Geosynthetics Asia'97, 26–29 November, Bangàlore, India

# FIELD MODELLED TESTS FOR ESTIMATING AN ANCHORAGE ABILITY OF GEOMEMBRANE LINER

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## ABSTRACT

In order to investigate the anchorage ability of a concrete trench, field pull-out tests were conducted. Section sizes of trench were varied ranging from 200 mm by 200 mm to 600 mm by 600 mm. The geomembrane were draped on the shoulder of its edge being placed on the bottom of trench. The trenches were filled with concrete. From the experiments, failure mechanism of concrete anchorages can be classified into four modes.

## 1. INTRODUCTION

The geomembrane, used as a liner on a side slope in waste landfills, needs anchorage in order to prevent a downward slide caused by its gravitation or by drag force of working vehicles. Generally, one of three anchor methods are used. They are called (1) frictional method, (2) trench and backfield method and (3) anchoring to a concrete structure method (G.N.Richardson and R.M.Koerner, 1986). The anchorage has to be designed so that it has sufficient resistance ability against thermal forces or driving forces caused by working vehicles. At the same time, the anchorage ability must be less than the failure strength of geomembrane. Therefore it is very important to evaluate exactly the ability of anchorage.

In Japan, a trench with about 300 mm width by 300 mm depth is usually dug on the shoulder of slope or bank by a backhoe, the geomembrane is then draped over the shoulder its edge being placed on the bottom of the trench which is then filled with ready mixed concrete. The size of cross sections has been empirically determined and it has not been established whether the size is enough or not in spite of the difference of geomembrane type or ground type. Therefore any procedure to calculate the anchorage capacity has not established up to the present.

In this paper the authors describe the field pull-out tests which were conducted in order to investigate the capacity of the anchorage. They find out that there are four modes of failure mechanisms controlling the resistance ability of concrete anchorages. They also present several points to notice at work.

## 2. PROPERTIES OF GROUND AND GEOMEMBRANE USED

### 2.1 Ground

Field pull-out tests were conducted on the ground made of loam of which soil properties are shown in Table 1. Two kinds of modeled slopes were constructed by cutting the natural ground and by embanking the excavated loam in situ. Both slope angles were 26.6 degrees, which is 2 to 1 ( horizontal to vertical).

The strength of the ground was investigated by cone penetrating test in situ and unconfined compression test in a laboratory. Wet unit weight of the ground was also investigated. Table 2 shows mechanical properties of the ground. Cut site (undisturbed ground) has average unconfined strength of 84 *kN/m2*. At bank site, unconfined strength was not tested because it was difficult to take an undisturbed sample. But its strength can be estimated as 32*kN/m2* in average from the values of cone resistance.

Table 1 **Soil properties of the test site**

| Top Size (mm) | Percent of fine-grained soil (%) | Specific Gravity (g/cm$^3$) | Liquid Limit (%) | Plastic Limit (%) |
|---|---|---|---|---|
| 2.0 | 44.0 | 2.62 | 108 | 66 |

**Table 2 Mechanical properties of the test site**

| Cut | | | Bank | | |
|---|---|---|---|---|---|
| Cone Resistance (kN/m$^2$) | Unconfined Strength (kN/m$^2$) | Wet Unit Weight (kN/m$^3$) | Cone Resistance (kN/m$^3$) | Unconfined Strength (kN/m$^2$) | Wet Unit Weight (kN/m$^3$) |
| 399-978 | 73-95 | 12.6-15.2 | 133-512 | not tested | 14.1-14.8 |

### 2.2 Geomembranes and Geotextiles

The types of geomembrane used were HDPE with smooth surface. Their thickness, tensile strength and elastic modules at 20 ℃ are shown in Table 3 .

Nonwoven stapled geotextiles was used as protection layer for geomembrane. Its unit area weight, tensile strength and elastic modulus are shown in Table 4 . This type geotextile is generally used nowadays in Japan.

**Table 3 Mechanical properties of geomembrane**

| Thickness (mm) | Tensile Strength (kN/m$^2$) | Elastic Modulus (kN/m$^2$) |
|---|---|---|
| 1.5 | 32,000 | 454,000 |

**Table 4 Properties of stapled non-woven geotextiles**

| Thickness (mm) | Unit Area Weight (kN/m$^2$) | Tensile Strength (kN/m$^2$) | Elastic Modulus (kN/m$^2$) |
|---|---|---|---|
| 10 | 11.8 | 330 | 130 |

## 3. PULL-OUT TESTS

### 3.1 Configuration and programs

Trenches of which cross section size varied ranging from 200 mm by 200 mm to 600 mm by 600 mm were dug on top surface 500 mm apart from the shoulder of cut slope and bank one, as shown in Fig. 1 . Then the geomembranes with a width of 500 mm were draped over the surface of its end being placed on the bottom of trench. Another end of geomembrane being 100 mm long far from the shoulder was joined to 5 mm thickness high modulus rubber sheet reinforced with textiles, which was in order connected to pull-out actuator through load transducer. The geomembranes were placed 500 mm apart each other.

As a standard, geotextile that could be used as protection layer against penetration of sharp material in practice was not placed over and beneath the geomembrane. However, regarding to giomembrene anchoraged by concrete of which area is 300 mm by 300 mm, stapled non-woven geotextile was placed in four different conditions, (1) over geomembrane, (2) beneath geomembrane, (3) over and beneath geomembrane, and (4) double layered .

After, a wooden mold which a length of 500 mm and width and depth corresponding to those of trench was placed into the trench and then filled with ready mixed concrete and cured for 7 days.

Table 5 presents a summary of the conditions of anchorage and geomembranes used.

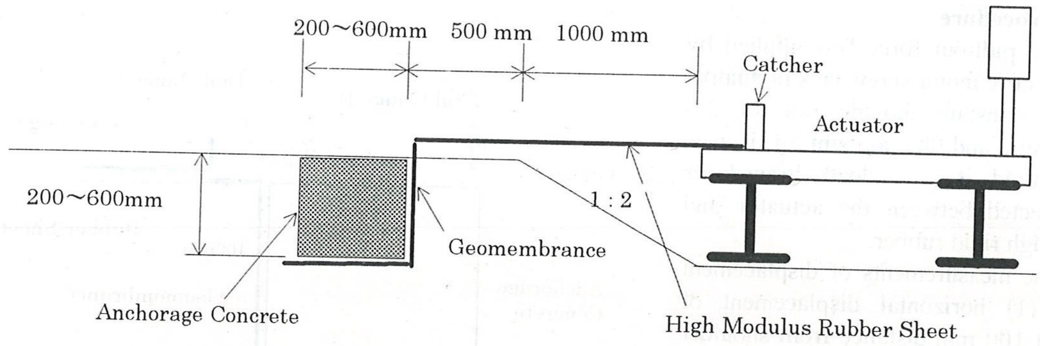



Fig.1 Schematic drawing of testing configuration

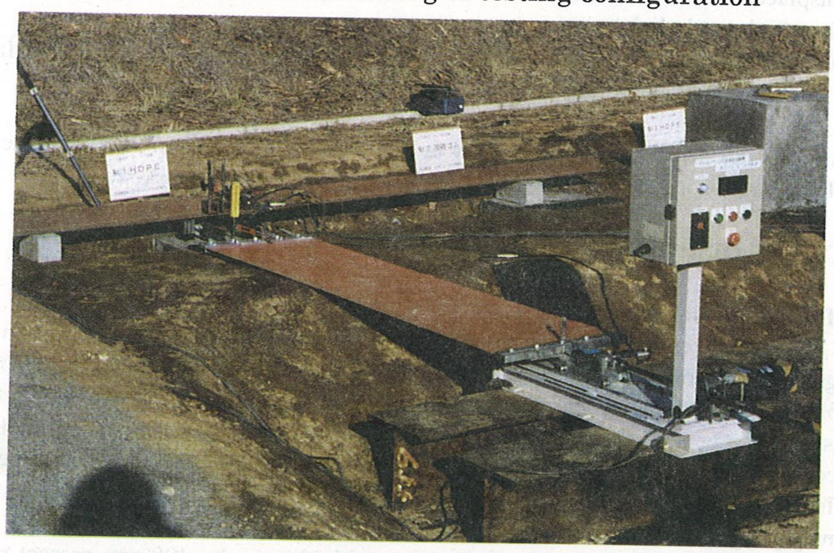


**Photo.1 View of set up of geomembrane and measuring equipment's**

**Table 5 Programs of pull-out tests**

| Test No. Cut or Bank | Trench size (mm × mm) | Concrete Weight (kN/m) | Geomemburene | Geotextile |
|---|---|---|---|---|
| 1 cut | 300×300 | 1.98 | single | none |
| 2 cut | 400×400 | 3.47 | single | none |
| 3 cut | 500×500 | 5.37 | single | none |
| 4 cut | 600×600 | 7.41 | single | none |
| 5 cut | 300×300 | 2.07 | single | over |
| 6 cut | 300×300 | 2.05 | single | beneath |
| 7 cut | 300×300 | 1.98 | single | over and beneath |
| 8 cut | 300×300 | 1.89 | double | over and beneath |
| 9 bank | 200×200 | 0.97 | single | none |
| 10 bank | 300×300 | 2.13 | single | none |
| 11 bank | 400×400 | 3.53 | single | none |
| 12 bank | 500×500 | 5.93 | single | none |

### 3.2 Procedure

The pull-out force was applied by an electric motor screw jack (actuator) at a constant moving rate of 2.0 mm/min and the amount of it was measured by a load transducer connected between the actuator and the high rigid rubber.

The measurements of displacement are (1) horizontal displacement of point 100 mm distance from shoulder on geomembrane through dial gauge **A**, (2) vertical displacement at front end of anchor concrete through dial gauge **B** and (3) vertical displacements at back end of anchor concrete through dial gauge **C**.

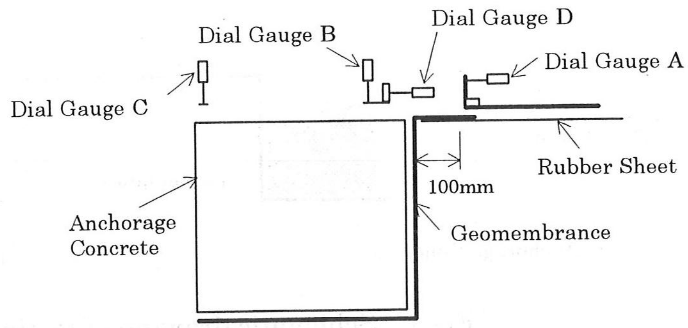



Fig.2 Points to be measured its displacement

These measuring points arc shown schematically in Fig. 2 and can be seen in Photo. 1. The measurements were controlled by a personal computer through data logger and stored in diskette.

## 4. RESULTS AND DISCUSSION

### 4.1 Effect of size of anchor concrete

The sizes of section area of anchorage concrete were varied from 200 mm by 200 mm to 600 mm by 600 mm. Figs. 3 and 4 show the relationship between pull-out force and horizontal displacement at point **A** on geomembrane and the relationship versus upward displacement at back end C of concrete, respectively.

From Figs 3, it can be seen that the curve of section size of 20 cm by 20 cm at bank site presents peak pull-out force *Tu* of 3.28 *kN/m* at horizontal displacement of about 20 mm and gentle decrease of the force after that. In this case, this values recorded when the concrete slipped out from trench without of geomembrane peeling off as shown in Photo. 2

The curves of section sizes of 300 mm by 300 mm and 400 mm by 400 mm present no peak pull-out force but gradual increase with increasing of horizontal displacement. In these cases, yielding crack could be seen on back wall, not front, of the trench as shown in Photo 3 .Therefore, it is acceptable to guess that the ultimate anchorage capacity will depend on the strength of the site soil and the amount of passive earth pressure subject to rotating force of anchorage concrete.

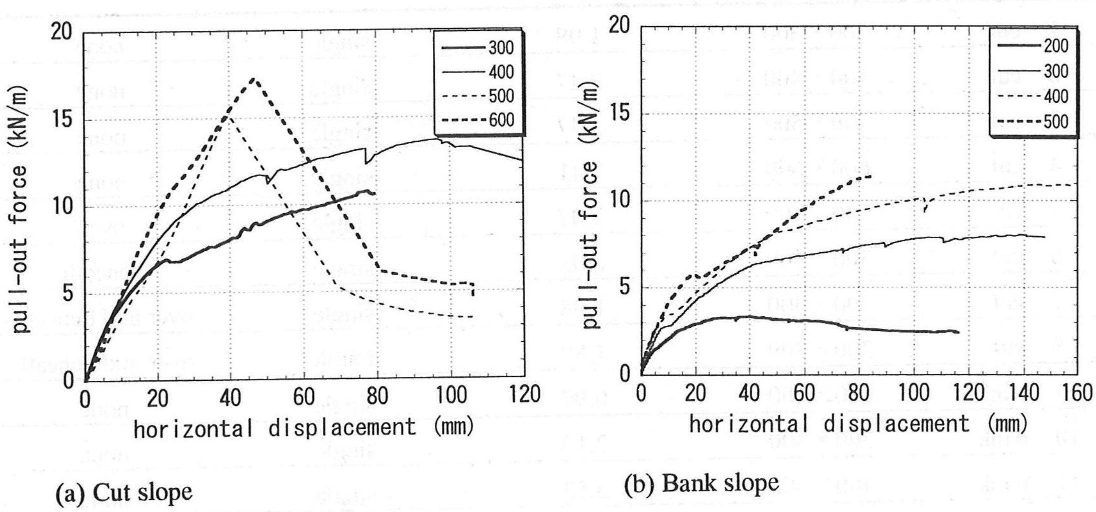
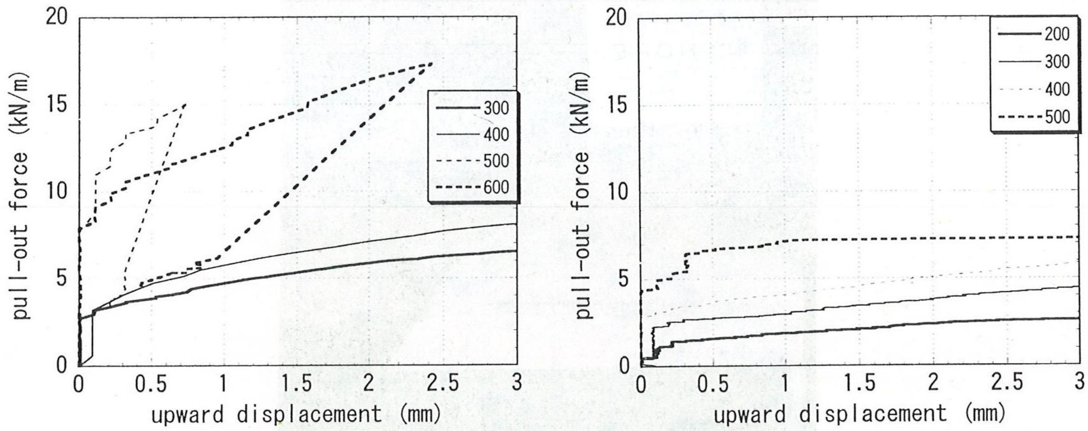



**Fig.3 Pull-out force versus horizontal displacement for various sizes of anchorage**




(a) Cut slope (b) Bank slope

**Fig.4 Pull-out force versus upward displacement for various sizes of anchorage**

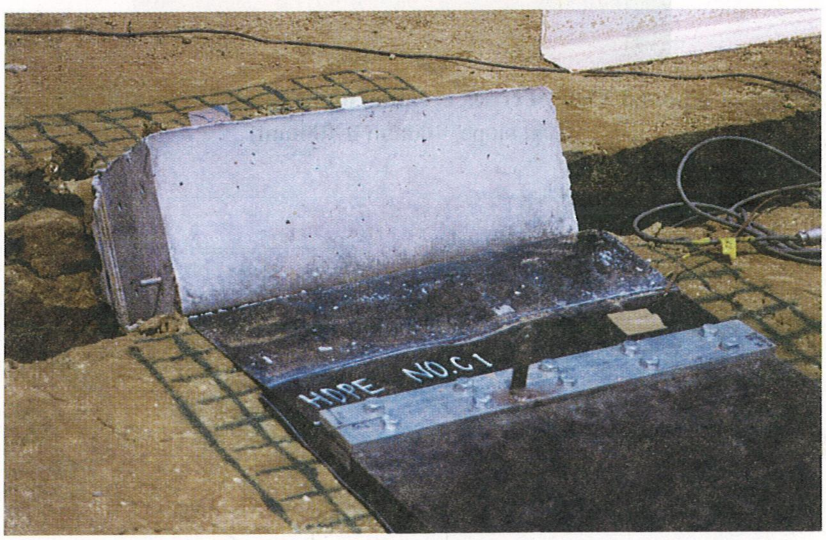



**Photo.2 View of slipping out of anchorage concrete** (bank slope, 200mm × 200mm)

The curves of section size of 500 mm by 500 mm and 600 mm by 600 mm present clear peak pull-out forces $Tu$ of 15.18 *kN/m* and 17.31 *kN/m* then sudden decrease of the force. These sudden fallings of pull-out force were recorded when HDPE peeled off the concrete and slipped out from the trench.

Fig. 5 shows the relationship between ultimate pull out force $Tu$ and size of anchorage concrete. The values of $Tu$ seem to increase with increasing of size but the relation is not linear.

In Figs. 4, we can see that upward displacement begins when the pull-out force reaches some value of $T_o$ and that the value of $T_o$ increase with increasing of section size. Fig. 6 shows the relationship between $T_o$ and gravitational weight of anchorage concrete. It can be seen that the value of $T_o$ which make the anchorage begin to move upward is consistent with the weight of anchorage concrete regardless of cut or bank.

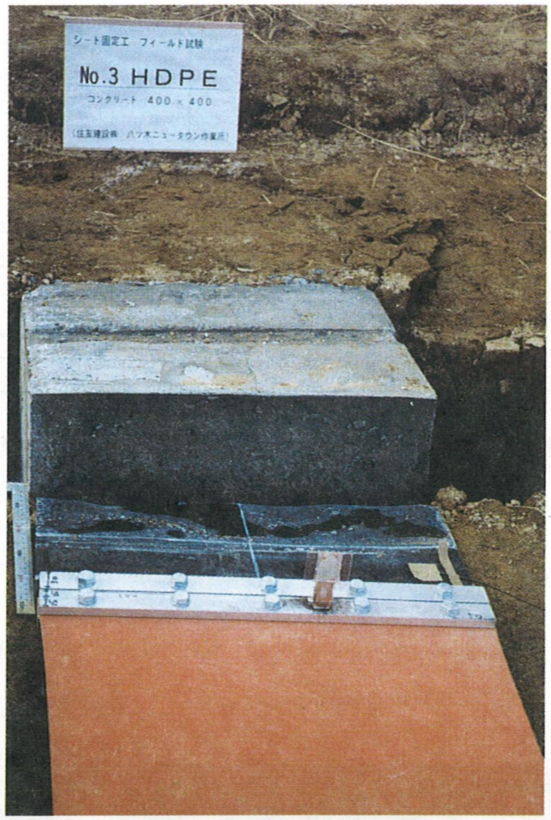



**Photo.3 View of crack creating on back wall of trench**
(cut slope, 400mm × 400mm)

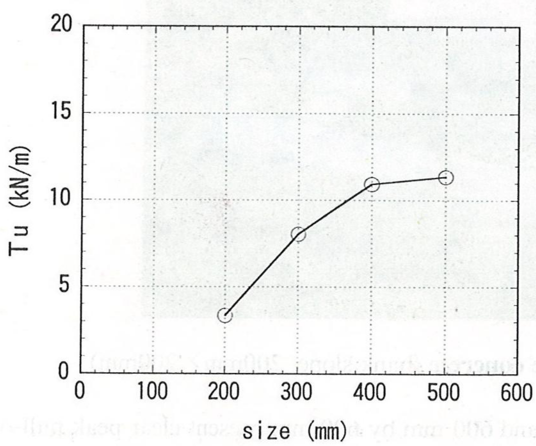



**Fig.5 *Tu* versus size of section area**

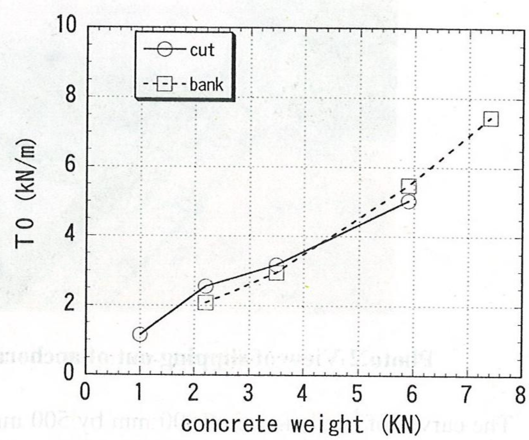



**Fig.6 *To* versus weight of anchorage concrete**

Fig. 7 shows the relationship between pull-out force and horizontal displacement at point **A** of HDPE geomembrane where the nonwoven geotextile was placed over, beneath or both the HDPE geomembrane. Comparing them to the curve with no geotextile, there is little difference of peak pull-out force when the geotextile was placed beneath HDPE. However, when the geotextile was placed above or both sides, the peak pull-out force decreased greatly by about 90 % of that in case with no geotextile. In case double layered ,the pull-out forces for upper geomembrane of double layered geomembrane was 50 % of no geotexitile case.

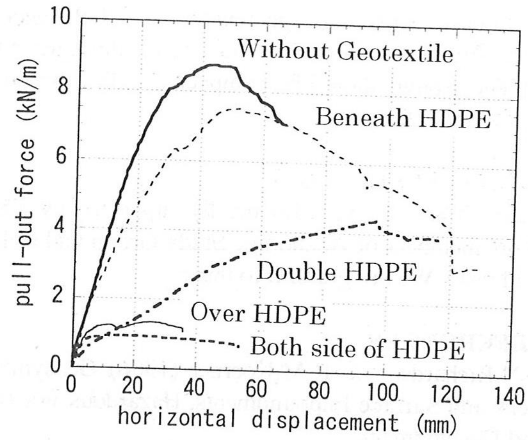



**Fig7. Pull-out behavior of HDPE with geotextile**

It is reasonable to consider that the resistance against pull-out force results from frictional shear force or bonding force etween geomembrane and adjacent materials. When the geotextile is placed between geomembrane and concrete this is over HDPE geomembrane, the frictional shear resistance between geomembrane and geotextile is far smaller than bonding force between geotextile and concrete. Therefore the resistance against pull-out force of geomembrane may decrease and result in reduction of *Tu* geomembrane.

### 4.3 Modes of mechanism mobilizing ultimate pull-out force

As mentioned above, the amount of ultimate pull-out force depends on different mechanisms.

The first is of anchorage concrete slipping out from trench without of geomembrane peeling off. This phenomena was observed in case of small section size of concrete such as 200 mm by 200 mm.

The second is shear failure of trench back wall subject to passive earth pressure from concrete. This was observed in case of section size with 300 mm by 300 mm and 400 mm by 400 mm.

The third is of geomembrane slipping out from trench. This was observed in case of large size concrete (high gravitational weight) with insufficient bonding force between geomembrane and concrete and in case of placing a geotextile between geomembrane and concrete.

The forth, this is not observed in series of tests, is tensile failure of geomembrane itself. The last mode is thought to happen when section size is much larger and the bonding is much stronger.

## 5. CONCLUSIONS

The authors described the field pull-out tests which were conducted in order to investigate the capacity of anchorage. As the results, The followings are concluded.

(1) When no geotextiles was covered over HDPE and geomembrane, pull-out force *To* corresponding to beginning of upward displacement of anchorage concrete was coincident with the amount of anchor concrete gravitational weight.

(2) When the geotextiles were laid over HDPE, the geomembrane was completely slipped out from the trench and ultimate pull-out force is less than anchor concrete gravitational weight. This behavior came from a lack of frictional resistance between HDPE and anchor concrete.

(3) Modes of mechanism controlling the ultimate anchorage ability of trench concrete can be classified into four types; 1) of anchor concrete slipping out from trench, 2) yielding of back wall of the trench, 3) of geomembrane peeling off from anchorage concrete and 4) tensile failure of geomembrane.

From the results obtained from field experiment, the authors would like to point out the followings that have to be taken care at working.

(1) When high frictional shear resistance between geomembrane and anchor concrete is required in order to mobilize sufficient anchorage ability, the surface of geomembrane should be cleaned before concrete be backfield.

(2) In case of placing a geotextile over HDPE geomembrane, some device such that the force applied to HDPE can be transmitted to concrete throughout the geotextile should be taken.
(3) The ground should be compacted well to become stable, especially at back wall of trench as well as shoulder of slope.

## ACKNOWLEDGMENT

These field tests were financially supported by The Landfill Technology System Study Party in Japan Many members of Anchorage Study Group and of Installation Group of it assisted us with conducting the field tests. We are grateful to them.

## REFERENCES

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