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No-Recess test site Hoeksche Waard (Netherlands)
Le site d'essai de No-Recess en Hoeksche Waard (Pays Bas)

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ABSTRACT: The No-Recess test site is situated in the Hoeksche Waard polder in the Netherlands with a 9 meter soft top layer of clay and peat. The purpose of this test site with five test embankments is to demonstrate the feasibility of new methods for the construction of (rail)road embankments in soft soils in the Netherlands. The geometry of the embankments with a high and a low part are representative for (rail)road embankments in the Netherlands. The embankments have been build in 1998 and will be monitored and evaluated during the next 2 years.

RÉSUMÉ: Le site d'essai de No-Recess est situé dans le polder de Hoeksche Waard en Hollande avec une couche supérieure douce de 9 mètres d'argile et de tourbe. Le but de ce expérimentation avec cinq remblais d'essai est de démontrer la praticabilité de nouvelles méthodes pour la construction de remblais des chaussees et de chemin de fer dans les sols doux en Hollandes. La géométrie des remblai avec un élevé et un inférieur partie sont représentatif pour remblai de chemin de fer et des chaussée. Ils sont construit en 1998 et ils seront surveiller et évaluer pendant les prochaines 2 années.

1 INTRODUCTION

No-Recess is the acronym for New Options for Rapid and Easy Construction of Embankments on Soft Soils. New techniques have been tested at the test site in the Hoeksche Waard near ‘s Gravendeel. This project is a joint venture of the Project organization High-Speed Rail South (PHZI) and the Ministry of transport, Public Works and Water Management, Road and Hydraulic Engineering Division (RWS/DWW). A part of this research has been subsidized by the European Community (EuroSoilStab lime-cement columns project). The techniques have been selected during a workshop in may 1997 in Delft by specialists from different countries (Duijvenbode. 1997). These methods have been applied on small or large scale but are not tested under Dutch circumstances in peat and organic clays.

1.1 *Construction methods for rail and road infrastructure*

The most common used structures for rail and road infrastructure in the Netherlands are embankments on wick drains and structures (bridges etc) on concrete piles. The thickness of the soft layer varies between 5 and 15 meters. The (dis)advantages of this construction on soft soils are summarized in the table 1. The No-Recess project investigates alternatives for the Dutch circumstances intermediate between these soft and stiff extremes. The construction costs of the new techniques must be lower than a concrete structure solution.

Table 1. Construction alternatives for road and rail infrastructure in the Netherlands on soft soils

Technique	Advantages	Disadvantages
Embankment of sand and wick drains	Flexible and cheap	Construction and maintenance risks
Concrete structure	Low maintenance	Expensive and not flexible

1.2 *Design specifications*

The No-Recess specifications have been formulated by the PHZI and RWS/DWW as follows:
- short construction time: less than 18 months;
- low residual settlements: less than 30 mm in the 30 years after 24 months after start construction;
- minimum construction risks;
- minimum surplus of soil;
- sufficient stiff behavior of the construction under dynamic loading by high speed trains;
- minimum damage during widening of existing rail or road construction;
- minimum influence on geo-hydrological situation.

PHZI and RWS/DWW evaluate the results for construction of low embankments after 6 months after start construction:
- total settlement less than 100 mm (only for widening of existing road);
- residual settlement in the next 30 years less than 100 mm;

Also for the high embankments, 12 months after start of construction:
- total settlement less than 100 mm (only for widening of existing road);
- residual settlement in the next 30 years less than 100 mm;

1.3 *Selection of new techniques*

Table 2 gives the new techniques which have been selected for testing in the No-Recess test site. Some of these new techniques have been tested in different test embankments. One test embankment will be used as reference. This reference is a test embankment with a traditional sand fill. Vertical wick drains and a surcharge have been used to accelerate the settlements.

Table 2. No-Recess techniques tested in the Hoeksche Waard

Technique	Description
Lime-Cement columns	Dry-mix method (Japan and Scandinavia)
Blast Furnace cement/Anhydrite binder	Combination of binders by Delft Geotechnics (Netherlands)
Fräs-Misch-Injectionsverfahren	Cut-Mix-Injection Process (Germany)
Geokunststoffummantelten Sandsäulen	Geotextile Coated sand Columns (Germany)
AUGEO piles	PVC pipe with filling of foamed concrete (Netherlands)
Load transfer platform	Geogrid-reinforced mattress on piles (United Kingdom)
Embankment of stabilized soil	On site Mix plant to stabilize the soil with a binder (Netherlands)
Dynamic performance	DyStaFit method (Germany) with United Kingdom expertise

2 SITE INVESTIGATION

The test site is situated in the trace of the High Speed railway link from Amsterdam to Brussels. The railway will be built on a low embankment in the Hoeksche Waard. The area of the test site is approximately 400x125m (Figure 1). Five embankments have been constructed with a high part (5 meter above ground level) with a slope to a low embankment (1 meter above ground level). The

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width of the top of the embankment at the top is 10 m. The test embankments in the Hoeksche Waard (HW) are numbered from HW1 until HW5 and are indicated on the location plan.

Figure 1 No-Recess test site Hoeksche Waard (NL)

2.1 *In-situ tests*

The in-situ soil investigation has been carried out before the construction of the embankments:

- piezo cone penetration tests to a maximum depth of 15 m below ground level (grid of 10 m);
- at each high part one boring to a maximum of 12 m for continuously undisturbed samples;
- field vane tests with a depth-interval of 1 m to a maximum depth of 9 m below ground level;
- Cone Pressuremeter tests with a average depth interval of 2 meter to a maximum depth of 9 m below ground level.

2.2 *Classification laboratory tests*

The classification laboratory tests consists of the following tests: classification every 1 meter (description, photographs, water content, bulk density, density of solids, pH value of the soil, Atterberg limits), Von Post classification (every peat layer), particle size distribution (1 per boring).

2.3 *Special laboratory tests*

The special laboratory tests consist of the following tests: organic content, carbonate content, Fall Cone strength, sulfate content (all tests every 1 meter) isotropic consolidated undrained multistage triaxial and oedometer compression tests (all tests 3 per boring).

2.4 *Geotechnical profiles*

The results of the soil investigation have been interpreted and translated to a geotechnical profile for each embankment. The general soil profile for the test site consists of a toplayer of very silty clay with an average thickness of 3.2 m. Under this layer a peat layer with a strongly varying thickness, averaging 1.5 m This peat layer, known as ‘Hollandveen’, overlies a thick layer of very silty clay, locally moderate to very organic and has a thickness of about 4 m. Under the clay layer a peat layer of about 1 m thickness is present referred to as the ‘Basisveen’. All of the above mentioned layers are Holocene deposits. The first meters of the underlying water bearing sand layer is characterized as medium fine, slightly silty sand. In the test site we have an artesian situation.

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3 TEST EMBANKMENTS

The five test embankments have been designed by engineers with relevant experience. The final geometry of the test embankment was specified to have a high part and a low part and slopes of 1:2 (v:h). At the end of the high part a imaginary bridge was situated with a transition zone of 10 m with a residual settlement starting from 0 to 30 mm. The construction time started when the working platform was made. After 18 months the embankments are given their final shape. A period of 6 months is reserved for the imaginary construction of the road or rail top structure. After this period or 24 months after the start of the construction the residual settlements must be less than 30 mm in 30 years. Other specs were already mentioned in paragraph 1.2. The different designs will be discussed in the next paragraphs.

3.1 *Conventional test embankment (HW1)*

The conventional test embankment is constructed to compare the performance of this construction with the other test embankments. The staged construction was completed in 6 months.

Table 3. Design characteristics of the conventional test embankment (HW1).

Variable	Low embankment	High embankment
Surcharge	1.8 m sand for 1 year	2.5 m sand for 1 year
Embankment	1 m sand	5 m sand
Wick drains	1 m triangular grid	1 m triangular grid
Depth of drains	1 m above sand layer	1 m above sand layer

3.2 *Stabilized soil columns(HW2)*

The Scandinavian lime-cement mixing method of stabilization soil was used in test HW2. This dry mix technique uses dried air to transport the binder. Scandinavian experience would use the combination of Portland cement and unslaked lime. In Dutch soils a new binder mix of blast furnace cement and anhydrite is expected to give better performance. For this reason the general name is “stabilized soil columns”. The columns and the block stabilization (overlapping short columns) are produced with a speed of 500 m^1 per day. The embankment was built in 1 month. More details of the design of HW2 are shown in table 4.

Table 4. Design characteristics of the stabilized soil columns test embankment (HW2).

Variable	Low embankment	High embankment
Surcharge	1 m sand for 1 year	1.5 m sand for 1 year
Embankment	1 m sand	5 m sand
Stabilized block	1.5 m	-
Columns	600 mm, 1.6m square grid	600 mm, 1-1.2 m square grid
Depth of columns	0.5 m in sand layer	0.5 m in sand layer
Binder*	200 kg/m3	200 kg/m3

* 80% Blast furnace cement / 20% Anhydrite, 50% higher dosage in lower 1,5 m (geo-hydrological barrier)

3.3 *Stabilized soil walls (HW3)*

Test embankment HW3 has been built on stabilized soil walls installed by the FMI process which stabilizes the soil in-situ with a cutting tree, on which the cutting blades are rotated by two chain systems. The cutting tree, which is inclined up to 80 degrees, is dragged behind the FMI machine. Due to the special configuration of the blades, the soil is not excavated but mixed with the cement slurry (mixed in place). The translation speed of the machine is circa 1 meter per minute with a maximum depth of 9 m (width is 500 mm). The embankment was constructed in 2 weeks. A summary of the design is shown in table 5.

Table 5. Design characteristics of the stabilized soil walls test embankment (HW3).

Variable	Low embankment	High embankment
Embankment	1 m sand	5 m sand
Load transfer platform	-	0.5 m with 3 geotextiles*
Stabilized block**	1.5 m depth x 1000 mm	-
Stabilized walls**	2 x 500 mm, 1-2.5 m distance	2 x 500 mm, 1-2.5 m distance
Depth of walls	9 m below ground level	9 m below ground level

* Tensar geogrid type SS20, SS30 and 80RE with crushed rock

** Binder dosage 150 kg/m3 , 80% Blast furnace cement / 20% Anhydrite

3.4 *Geotextile Coated sand Columns (HW4)*

In HW4 we tested the Geotextile Coated sand Column (GCC) system. The first step is to vibrate a casing with two valves at the bottom until it reaches the sand layer. A layer of 40 cm sand/bentonite is made. A geotextile stocking is installed and filled with 1 meter of bentonite/sand mixture to create a geo-hydrological barrier. The rest of the column is filled with sand until the top of the casing. The casing is vibrated and pulled upwards, compacting the sand. A production rate of 40 columns a day seems possible. Table 6 shows the design of high and low embankment with a load transfer platform of geotextiles. The embankment was built in 6 weeks.

Table 6. Design characteristics of the Geotextile Coated sand Columns test embankment (HW4).

Variable	Low embankment	High embankment
Surcharge	1 m sand for 1 month	-
Embankment	1 m sand	5 m sand
Excavation	1.5 m	-
Load transfer platform	1 geogrid Fortrac 80/80-10	3 geogrids Fortrac 200/30-30
Columns	GCC system 800 mm*	GCC system 800 mm
Distance columns	triangular grid 2.4-3.4 m	triangular grid 2.0-2.4 mm
Depth columns	9 m below ground level	9 m below ground level

* Geotextile Coated sand Column with a geo-hydrological barrier of sand/bentonite (12%)

3.5 *Stabilized soil test embankment on piles (HW5)*

In test embankment HW5 the sand in the embankment is replaced by stabilized soil from another site. This stabilization is made using an ARAN installation (mix-in place plant). The piled foundation is made with wooden piles and the AuGeo pile system. The AuGeo pile procedure is simple. A Cofra stitcher (normally used for the installation of vertical wick drains) pushes a steel plate into the ground with a casing (180x180x6.3mm) with a maximum pressure of 25 ton. A PVC pipe (160x2 mm) is sealed at the bottom, inserted in the casing and filled with the foamed concrete (unit weight 1200 kg/m3). The casing is lifted and the PVC pipe is cut off after sufficient hardening of the concrete and covered with a concrete tile of 300x300 mm. The production of this system is 200 piles a day. The stabilized embankment was built in 6 weeks. (Cortlever 1998)

Table 7. Design characteristics of the Stabilized Soil test embankment (HW5).

Variable	Low embankment	High embankment
Embankment*	1 m stabilized soil	5 m stabilized soil
Load transfer platform**	2 geogrids Fortrac R320/50M	2 geogrids Fortrac R200 /50 M
Pile type	AuGeo pile system	AuGeo pile system / wooden piles
Distance of piles	1 m square grid	0.8 m square grid
Depth of piles	12 m below ground level	12 m - 13,5 m below ground level

* Binder dosage 120 kg/m3 , 80% Blast furnace cement / 20% Anhydrite

** Total thickness of 30 cm with a fill of crushed concrete.

4 MONITORING

The monitoring instruments were installed after the construction of the foundations and before the construction of the embankment. The monitoring will be continued until the end of 1999.

4.1 *Local coordinate system*

Each embankment has its own positive oriented world coordinate system with its origin in the center. The X-axis is in the length direction of the embankment and the Y-axis in the width direction. The Z-axis origin correspondent with the Dutch Datum level 'NAP'. This system makes its easy to point out the location of the different field tests and monitoring instruments. Settlement of the five embankments is measured with respect to the two Fixed Cone Points.

4.2 *Monitoring instruments*

The monitoring program for each embankment is schematized in figure 2. The frequency of measurements is derived from the golden section starting after the installation of the monitoring equipment and before the construction of the embankment: 1,2,3,5,8,13,21,34 etc. days. The start of the monitoring in 1998 differs per test embankment and are respectively 20 February (HW1), 29 June (HW2), 27 March (HW3) 17 July (HW4) 29 September (HW5). The measurements (vertical and horizontal displacement, pore water and soil pressures) are summarized in the table 8:

Table 8. Monitoring program

Description	Instrument	Location
SETT	Settlement top layer	5x5m grid at top of embankment
SETH	Settlement hose	Longitudinal section and low and high cross section
SETP	Settlement plate	Longitudinal section every 10 m and 2 cross section
EXTM	Extenso meter	5 levels in soft layer under high embankment
INCP	Inclinometer	3 in cross section high embankment
PWSP	Pore water stand pipe	1 at ground level under high embankment
PWPT	Pore water pressure transducer	3 levels in soft soil layer
SPCL	Soil pressure Cell	1 beside the column and 1 at the top

5 PRELIMARY RESULTS

It is to early to present the monitoring results of the different embankment. The first results of the stabilized soil columns are published (Duijvenbode 1998). The quality has been tested with the inverted wing penetrometer (diameter 400 mm). The measured drawing forces (pull out resistance) gives an impression of the undrained shear strength of the column. To improve the quality of the columns some tests have been made with a combination of a sand column (diameter 350 mm) which is stabilized with the surrounding soil as a stabilized soil column (600 mm). The results seems promising as shown in figure 3 and 4. The addition of sand seems to improve the quality of the in-situ stabilized columns.

6 EVALUATION

The results seems promising but the first evaluation will be at the end of 1998. The test embankments HW1 and HW2 will be reshaped in 1999 according to the final geometry. The dynamic behavior will be tested with the DyStaFit. This vibrator with a diameter of 2,5 m simulating the vibrations of a high speed train. A second evaluation is planned in 2000. The performance of the tested techniques will be evaluated according to the specs. The monitoring time is based on a average construction time of 3 months. A construction time of 6, 12 or 24 months correspondences with a monitoring time of 100, 300 or 600 days. The settlement S= $(Z_i\text{-}Z_0)$ will be monitored and evaluated. The logarithmic rate of settlement LRS = $(Z_{i-1}\text{-}Z_i)/\log(t_i/t_{i-1})$ can be used as an evaluation parameter for the residual settlement.

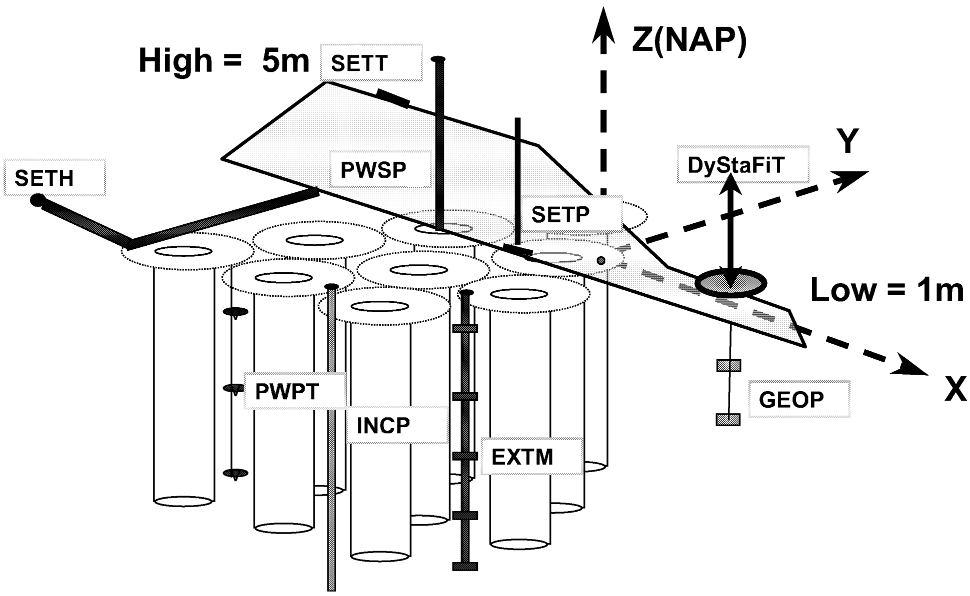

Figure 2. Instrumentation of test embankments

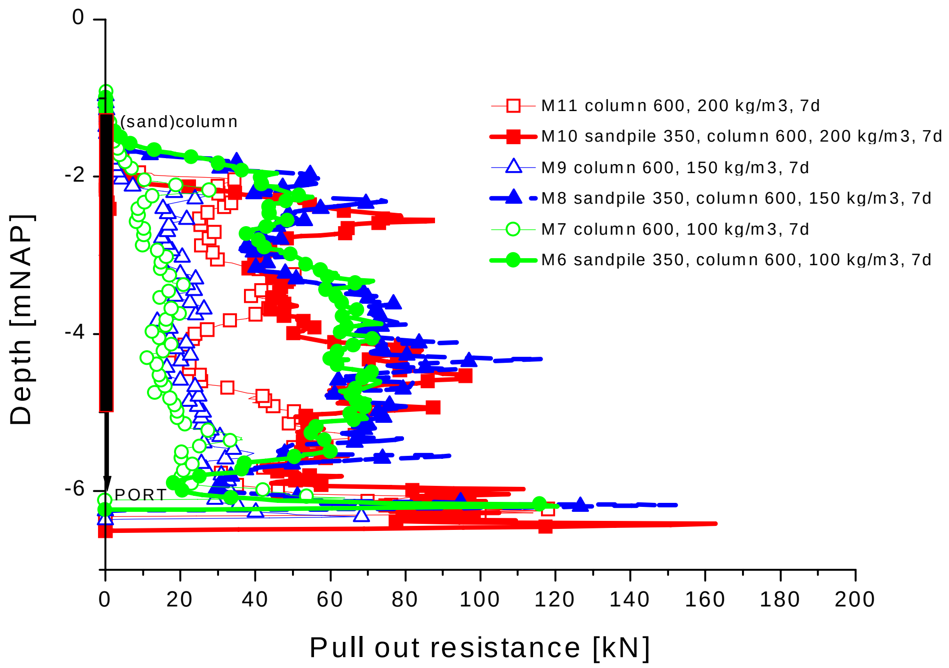

Figure 3. Inverted wing penetrometer results of single stabilized (sand) soil columns (HW0)

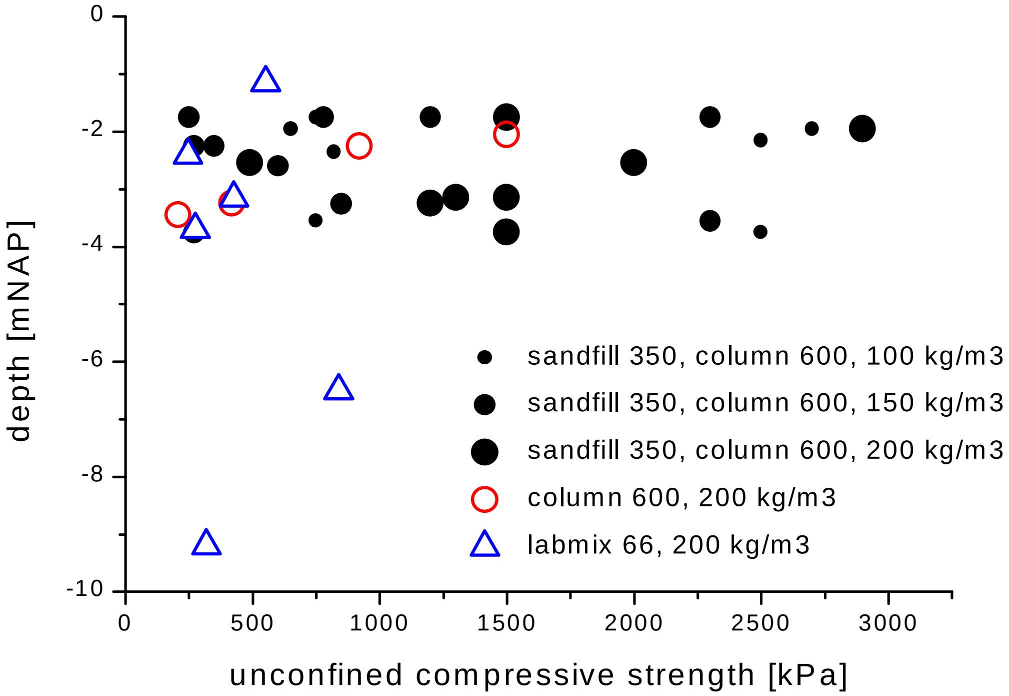

Figure 4. Unconfined compressive strength tests of samples of the stabilized (sand) soil columns (HW0)

7 CONCLUSIONS

Five test embankments have been constructed at the No-Recess test site in the Hoeksche Waard in the Netherlands. Several new techniques have been used: stabilized soil columns, stabilized soil walls, geotextile coated sand columns, geogrid-reinforced mattress and a piled and stabilized soil embankment. It is expected that the specs will be fulfilled to construct rail and road embankments with a short construction time and less long term deformations in soft soils in the Netherlands.

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