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Sub-Strata Treatment

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Sub-strata Treatment for A Building Using Rope Drains

by

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Introduction

Rope drains have been developed by the Central Building Research Institute to function as vertical drainage paths for pre consolidation of compressible soil strata, The flexible rope drains having 70 mm outer dia are made by rolling long strips of 150 mm wide. 10 mm thick coir mate (Figure 1a and Figure 1b). The cylindrical drain with contineous drainage path along its length showed very high permeability and the soil in contact would not penetrate inside to choke the drainage efficiency, History of its development and success of its performance in the field have already been reported.

The present paper describes first application of the technique for strengthening of ground for a three storeyed building at Andul Radar Station, West Bengal.

Background for Use

The Radar Station at Andul is situated by the side of the Calcutta—Bombay National Highway and is at a distance of about 40 km from

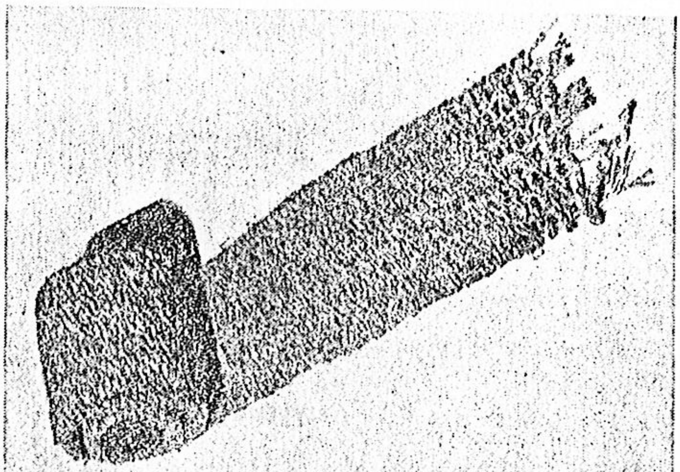

FIGURE 1a Coir mat strip

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FIGURE 1b Prepared drains rope

Calcutta. The premises of the Radar Station is a filled up land on a low lying paddy field and the height of the fill is about 2 m from the surface of the paddy field. Filling was done a few years ago with silty-clay soil collected from near by borrow pits. The Radar Station main building was rested on long driven cast-in-situ concrete piles and was in an intact condition. A three storeyed building was to come up adjacent to the main building. The lay-out of the proposed foundation is shown in Fig-2. The foundation consists of footings connected with strip to support the walls. The depth of foundation is 90 cm from existing ground surface. Taking cognition of serious settlement failures of some existing light structures on shallow foundations at the site, it was felt that any building on such foundation would undergo heavy settlement. Use of conventional concerte piles of large lengths was not feasible considering the heavy cost involved. Therefore, strengthening of ground by pre-consolidation was considered as an alternative. For loading, any quality of soil could be available from adjacent borrow pits.

Soil Condition at the Site and Design of Drainage System

The site is situated in the silty-clay deposit of the reign. The top 2 m thick silty-clay fill is still in an uncompacted state. This is underlain by the virgin soil of the low lying paddy field. The 6 m thick silty-clay layer

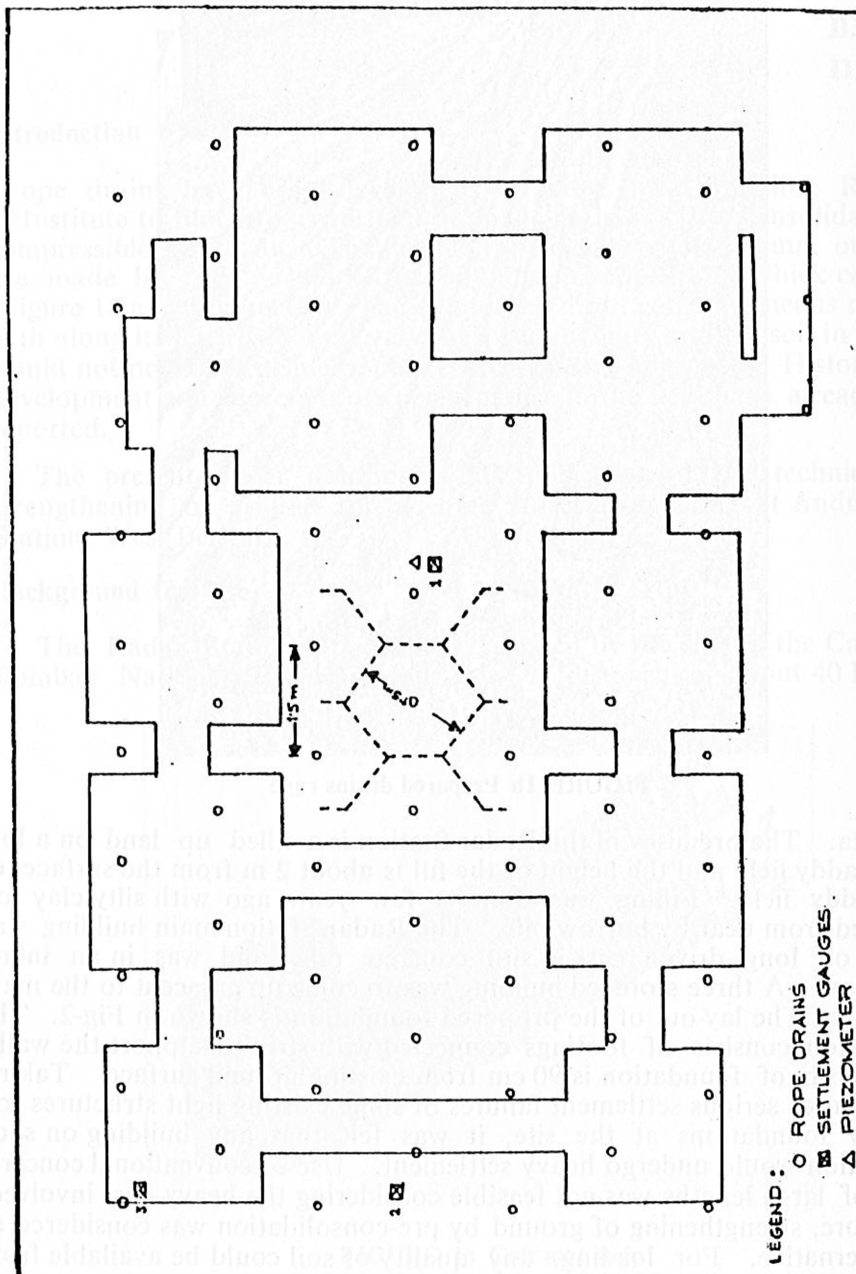

FIGURE 2 Layout of the proposed foundation showing distribution of drains and position of gauges

below the filll is also in a soft and saturated state. This is followed by a stiff layer of silty-clay with sand admixture. Ground water table is present at a depth of 3.5 m. The bore log and sounding curve for Static cone Penetration Test is shown in Figure 3, which bring out the nature of soil stratification at the site.

Giving consideration to the sub-strata condition prevailing at the site, it was considered enough to pre-consolidate the layers extending up to 10 m depth (Figure 3). The width of the building is 6.1 m, the depth 10 m would be about 1.5 times the width considering the depth of foundation as 1 m. It is khown that spacing has a pronounced effect on the efficiency of a system of drains. Therefore, while selecting the spacing of the drains in the present case, economy of use as well as efficiency of the system of drains were kept in view. To maintain a ratio of 20 for half of the spacing distance, R, to the radius of the drains, r_w, a spacing of 1.5 m was adopted (Figure 2). Hexagonal grid pattern of drain placement was used and the boundary condition for such a distribution of drains is also shown in the figure.

Prediction of Settlement

To cater for the need of the building, a load intensity of 0.7 kg/cm² was proposed to be applied over the rope-drain installed area. With this intensity of loading, the predicted total settlement and degree of consolidation etc. were worked out as.

(*i*) Total settlement.

To forecast the total settlement, the following formula was used

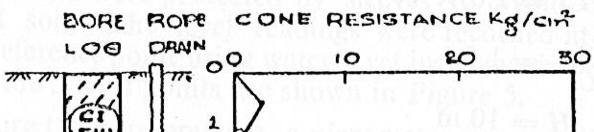

FIGURE 3 Borelog and static core resistance.

$$S = \frac{C_c}{1+e_0} \cdot H . \log \frac{P_0 + \Delta p}{P_0} \qquad \ldots(1)$$

The depth of 10 m was considered in five 2 m thick layers and settlement in each layer was worked out. Stress distribution Δp, at the mid point of the layers was obtained from Newmark's chart.

On basis of $C_c = 0.40$ for the top 2 m thick layer and $C_c = 0.33$ for the underlying four layers, the total settlement for a raft was found to be 49 cm with the superimposed load intensity of 0.7 kg/cm². 90 percent of this value is 44 cm.

(*ii*) Degree of Settlement

To calculate the degree of settlement, the following equation was used

$$(1-U) = (1-U_z) . (1-U_r) \qquad \ldots(2)$$

Where,

U—degree of consolidation for three-dimensional flow.

U_z—degree of consolidation for one-dimensional flow-

U_r—degree of consolidation for radial flow.

In the present case, by trial and error, a value of 11 per cent for U_z was found to fulfill the condition U = 90 per cent

The following parameters were used for calculations,

$$C_r = 2.6 \times 10^{-3}$$

$$\frac{C_{vr}}{C_v} = 1.5$$

$$H = 10 \text{ m}$$

$$2R = 1.5 \text{ m}$$

$$\frac{R}{r_w} = 20$$

On the basis of U_z = 11 percent, the time for 90 percent consolidation for three dimensional flow with rope drains works out to 43 days. Without rope drains, the predicted time for 90 percent consolidation is 3770 days.

Installation of Rope Drains

To cover an area of 8 m × 12.5 m, 70 rope drains were installed in 7 rows with 10 rope drains in each row. The spacing of drains in a row was 1.5 m centre to centre. Three more rope drains were installed to cover a small projected area of the building. The drains were prepared in 10.5 m lengths by rolling 150 mm wide and 10 mm thick coir mate. The effective diameters of the rope drains were 70 mm.

The drains were installed by driving steel casing pipes with the rope drain inside. The drain was securely tied with the detachable steel conical shoe closing the bottam of the steel casing pipe. To make use of simple equipment and to eliminate high driving rigs, the steel casing pipes were in 3 m lengths, which could be connected to one another with proceed of penetration. The special driving head used for receiving the hammer blows was provided with a window at the side. Through the window the extra length of the rope drains protruding out of the casing pipes could hang and did not receive any hammer blow. The driving was done by blows from a 500 kg. drop hammer operated by a diesel-power driven winch. The simple appliances are shown in Figure 4 on reaching the desired depth of 10 m, the casing pipes were withdrawn leaving the rope drains embeded into the ground. It was possible to install 6 drains in a day of 8 working hours.

Loading and Settlement

On completion of installation of rope drains, load was applied and the progress of settlement under loading was recorded at regular intervals.

(*i*) Loading—A 7.5 cm thick sand blanket was laid over the area and load was applied by raising an earth embankment with clayey-silt soil collected from a nearby borrow pit. To maintain the required area at the top of the embankment, its base extended beyond the boundary line of the drain installed area by about 2 m. The load intensity of 0.7 kg/cm² could be approximately achieved by 4.5 m height of the embankment.

(*ii*) Settlement—To record the progress of settlement at the site, level points were established at 3 locations *viz*, (*i*) at the centre of the treatment area, (*ii*) at the centre of the smaller side of the area and (*iii*) at the corner of the area (Figure 2). The reference point was established on the adjacent Radar-Tower resting on long driven cast-in-situ concrete piles.

The level points consisted of a 20 mm dia 6 m long conduit pipe fixed to a 30 cm × 30 cm base plate. The level points were vertically rested on the ground and were protected by sleeves to avoid contact with the embankment soil. The level readings were recorded at regular intervals against the reference point using water-level instrument. The establishments recorded by the 3 level points are shown in Figure 5.

To measure the pore pressure, a piezometer was installed at the centre of the drain distributed area. The initial level of ground water was at a depth of 3.5 m below existing surface. With increase of loading, the piezometric height rose and almost touched the zero level within 25 days, when placement of load was nearing completion. Unfortunately at this stage, the piezometer was disturbed and further readings could not be taken.

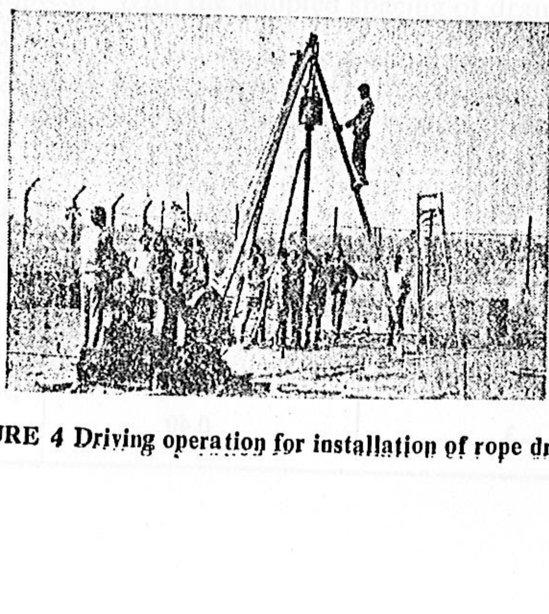

FIGURE 4 Driving operation for installation of rope drains.

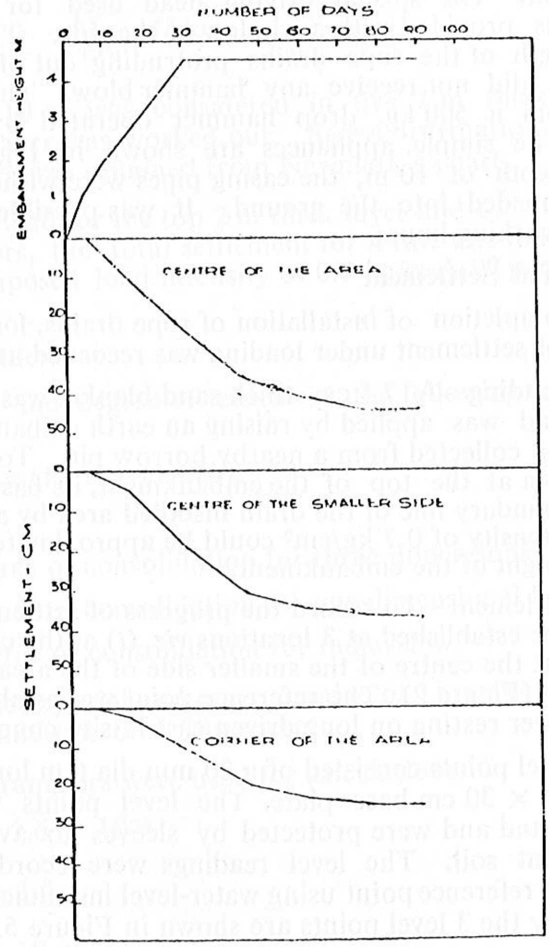

FIGURE 5 Programs of loading and settlement of ground

Effect of Treatment

Wnen the progress of settlement almost died down as indicated by the asymptotic trend of the settlement curves (Figure 5), the superimposed load was removed.

To record the achieved improvement, bore holes were sunk in the the treated are and undisturbed soil samples were collected and tested in the laboratory. Positive improvement was shown by the increased values of cohesion, *C*, after treatment as shown below,

Depth m	*C* kg/cm²	
	before treatment	after treatment
1	0.40	0.60
3	0.40	0.70

When trenches were cut for foundation work, the achieved improvement could also be visualised from the well compact structure of the exposed soil layers.

Cost Analysis

The cost of full treatment of the site is given below,

(*i*) Price of coir mat at site		
Including wastage, the total length of coir mat consumed — 800 m.		
Cost of coir mat at the site @ Rs. 8.00 per meter ...		Rs. 6400.00
(*ii*) Charge of Installation		
Lump sum contract including charge of mobilization at site, fabrication of rope drains and installation ...		Rs. 7700.00
(*iii*) Loading and unloading		
Lump sum contract including cost of sand for the blanket, soil cutting from borrow pit, haulage, raising of embankment followed by removal of soil and back filling of the borrow pits after pre-consolidation. ...	Rs.	9000.00
Total	Rs.	23,100.00
SAY	Rs.	23,000.00
Cost per square meter of area ...	Rs.	23,100.00

Price of material at site, Charge of installation, Cost of preloading are in the proportion 1 to 1.2 to 1.4.

Discussions

To achieve better efficiency, installation of rope-drains in hexagonal grid pattern was adopted. With the adopted spacing of drains, the settlement of the ground was complete within a very short period and the settlement curves tended to become asymptotic within 45 days after loading. If half of the loading period, that is, 15 daps is counted in addition to 45 days, than the actual time becomes 60 days. Against this the predicted time for 90 percent settlement for three dimensional flow with rope drains is 43 days. This difference between the predicted time and the actual time taken is not wide considering the uncertainties involved in determination of the degree of consolidation at any time using the theory. The total measured settlement at the centre of the loaded area was 45 cm. This also compares well with the predicted 90 percent settlement (44 cm). Without rope drains, a period of more than 10 years would be necessary to realize 90 percent settlement. This proves the efficiency of the system of rope drains beyond doubt.

The achieved improved strength of the ground has also been clearly brought out by the substantial increases of, C, values after treatment. From analysis of cost it can be noted that the ratio of the cost of material to the charge of installation to the cost of preloading and removal was 1 to 1.2 to 1.4. The cost of full treatment of the 1 m×12.5 m area being Rs. 23,000.00 is quite reasonable. In fact, only the cost of mobilization of men, equipment and material at the site for conventional concrete piles would be more than Rs. 50,000.00 according to the prevailing market rate. In addition to that, the cost of piles has to be borne, which would be of the order of Rs. 40.00 per Ton capacity of the pile for this region. In other words, strengthening of ground with use of rope drains in the present case has been quite economical. Observation on the long term performance of the building will be kept.

Concluding Remarks

First application of rope drains were made to improve substrata condition for foundation of a 3 storeyed building at Abdul Radar Station, West Bengal. The following concluding remarks are offered,

(*i*) The application brought considerable economy over conventional concrete piles.

(*ii*) Simple appliances were used for installation of the drains.

(*iii*) The efficiency of the drains was proved beyond doubt as 90 percent of the predicted settlement occured in 45 days after full loading in the field. Without rope drains, the period would be more than 10 years.

(*iv*) The realized settlement as well as its period of occurance compared well with the predicted values.

(*v*) An expenditure of Rs. 230.00 was incurred for treatment per square meter of area involving cost of material, charge of installation and cost of loading and unloading. The ratio of the cost of material to the charge of installation to the cost of loading and unloading was 1 to 1.2 to 1.4,

(*vi*) The performance of the building will be kept under observation.

Acknowledgement

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References

DASTIDAR, A.G. (1973). "Silver Jubilee Lecture on Applications of Soil Mechanics with particular reference to problem in India". *Indian Geotechnical Society Symposium of*, Regional Engineering College, Kurukshetra, December.

DASTIDAR, A.G., GUPTA, S. and GHOSH, T.K. (1969). "Application of sand wicks in a housing project" *Proceedings of the Seventh International Conference on Soil Mech. and Found. Engg.*, Mexico, Vol. 2, pp. 59-64.

DINESH, M. JAIN A.S., SENGUPTA D.P. and SHARMA D., (1977). "Consolidation of Ground by vertical Rope Drains", *Indian Geotechnical Journal*, Vol. 7, No. 2.

LEONARDS G.A. (1962). "Foundation Engineering", *McGraw Hill Book Company Inc. Newyork*, pp. 177-176.

RAO, D.J., MADHAV, M.R. and RAO, K.K., (1971). "Design procedures for sand drains," *Journal of the Institution of Engrs.* (India), Vol. 51, No. 9, Pt. CI 5, pp. 235-239.

SING, A. and PUNIMA B.C. "Soil Mechanics and Foundation Engineering".

SUBBARAJU, B.H., NATRAJAN, T.K. and BHANDARI, R.K., (1973), "Field performance of drain wells designed expressly for strength gain in soft marine clays", *Proceedings of the eighth International Conference on soil Mech. and Found. Engg.* Moscow, Vol. 2, pp. 217-220.