Lecture 7

NPTEL Course

GROUND IMPROVEMENT

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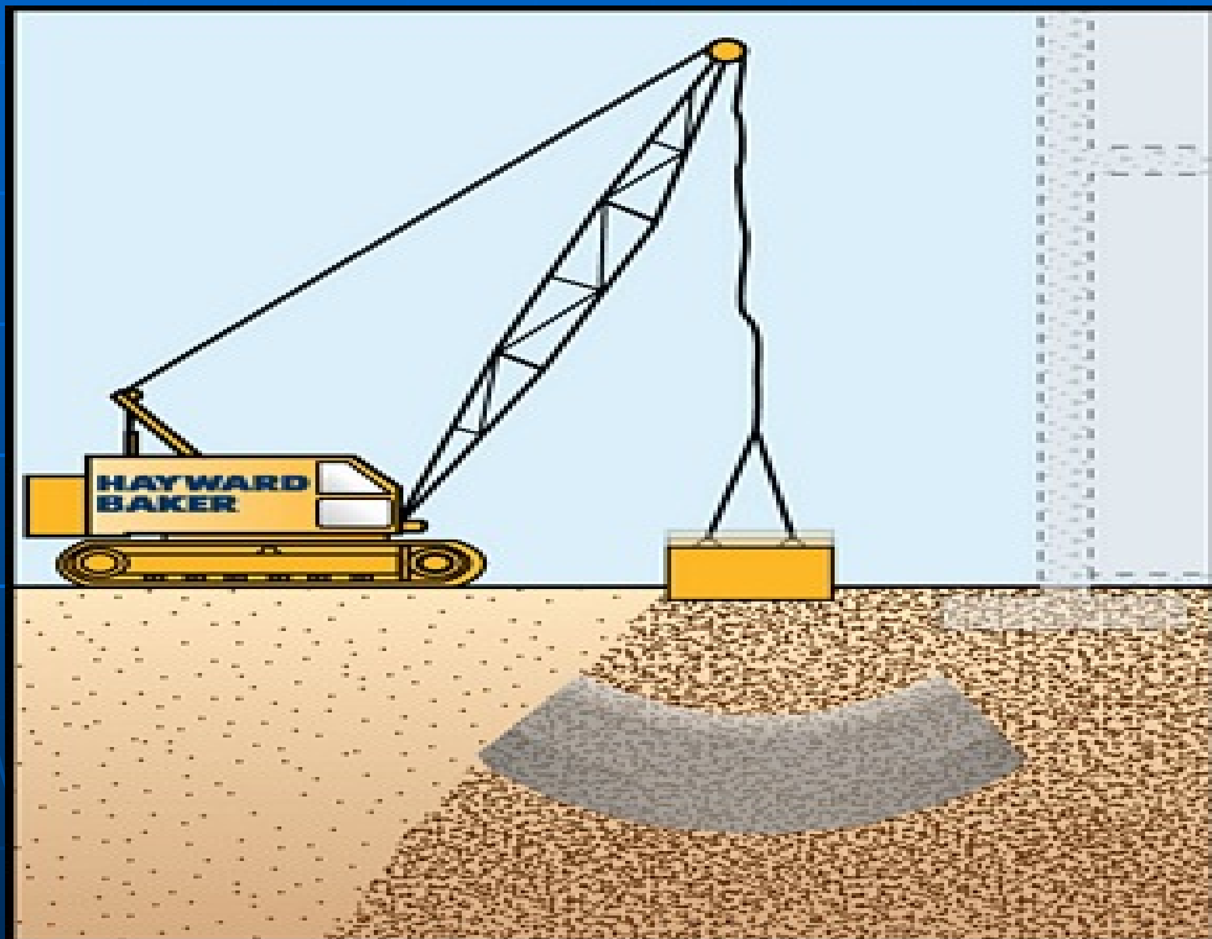
DYNAMIC COMPACTION



INTRODUCTION

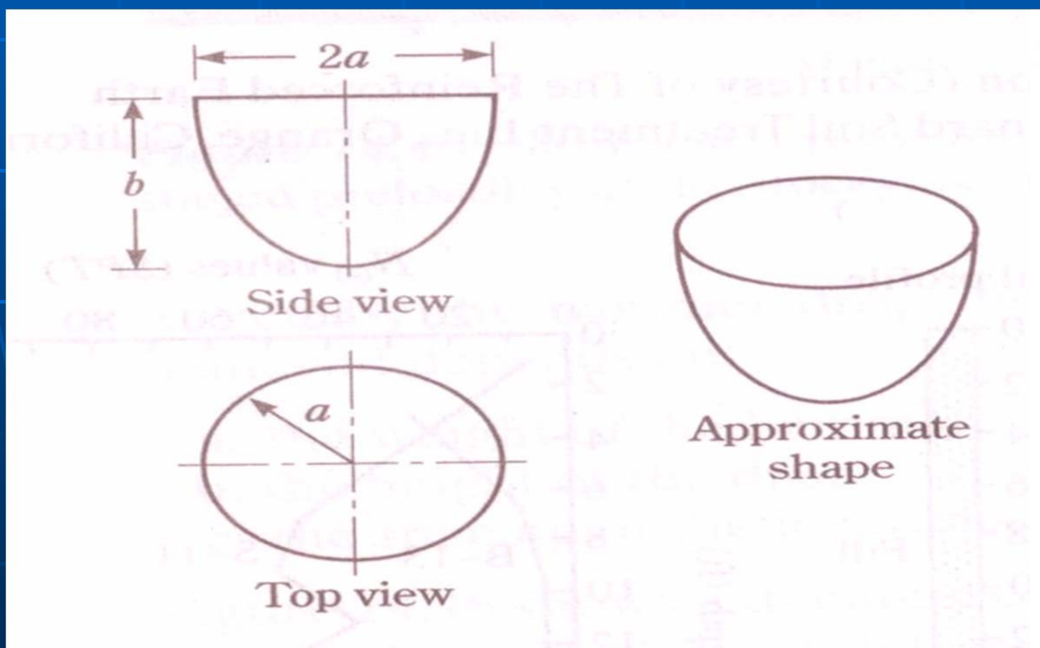
- Dynamic compaction is a ground improvement technique that densifies soils and fills by using a drop weight.
- The drop weight, typically hardened steel plates, are lifted by a crane and repeatedly dropped on the ground surface.
- The drop locations are typically located on a grid pattern, the spacing of which is determined by the subsurface conditions and foundation loading and geometry.
- Treated granular soils and fills have increased density, friction angle and stiffness.

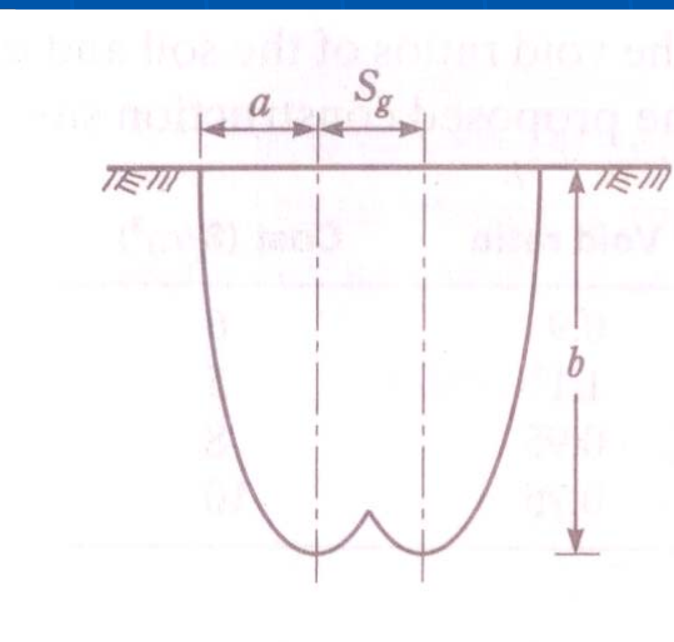
- The technique has been used to increase bearing capacity, and decrease settlement and liquefaction potential for planned structures.
- In shallow karst geologies, it has been used to collapse voids prior to construction, thereby reducing sinkhole potential.
- Dynamic compaction has also been used to compact landfills prior to construction of a parking lots, roadways, and to stabilise large area of embankment works.

- One of the most important considerations regarding the applicability of dynamic compaction is the type of soil being densified.
- In general, dynamic compaction is most beneficial on a category of soil known as granular materials.
- Granular materials enable excess pore water pressures that develop during the densification process to dissipate rapidly.
- Dynamic compaction will be effective in silts, clayey silts and sandy silts.

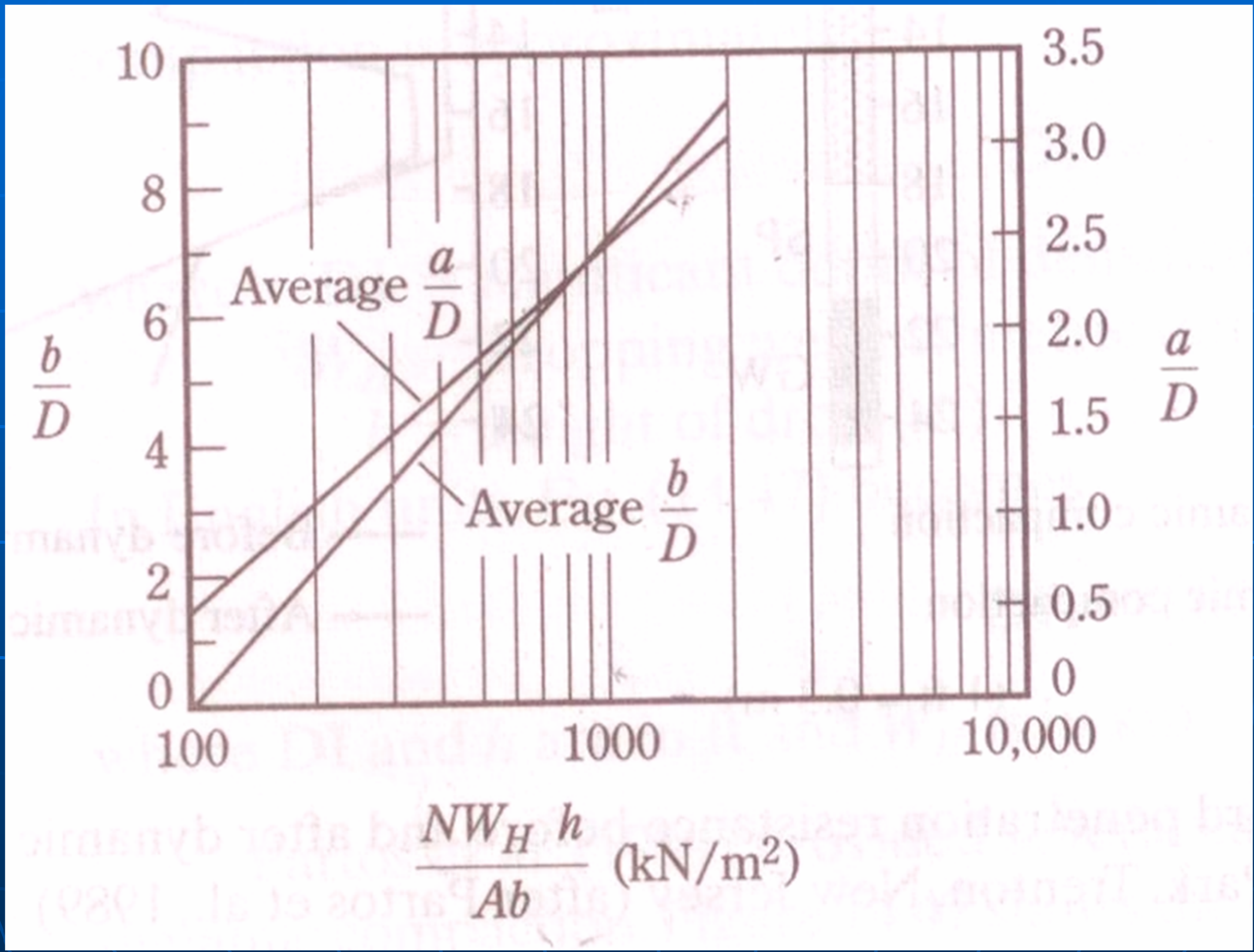
Approach for design

Poran and Rodriguez (1992) suggested an approach for design of dynamic compaction scheme in a project based on the approximate shape of the area compacted which is assumed as follows.





Approximate grid spacing



Plot of a/D and b/D vs. NW_Hh/Ab

1. The required significant depth of densification, DI is obtained from

$$DI = \frac{1}{2}\sqrt{(W_H h)}$$

Where DI = significant depth of densification (m)

W_H = Weight of hammer (metric ton)

h = height of drop (m)

2. From the figure given above, DI = b

3. The hammer weight (W_H), height of drop (h), dimensions of the cross section, and thus the area A and depth D is determined

4. Determine DI/D = DI/b
5. Using the plot given by Poran and Rodriguez (1992), determine the magnitude of NW_Hh/Ab for the value of b/D obtained.
6. Since the magnitude of W_H, h, A and b are known (or assumed), the number of hammer drops can be estimated .
7. With known value of NW_Hh/Ab, determine a/D and thus a.
8. The grid spacing, S_g, for dynamic compaction may now be assumed to be equal to or somewhat less than a.

The following is a typical example,

Weight of the hammer, W_H = 185kN

Height of drop, h =26m

Width of hammer, D = 5m

1. DI = $\frac{1}{2}\sqrt{(W_H h)}$

   $=\frac{1}{2}\sqrt{(18.5*26)}$ =10.96m
2. DI = b = 10.96 m, assume D= 5m A= 25 sq.m
3. DI/D=b/D= 10.96/5 = 2.2
4. From the plot given in fig 3 we got NW_Hh/Ab = 220 kN/m^2
5. Since we know W_H, h, A and b. Number of hammer drops, N= 14 blows

6. With the known value of $NW_H h/Ab$, determine a/D from the fig 3 and thus a = 16 m .
7. The grid spacing, $S_g \underline{\sim}$ a = 16m.

Thus using a square plate of 5m for a height of drop of 26m (14 number of blows) at grid spacing of 16m, using a weight of 18.5 t tamping will enable 10.96 m depth of improvement.

In Situ Evaluation of Deep Compaction

The effectiveness of deep compaction is noted from analysis of construction process, pore pressure and settlement records, requirement of imported fill to achieve a certain grade, energy consumed by the equipment etc.

In Situ Evaluation of Deep Compaction

1. Deep penetration tests

a. Standard penetration resistance (SPT)

Correlations with SPT and friction angle and relative

density are available. (Ex; SPT 30 indicates dense RD)

b. Cone penetration resistance (CPT)

Correlations with Cone resistance and overburden pressure, and relative density are available

2.Compressibility estimates from penetration tests

a. Soil modulus and SPT results (E = 2.8 N MPa)

b. Stress- Strain parameters from cone penetration resistance (Constrained modulus $E = 2.5\ q_c$)

3. Stress-Strain modulus from pressuremeter tests

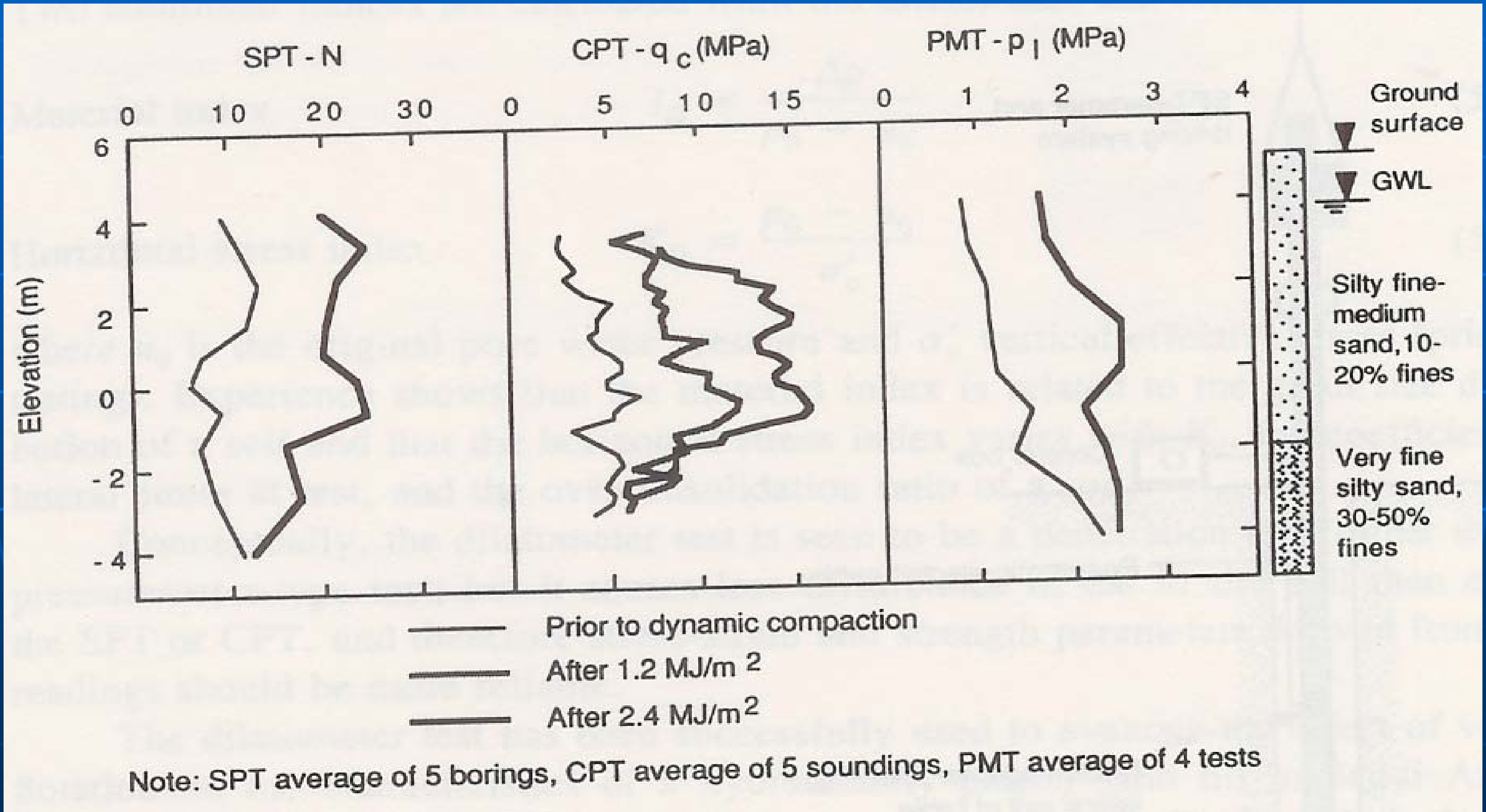
a.Menard Pressuremeter

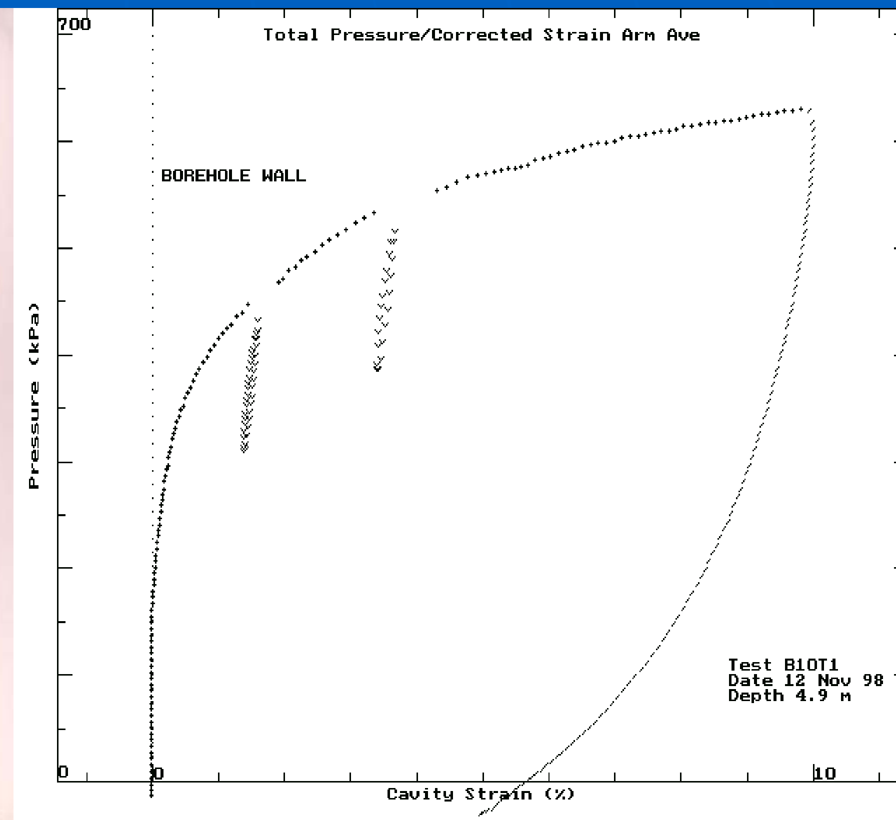
b. Self Boring Pressuremeter

4. Dilatometer tests

5. Shear wave velocity measurements

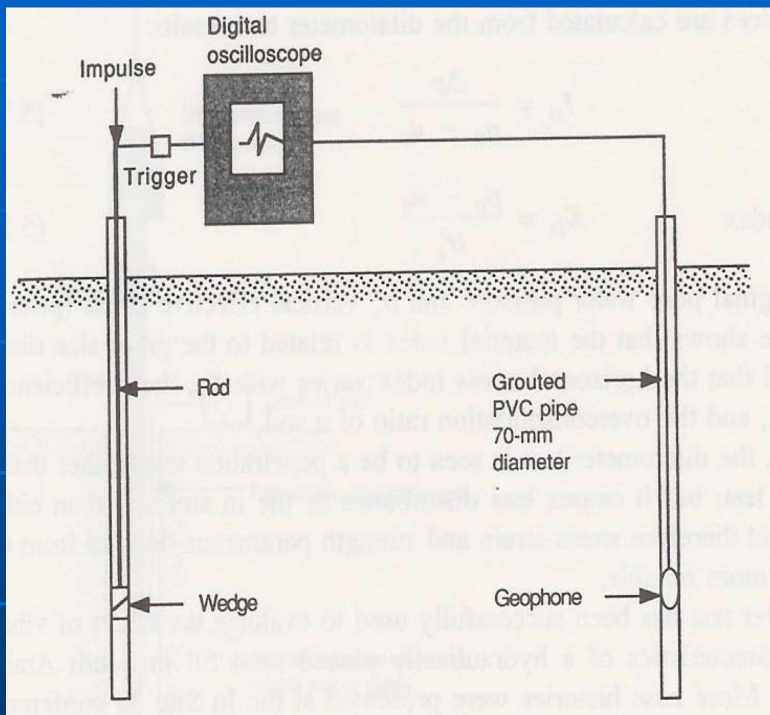
Degree of ground improvement achieved by dynamic compaction



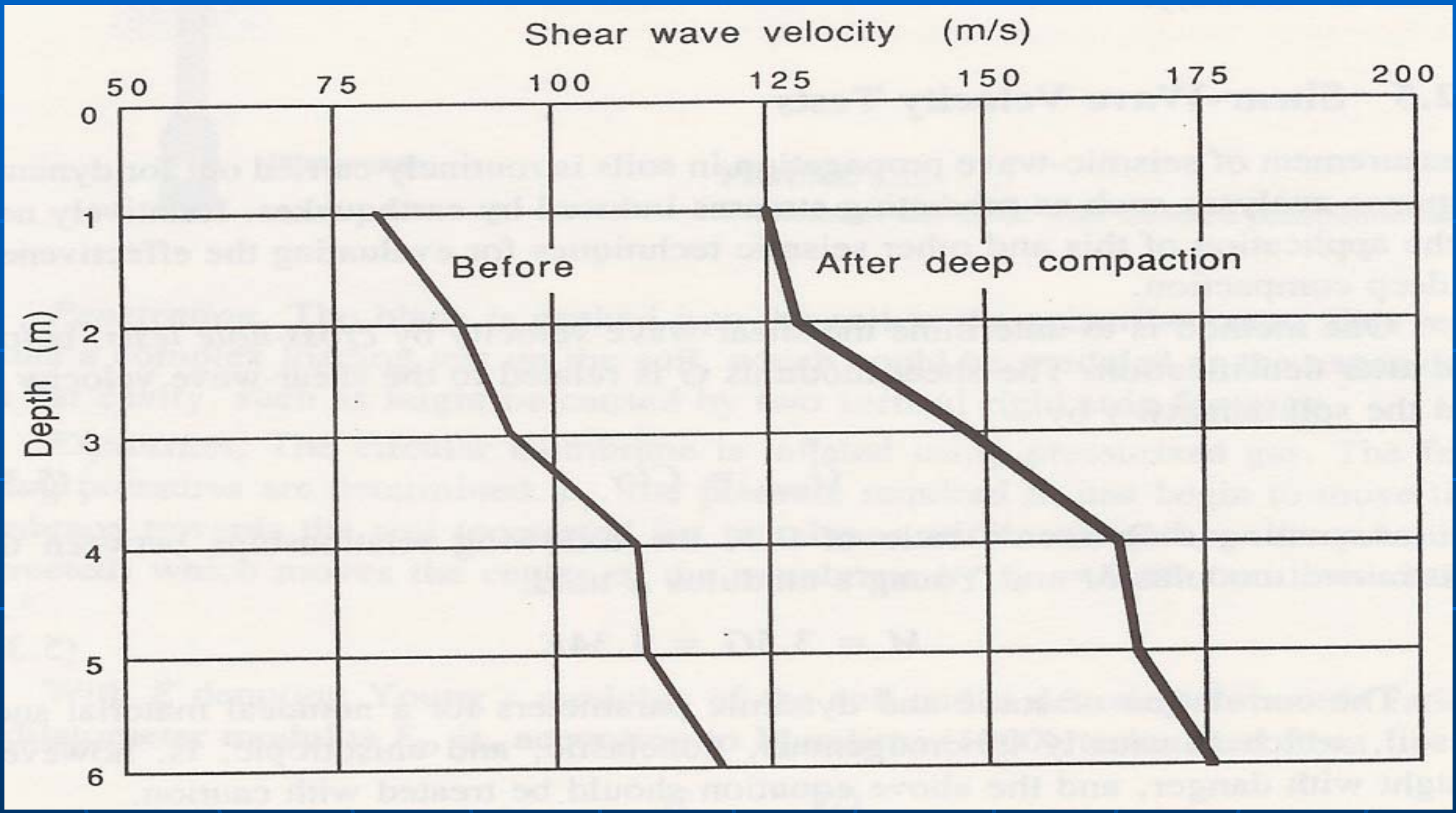


Self boring pressuremeter and kit

Shear –Wave Velocity tests



Flat Dilatometer tests



Shear- Wave velocity profiles observed before and after deep compaction

CASE STUDIES

Nice airport new runway - France

- An extension was made for the existing Nice airport by constructing two new runways 3200 meters long, parallel to the shore line on a reclaimed land.
- The soil conditions prevailing were loose fill, some stiff marls and deposits of soft sandy silts.
- Hence there was a need for heavy dynamic compaction in and around the runway.

- The project involved the placement of about 20,000,000 m^3 of fill to build a reclaimed platform of 200 ha. The borrow pit was situated at 13 km from the main site. The transport was made by means of a fleet of 38 dumper trucks with trailer 145 tons total weight.
- The evolution of pore water pressure was continuously monitored at various depth during DC. Works have been done in successive phases with sufficient resting periods to avoid building excess pore pressure. The volume versus DC energy governed the intensity of the treatment. During Dynamic Compaction and after treatment numerous CPT, PMT, have been performed to control fill characteristics.

Shuaiba IWPP III - Desalination Plant - Saudi Arabia

- Shuaiba Independent Water & Power Project (IWPP) was planned to meet the growing demands of water and electricity in Saudi Arabia's Shuaiba region, 110 km from Jeddah.
- Site had two types of soil profiles. In the first profile there was loose to dense silty sand and second profile was composed of soft silt or very loose silty sand. This layer was followed by the bedrock.

- The project consisted of 12 evaporators, 3 water tanks and a number of related buildings. The tank's diameter and height were respectively 106.6 m and 20 m. The design criteria stipulated a bearing capacity and maximum settlement of respectively 200 kPa and 75 mm for the tanks. For the other structures, the same were required to be 150 kPa and 25 mm respectively.
- Due to the presence of loose sands and soft silts, it was decided to optimize the foundation solution by implementing dynamic compaction and dynamic replacement in the project. The choice of this technique was dependant on the soil characteristics.

- Upon completion of soil improvement works, 75 pressure meter tests (PMT) and one zone load test were used to demonstrate that the acceptance criteria had been achieved. The results of the tests clearly indicated that success of the ground improvement project, and the ability of the foundations to safely support the design loads.

Abu Dhabi New Corniche Road-UAE

•New Corniche road was widened up to 200m by reclamation of 900000 m^2 using dredged sand for a depth varying from 4m to 12m.

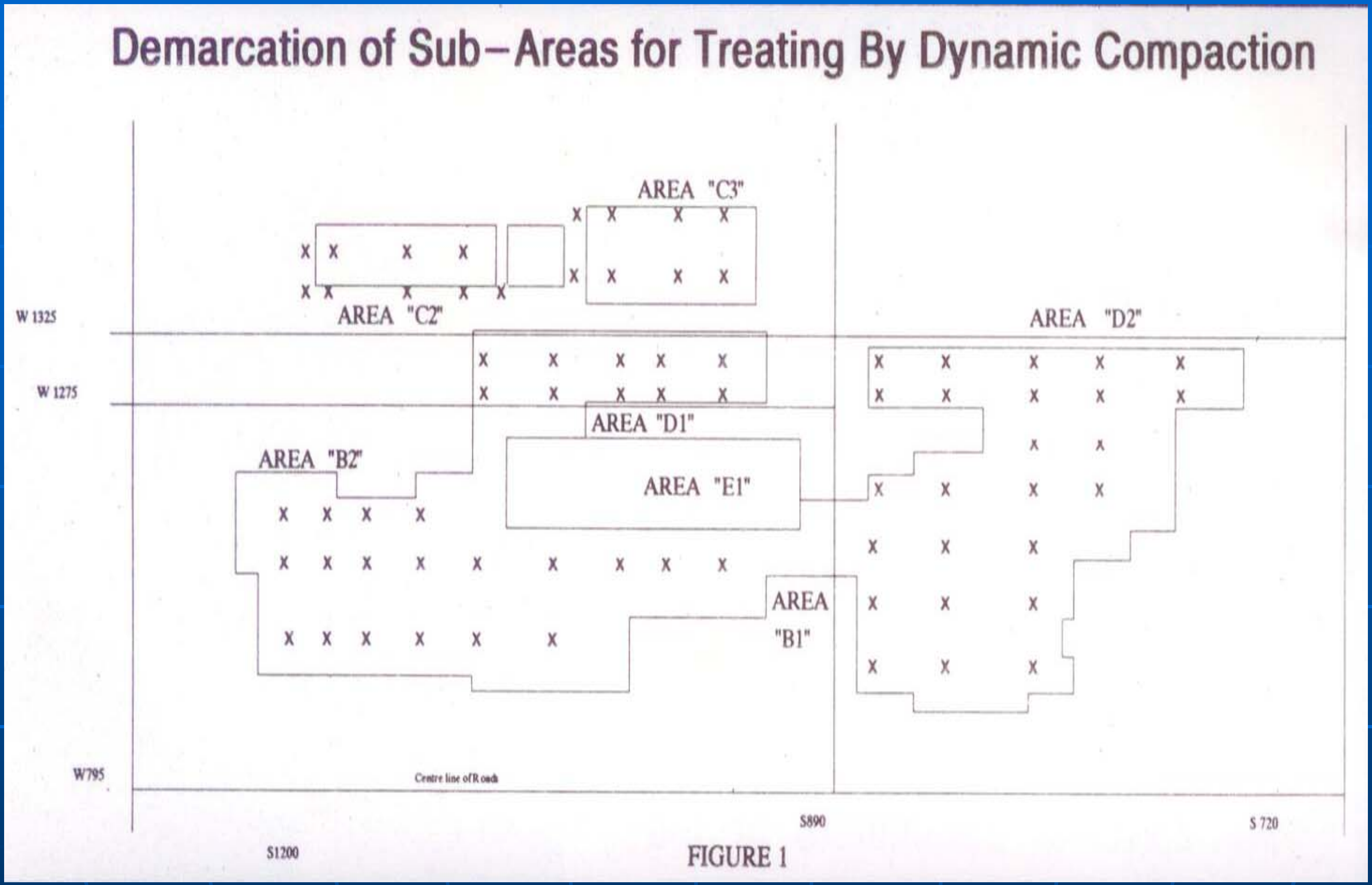
•This structure, of length 4750m, anchored with sheet piles, could not be embedded into hard bedrock, and it was necessary to be equilibrated by a well compacted submarine backfill to generate necessary horizontal reaction.

• Dynamic Compaction (with 15T pounder)and High Energy DC(with 25T pounder) was done for main part of fill with special emphasis on areas with silt pockets.

•Same treatment for sea wall area, with a denser grid on an initially enlarged and raised platform, later excavated after soil improvement completion in order to reach final shape. Measurements were done with PMT and finite elements analysis calculation.

Dynamic compaction for T.C.L. fertilizer complex at Babrala, U.P.

- The soil at Babrala consisted of a surface layer of loose silty sandy clay of 1-2 meters depth underlain by loose fine sand depths of 10-12 meters. This in turn is underlain by silty sandy clay.
- Parameters available at site before the treatment indicate that the allowable net bearing capacity was 60 kPa. A seismic risk analysis of the site fixed the design earthquake as one of magnitude 6.4 with a peak acceleration of 0.2g which could induce significant liquefaction.



➢The effectiveness of this technique at the site was established by treating two areas, 30x30 meters each, by dynamic Compaction.

- Measurement of improvement was done by SPT and SCPT testing. The results of the exercise are shown in fig. 2. The results also demonstrate the increase in strength with time.

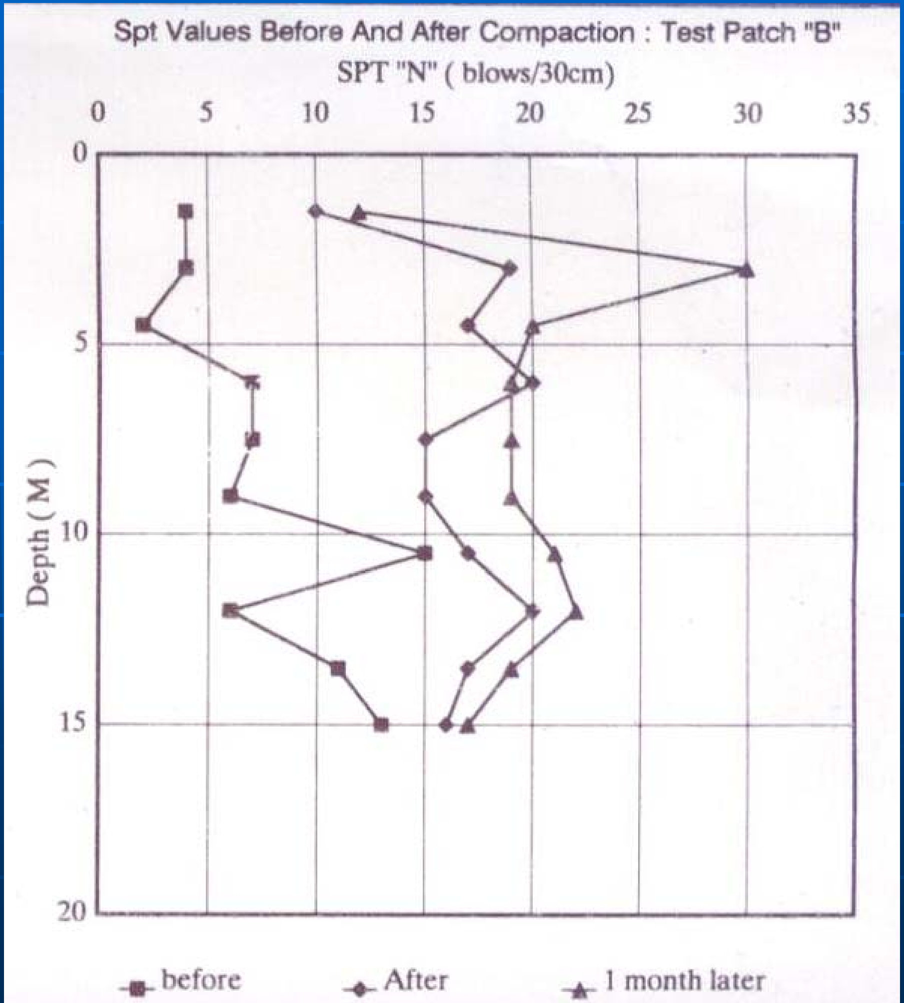


FIGURE 2

Targeted response and treatment

- Based on the results from trials, modifications were introduced to obtain an allowable bearing pressure of 200 kPa at 2m depth and that no liquefaction will occur in the improved ground during the design earthquake.
- Treatment consisted of four passes. The first pass was with a 10 ton hammer falling 16m. The second pass was similar. But the locations are staggered. The third pass is with 15 t hammer falling 16m. The final pass was with a 5 ton hammer falling 16m on a grid of 2.5x2.5m.

Quality monitoring

The treated soil was by the SPT ‘N’ values as assurance against liquefaction and allowable bearing pressure are specified in terms of SPT ‘N’ values obtained.

- The area treated was divided into sub areas as shown earlier and the results of the program are shown in figures 3,4,5.

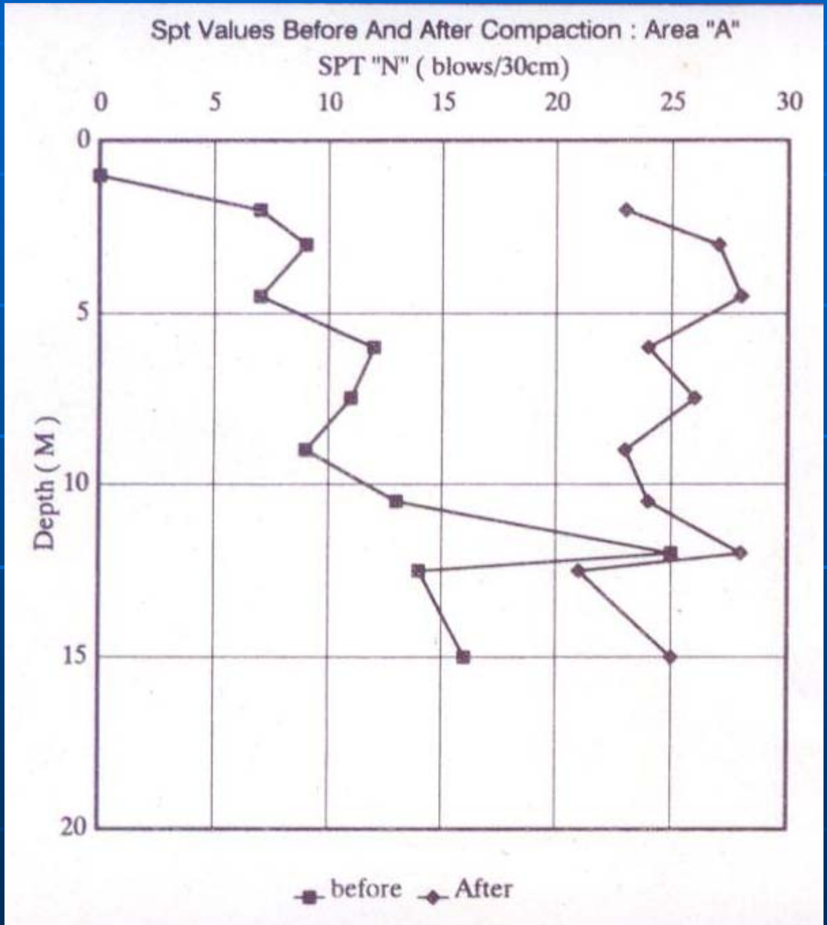


FIGURE 3

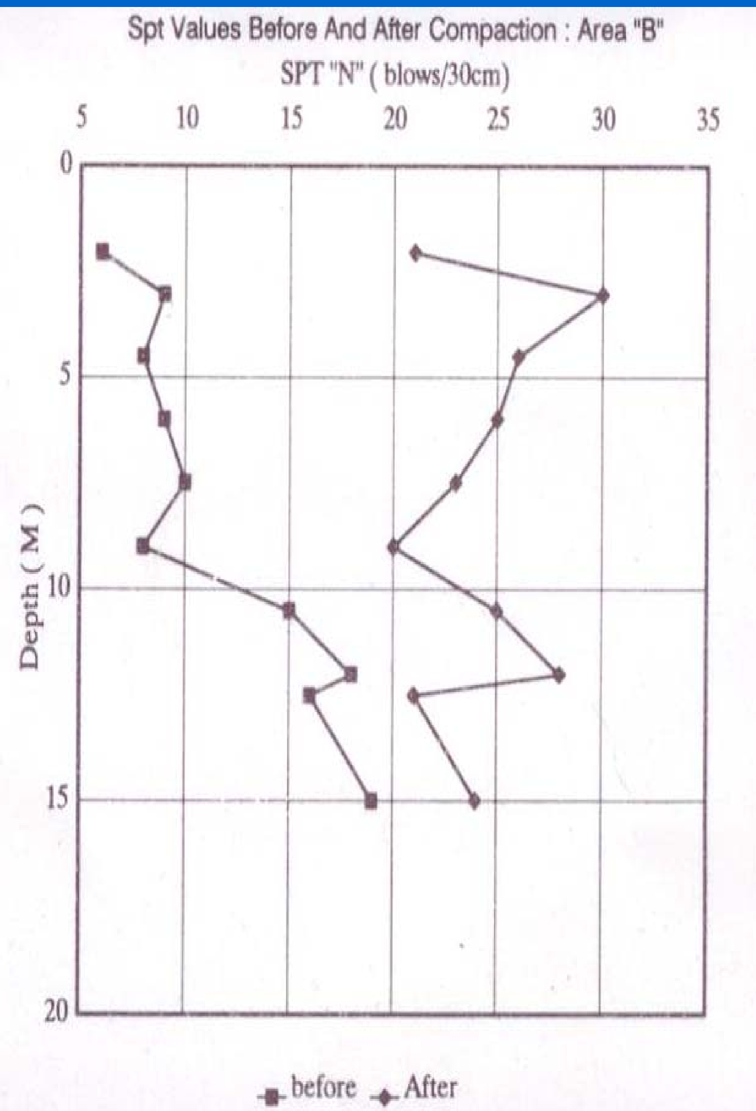


FIGURE 4

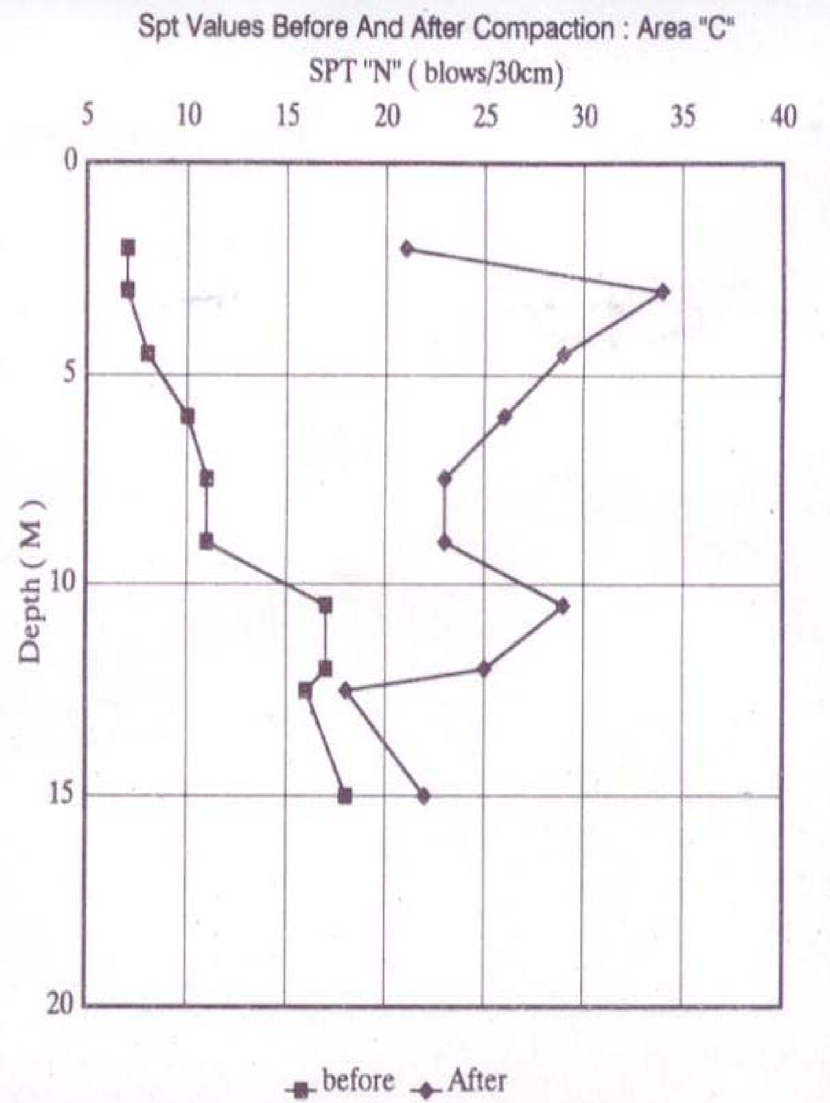


FIGURE 5

Conclusions

- Dynamic Compaction was successful in significantly increasing the strength of the soil. This translates to a more than threefold increase in bearing capacity over that of the initial design recommendation prior to treatment.
- The soils treated were loose sands to a depth of 12.5 meters. Bearing capacities were increased from 60 to 200 kPa and the site earthquake proofed to the design earthquake.

•Ground Improvement using dynamic compaction is very cost effective and competitive with alternate foundation systems such as piling, excavation and backfilling and other similar techniques.

•Useful when large foundation areas need treatment and cost effective depending on the size of the project, type of soil conditions, depth of treatment required, cost of suitable fill material etc.

Acknowledgments

Engr. Sarfraz Ali, Prof. Gandhi IIT Madras.

http://www.haywardbaker.com/

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