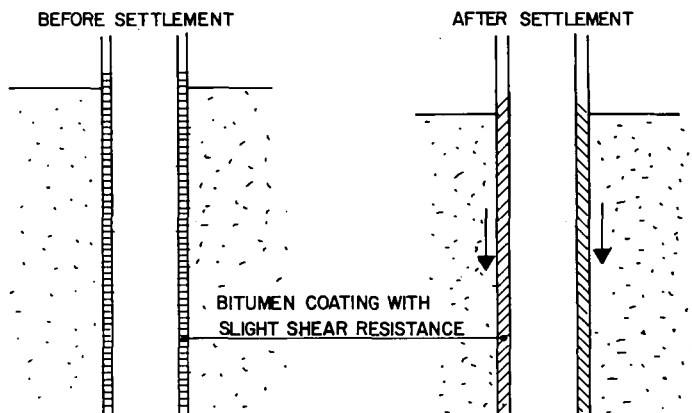


Figure 15

These measures will in general cause an increase of costs. Thus an average house in an area with the bearing layer situated on the level minus 10 m will be about Dfl 5000.- to Dfl 8000.- more expensive than a similar house with the bearing layers on less than 1 m below the ground level.

This increase of costs is caused by the pile foundation. The layers with less bearing capacity however do not exclusively have to consist of peat. Also layers of clay and layers of sand with a bad bearing capacity will generally need a similar pile foundation as is needed for a house in areas with peat in the topsoil.

Also other, above mentioned, negative qualities of peat, as the slight shear resistance and the causing of negative skin friction are no specific qualities of peat soils.

In saggy layers of clay the same phenomena are found as well and here too the construction will have to be adapted to these circumstances.

11.4.7 The stability of soil retaining constructions

With soil with a good shear resistance soil retaining constructions may be anchored to the soil by means of anchor plates (Figure 16).

If the values for T are very small no stability is possible.

In general the shear resistance of peat soils is very slight. Besides,

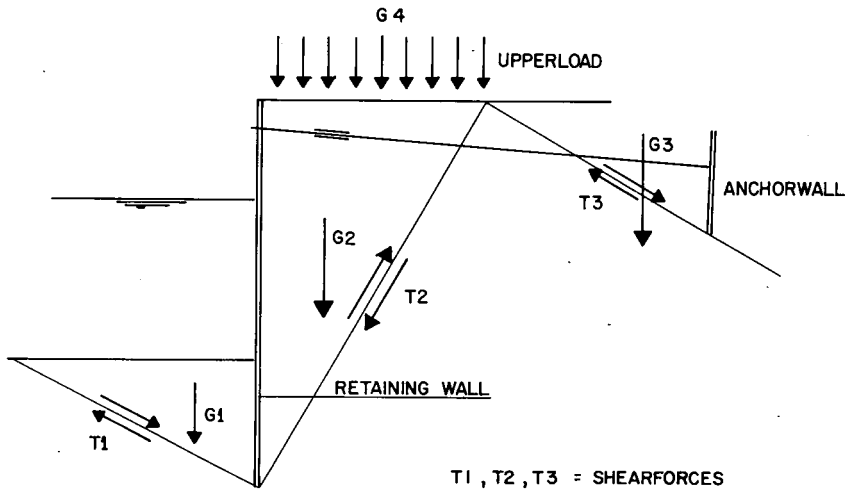


Figure 16

the permitted shearing stress depends upon the vertical granular stress and this too is usually very small with peat. It is therefore mostly impossible to anchor soil retaining constructions of some importance in this way. In that case more complex foundation systems will have to be chosen, or draught anchors will have to be applied in the layers of sand that are usually situated deeper (Figure 17).

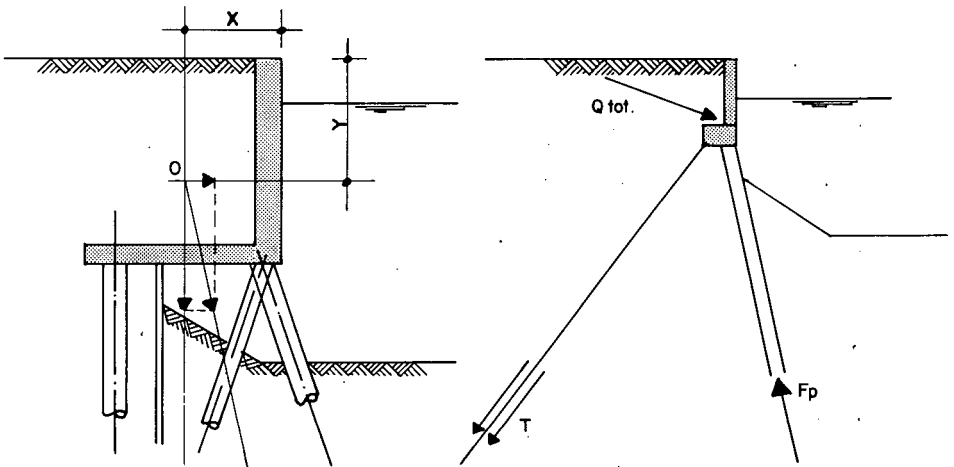


Figure 17

In special cases other methods to take up the horizontal forces are being used. An example of this is the connection between the land abutments of a number of movable bridges in Boskoop (Figure 18, Photo 5). The displacement of the abutments of some millimetres might already cause that the movable part will no longer move. To this end the abutments have been braced with U-shaped concrete blocks. These blocks are prefabricated and applied before the pouring of the concrete abutments, and anchored to these.

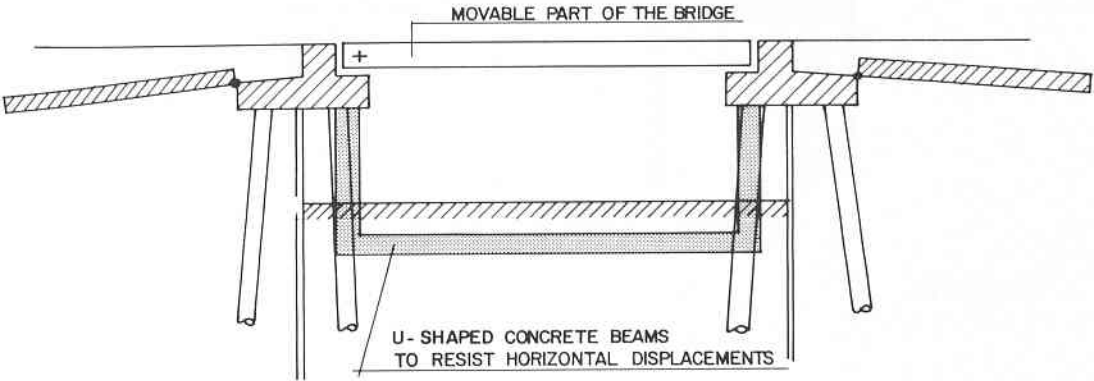


Figure 18

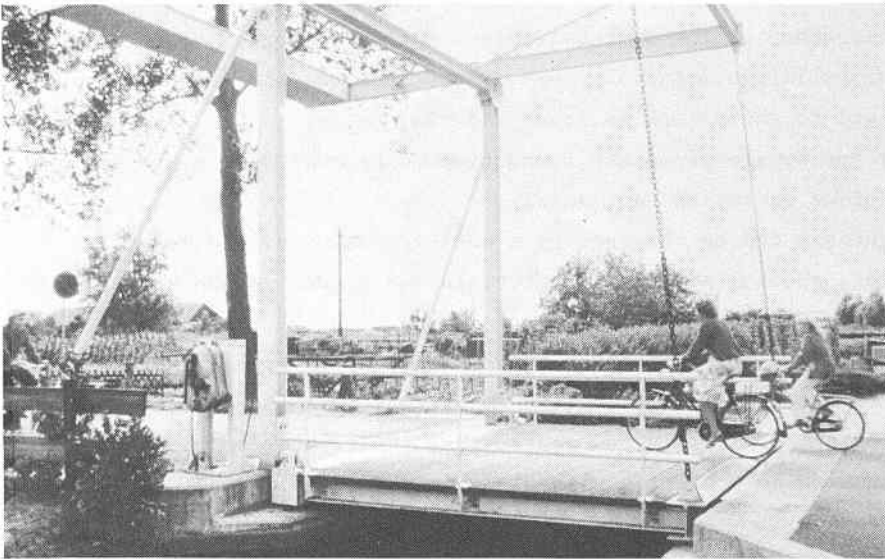


Photo 5. Movable bridge in Boskoop

Such a possibility also arises with two soil retaining walls on a short distance, with which a braced floor can be applied on the bottom of the canal or harbour (Figure 19).

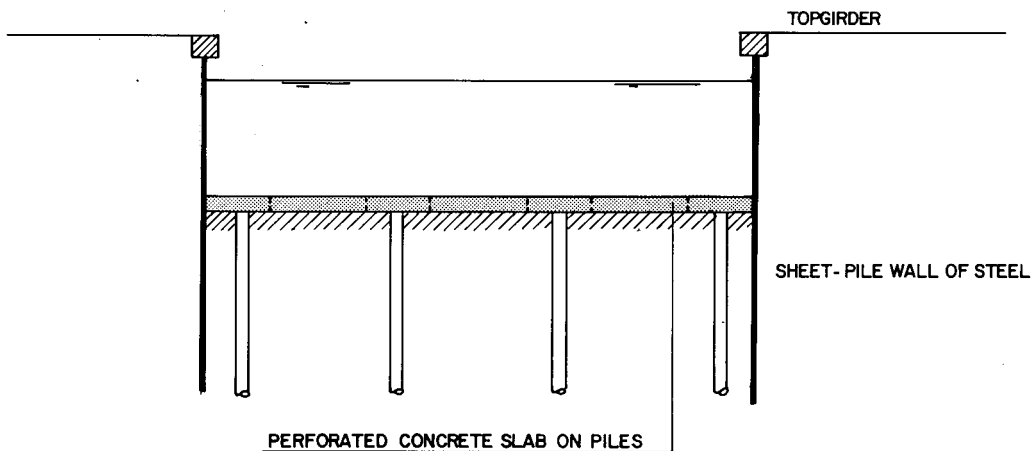


Figure 19

11.4.8 Aggressive groundwater

As a consequence of the aggressiveness of groundwater in peat areas the attack of buildings materials such as concrete and steel is a multiple with regard to the attack in sand- and clay areas.

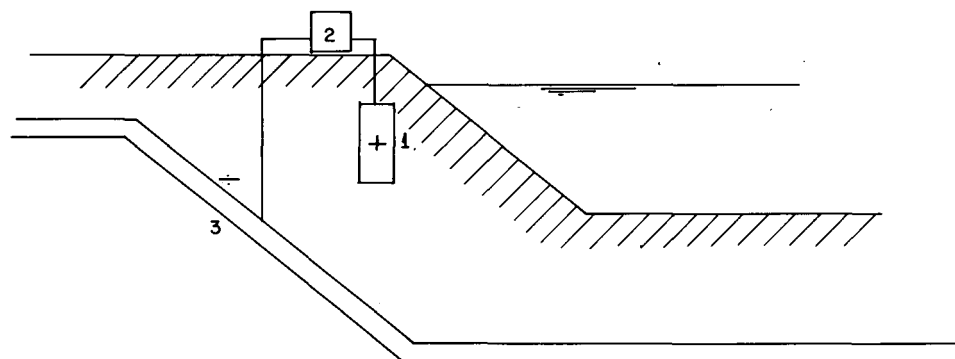
Concrete for sewage pipes and foundation works must have a great tightness in order to resist peat acids.

This tightness can be obtained by a well gradation of the materials sand and gravel, special additional materials and a good mechanical compaction of the concrete mortar.

Also with such a composition of the concrete it is usually necessary to provide the surface with a coating to prevent that the concrete gets so heavily attacked within a few years, that the reinforcement will rust. Steel can also be protected with a coating, adapted to the aggressive environment.

Besides, steel may be provided with a cathodic protection. With this a metal object is applied at some distance of the object that is to be

protected. By taking care that the electric potential of this object is constantly higher than the potential of the object to be protected, the last then forms the cathode in the electric system and corrosion is prevented (Figure 20).



- 1 ANODE
- 2 MEASURING - APPARATUS
- 3 PIPELINE TO BE PROTECTED

Figure 20

11.5 Future developments in peat areas below sea-level

11.5.1 Introduction

The old peat areas are less densely built up than areas with a different subsoil. Towns have developed along waterways and on the edges of the peat area on the sandy subsoil.

The result has been that the Holland-Utrecht peat area is practically enclosed by towns. Within the peat area itself, some larger centres as Gouda, Alphen and Woerden are found, that have all arisen along waterways that cross the peat area.

11.5.2 Urban development

In the third memorandum on Physical Planning Section 3d, governmental decision on rural areas, the Holland-Utrecht peat area and the river forelands are mainly considered as:

- areas with alternately agricultural, natural and other functions in larger physical units and
- open spaces with a restrictive policy with regard to growth and spreading of the population.

A restrictive policy with regard to growth and spreading of the populations means that the population cannot be spread out over all centres and that efforts will be made to reduce the in-migration surplus to zero or to strive to obtain an out-migration surplus. For large parts of the peat areas north of Amsterdam also a restrictive policy with regard to growth and spreading of the population holds. For an important urban development on peat soils only Capelle on IJssel is mentioned.

Other locations do have a saggy subsoil or probably peat at some depth. The houses that have yet to be built in the open Holland-Utrecht peat area should mainly be established in the centres Gouda, Alphen, Woerden and Gorinchem.

Around Amsterdam and Rotterdam some motorways have been planned, of which building could be started before 1990. The motorway Utrecht-Leiden is not as yet a complete dual carriage way.

Building of the last part of the motorway here could also be started before 1990.

11.5.3 Landscape, nature and recreation

The landscape of peat soils has great cultural-historical and natural values. Lake districts with various stages of peat lands have a rich flora and fauna.

Four areas, with amongst others peat soils below sea-level, have to this end been selected as potential national parks, namely Northwestern Overijssel, that has been an experimental area as a national park, the Vechtplassen and Southwestern Friesland.

The motives for realization of the national parks are also to be found

in the field of recreation.

In protected landscapes agriculture is often limited in its development by its environment, by its grouping in plots, accessibility (sometimes by boat) and bearing capacity.

Preservation of landscape and land use automatically imply the creation of reservations and management agreements, for instance fixing of mowing dates and subsidized reed culture. With regard to tourism, management is thus, that vulnerable parts are closed for the public, whereas in other parts access will only be partly permitted, especially to boats.

The stimulation of tourism is directed to areas where tourism is admissible because of biological values and physical possibilities. Quiet forms of recreation, as angling, will be stimulated. Footpaths are being made connected to stops of public transportation.

For the rest it is a fact, that touristic pressure, especially caused by day-trippers, is considerable in these areas. Also pressure of sojourn recreation is considerable in Southwestern Friesland and the Vechtplas-sen area.

On supreme days 10,000 recreative vessels are found in these regions. Finally it may be stated, that areas with predominantly peat soils still possess a relatively open character, owing to the unfavourable qualities of the soil. Their most important destination will be agricultural and recreational. A different sort of use will not take place other than for very pressing reasons.

Note

¹ Involved in the composition of this article were:

H. Hidding

R.T.J. de Ruijter

H.W. Sinke

A. Talsma

H.E. Zonderland

all working with Ingenieursbureau 'Oranjewoud' B.V.

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APPENDIX 1

ROUGH SURVEY CONCERNING THE COSTS
OF LAYING OUT 'AVERAGE' SPORTS-
GROUNDS ON VARIOUS FOUNDATIONS

Sportsgrounds 'Cellesbroek-Middenwetering' in Kampen
total area about 6,000 ha

3 football grounds + 1 training ground	3.10 ha
other grassfields and verges	1.00 ha
plantations: forest trees and trees	1.20 ha
pavements: access road	
carpark (for about 60 cars)	0.30 ha
footpark (about 600 m')	0.10 ha
ditches, buildings and so on	<u>0.30 ha</u>
	6.00 ha

These sportsgrounds have been laid out (completed in September 1980) on a foundation, consisting of a topsoil of heavy sticky clay, thickness about 0.20 m, lying on a peaty subsoil, mainly wood peat.

This peat layer varied strongly in thickness from 1.50 m to over 6.00 m.

In the following survey the parts of work and the costs of laying out belonging to them have been further specified.

Besides, estimates have been made of the costs of laying out, in case these sportsgrounds would have been laid out on a clayey soil or on a sandy soil.

Nr.	Part of work	Costs* of laying-out/construction			Causes of differences in costs
		peat soil	clayey soil	sandy soil	
1	Preparation of work-measuring works	10.000,--	10.000,--	10.000,--	
2	Clearing works	15.000,--	15.000,--	15.000,--	
3	Tree moving and treatment	20.000,--	20.000,--	15.000,--	transportation, anchoring
4	Drainage				in peat areas high level of ditchwater
	- pumping-infiltration	25.000,--			
	- drainage	85.000,--	60.000,--*	35.000,--**	* sand in trenches instead of flugsand
					**intensity; no assembled drainage system; do not fill up trenches with sand
	- sewerage - rainwater	30.000,--	30.000,--	30.000,--	
5	Earthworks				
	- filling up of ditches	40.000,--	15.000,--	10.000,--	on peat filling up with flugsand; on clay-sand filling up with soil from ground, on sand less and smaller ditches
	Transport	225.000,--	150.000,--	115.000,--	

* In Dutch Guilders

Nr.	Part of work	Costs* of laying-out/construction			Causes of differences in costs
		peat soil	clayey soil	sandy soil	
6	Transport	225.000,--	150.000,--	115.000,--	workability
	- earth moving - digging	50.000,--	50.000,--	30.000,--	
	Laying out of grassfields				
	- other grass and verges	25.000,--	25.000,--	20.000,--	
7	- sportsfields	145.000,--	100.000,--	70.000,--	workability
					workability; measure of sand covering, passability of ground
8	Plantations	25.000,--	25.000,--	25.000,--	workability
9	Pavements	240.000,--	160.000,--	140.000,--	construction: on peat: cloth and slags; on clay and sand: excavation
10	Fencing				
	- fencing ground	25.000,--	25.000,--	25.000,--	
11	- fencing sportsfields	45.000,--	45.000,--	45.000,--	
	Campsheddings etc.	10.000,--	5.000,--		
12	Sprinkler irrigationsystem	35.000,--	35.000,--	45.000,--	filtration well instead of open drainage
12	lighting	P.M.	P.M.	P.M.	workability
	Maintenance for 1 year	20.000,--	20.000,--	15.000,--	
	Costs of laying-out/ construction	845.000,--	640.000,--	530.000,--	

* In Dutch Guilders

	peat soil	clayey soil	sandy soil
Amount carried forward	845.000,--	640.000,--	530.000,--
Costs of management about 15 %	125.000,--	95.000,--	80.000,--
	970.000,--	735.000,--	610.000,--
V.A.T. 18 %	174.600,--	132.300,--	109.800,--
	1.144.600,--	867.300,--	719.800,--
For rounding off	5.400,--	7.700,--	5.200,--
	<u>1.150.000,--</u>	<u>875.000,--</u>	<u>725.000,--</u>

Relation of costs	peat soil	clayey soil	sandy soil
items - 1 + 2 + 3	1,15	1,15	1
- 4 + 5 + 6 + 7	1,95	1,40	1
- 8	1,70	1,15	1
- 9 + 10	1,15	1,05	1
- 11	0,80	0,80	1
- 12	1,35	1,35	1
TOTAL	<u>1,60</u>	<u>1,20</u>	<u>1</u>

APPENDIX 2
FILLING MATERIALS

Scum slags

(Blast furnace) slags come into being as a residuum with the melting of iron ore and consist of liberate non-metals, ashes of coke and additives as chalk, necessary with the melting process, all in a condition of heating.

The slag, that rises to the surface because of a lower specific gravity than that of metal, is caught in pans. The chemical composition of iron blast furnace slag is mainly:

28-50% CaO

28-40% SiO₂

5-20% Al₂O₃

0-10% MnO

2-15% MgO

½- 2% S

0- 2% FeO

0- ½% P₂O₅

0- 2% Na₂O + K₂O

With a process of slow cooling after pouring off of the pan, a slag with a tight structure is obtained.

By means of a special process a scum slag may be obtained. With this, the heated slag is passed through a stirring machine, while steam under high pressure is syringed.

Scum slags are a hydraulic, voluminous, highly porous and easily breakable material, with an uncompacted volume weight of 0.7-1 g/cm³.

Flugsand

This is a natural product, that has come into being with the vulcanic eruptions in the Eifel mountains, in the quaternary age (1-3 million years ago). The many creater-lakes, the so-called *Maare*, occurring in the Eifel mountains, testify to these vulcanic eruptions.

In this respect the Laacher See, with the abbey Maria Laach situated on it, is well known.

With the eruptions various types of stones were brought up, with large contrasts in appearance and qualities. To this end the hard and solid basalt should be compared to '*bims*', that is provided with gas channels by the production of steam with the eruptions and has obtained a foamy structure because of that.

According as the grain size of the pieces was finer, they were blown further away up to many kilometres, by the force of the eruption.

For this reason the fine '*bims*' obtained the name 'flugsand'. Its grain size is 0-8 mm and from a laboratory investigation the following was learnt:

dry volume weight with Florida compaction with 10% moisture	0.92 g/cm ³
apparent specific gravity	1.76 g/cm ³
hollow space with Florida compaction (pores between the grain)	48 full %

Expanded clay grain

The expanded clay grain is produced in a rotary furnace, at a temperature of approximately 1100^o Centigrade.

The round grain has a hard brown crust and a cellular nucleus.

The cells with stagnant air render a - for a stony material even exceptional - low weight of 0.35 g/cm³, poured, for grain size 10-16 mm.

Other qualities are:

- frost resistant
- strong and no deformation, not even with prolonged loading
- resistant to any form of attack as decay, fungi, chemicals, etc.
- draining

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During the last few years I have developed a keen interest in Dutch soil mechanics problems, partly through literature studies, partly through discussions with my colleague Prof. I.M. Beattie, who visited The Netherlands a few years ago, and partly through contact with Dutch-born persons in Fredericton. The foundation problems in The Netherlands are without question quite unique and obviously require much ingenuity for their proper solution, as evidenced, for example, by Van den Kerkhoff's paper.

It is evident that the author has been aiming at a general rather than a specific or detailed account of foundation problems with Dutch soils, and he has indeed succeeded in arousing interest in this topic. On account of the time span of construction involved (some 1100 years) and the very extensive field of construction covered, his paper invites a number of comments and questions, particularly from a reviewer who is not very familiar with Dutch soil mechanics conditions.

During my work with organic soils in Canada, it has become increasingly evident that the term *peat* can represent just about any organic, diatomaceous or calcareous soil that has a mineral content of up to 80%. The corresponding range of geotechnical properties¹ for this very large group of soils is extremely wide. Since the present paper does not include any boring logs or geotechnical properties, it is unfortunately not possible to draw any comparisons with peat in other countries or within The Netherlands.

The soil mechanics aspects of peat described in Section 11.3.2 suggest to the reviewer that some of the peats referred to may be sedentary and

others may be sedimentary². Thus a fibrous structure, a very high water content, a natural density comparable to that of water, and a very high compressibility are typical of sedentary peats. Slow consolidation (several years required for dissipation of pore pressures), varying degrees of organic content (Fokkens), shear deformation (lateral displacement), and low shear strength are typical of sedimentary peats.

In the case of sedentary (fibrous) peats, the reviewer has found that they typically have an angle of internal friction of about 30° . When subjected to vertical compression, the fibres act as horizontal reinforcement, inducing a lateral internal resistance that effectively counteracts lateral expansion (shear deformation) under a normal range of vertical loads (up to about 40 kPa). In general, vertical (sand) drains³ do not seem to accelerate consolidation, partly because $k_h > k_v$ and partly because of smearing, clogging and horizontal consolidation. The latter is caused by the high horizontal hydraulic gradient near the drains.

In the case of sedimentary peats, shear deformations are generally quite pronounced, on account of high pore pressures, low undrained strength, low permeability, and a general lack of fibre reinforcement. These soils are in fact quite susceptible to local (and hence general) undrained failure as a result of the generation of pore pressures. This generation of pore pressures is again a result of a very high porosity and thus a potentially unstable structure. The secular effect would therefore be very pronounced, but it would not occur after dissipation of pore pressures. On the contrary, the secular effect would *create* pore pressures. In regard to secular effects, the equation attributed to Koppejan (Chapter 11, Figure 4) is not the same as either of those suggested by Koppejan in his Rotterdam conference paper (ISSMFE, 1948, Vol. III, pp. 32-37), viz. equations I and II. Has Koppejan revised his 1948 equations?⁴ The secular effect is stated by the author to be attributed to the water that is bonded to the soil particles or to the connections between the soil particles or to both. The reviewer must take exception to this statement, having found no evidence of such bonds in sedentary peats (other than a slight capillary action). In sedimentary peats, such bonds may certainly exist, but they do not in any way seem to control the secular effects. Rather, the controlling factor appears to be the long-term (secular) behaviour of the organic material itself. For example,

secular consolidation was found by the reviewer to occur in dry wood waste (sawdust, bark), fibre glass, and steel wool. If the rate of secondary (secular) consolidation exceeds the rate of possible drainage (low permeability), pore pressures will be generated, whether the water is bonded or free.

Returning to the question of vertical (sand) drains,³ the reviewer would be interested to know if and under what circumstances they have actually been successful in The Netherlands. Experiences in Scotland and Canada have been largely negative.

The use of 'flugsand'⁵ has caused the reviewer some puzzlement. Its very low dry (and wet) density suggests that it has an extremely low specific gravity and an extremely high porosity as placed. What are the geotechnical properties of this material?

In regard to the use of light-weight material, one technique used in Norway and Canada is to estimate the settlement to be expected under a certain thickness of mineral fill. Light-weight fill (e.g. sawdust, compressed peat) is then placed to a thickness equal to or greater than the expected settlement, followed by the mineral fill. Under ideal conditions, the top of the light-weight fill settles to the ground water level. Is this technique used in The Netherlands, and if so, has it been successful?⁶

The reviewer would also like to obtain some information on the current approach to the erection of buildings on peat.⁷ The author states that buildings are very sensitive to settlement and that they must therefore be founded on piles to firm ground. The alternative approach would be to accept the settlement (or to reduce it through surcharging) and to design the buildings so that they can settle without significant damage. Is this approach being pursued or practised in The Netherlands? If so, considering your rather unique soil conditions, what are your experiences with such an approach? It is noted (Section 11.4.6) that after a few years, the remaining settlement is generally limited to 'several centimeters' only. Ideally therefore, the fill should be placed a few years before the start of building construction.

The author's contentions with respect to friction piles⁸ are not fully understood. The frictional resistance is claimed to be small in both peat and clay. This is certainly the case in peats, whether sedentary or sedimentary. In clay, however, friction piles are used extensively, and

they derive practically all their bearing capacity from skin friction. Perhaps the clays referred to by the author are organic compressible clays? In the case of negative skin friction, the reviewer would be interested in some details concerning bitumen coating. The illustration (Figure 4?) is missing in the reviewer's copy. Does this illustration corroborate the statement that no friction is transferred to the pile? Finally, on the subject of bridge (*beweegbare bruggen*)⁹, the statement that a displacement of only a few millimetres can cause jamming seems to imply an unusually strict geotechnical requirement. Is it not possible to allow for a displacement of several centimetres rather than millimetres?

Notes

(J. van den Kerckhoff and co-workers)

¹ *Some geotechnical properties*

- volume weight (wet): 0.9-1.1 g/cm³
- volume weight (dry): 0.1-0.3 g/cm³
- water content: 300-800%
- cohesion: 0-5 kN/m² (kPa)
- angle of internal friction: 15^o-20^o
- cone resistance: ca. 0.2 MN/m² (MPa)

The peat in the excursion area has a thickness of 4 to 10 metres, often in combination with saggy layers of clay, because of which the total compressible mass is often approximately 10 m.

² *Kinds of peat*

Descriptions can be found in the Sections 1.4.2.2; Chapter 5, the Figures 1, 2, 3 and 4, Table 2 and Section 5.3.1; and Chapter 9.

³ *Vertical drainage*

From 1952 onwards, vertical sand drainage has been applied in The Netherlands, especially in the area around Rotterdam. The diameter of the drain usually amounts to 0.25-0.3 m, the drain distance is 2 to 4 m and the length may rise to 30 m.

In The Netherlands the reputation of sand drainage is generally good. This is partly caused by the structure in layers of the subsoil, because of which the horizontal permeability is often larger than the

vertical permeability.

Sand drainage is applied by means of syringing with water and ramming. With ramming a good drainage path will come into being, whereas with syringing the hole could be more irregular, by leaching of layers of sand.

With syringing the smearing effect is absent and an increase of the confinement of water as a result of displacement of soil as with ramming will not either take place.

Synthetic drains are brought to depth with the aid of a steel pipe duct by pressing, ramming, vibrating or syringing.

The volume of these drains is small, because of which little displacement of soil will occur. The site of work will remain clean and will not be polluted by argillaceous and peaty rinse water as would be the case with the application of sand drainages.

The price of the synthetic drains per m² is higher than that of sand drains, starting from a same measure of acceleration of consolidation.

⁴ *Equation of Koppejan and secular effect*

The equation of Koppejan, presented in Rotterdam (ISMMFE, 1948, Vol. III page 36) runs as follows:

$$S = h_o \left(\frac{1}{c_p} + \frac{1}{c_s} \log t \right) \ln \frac{p_o + p}{p_o}$$

The same equation has been used in the marginal note belonging to Figure 4, Chapter 11.

For a period of 30 years $\log t \approx 4$.

For peat the factor $\frac{1}{1/c_s + 4/c_p}$ usually lies between 2 and 10.

The values for c_s and c_p are, as a rule, not fixed.

After reaching a certain grain tension (marginal tension) often a smaller value for c_s and c_p is found.

With experiments on clay and peat even after the end of the consolidation period settlement will go on and no end value is reached, not even with experiments that have been continued for years.

The cause of this is not quite obvious, and is partially attributed to water, present in very narrow pores, and therefore more bonded.

The secular effect, found by professor Landva in dry wood waste, may perhaps be compared with creep effects, as they occur with wood and

concrete.

5 *Flugsand*

As an addition to the further description in Chapter 11, Appendix 2, we may state, that the stability of flugsand may at least be compared with that of sand.

After compaction counted may be with an angle of internal friction of approximately 40° .

Furthermore clay percentage is less than 10% and the median of the size of the particles approximately 600 μm .

The permeability is approximately 4 mm/sec.

6 *Lightweight fill*

(From the editors) Turves (blocks of dried peat), formerly used for fuel, were used as light-weight fill in the peat district discussed during the symposium.

Today peat harvesting for fuel is (practically) finished in The Netherlands, this material is not available anymore, or has to be transported too far.

Sawdust was never used to our knowledge.

7 *Foundations*

In The Netherlands buildings are designed thus, that they will not be susceptible to settling. A number of reasons for this can be mentioned:

- floors that will have to remain level
- building in more storeys and large units with a rigid centre (lift-shaft)
- eccentricity, caused by irregular settlements, will introduce increasing loads
- jamming of doors and windows
- disturbance in pipes for gas and water

In farm building experiments with slags have taken place. Instead of pile foundations a concrete floor was applied on a layer of slags. On this the stables of wood were built. Generally speaking this has not been very successful because of irregular settlements afterwards.

8 *Jacket friction*

Positive jacket friction on foundation piles in layers of clay and peat will only occur with strongly cohesive soils.

These layers of clay and loam only occur in a few areas in The

Netherlands. In general the layers of clay are saggy and also in the layers of peat practically no frictional forces between pile and soil will come into being.

This holds for positive as well as for negative friction.

The negative skin friction therefore will occur in those layers with a large frictional resistance between pile and soil, that are exposed to settlement because of the more sagging layers in the subsoil.

To prevent this negative skin friction piles are sometimes provided with a bitumen coating, which will undergo extensive deformations even with slight shearing forces. The bitumen coating then functions as a sort of lubricant between soil and pile.

The surrounding soil will settle, but will exercise little or no shearing forces on the shaft of the pile.

⁹ *Land abutments of bridge* (cf. Photo 5 in Chapter 11)

In order to prevent pushing effects the space between land abutment and bridge deck is limited.

A part of the available space is necessary for the thermic changes in length, so that there are few possibilities for displacement in a horizontal direction.

Besides, horizontal displacements will mostly be uneven, because of which a distortion of the movable part in the horizontal surface may be caused as well.

This may lead to jamming of the bridge length- or crosswise and possible failures in the regulating equipment for the operation of the bridge.