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Experimental studies to improve the surface land reclaimed from the sea

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ABSTRACT: Silty and clayey soils dredged from bay bottom exhibit so extremery soft layers. Physical properties of those reclaimed soils and relationships between moisture content and density, shear strength after dredging have been investigated. Then the methods of treatment to improve those poor shallow layers were experimentally studied. Earth reinforcing techniques are, a) direct spreading, b) net spreading, c) sheet spreading, and d) lime stabilization. Observed results were compared with each other, and applicabilities of those methods to ultra soft layers were evaluated.

1 INTRODUCTION

1.1 Case study of Nakagusuku Bay Harbor, Okinawa

Nakagusuku Bay Harbor(New Harbor District) is located at the east coast of the middle-southern part on Okinawa Island. As shown in Fig.1, the area is surrounded by Katuren Cape and Chinen Peninsula, consequently the bay may naturally be suitable for major harbor.

New harbor district was planned to be about 340ha area reclaimed from the sea by a quantity of about 10,500m^3 of dredged soils which were sediments (inflow from

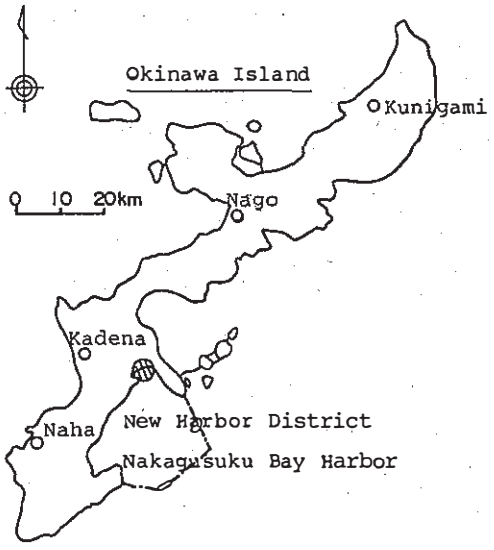

Fig.1 Location

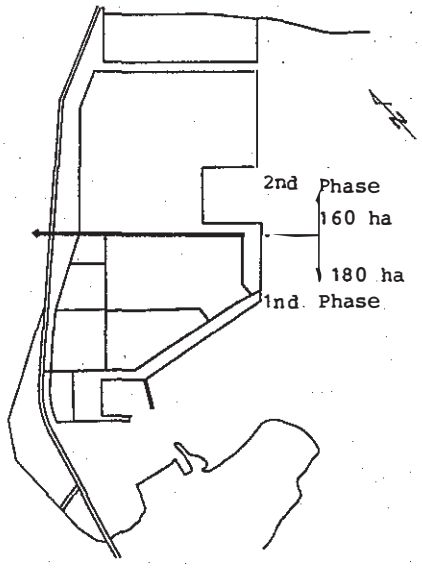

Fig.2 New Harbor District

Table.1 Physical Properties of Insitu soils

Depth (m)	Sand&Gravel (%)	Silt (%)	Clay (%)	Spesific Gravity	Moisture (%)	Wet Density (tf/m^3)	Liquid Limit	Plasticity Index
-5.5	30.0	50.0	20.0	2.77	35.0	1.90	42.0	20.0
-7.5	20.0	40.0	40.0	2.77	35.0	1.76	60.0	36.0
-10.0	5.0	55.0	40.0	2.78	52.0	1.72	65.0	40.0
-13.0	2.0	38.0	60.0	2.78	55.0	1.70	72.0	47.0

surrounding land). For the present time this new district is divided into two blocks as shown in Fig.2 and about 180ha is now under construction since 1959.

1.2 Physical properties

Nakagusuku Bay appeared as a result of subsidence at the south east side of Okinawa Island for the reason of tectonic phenomenon, and so the bottom geological features consist of Shimajiri Formation (Tertiary mud rock; silty clay, and sandstone) overlaid by Holocene alluvium deposits. Most dredged soils contain much more fine grained soils, consequently the reclaimed area makes ultra-soft ground. Physical properties of dredged soils in depth are presented in Table 1 and typical grain size percentages in depth at some spots are shown in Fig.3. Immediately after dredging the surface lands exhibit potage-like aspects.

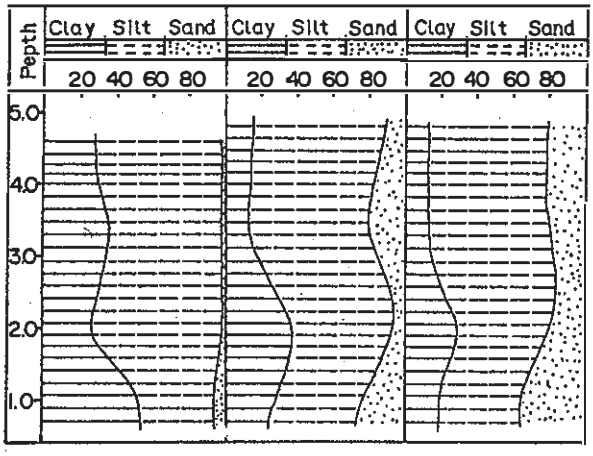

Fig.3 Texture of Dreged Soils

Photo.1 Surface Cracks

1.3 Examinations for reclaim, drainage, and surface layer stabilization methods

In order to keep trafficability on the newly reclaimed land, the examinations of suitable method of reclaim, drainage, and stabilization were made by the procedure shown in Fig.4. Considering that Okinawa Islands have subtropical climatic features, drying naturally these wet surface layers by the sun shine may be advisable (Photo 1). However the dry layers had only 2-3cm thickness, so it was considered that natural drying method would take much time to drain water from deeper layer. Then surface drainage by gravitation (slope, trench etc.) and subsurface drainage by inserting drain materials into the earth were examined. The test results relating to the relationships between depth and water content, vane shear strength, and wet density with lapse of time are shown Figs.5,6,7. It could been seen that it was applicable to adopt the procedure of some artificial methods with natural drying for the reclaimed land. Finally in order to improve the bearing capacity of the very soft layer, surface layer stabilization methods (over-layer method) were investigated.

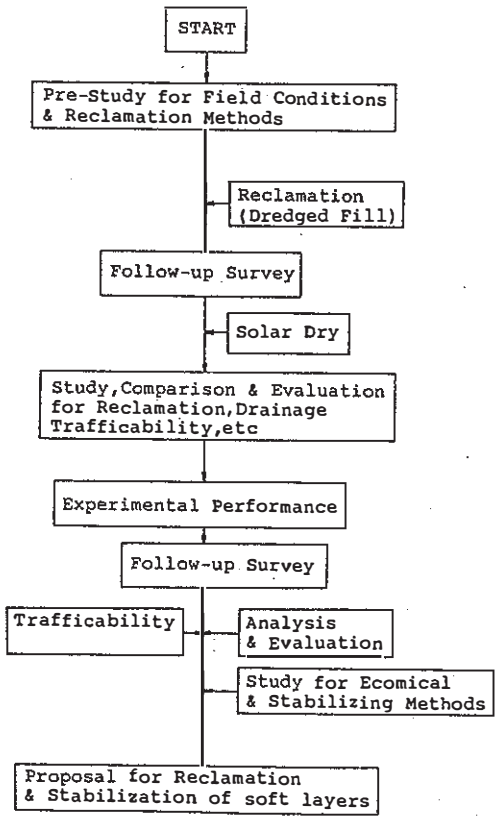

Fig.4 Flow Chart

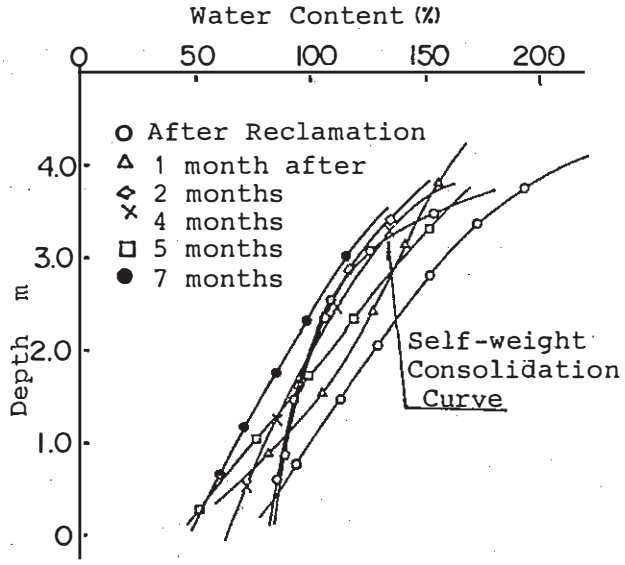

Fig.5 Relationship between Water content and Depth

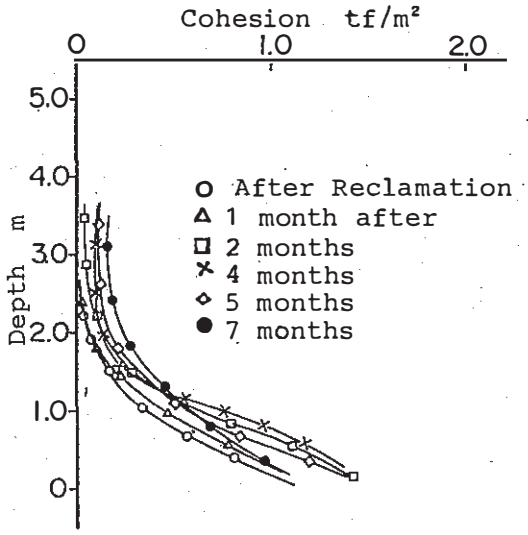

Fig.6 Relationship between Cohesion and Depth

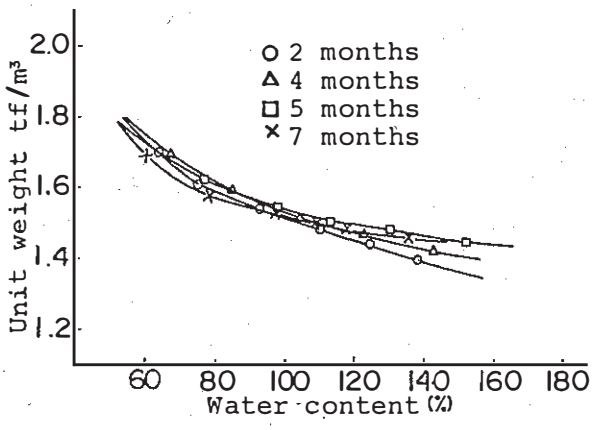

Fig.7 Relationship between Unit weight and Water content

2 INVESTIGATIVE STUDIES

2.1 Preparatory studies

There are some historical or geotechnical reviews of subsurface stabilization methods by T.Yamanouchi(1978), J.K. Mitchell(1981), and T.Okumura(1984) etc. In Figs.8 and 9, applicable earth reinforcement methods in relation to grain size ranges and water contents are shown. From those data the case of Nakagusuku Bay Harbor reclamation was examined relating with the physical properties of dredged soils. Also some trial examinations of natural (self weight) consolidation behavior was evaluated and by observation the settlement in 10-14 days after reclamation was nearly the same as laboratory tests. Since then it was observed that creep settlement (may be secondary consolidation) followed. Increments of strength were calculated by a normal procedure and those were compared with the results of sounding in the soft layer (by Vane shear test) for the lapse of time after reclamation had been performed.

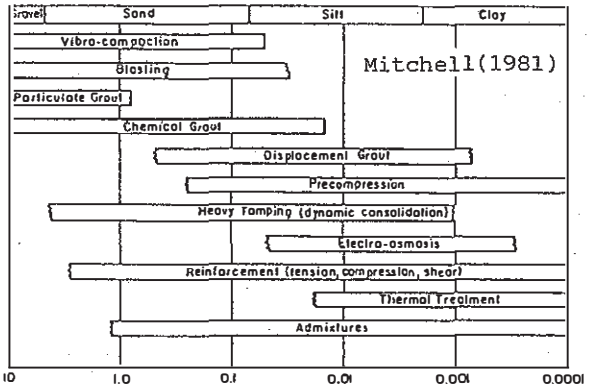

Fig.8 Applicable Grain Size Ranges for Different Stabilization Methods

2.2 Experimental studies

Experimental studies were performed to examine the surface layer for keeping trafficablity.The test program was carefully examined and the selections of some earth reinforcing methods which were applicable and suitable for the local soils in site were discussed. Experimental performances were then executed with special care being taken for the preparation, materials, the procedures, and the weather. The test spot was divided into several zones for each examination performance as shown in Fig.10.

To improve the trafficablity (bearing capacity) of soft ground, usually there are

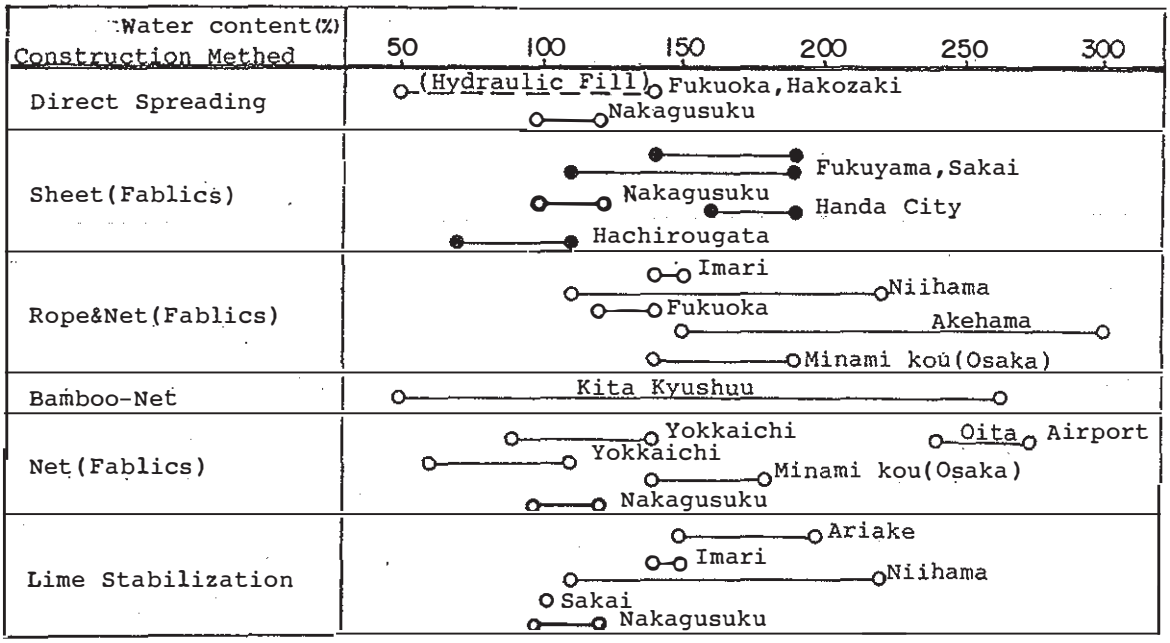

Fig.9 Relationship between improvement method and water content of soft subsurface layers ○: Actual water content ●: Estimated water content ---: Range of measurment

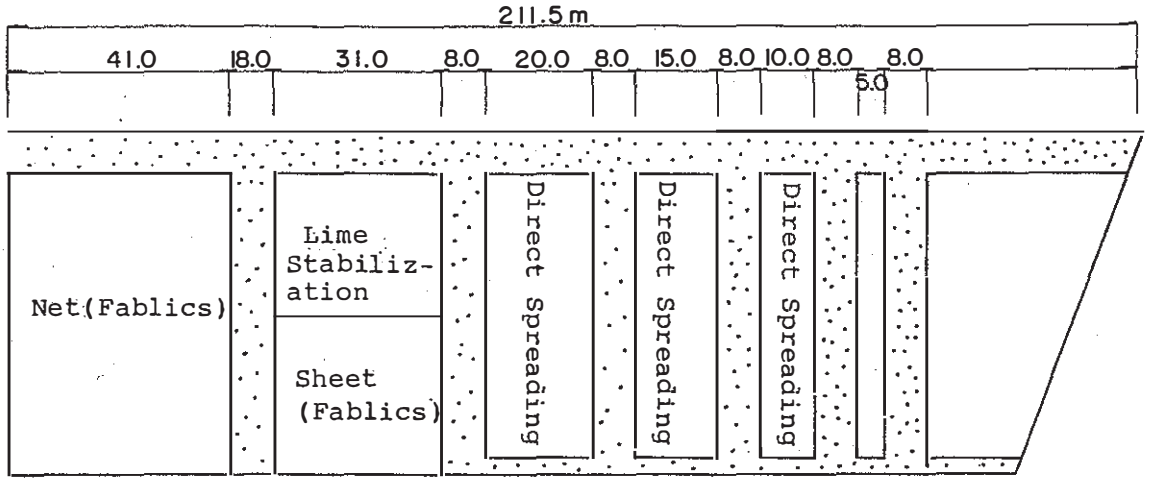

Fig.10 Zoning for Experimental Performance

two types of treatment of surface layers, that is one using the competent soil materials and another using the materials other than soils (reinforcement materials or chemical materials). In this test program, the following methods were adopted.

a) Direct Fablics: Sandy,gravelly(corals) soils were applied for inducing drainage.

b) Net Fablics: Nets A, B,and C were used for supporting the point or concentrated load (tension)

c) Sheet Fablics: Polyester sheet reinforced by making grill was used

d) Lime stabilization: Caustic (quick) lime was used for the effect of chemical reaction

2.3 Results and discussinos

As shown in Photo.1, thin surface layer (2-3cm) can not stand a walk, here we have to increase the strength of the layer (thicken more than 10cm, lower water content less than 60%, and strength more than $qu=0.6tf/m^2$) according to the data of site investigations. Therefore we examined the four kinds of reinforcement method by the preparatory studies, and a few examples of test results regarding variations of water content, wet density, vane shear strength and settlement etc. after the reclamation with the lapse of time are presented in Figs.11,12; Figs.13.14; and Figs.15,16.

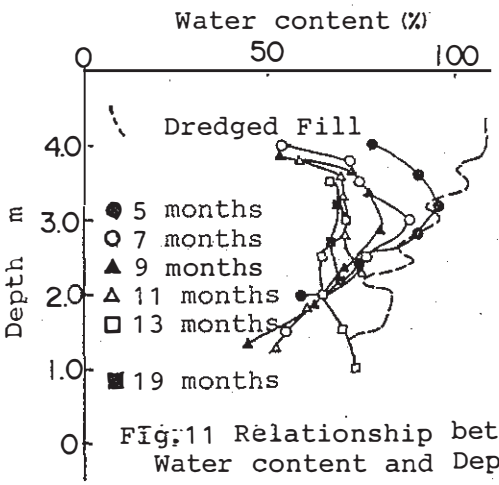

Fig. 11 Relationship between Water content and Depth (Direct)

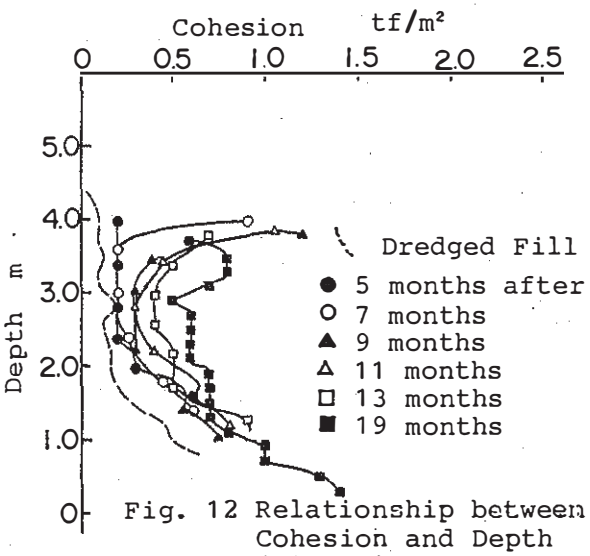

Fig. 12 Relationship between Cohesion and Depth (Direct)

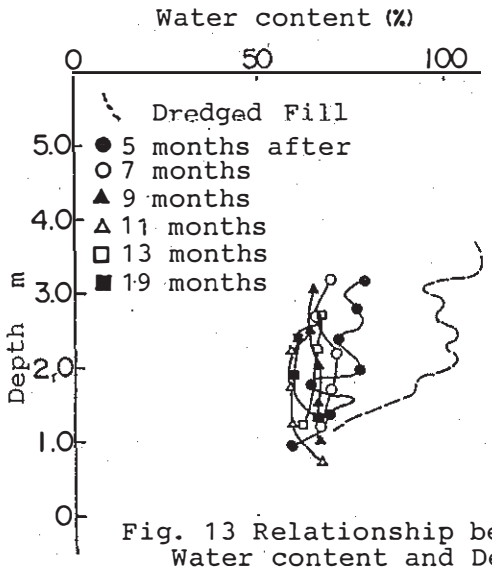

Fig. 13 Relationship between Water content and Depth (Net)

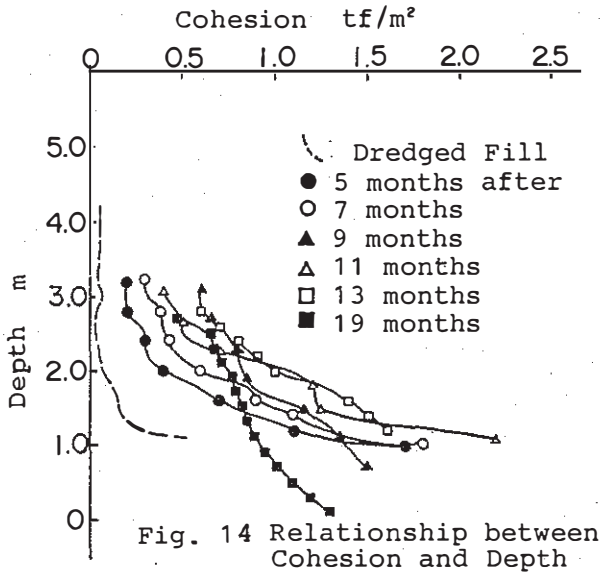

Fig. 14 Relationship between Cohesion and Depth (Net)

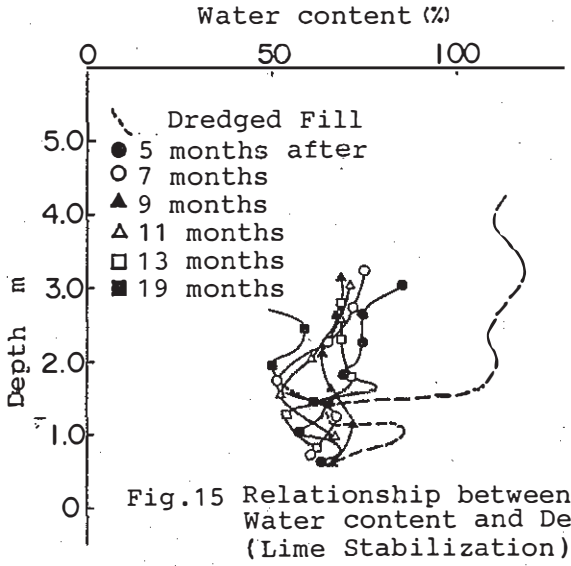

Fig.15 Relationship between Water content and Deph (Lime Stabilization)

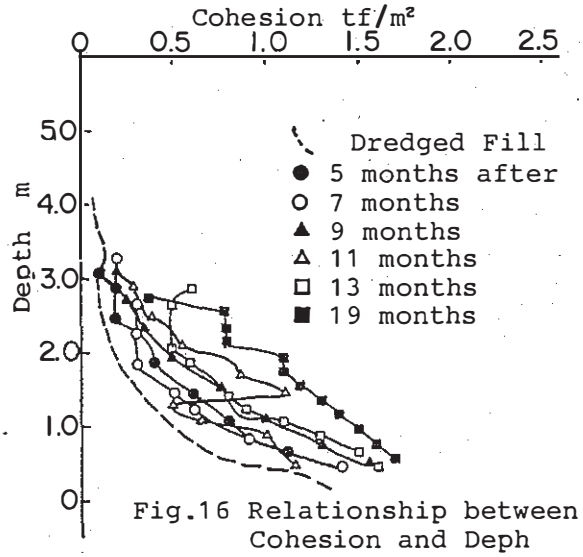

Fig.16 Relationship between Cohesion and Deph (Lime Stabilization)

a) Direct spreading; this method dries rather rapidly the surface layer and it is preferable for a wide reclaimed land to make the working roads. The working roads need the thickness of 1.0-1.5cm to stabilize, but sometimes there happens cracking where soft muds spout out. Width of spreading shoud be more than 6m, and it is desirable for this case to keep 7.0m. The depth of spreading was precisely checked by Swedish penetrometer and the average thickness was 3.0cm which was changeable with water content and vane shear strength of the reclaimed layers. It was found that the heaving and influence range of the spreading were respectively 30-60cm and 15-25m at the site.

b) Net spreading; For convenience sake to operate, 6m*15m net role was adopted, and the overlap had to be kept at least 30cm in length. Also joints of nets had to be tighten because of rupture after fill completion. Piling of the spreading materials or smaller bulldozer on the layer made surrounding nets often unstable (warping) and spreading depths were in the range of 0.8-1.2cm after completion. So there is a quite problem resulting from the lower strength of the layer in the first spreading works. It is advisable in this case to adopt the bulldozer of 0.11 -0.15kgf/cm^2 contact pressure type. The mechanism of bearing capacity of the net spreading may be similar to other cases, but it is still complicated for these soft layers of Nakagusuku Bay Harbor.

c) Sheet spreading; The most important difference between the net and sheet is that the net has rigidity of the materials, but the sheet has not, and the frictional force of the net is higher than that of the sheet. The fixation(anchoring) of the sheet ends were set into the temporary work roads and piling spots of sandbags. It was found sometimes that the sheet was torn up due to the full weight of spreadings (sand or gravelly soils) introducing tension forces

d) Lime stabilization; Some laborratory tests were performed to collect the data for lime stabilization of the dredged Shimajiri clayey soils. The content of the additive was fixed by the laboratory data to be 120kgf/m^3. Dehydration of the soils by mixing, with lime clearly improved the layer soils, and about two hours later after mixing, it was possible to walk slowly on the layer. It is advisable that the layer stabilized by lime should be covered by over-layer (sandy, coral gravelly soils) of at least 30cm thickness.

3 CONCLUSIVE REMARKS

Applying the method of direct spreading of sandy or gravelly soils with solar drying procedure is preferable, and may be reliable and economical if the layer is left for somewhat long duration having suitable thickness and width

Workability of gravelly (corals) soils applying the soft layer on the net spreading is preferable to the sand applying.

Stabilization effects of bearing capacity of the layer by net tensile strength and continuous drainage (consolidation) were recognized. Also stitches of the net may cooperate well with Shimajiri silty and clayey soils in generating frictional forces, consequently it is not necessary to fix the net ends.

Comparing with the net spreading, the sheet spreading may have difficulties to be repaired if it is damaged by coral gravels and shell fragments of dredged soils

The sheet spreading may not be suitable for impervious soils and the excess water can easily stay over the sheet.

The problem of lime stabilization is dependent on the weather condition (rainy or windy day should be avoided), and so lime mixing performances should be carefully controled.

Surrounding parts of lime stabilized soils are still very soft and drainage effect for those parts can not be expected.

Finally, even if the difference of the cohesive strength of the layer soils be so small, it may have an influence largely on the cost of the surface layer stabilization performance.

ACKNOWLEDGEMENT

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