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NATURAL FIBRE PREFABRICATED DRAIN — A CASE STUDY

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ABSTRACT

.A natural flexible prefabricated drain assembled by using jute and coir natural fibres has been in use for deep soil stabilisation in some countries for over a decade now. Excellent performance record, adaptability, versatility and most of all, its environmental acceptability are the virtues contributing to its growing popularity.

The natural fibre prefabricated drain has gained popularity over its synthetic counterparts in Indonesia and most recently in Japan. In this paper, the author reports one recent study involving such a drain application in a soil improvement project involving deep seated marine clay for the redevelopment of Hiroshima port in Japan.

INTRODUCTION

The general form of Fibredrains (FD) is a rectangular strip 80-100 mm in width and 8-10 mm in thickness. Four coir strands of 5-6 mm in diameter made of coconut fibre are enveloped by two layers of jute burlap to arrive at the above dimensions. Jute burlap is manufactured from jute fibres available in many parts of east and south Asia. Three longitudinal stitches hold their coir strands in separate flow channels within the jute burlap. Fig 1. Shows the structure of FD. Table 1 presents some of the physical properties of FD. FD is a green product which is biodegradable, ecologically harmonious and environmentally friendly. The relatively low cost of manufacture using indigenous materials and local labour makes the FD attractive in countries where jute and coir are abundant.

The details of development laboratory and field testing and salient properties of FD have been published (1-4). There have been several field applications of this natural prefabricated drain in Singapore, Malaysia and Indonesia (2,4,5). Particularly in Indonesia it has gained popularity over the past few years and is preferred over other vertical drain types because of its adaptability, flexibility, efficiency and cost effectiveness. Its short term durability has been found to be more than sufficient for consolidation periods of up to 2 years while embedded in deep clay deposits. Only recently the FD has been used in soft clay consolidation projects (6,7,8). Because of the confidence gained over the past few years of usage, Japan has started using millions of metres of FD each year. The main considerations in Japan contributing to increasing popularity of FD is its biodegradability and excellent performance record (8,9). In this paper, details about the first FD application in Japan are briefly presented. The superior performance of FD over sand drains (SD) and plastic bound drains led to its large scale adoption in the project.

Table 1.: Physical Properties of Fibredrain

PROPERTIES	TYPICAL VALUE	TEST METHOD	MINIMUM SPECIFIED BY FHWA*
Filter Material			
Weight [gm/m²]	600 - 650	ASTM D3776	
Grab Tensile Strength [kN]	2.908	ASTM D4632	0.356
Trapezoidal tear [kN]	0.3465	ASTM D4533	0.111
Mullen burst strength [kN/m²]	> 1382	ASTM D3786	898
Puncture strength [kN]	0.631	ASTM D4833	0.223
Elongation at break [%]	42	ASTM D4632	
Permeability [cm/s]	0.01	ASTM D4491	
A O S [μm]	200-600	ASTM D4751	90-120**
Drain Properties			
Discharge capacity [m³/yr]	200¶ at 10 kPa and 25 at 300 kPa	ASTM D 4716	100
Weight [gm/m]	300		
Width [mm]	80-100		
Thickness [mm]	8-10		
Roll length [m]	150,300,450,1000		
Roll weight [kg]	45, 90,135, 300		

* FHWA: Federal Highway Authority of USA
** Double Filter layers prevent clogging and increase filter permeability
¶ More discharge capacity is required at the surface and less at greater depth

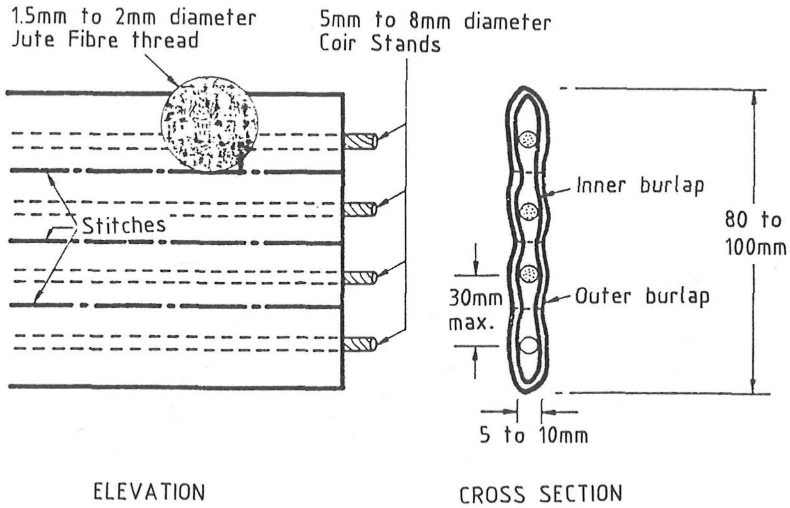

Fig 1.: The Structure of Fibredrain

USE OF FIBREDRAIN IN JAPAN

FD was installed successfully in one project site at Hiroshima, Japan. It was also tested with other prefabricated vertical drains (PVD). In another site at Yokohama area. Preliminary observations show that all PVDs work equally well in the peaty clay soil. The need for heavy tamping application in peaty soils and ecological and environmental issues were major considerations for the choice of the FD to be adopted.

The installation of FD in one project under the jurisdiction of Hiroshima Prefecture Government has been reported (7). A spacing of 1.1 m on a square grid was chosen for this purpose. Sand drains were also installed at 2.5 m square spacing I the same site for comparison. The site was underlain by about 15-18 m of Ariake Clay. The monitoring of the site was implemented using piezometers and multi-layer settlement gauges.

Feature of the Project

Hiroshima prefectural government planned the reclamation project for redevelopment of Hiroshima Port. In this project, the sand drain method was planned to be introduced at the stage of design, but the shortage of sand for implementation of future projects led the prefectural government to consider the use of FD. However, since the FD had never been utilised in a coastal area in Japan. The FD and SD were installed and field tested to evaluate the performance of FD. The properties of Ariake marine clay are shown in Fig 2.

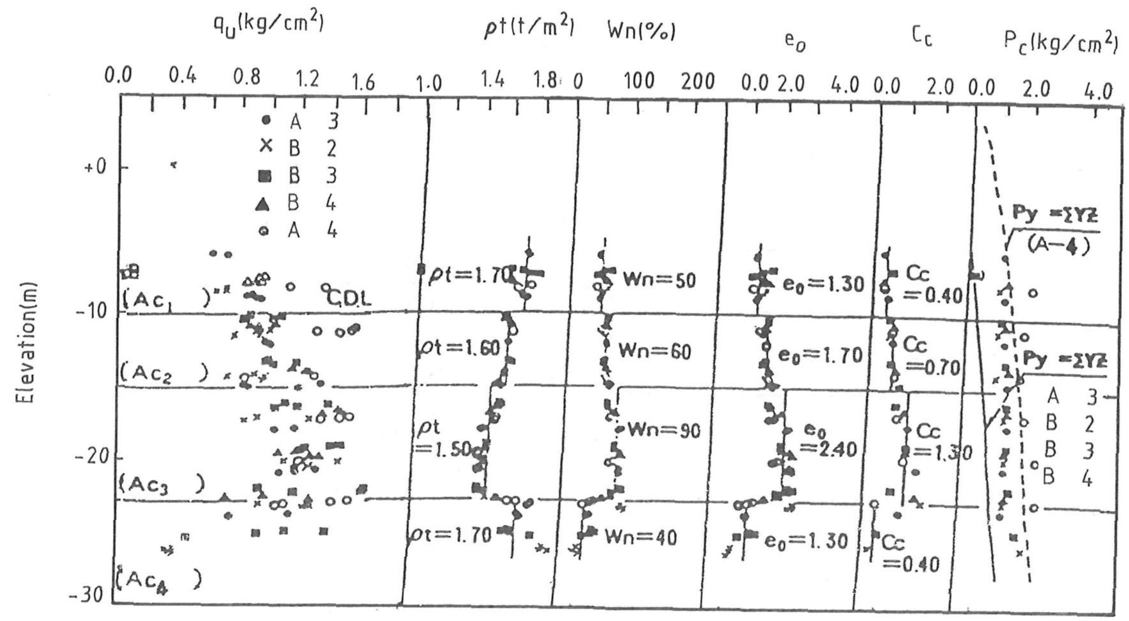

Fig 2.: Properties of Ariake Clay at Hiroshima, (7)

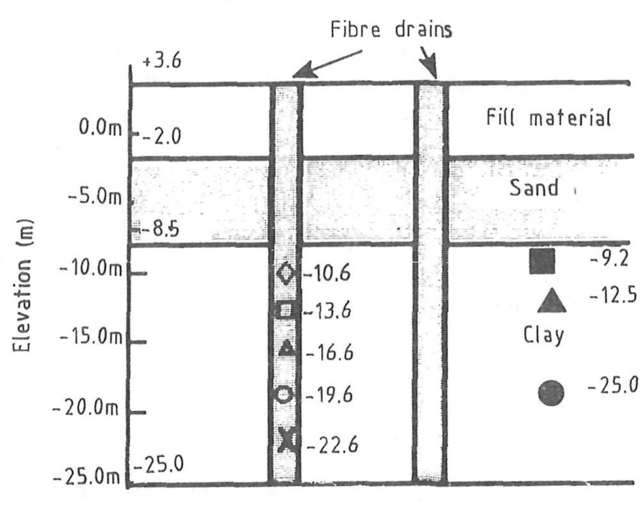

Fig 3: Piezometric Locations in FD Area Surrounding Clay (7)

The piezometers installed in clay in the SD area were monitored for a period of about 7 months. The piezometers were placed at El-9.2,m,-12.5m and -19, where the clay occurs between El-8.5m and -25m. Above the clay layer, a sand layer existed between El-2m and -8.5m, while the fill material rose from El-2m to +3.6m. A considerable excess pore pressure remained in the clay at the end of eight months in the sand drain area.

Piezometers in the FD area were installed within the drain core to investigate the well pressure within the drain. These were placed at El -10.6m, -13.6m, -16.6m, -19.6m and -22.6m. Fig 3. shows the location of all the piezometers. Within the same eight-month period, the piezometers in the FD core showed only an excess pore pressure not exceeding 10 kPa (1 tf/m^2). Fig 4. Shows the surface settlement monitored in the two installations compared with the predicted values based on Barron's theory with well resistance. The performance of both drain types, when compared with the predictions, appears to be nearly identical from the point of view of surface settlement monitored. It should be noted that the required axial permeability is 5 x 10^{-3} cm/sec at 1- kPa and 9.9 x 10^{-2} cm/sec at 300 kPa. Since all the piezometers within the FD show only negligible well pressure, well resistance is insignificant and hence axial capacity is more than adequate. Fig 5. Compares the porewater pressure distribution within and outside the FD areas. It is realised that the distribution of excess pressure in FD was 5-10 kPa at the time of filling and became approximately zero afterwards while the excess pressure in the clay increased instantly upto 60 kPa after embankment filling and decreased with the progress of consolidation. Furthermore, the excess pore pressure at the bottom in FD was nearly zero.

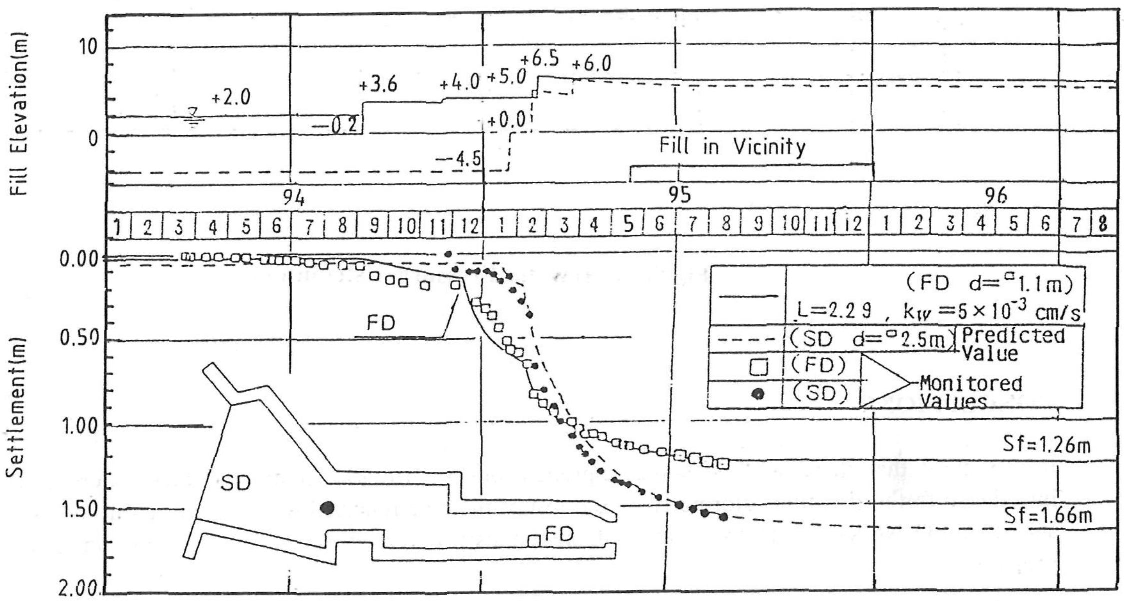

Fig 4.: Surface Settlement in Sand Drain and Fibredrain Areas

It was found through these field test monitoring studies that no worry about consolidation delay is necessary for using FD because of its characteristics of enlarging the cross sectional area with the progress of consolidation and environmental friendliness (6) as well. Therefore FD was introduced to the major soil improvement works in the Port Hiroshima redevelopment project instead of SD, where the spacing of FD was increased from 1.1m to 1.3m based on the positive field data.

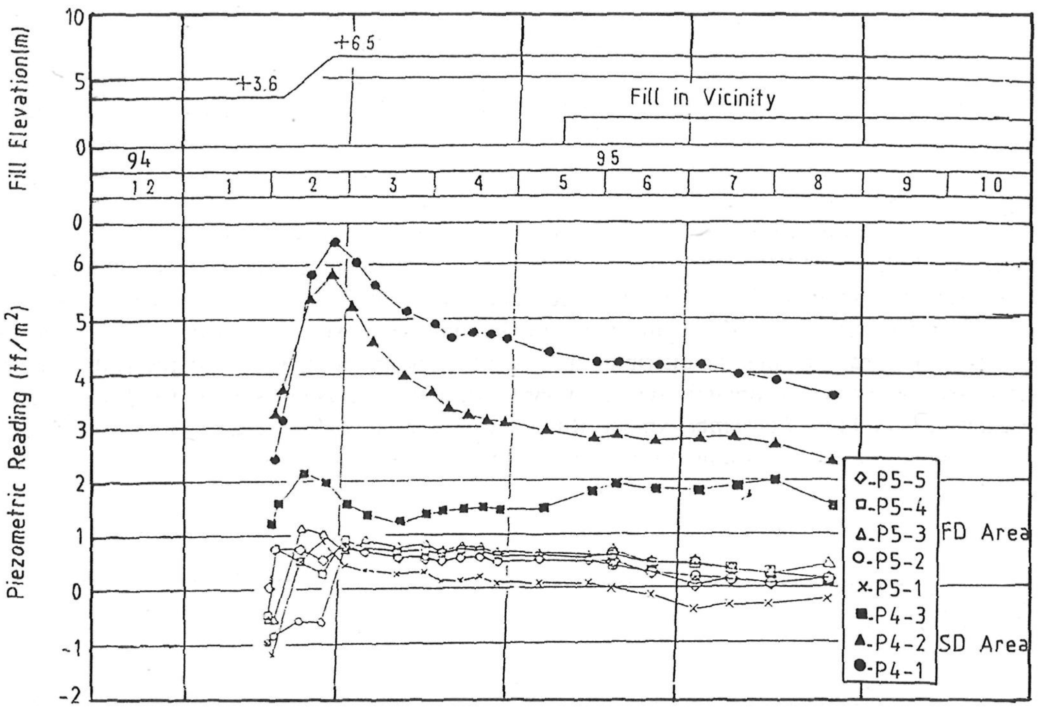

Fig 5.: Porewater Pressure Distribution

CONCLUSIONS

It is natural that there will be some apprehensions to use FD in any country where it is introduced forthe first time. Normally a field test of the type reported will be carried out to make sure that FD works satisfactorily and advantageously before it is accepted for use in major projects.

Natural fibre prefabricated drains proved to be preferable and advantageous over conventional sand drains for use in soil improvement works at the reclamation project to redevelop Hiroshima port in Japan. This study only confirmed the pilot studies conducted in Singapore, Malaysia and Indonesia. Apart from the environmental acceptability, the other points in favour over sand drains and plastic prefabricated drains were the efficiency in excess prewater pressure dissipation, reduced well resistance, speedy installation and cost effectiveness. The question of durability never arose and indeed the biodegradability was a plus point as the performance over 6 months to 1 year could suffice the needs of most soil improvement projects. The study reported was the first application of FD which led to its large scale application in the Hiroshima port development project, Japan. Following the successful performance of FD in this project, it has been used in several other large projects in Japan over the past 2-3 years. The case studies on those projects would be published when field data become available.

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