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Performance of shallow cover method with geogrid on pipe at site

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ABSTRACT: When there is no flow in large diameter pipeline, they may be uplifted by groundwater buoyancy. To avoid this phenomenon, pipe must be buried with deep cover of depth. Shallow cover method with geogrid, wrapping gravels by geogrid and install them on pipe, is effective countermeasure to overcome uplifting problems and to reduce construction cost. This new geogrid utilization, its effectiveness and unification of geogrid and gravels were confirmed in some laboratory tests. In this paper, stability of shallow cover method with geogrid was confirmed at actual 2600mm pipeline in one-year measurement.

1 INTRODUCTION

Agricultural water has been mainly transported thorough open channel. Recently, urban area expansions restrict ground surface usage and severe flow control become necessary. So, large diameter pipelines have been took place for open channel. In the agricultural off-season, there is no demand from farm field, so there is no water transported in pipeline. Groundwater level rise when large amount of water pored in ground by rainfall. Vacant pipeline have danger to be uplifted by buoyancy of groundwater. Figure.1 shows uplifted accident.

Figure 1. Uplifted accident

To avoid uplifting, large diameter pipeline is buried with deep cover of depth. To bury in deep ground, it is necessary to excavate large amount of soil. If there is restriction of land use, long sheet pile is required to excavate. Such deep excavation and long sheet piles increase construction cost and construction period.

To reduce these cost, shallow cover method with geogrid was invented. This is new geogrid utilization wrapping gravel and installed on pipe. These gravel and geogrid help to resist uplifting force by buoyancy. It requires no special tool or skill for installation. And this method can be applied to various sites by proper design and construction.

Mohri had conducted model experiment for uplift resistance of buried pipe in 1998. It was confirmed that this method using geogrid was effective as a result of experiments. These experiment results show that the resistance force of this method could be increased significantly by the incorporation of geogrid and crushed gravels for backfilling materials, the cover of depth could be reduced approximately half of regular method.

Mohri and Fujita had measurement actual 2400mm diameter pipe performance on site in 1998.

In this paper, actual site experiment for larger diameter pipe was carried out to confirm method's effectiveness. Behavior of actual 2600mm diameter pipeline during and after construction was measured by displacement, pressure gauge and strain gauge.

2 SHALLOW COVER METHOD WITH GEOGRID

2.1 *Theory*

Figure.2.1 shows illustration of pipe section. When groundwater level rise, buoyancy force U acts on pipe. In conventional theoretical pipeline design, only W1-1 area weight and pipe weight resist against U. In shallow cover method with geogrid W1-2, W2 and part of W3 areas are expected to resist against buoyancy with W1-1.

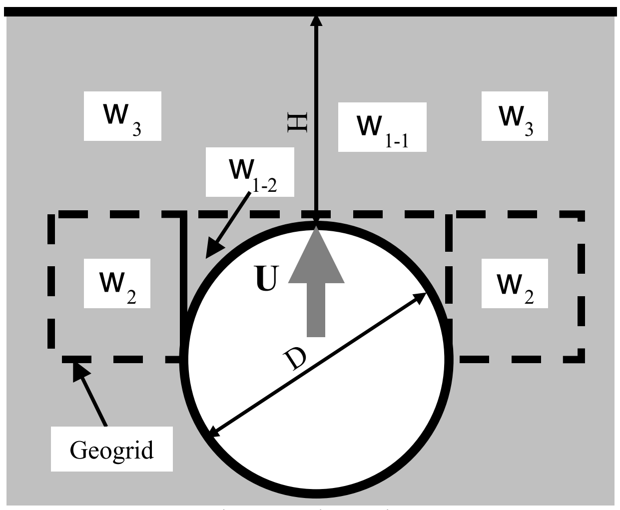

Figure 2.1. Pipe Section

2.2 *Installation Procedure*

Figure.2.3(a) to Figure.2.3(d) show the procedure of shallow cover method with geogrid. There is no difference in backfilling up to spring-line level from normal installation procedure.

a) Installation of geogrid

Firstly, install a continuous single geogrid onto pipe. Both ends are laid vertically along sheet pile. It is necessary to keep space between geogrid and sheet pile for compaction.

b) Backfilling of gravel

Backfill gravels inside geogrid area. Gravels are used from spring-line level to top-crown level to get high stiffness for pipe support and to prevent deflection. As shown Figure.2.3(b), install and compact gravel before install sand between geogrid and sheet pile.

c) Joint geogrid

Tighten both ends of geogrid by use of rope. It is important not to loosen geogrid.

d) Backfilling and extraction of sheet pile

Install Backfilling sand between geogrid and sheet pile. After compacting sand, make normal backfilling up to design level. Finally, remove strut and wale, and extract sheet piles. During construction, it is necessary to drain groundwater completely by water pump not to uplift pipe, since sufficient cover is not yet installed.

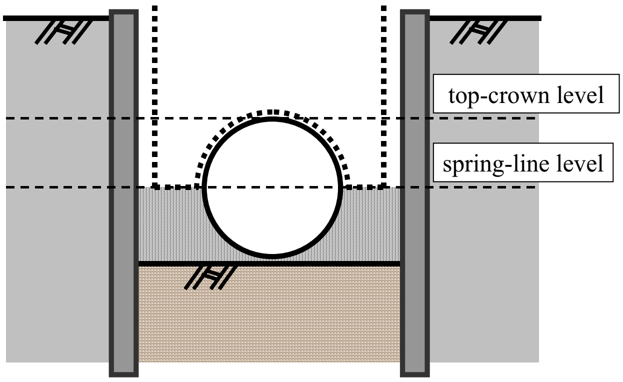

Figure 2.3.(a) Installation of geogrid

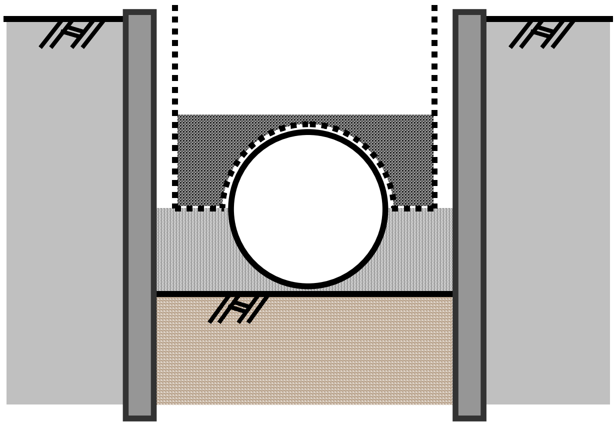

Figure 2.3.(b) Backfilling of gravel

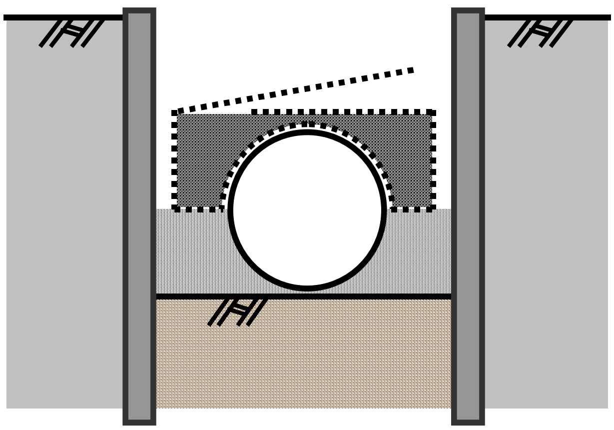

Figure 2.3.(c) Joint geogrid

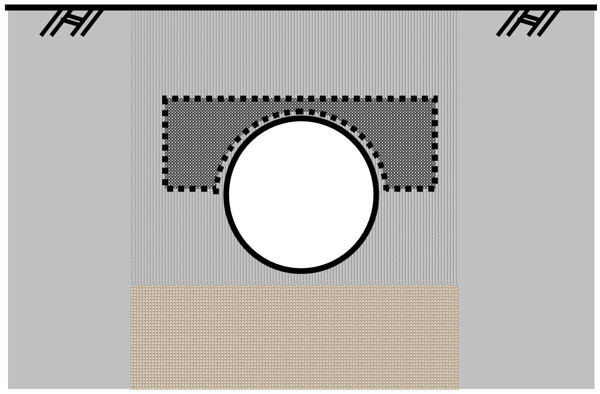

Figure 2.3.(d) Backfilling and extraction of sheet pile

3 SITE TEST

Measurement was conducted main agricultural pipeline at Nishi-Shirakawa in Fukushima prefecture Japan. Base ground was sand with 2-3m deep cover on soft rock.

Figure.3.1 shows outline of site. Diameter 2600mm (Fiber Reinforced Pipe with Mortal) pipeline was buried in 4.1m wide trench with 2.0m cover of depth. Gravel (Maximum Dry Density: 1785 kg/m^3,Dry Density:1680-1756 kg/m^3) was used for basement and backfilling material in geogrid. Sand Maximum Dry Density: 1916 kg/m^3, Dry Density: 1818-1829 kg/m^3) was used for upper part of pipe for backfilling material. Geogrid (T_{max}=27kN/m) was used for countermeasure against upliftment. Applied geogrid was bi-axial polypropylene and high strength aramid fiber coated by PVC.

To measure behavior of pipe and geogrid, following points are measured by measuring instruments. Measuring was conducted twice a day automatically from August 2000.

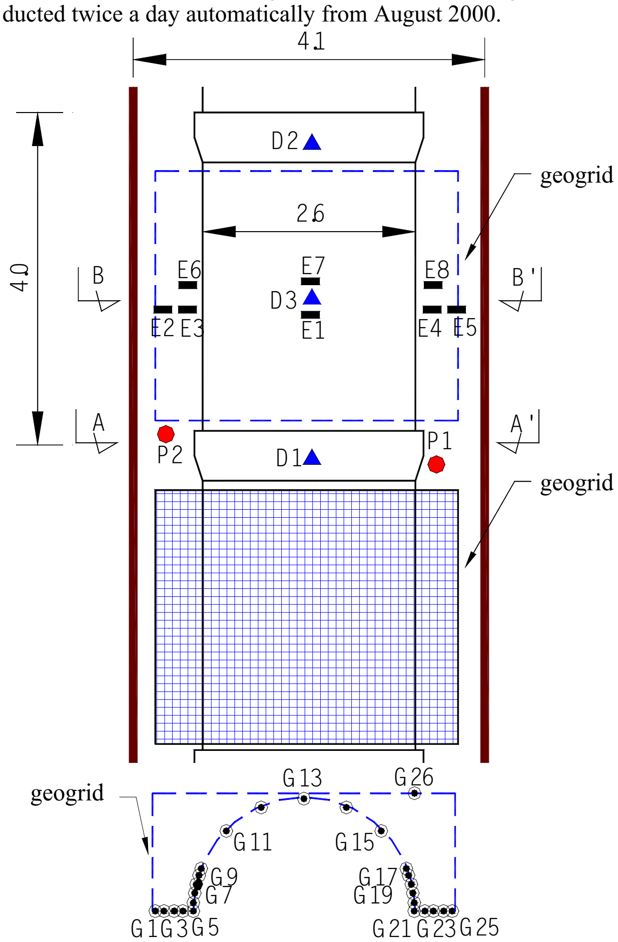

Figure 3.1. Outline of site

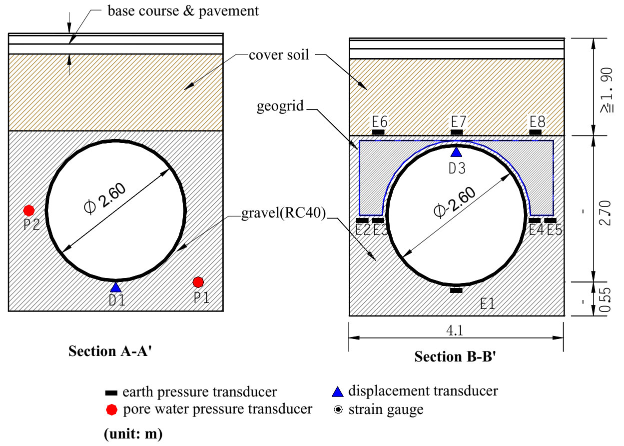

Figure 3.2. Section of site

a) Groundwater Level
Pore water pressure transducers (P1, P2) measured groundwater level. They were installed near pipe.

b) Displacement of Pipe
Displacement transducer (D1, D2) measured vertical displacement. They installed under pipe.

c) Deformation of Pipe
Pipe deformation was measured by displacement transducer (D3). It was attached in pipe.

d) Earth Pressure
Earth pressures were measured by earth pressure transducers (G1-G26). Bound effects of gravel wrapped by geogrid are confirmed by measuring earth pressure act on gravel.

e) Strain of Geogrid
Not to loosen geogrid, tensional force must be applied during construction. Initial stresses were measured by strain gauges. When pipes uplifted, stress concentrated part of geogrid.

4 RESULTS AND DISCUSSIONS

4.1 *Behavior during construction*

In shallow cover method with geogrid, tensional force applied to geogrid at construction stage. These forces resist against buoyancy force as one of the main resistance forces. Here discuss mechanism of tensional force by pipe deflection and tensional strain of geogrid.

Figure.4.1 shows deflection of pipe from installation of pipe on gravel base to backfilling of sand. Pipe deflected little up to spring-line backfilling. After backfilling to 0.6m from spring-line level, pipe sunk and pipe deformed elliptically by side earth pressure. Pipes sunk gradually after backfilling cover soil. They sunk 20-35mm in total. Deformation of pipe began 0.9m from spring-line level backfilling, and it deformed most at top crown level, and recovered by backfilling.

Figure.4.2 shows strains of geogrid at backfilling level at 0.6m, 0.9m, top crown, cover soil. At 0.6m level from spring-line, tensional strain of geogrid showed small value, however at 0.9m from spring-line level, they increased sharply, after backfilling cover soil, these values were 8000-18000 microns strains around top crown. Figure.4.3 shows relationship between strain and tensional force. 18000 microns strain corresponds to about 5kN/m tensional force.

Strains at both sides were different. These difference came form backfilling procedure. Left side (G7-12) preceded right side (G14-19) at every 0.3m deep backfilling.

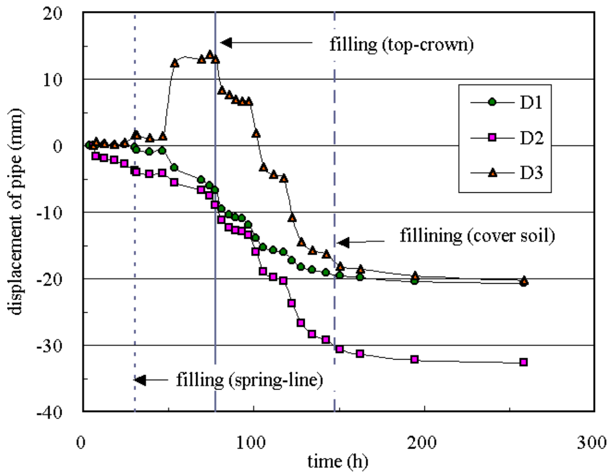

Figure 4.1. Deflection of pipe

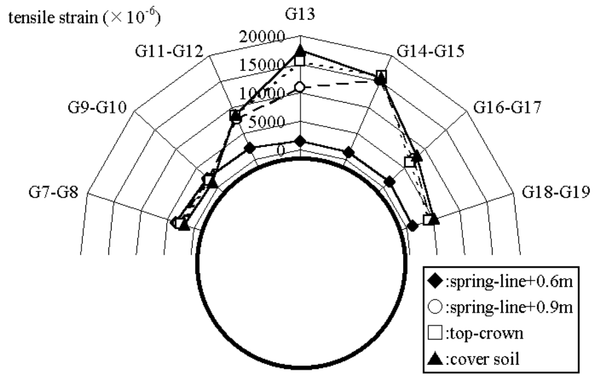

Figure 4.2. Strains of geogrid during construction

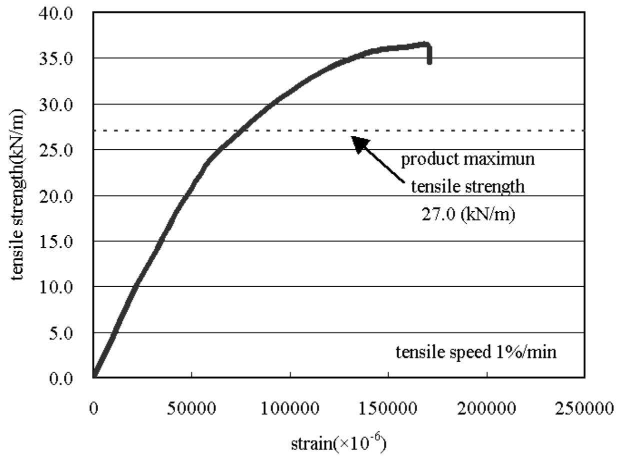

Figure 4.3. Relationship between strain and tensional force

4.2 *Behavior after construction*

a) Groundwater Fluctuation
Figure.4.4 shows groundwater fluctuation and pipe deflection measured by water pressure transducers. Groundwater level fluctuated by influence of rainfall. Groundwater level exceeded top-crown level for several time. At that time, large buoyancy force acted on pipe. After construction, there were little changes for each displacement transducer. From these results, test pipe remained stable after construction even large change of buoyancy.

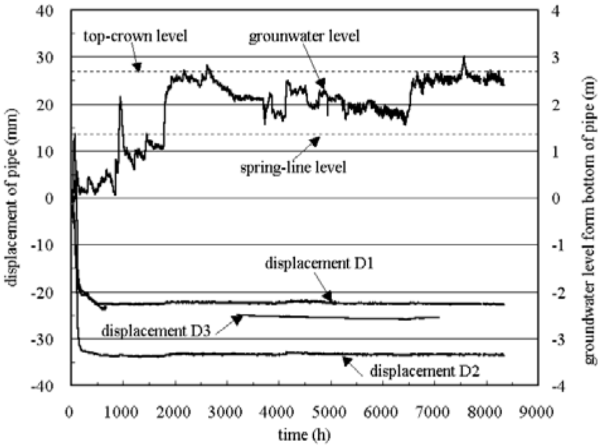

Figure 4.4. Groundwater fluctuation and pipe deflection

b) Earth Pressure

Figure.4.5 shows earth pressure at bottom and spring-line level. Figure.4.6 shows earth pressure at top-crown level. For bottom earth pressure, gradually decrease of value was measured. These decreases almost correspond to groundwater level fluctuation. From these data, pipe had been influenced by buoyancy. On the other hand, earth pressures at top-crown gradually increased. These increases mean upper part of pipe had been influenced by pipe upliftment force. From Figure.4.5 and Figure.4.6, whole geogrid and gravels had been influenced by groundwater buoyancy, however, pipe itself had not been displaced compared to these earth pressure changes. From these results, unification of geogrid and gravel can be confirmed.

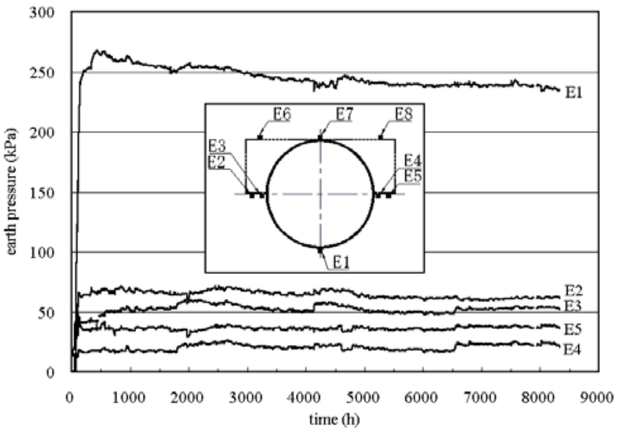

Figure 4.5 Earth pressure at bottom and spring-line level

c) Strain

Figure.4.6 shows distribution of tensile strain of geogrid. After construction, strains keep small value. These values correspond to 5% of maximum product tensile strength of geogrid.

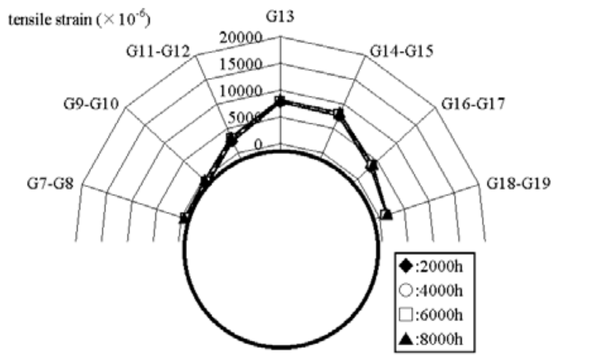

Figure 4.6. Strain of geogrid after construction

5 CONCLUSIONS

Through one-year measurement, following results were confirmed.

1) Pipes weren't uplifted by buoyancy.
2) Deflection of pipe was very small.
3) Geogrid and gravels were bound in ground.
4) Geogrid had sufficient strength against tensional force.

From these results, shallow cover method with geogrid is effective countermeasure against uplifting. This method can be applied according to site conditions by proper design.

Shallow cover method with geogrid method shows good possibilities to extend new geogrid utilization not only earth reinforcement. Construction cost was reduced by about 10% compared with conventional method.

6 ACKNOWLECGEMENT

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