SETTLEMENTS OF AN EMBANKMENT FOUNDED ON A SOFT SOIL

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Abstract

The construction of a pre-loading embankment was begun in December 2001. The total height of the embankment, which remained in place until March 2002, was 9 m, and it was founded on a marshland soft soil. Because of the nature of the foundation soil, a monitoring system was installed in order to assess the embankment settlements. The measurements of settlements were obtained by field instrumentation, which consisted of ten settlement plates, enabling optical levelling measurements at these points, and one measuring tube, which was installed beneath the embankment and used to assess the settlement profile of the embankment using a hydrostatic profile gauge. The settlements measured by the hydrostatic profile gauge showed a continuous increase in the vertical displacement after the end of construction for approximately half a year. The maximum measured settlement was 43 cm. It was shown that the results are very similar to those observed on settlement plate SP-3, which was located very close to the measuring tube. The use of a measuring tube and a hydrostatic profile gauge, which do not interfere with the construction works, proved to be a very practical solution.

1. Introduction

The location of the embankment was on the Barje marshland, just a few kilometres south of the city of Ljubljana (see Figure 1). Because of the nature of the foundation soil, a monitoring system was installed in order to assess the embankment settlements. Settlement measurements indicated the time which needed to elapse before removal of the temporary surcharge load. It was the first time in Slovenia that a hydrostatic profile gauge was used to measure settlements at a selected profile beneath the embankment (the length of the measuring tube was 80 m). Before this, only settlement plates - consisting of a steel square plate, placed on the original ground surface, to which a riser pipe is attached which, in turn, permits optical levelling measurements to be taken - to measure settlements of embankments were used.

Figure 1. Location of the pre-loading embankment

2. Embankment construction

Construction of the pre-loading embankment, which was founded on a compressible marshland soft soil, was begun in December 2001 (see Figure 2). It remained in place until March 2002 (see Figure 3). The lower strata of the embankment were 3 m high and made from ash from a thermo-electric power plant, whereas the upper strata, made from the crushed stone, were 6 m high. The total height of the embankment was thus 9 m.

Figure 2. The embankment at an early stage of construction

Figure 3. The completed embankment

3. Field instrumentation

Settlements were measured by means of field instrumentation, which consisted of 10 steel settlement plates (SP-1 to SP-10), laid in 3 lines across the embankment, and 1 plastic measuring tube (MT-3, length = 80 m), placed at the selected profile (see Figure 4). The settlement plates were installed at the bottom of the lower stratum of the embankment, just ahead of the start of the construction works. The measuring tube was placed in an ash stratum, about 1.0 m below the crushed stone embankment, after the ash embankment had been completed (see Figure 5). Movement of the plates was determined by conventional geometric levelling, whereas the vertical movement of the tube, at points 0.5 m apart, was monitored using a hydrostatic profile gauge.

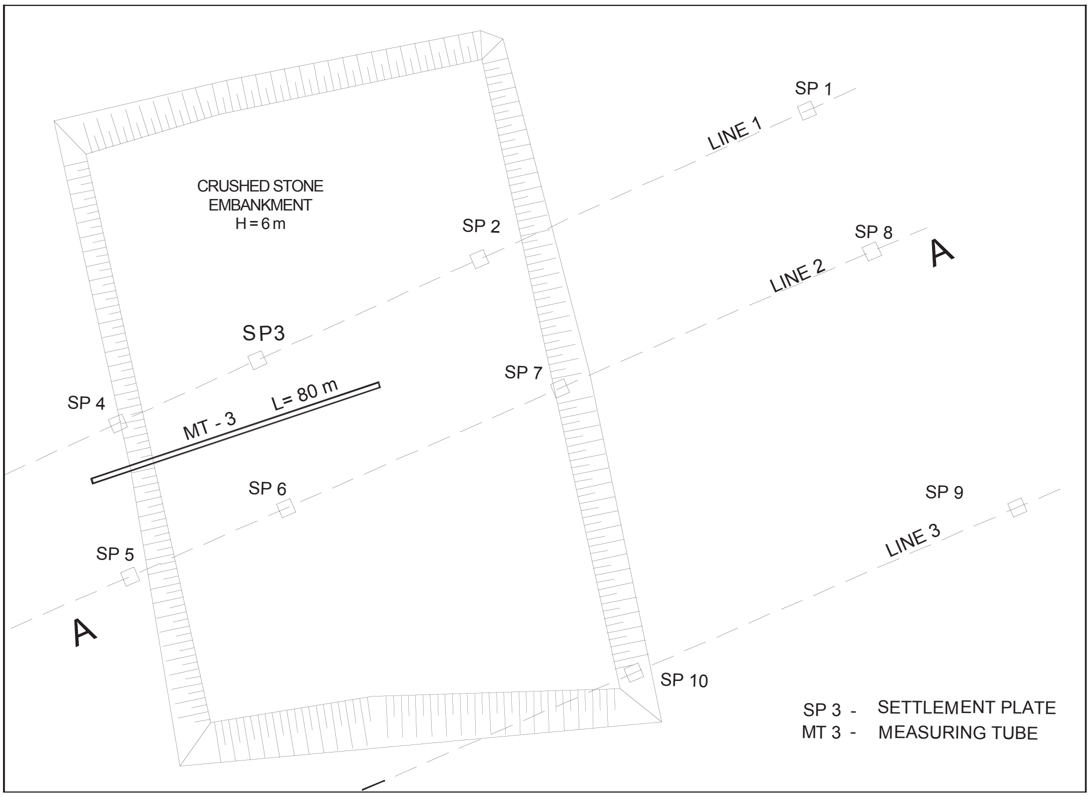

Figure 4. Field instrumentation of the embankment – plan

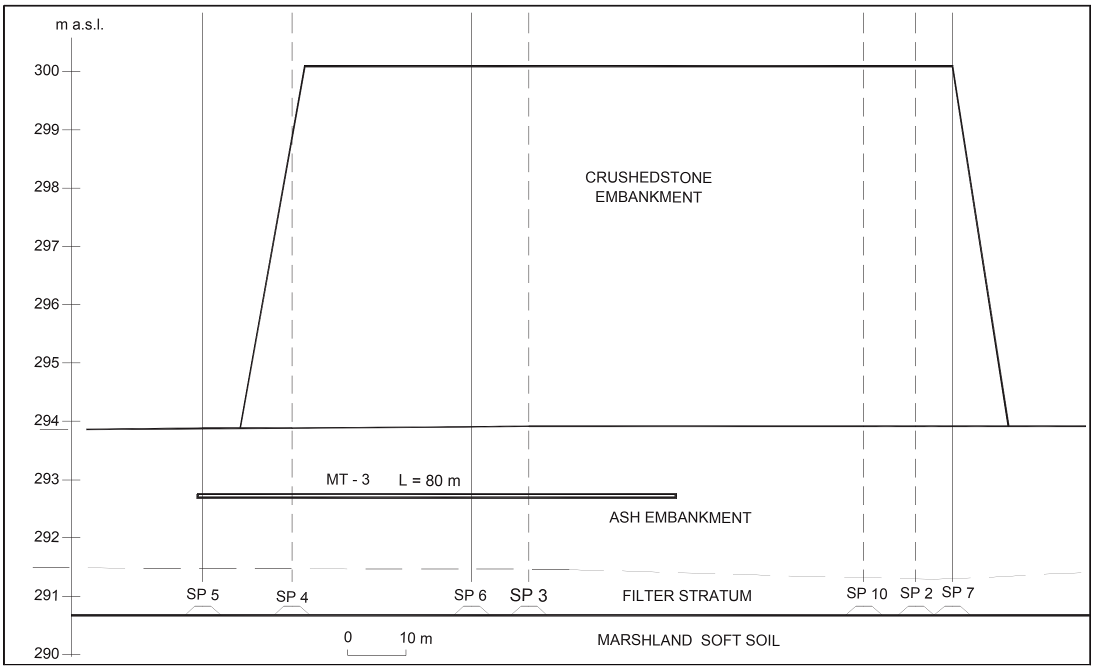

Figure 5. Field instrumentation of the embankment – cross section A-A

3.1 The hydrostatic profile gauge

The hydrostatic profile gauge consisted of a control unit, a readout unit and a length of triple tubing connected to a settlement probe, which can be pushed (with aluminium rods) or pulled (with a draw-cord) through the access tube (see Figures 6 and 7). Two of three small tubes are filled with water and are constantly back-pressurized in order to overcome surface tension effects, and to prevent the formation of bubbles. Measurements of elevation are taken at regular intervals in an access tube, which is laid in a sand-filled trench. The hydrostatic head at the probe 'H' is measured with the aid of a differential pressure transducer. These readings are related to a reference pin outside the tube and in this manner a complete profile of the tube can be established. By comparing profiles taken at different times, the vertical displacement of the tube can be determined to an accuracy of ± 1.0 cm, which is excellent for this application.

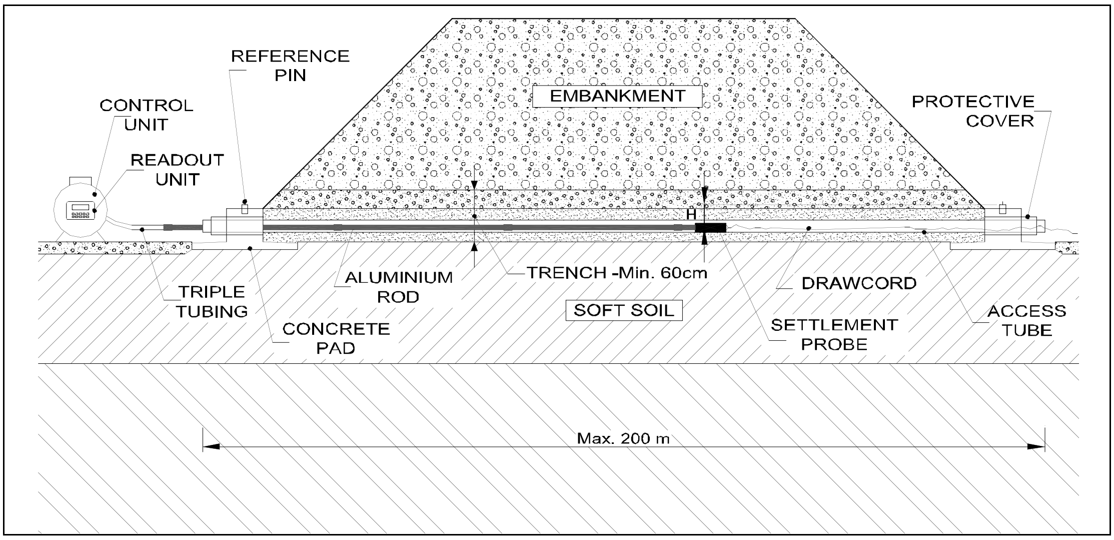

Figure 6. Schematic arrangement of the hydrostatic profile gauge

Figure 7. Measurement using the hydrostatic profile gauge (the probe is being pushed)

4. Results

4.1 Settlement profiles at different times along the measuring tube

Figure 8 shows the settlements measured using the hydrostatic profile gauge along the measuring tube MT-3, at points 0.5 m apart, at different times since the 1st measurement. The settlements showed a continuous increase in vertical displacement after the end of construction for approximately half a year. It can be seen that, 256 days after the 1st measurement, the maximum measured settlement was 43 cm.

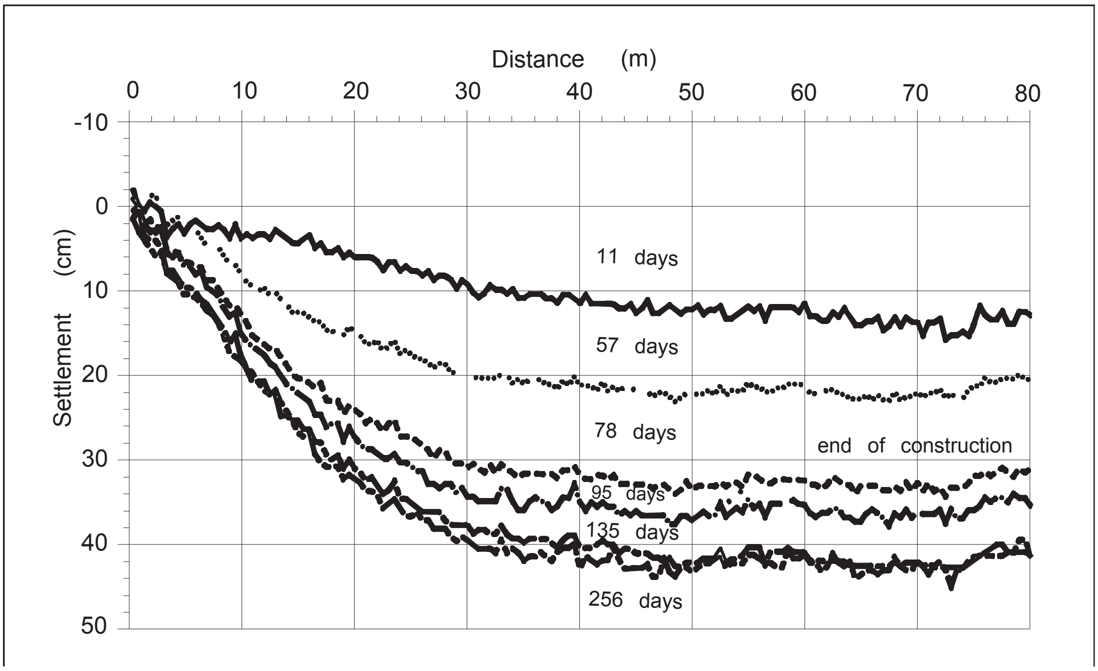

Figure 8. Settlement profiles at different times (since the 1st measurement) along the measuring tube MT-3

4.2 Comparison of settlement development measured using 2 different methods

Figure 9 shows a comparison of settlement development measured in the measuring tube MT-3 with the settlements observed on plate SP-3, which was located very close to the tube (see Figure 4), and progress of the embankment construction. The measurements were not all carried out at the same time, and the measuring tube was installed about 2 m above the mentioned settlement plate (see Figure 5), which had problems connected with the attachment of riser pipes and also with movements due to the effect of site transport. In spite of all this a comparison of the two different methods shows that the magnitude of the measured settlements and the settlement development are very similar.

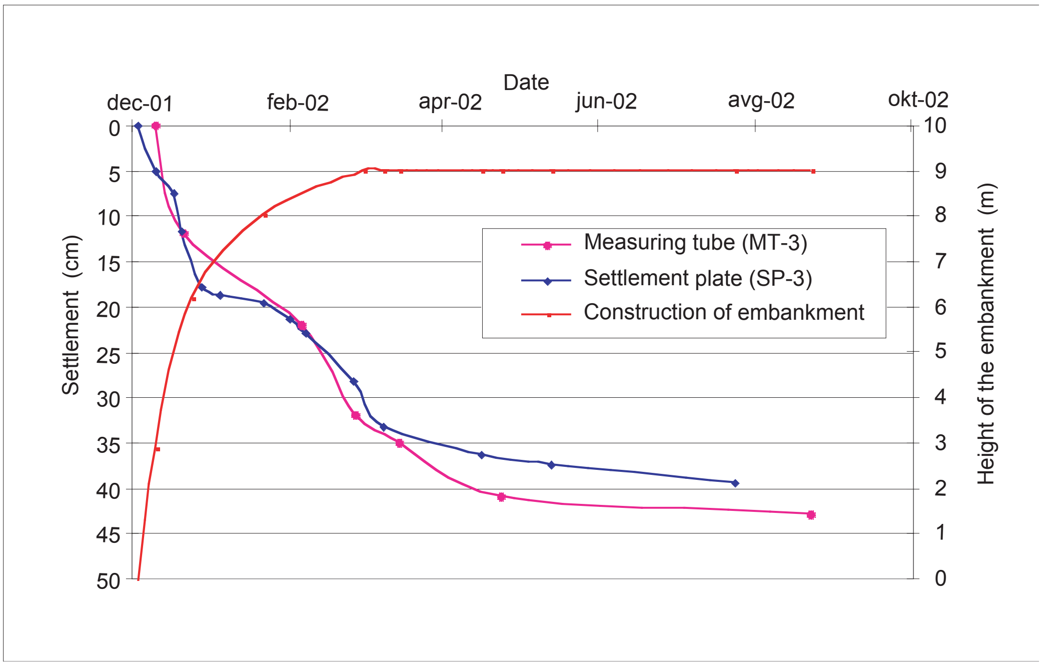

Figure 9. Settlement development measured using 2 different methods, compared to the progress of embankment construction

5. Conclusions

The use of a measuring tube and a hydrostatic profile gauge, which do not interfere with the construction works, proved to be a very practical solution. The result is not only a single settlement (like that measured using a settlement plate), but also the settlement profile, obtained using a measuring tube. There were some difficulties connected with the settlement plates (the attachment of riser pipes, movement because of the effect of site transport, etc.). In future, the monitoring system for embankment settlements will be improved with the replacement of settlement plates by measuring tubes monitored using a hydrostatic profile gauge.

References

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