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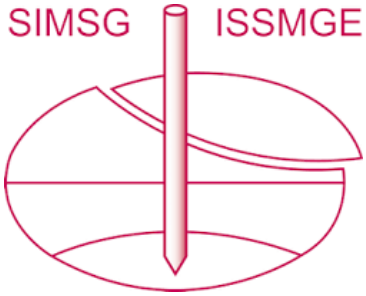

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Stabilisation of a bridge on a sliding slope using a drainage screen

La stabilisation d'un pont sur une pente instable au moyen d'un écran de drainage

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SYNOPSIS: By careful site investigation a slip surface was revealed below the foundation of a concrete bridge along which two foundation piers were creeping downhill. High pore pressures in the sandy seams of the subsoil seamed to be the apparent cause of the slope instability. A novel type of drainage screen uphill the bridge together with underpinning was successfully employed and stoped further slide movement.

1 INTRODUCTION

The north-south motorway from Vienna to Graz crosses a hilly area of periglacial origin whith a well developed drainage pattern which is generally prone to slope instabilities. A multispan prestressed concrete bridge (fig.1) was built over a relatively flat side valley which slopes at an angle of about 7° towards main drainage valley.

Already during construction of the bridge foundation an instability of the slope was suspected and a subsequent precision survey carried out twice a year at markers within the slope uphill of the bridge (fig.2) and at three central bridge piers, indicated that the ground surface as well as the bridge piers were progressively moving downhill at a mean rate of about 35 mm a year.

In addition to this it could be demonstrated that pier no.2 and no.3 had undergone settlements of 90 mm and 40 mm respectively since its contruction. Two inclinometers were then installed, one uphill and one downhill of pier no.3 (fig.2). Even over a relative short observation period of 3 months it could be demonstrated that a slip surface had developped below the base of the pier foundations. Apparently the whole slope was creeping downhill along this slip surface.

2 SITE INVESTIGATION AND MONITORING

Each of the bridge supports was founded on a 3 m diameter solid concrete pier with its base at about 10 m below ground level (fig.1), keyed into a tertiay compact layer of fine sandy silt, generally a good foundation material. The soil above the foundation layer consists of varying layers of sandy clayey silt interspersed with thin layers of fine to medium silty sand.

When the problem of the deformation of the bridge foundation became apparent additional site investigation was ordered together with the installation of 2 no. further inclinometers and 4 no. multiple level piezometers (fig.2) in order to monitor the ground movements and the pore pressures in the various layers. The resulting observations showed relatively high piezometric pressures in the sandy seams of the subsoil, especially in the zone near the slip surface.

3 REMEDIAL MEASURES

Various solutions for stabilising the pier foundations and the slope were investigated. This included underpinning the existing relatively shallow piers and constructing around each pier a large diameter well at sufficient distance

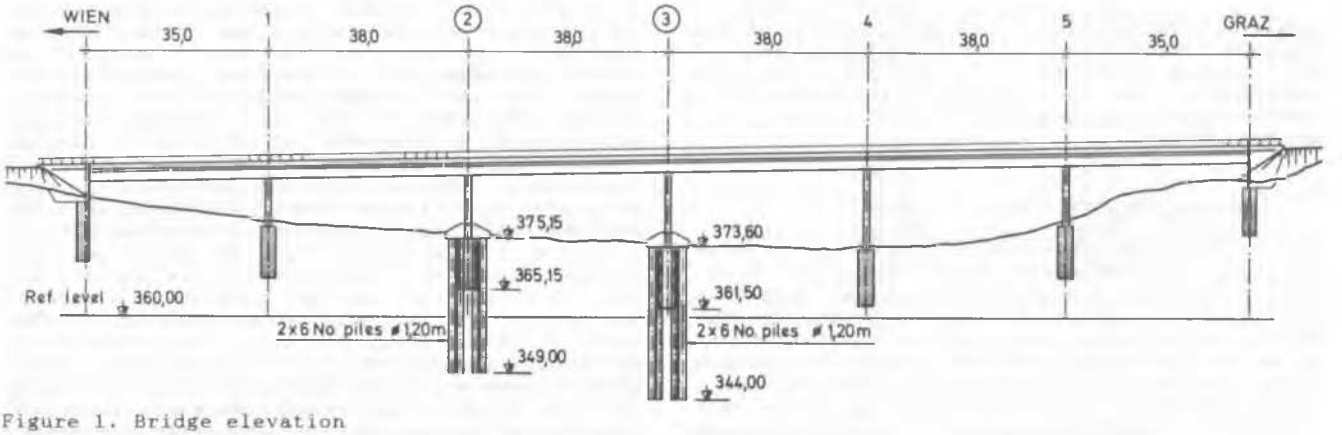

Figure 1. Bridge elevation

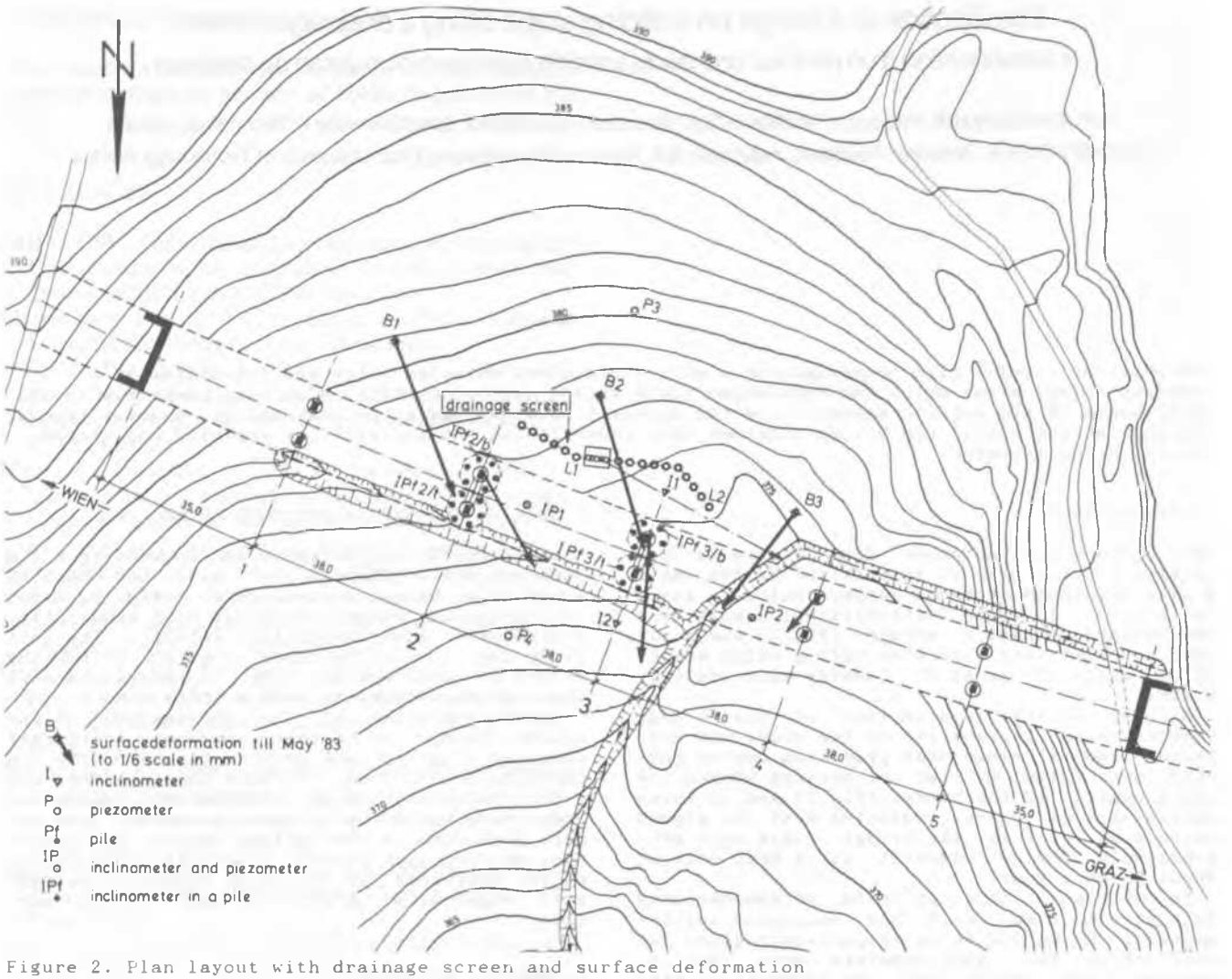

Figure 2. Plan layout with drainage screen and surface deformation

from the underpinning to allow for further creep of the unstable slope ("button-hole" solution).

This solution would have provided only a limited life considering a continued creep of the slope. Besides of difficulties expected in its construction, this solution proved to be very costly. Therefore an alternative solution was suggested which promised a cure of the cause of the creeping slope: relieving the excessive pore pressures in the sandy seams of the sub-soil in combination with underpinning the bridge piers by bored piles.

3.1 Construction procedure

This finally adopted solution consisted in constructing around each pier foundation 6 no. bored piles with a diameter of 1.20 m in a predetermined construction sequence (fig.4). The maintenance of this sequence was important as it helped to minimize the inevitable settlements of the old foundation during pile construction.

The bottom of the underpinning piles were founded at depths of about 30 m below ground surface within a layer of overconsolitated very compact clayey silt, locally called "Opok". The heads of these piles were connected with the top of the old foundation piers by a hexagonal pile cap prestressed on two directions (fig.4).

In order to stabilize the slope it was decided to eliminate as much as possible the build-up of high pore pressures in the sandy seams of the subsoil by means of a drainage screen located uphill of the bridge (fig.2). This drainage screen consists of 21 no. vertical drainage piles with a diameter of 1.20 m to varying depths of 20 m to 32 m below ground level with a centreline distance of 2.70 m and connected with each other near the bottom by a 3 inch pipe. The drainage piles were constructed like cased bored piles but filled with gravel instead of concrete as the casing was withdrown. Before filling the bore with gravel a man was lowered in a cage to the bottom of the hole. From there he drilled with a small electric drill, equipped with extensible auger rods, a 3 inch diameter horizontal cased hole until he made connection with the previously constructed drainage pile. All drainage piles were filled with gravel only to

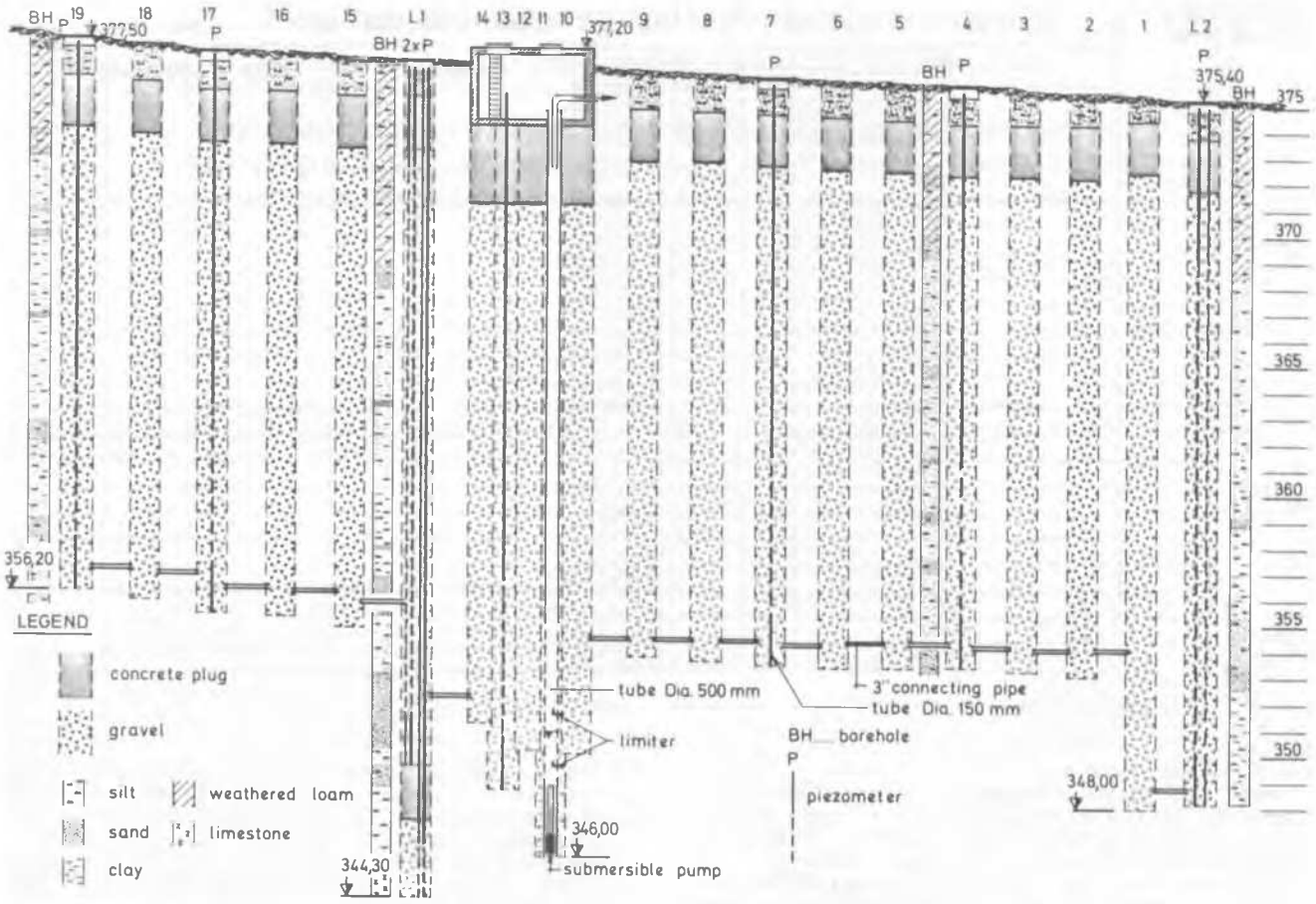

Figure 3. Elevation of drainage screen with pump chamber

about 3 m from the surface and than closed by a 2 m concrete plug (fig.3).

Near the centre of the screen 5 no. drainage piles were inter-connected by overboring. In one of these drainage piles an electric submersible pump with a riser pipe to the top was installed. Water draining from the screen was automatically pumped off at preset pressure levels (limiters) (fig.3).

On top of the 5 no. centre piles a pump chamber was constructed housing the electric installations. From the pump chamber the riser pipe was connected by a buried pipe to a surface ditch.

In 7 no. out of the 21 no. drainage piles, single or multiple piezometer were installed in order to monitor the water levels during the operation. The water drained off through the sreen was measured by an electrical chart recorder and also the discharge point: it amounts to an average of 6400 litres per 24 hours. Thus the working efficiency of the screen could be proven.

4 CONTROL MEASUREMENTS

After completion of the remedial works three types of control measurements were initiated following a predetermined time program in order to observe and check the continued efficiency of

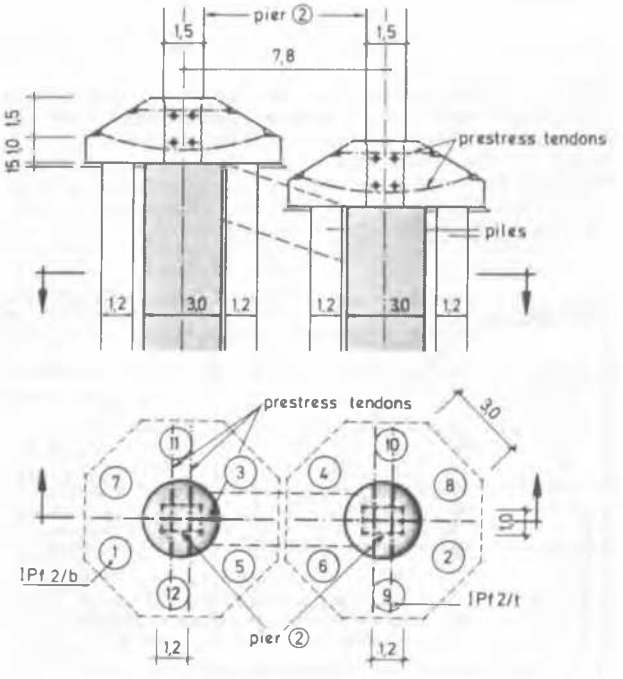

Figure 4. Pile cap section and plan

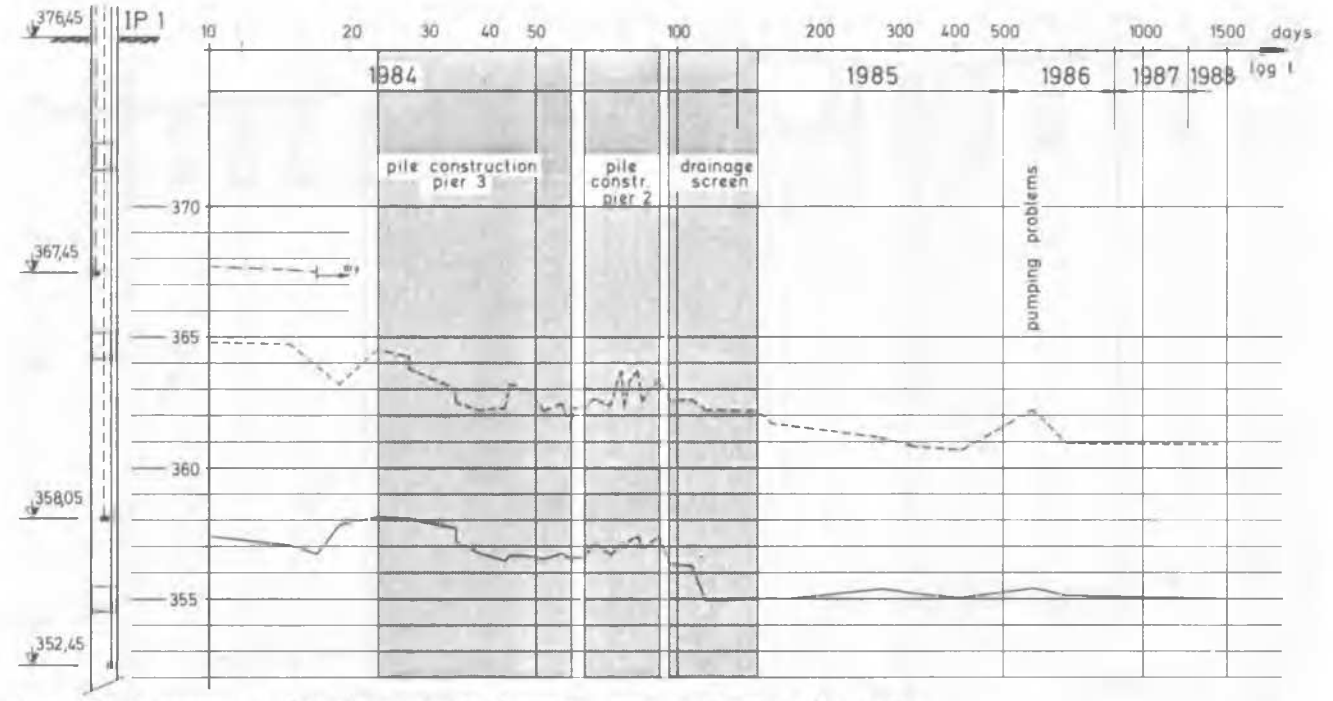

Figure 5. Piezometric levels at IP 1 observed over a period of 4 years

the remedial measures:
- settlement measurements by precision nivellements at the bridge supports (fig.6)
- inclinometer observations in order to monitor any ground movements within the slope
- observations of all installed piezometers in order to monitor the effectiveness of the drainage screen (fig.5)

4.1 Results

- An observation over a period of four years showed that no further settlement of the bridge foundation has occured.
- Annual measurements of the inclinometers showed no further underground movements over a 4 year period i.e. the creeping of the slope has apparently stopped.

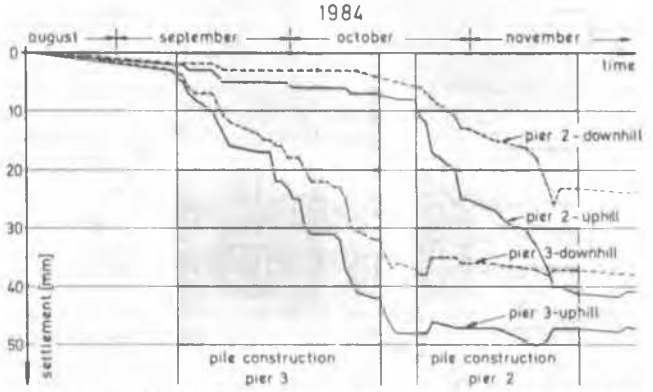

Fig 6. Settlement of piers during construction

- The piezometer observations over a period of more than 4 years proved the effectivness of the drainage screen, as demonstrated (fig.5). The reduction of the piezometric levels on operation of the screen can be seen clearly, which was generally maintained throughout the observation period.

5 CONCLUDING REMARKS

The described stabilisation of a bridge foundation creeping downhill along a slip surface which had developed below the base of the foundation employes a drainage screen to relieve the pore pressures in the sandy seams of the subsoil and thus increases the effective stress in the soil. This together with underpinning the existing foundation proved to be successful over an observation period of several years. Under similar soil conditions the method of using a drainage screen could be considered as a viable alternative to more expensive alternative methods of slope stabilisation.

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