Lecture 8

NPTEL Course

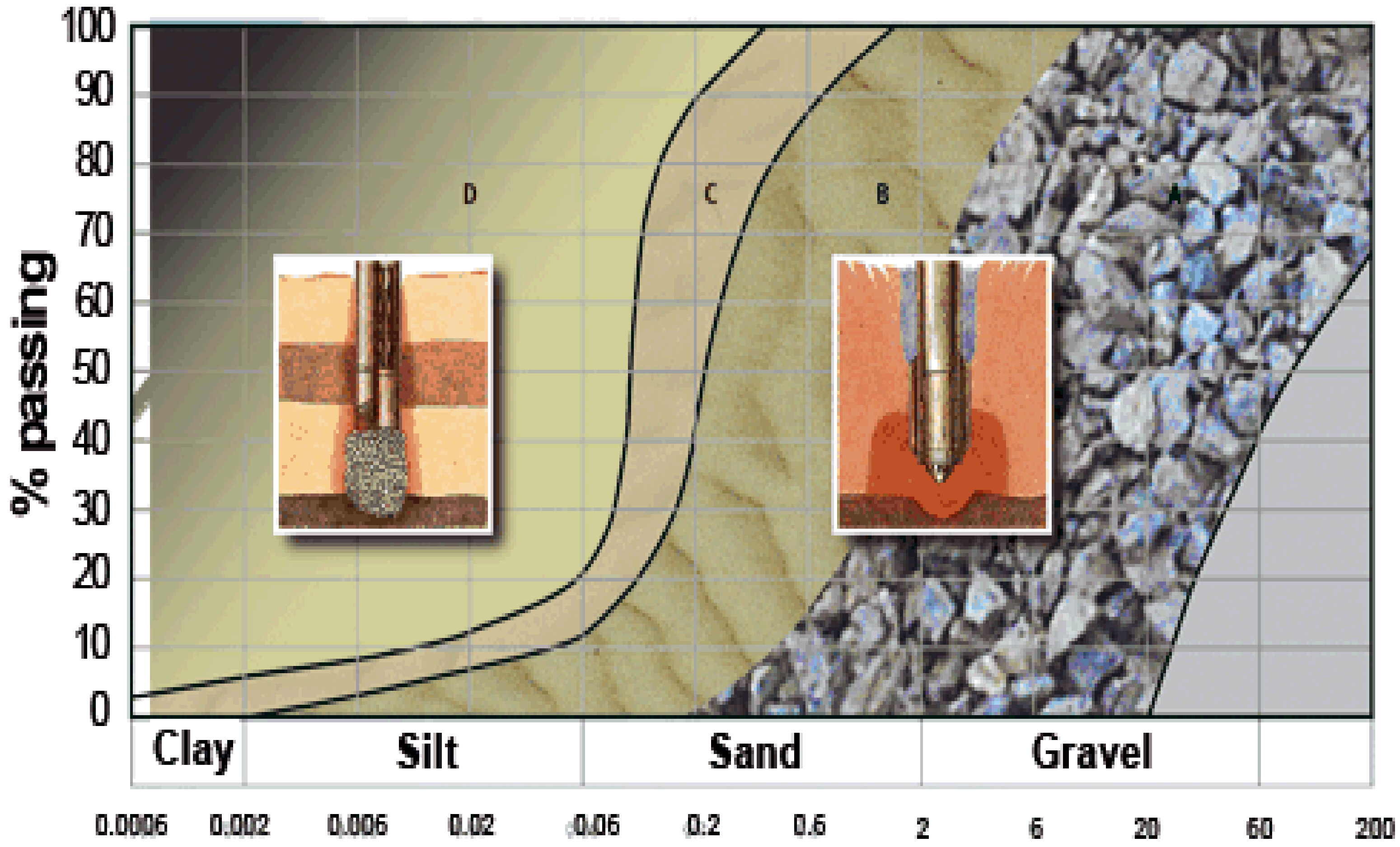
GROUND IMPROVEMENT

Prof. G L Sivakumar Babu
Department of Civil Engineering
Indian Institute of Science
Bangalore 560012
Email: gls@civil.iisc.ernet.in

Vibro-compaction methods

- Compaction at selected locations using vibrations and vibratory equipment results in compaction to large depths.
- The zone of compaction around a single float is a function of type of float
- The success of in situ densification depends on grain size distribution of the in situ soils, and that of backfill soil

Use of grain size analysis a soil to decide on compactability



Soils in zones **A** and **B** can be compacted by the deep vibratory compaction method **vibro Compaction** (also called “**vibroflotation**”), while soils of zones **C** and **D** cannot be compacted by vibration alone.

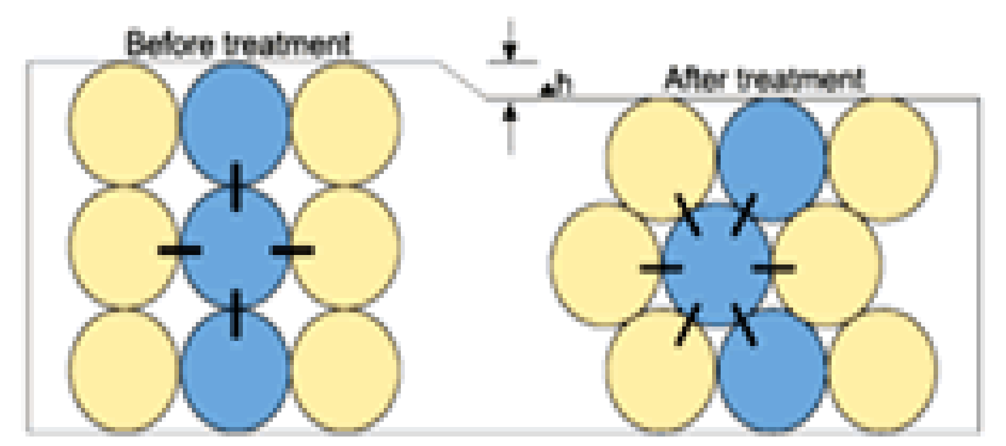
Soils in zone **C** are often found on sites where liquefaction due to earthquakes is of concern. These soils can be compacted during the installation of **Stone Columns**.

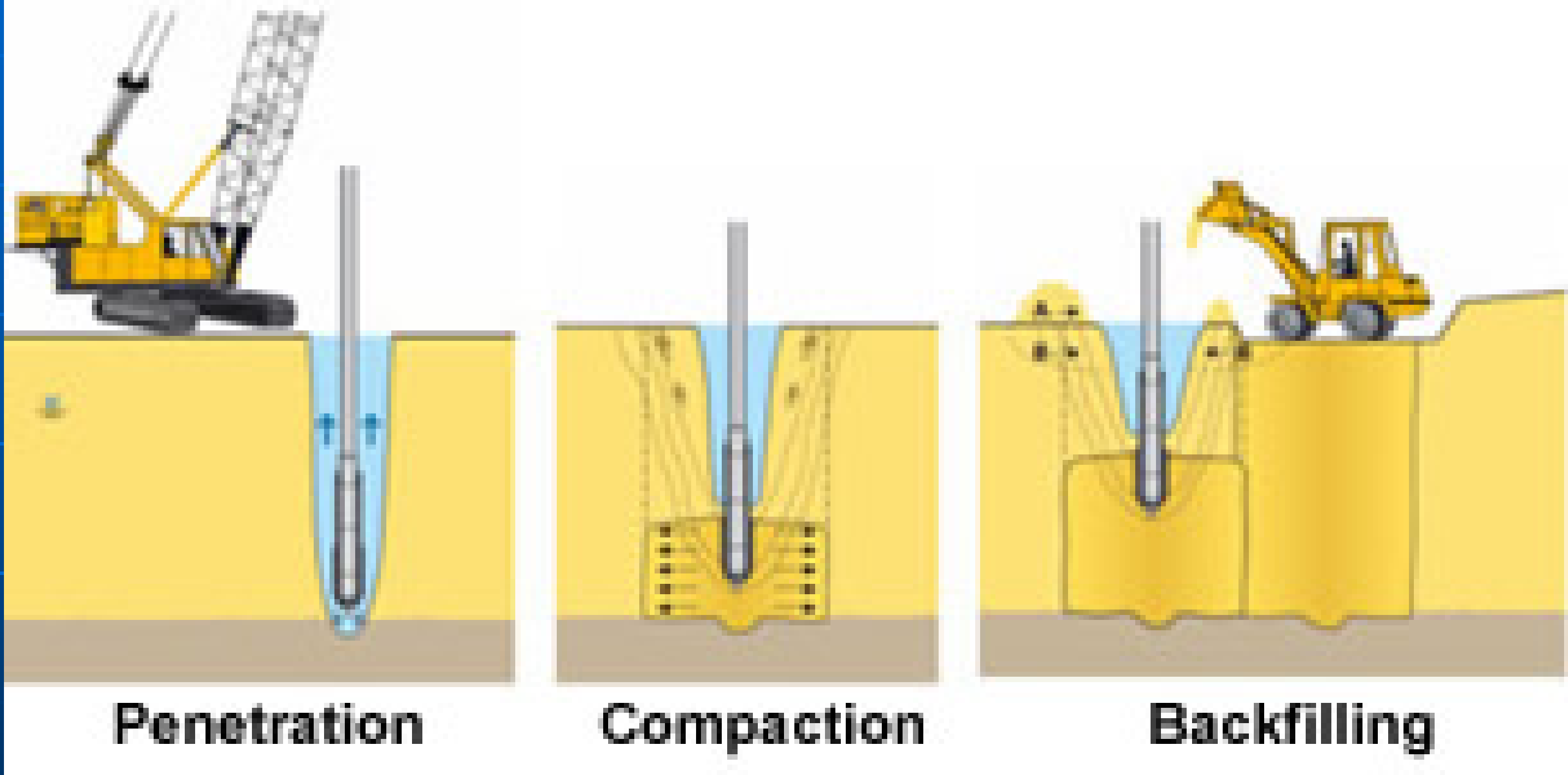
Soils in zone **D** are not compactable by vibration, but can be substantially reinforced, stiffened and drained by installing **Stone Columns**.

- Vibro floatation refers to compaction of soil using a vibrofloat in horizontal motion from the vibrator inserted into the ground. Utilization of a top pile driving vibrator in a vertical mode is less efficient.
- Utilization of the concept of frequency of vibrofloat matching that of natural frequency of in-situ soil is also done in vibro-compaction (Eg: Miller Resonate compaction technique).
- Vibro-replacement uses the same equipment as in vibro-compaction and uses water/air as the jetting medium, and graded stone aggregate as backfill.

Vibro Compaction

The objective in Vibro-compaction is to achieve densification of coarse grained soils with less than 10-15% silt. The effect of the process is based on the fact that particles of non-cohesive soil can be rearranged by vibration.




Penetration
Compaction
Backfilling

- **Applicable soils**
- Coarse grained soils with silt/clay content less than 10-15%
- **Effects**
- Increased shear strength, Increased stiffness, Reduced liquefaction potential
- **Common applications**
- Buildings, Chemical plants, Storage tanks & silos, Pipelines, Wharf structures, embankments, Roads
- Both land / offshore applications

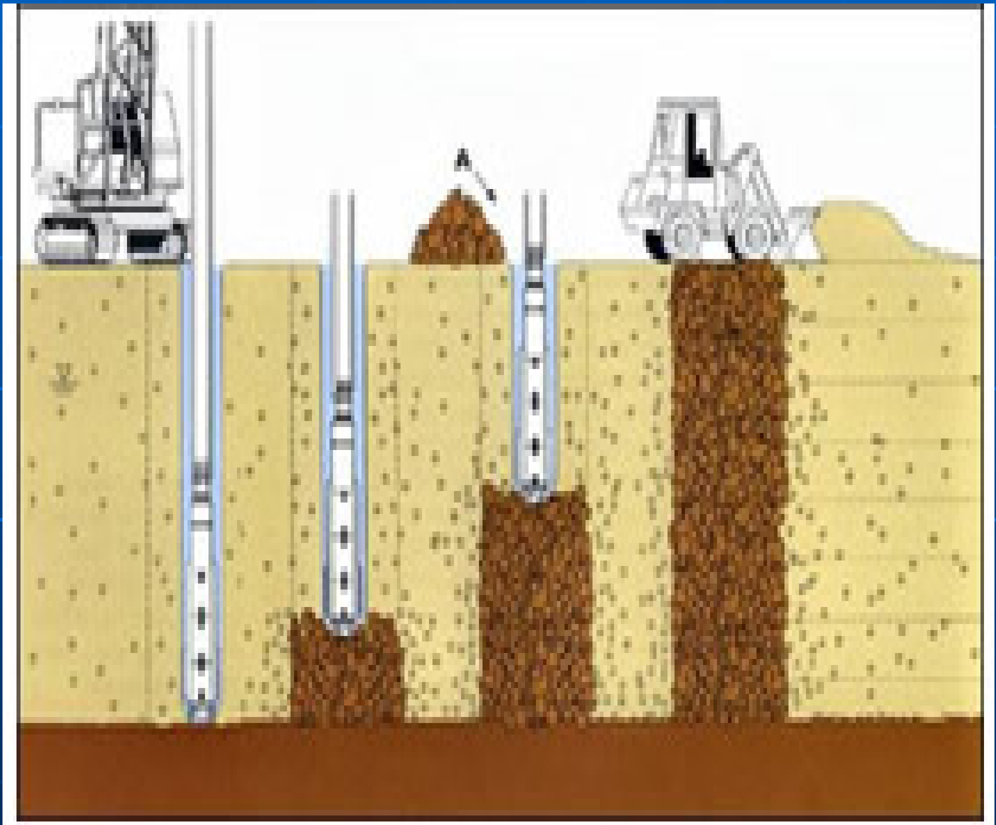
- Maximum depth 60 m

Vibro Replacement

- Vibro Replacement is a technique of constructing stone columns through fill material and weak soils to improve their load bearing and settlement characteristics. Unlike clean granular soils, fine grained soils (such as clays and silts) do not densify effectively under vibrations. Hence, it is necessary to form stone columns to reinforce and improve fill materials, weak cohesive and mixed soils.

- **Principle of Vibro Replacement**

The stone columns and intervening soil form an integrated foundation support system having low compressibility and improved load bearing capacity. In cohesive soils, excess pore water pressure is readily dissipated by the stone columns and for this reason, reduced settlements occur at a faster rate than is normally the case with cohesive soils.



A schematic showing the vibro replacement process

- **Principle** Reinforcement and Drainage
- Applicable soils

  Mixed deposits of clay, silt and sand, Soft and ultra soft silts (slimes) Soft and ultra soft clays, Garbage fills
- **Effects**

  Increased shear strength, Increased stiffness, Reduced liquefaction potential
- **Common applications**

  Airport taxiways and runways, Chemical plants, Storage tanks & silos, Pipelines, Bridge abutments and approaches, Offshore bridge abutments, Road and railway embankments, Both land / offshore applications

- Maximum depth 20-40 m
-

STONE COLUMNS

In soft clayey materials they are useful.

- Vibro - compozer (Japan)
- Vibro-floatation (vibro-replacement) (European)

0.4 -1.0 m layers are compacted

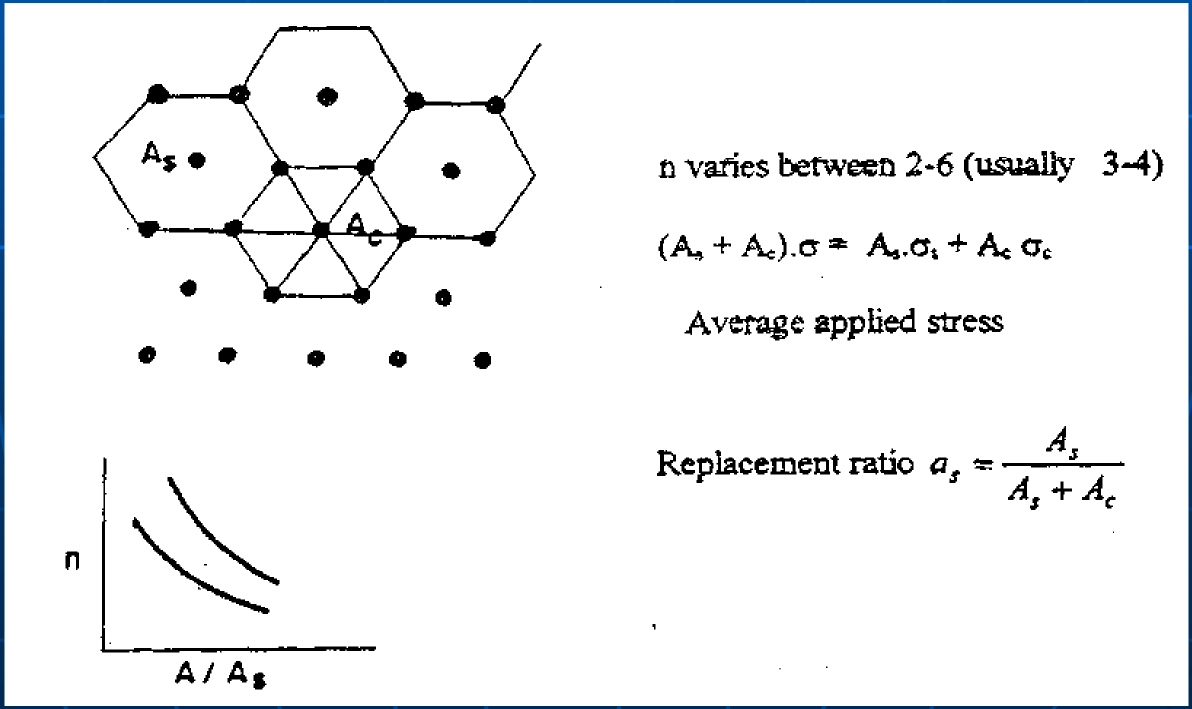
- Casing driving
- Boring (very similar to procedures in sands)
- Sometimes injection → mortar columns
- 0.6 -1.0 m diameter depending on the material (up to 20 m)
- crushed rock 20 - 75 mm popular
- Square or triangular pattern, *1.5 -3.5m* spacing

- They provide strength reinforcement to the soil.
    - Settlement
    - Stability
- They act like vertical drains.
- 0.3 m blanket: drainage and structural stress distributing layer.
- Columns should extend to a firmer soil below.
- Because of the relatively high modulus of the columns, a large proportion of the vertical load applied to the ground surface is transferred to the columns. They are similar to pile foundations (but, pile caps & structural connections are not required).

- Factors which govern the soil-column behaviour (Hughes et. al. (1975) are
  - Untrained shear strength of the soil
  - *In*- situ lateral stress of the soil
  - Radial stress - strain characteristics of the soil
  - Initial column dimensions
  - Friction angle ’ & stress - strain characteristics of the column material
- 200- 300 kN are the typical design values in soft to medium clays

- a conservative approach is treating stone columns like piles where as in a rational approach, loads are distributed between soil & stone columns as a ratio (stress concentration factor, n) of vertical stress (σ_s) in the stone column and the vertical stress (σ_c) in the soft ground.

$$n = \frac{\sigma_s}{\sigma_c}$$



n varies between 2-6 (usually 3-4)

$(A_s + A_c).\sigma = A_s.\sigma_s + A_c\,\sigma_c$

Average applied stress

Replacement ratio $a_s = \dfrac{A_s}{A_s + A_c}$

$$\sigma_c = \frac{\sigma}{\left[1+(n-1)a_s\right]} = \mu_c.\sigma$$

$$\sigma_s = \frac{n.\sigma}{\left[1+(n-1)a_s\right]} = \mu_c.\sigma$$

and the settlement reduction ratio is

$$\beta = \mu_c = \frac{1}{\left[1+(n-1)a_s\right]}$$

assuming the clay and the columns settle equal amount

Ultimate bearing capacity of stone column=q_u

$q_u = \tan^2 (45+ \frac{\Phi}{2})(4c_u+ \sigma_r')$

C_u = undrained strength of clay

σ_r= effective radial stress as measured by pressuremeter (nearly $2C_u$)

Φ’=effective frictional angle of the material

For C_u =20kPa, Φ’= 40º

$q_u = \tan^2 (45+20)*6*20 = 55.1$kPa

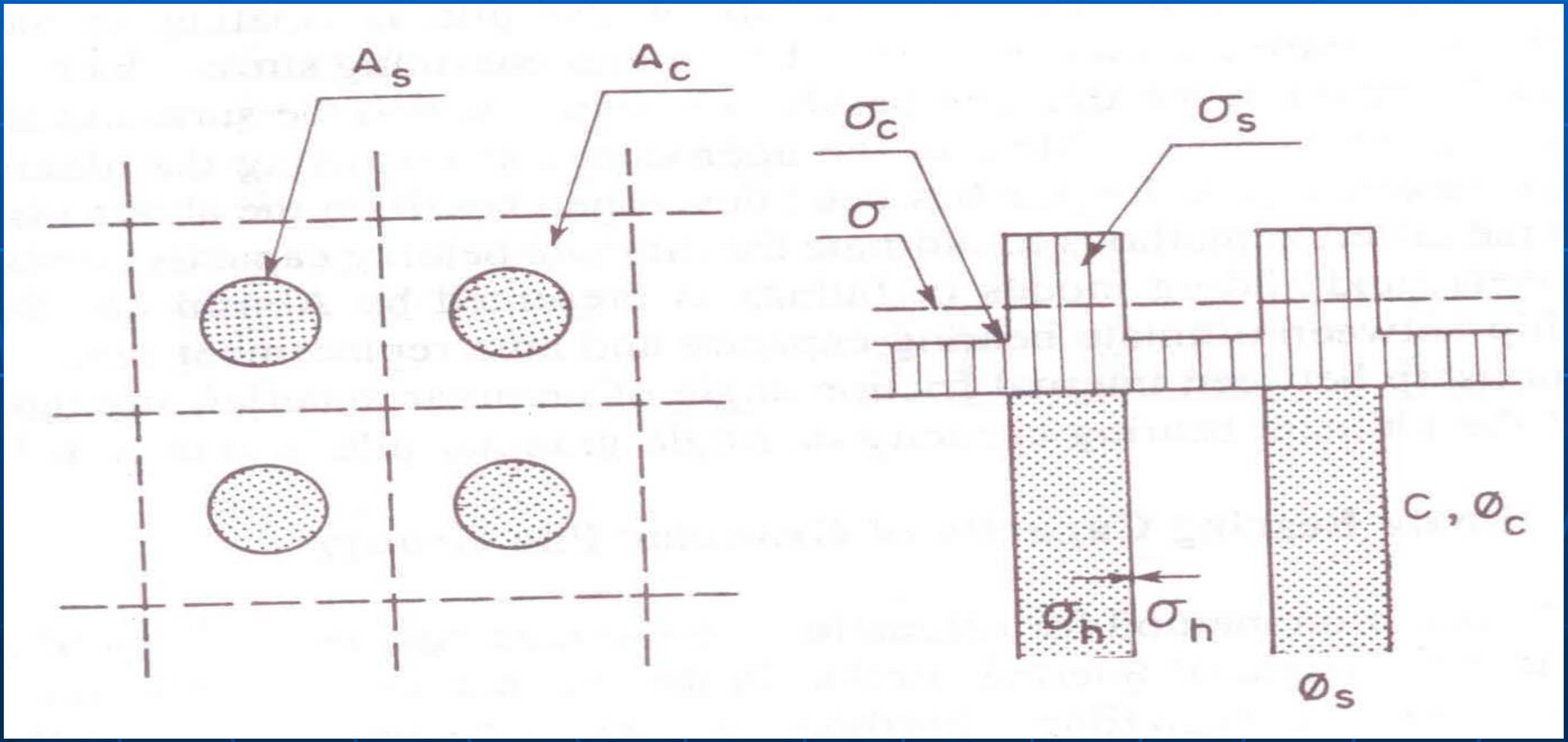
Ultimate load on a 1m diameter stone colum =55.1*1*0.785 = 433 kN

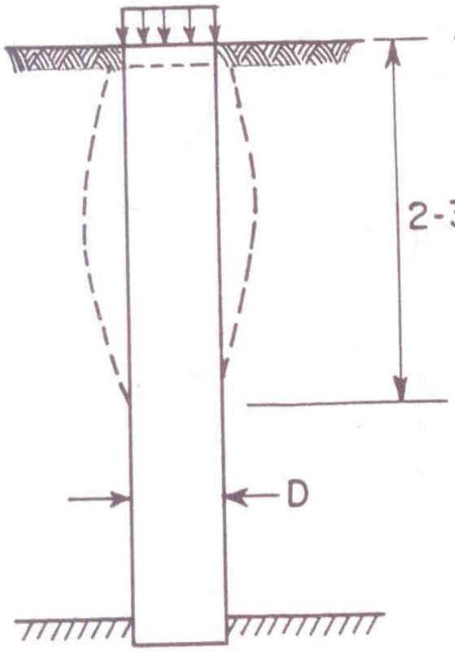
$$\sigma_v = \frac{25 \quad c_u}{S.F.}$$

- settlement of a stone column foundation depends on;
  - column spacing
  - soil strength

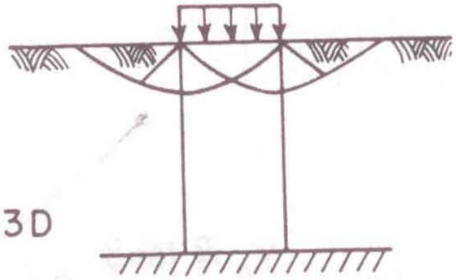
For an equilateral triangular pattern of granular piles

Equivalent diameter= D_e =1.05S
For square pattern = D_e = 1.13S

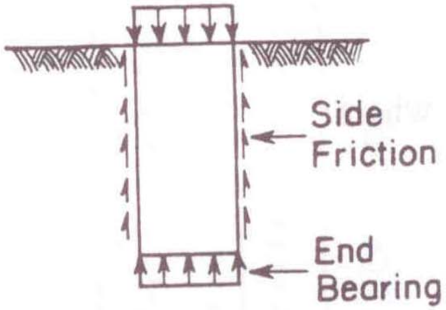




a) Long Stone Column with Firm or Floating Support-Bulging Failure



b) Short Column with Rigid Base-Shear Failure



c) Short Floating Column-Punching Failure

Note : Shear Failure could also occur

Ultimate bearing capacity of a group of piles is given as

$$q_{ult} = \sigma_3 \tan^2\beta + 2\,C_{avg}\tan\beta$$

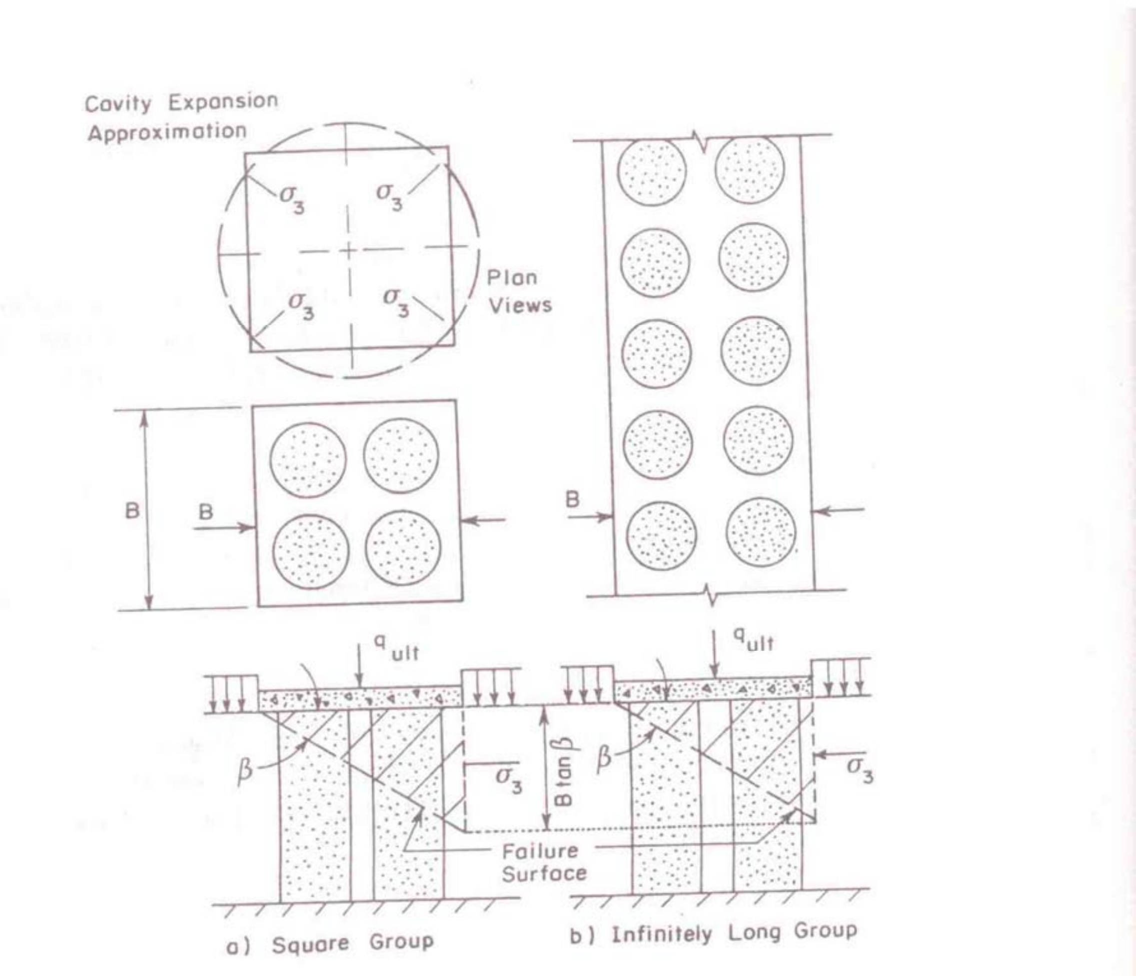
$$\sigma_3 = \frac{\gamma c\ B\ \tan\beta}{2} + 2C$$

$$B = (45 + \frac{\phi_{avg}}{2}); \quad C_{avg} = (1 - a_s) * C$$

$$\Phi_{avg} = \tan^{-1}(\mu_s \text{ as } \tan\Phi_s)$$

γ_c = saturated unit weight of clay (Eg: 20kN/m^3)

B= foundation width (Eg: 10m)


Cavity Expansion Approximation
σ_3
σ_3
σ_3
σ_3
Plan Views
B
B
B
q_{ult}
q_{ult}
β
β
σ_3
B tan β
σ_3
Failure Surface
a) Square Group
b) Infinitely Long Group

Continued…

where

β=failure inclination

C= undrained shear strength of clay

Φ_s = angle of internal friction of stone material

Φ_{avg}= composite angle of internal friction

C_{avg} = composite cohesion

Example

This approach is good for $C_u \geq 30kPa$

Using $C_u = 30kPa$, $\Phi_s = 40^o$, $a_s = 0.5$, $\mu_s = 0.5$

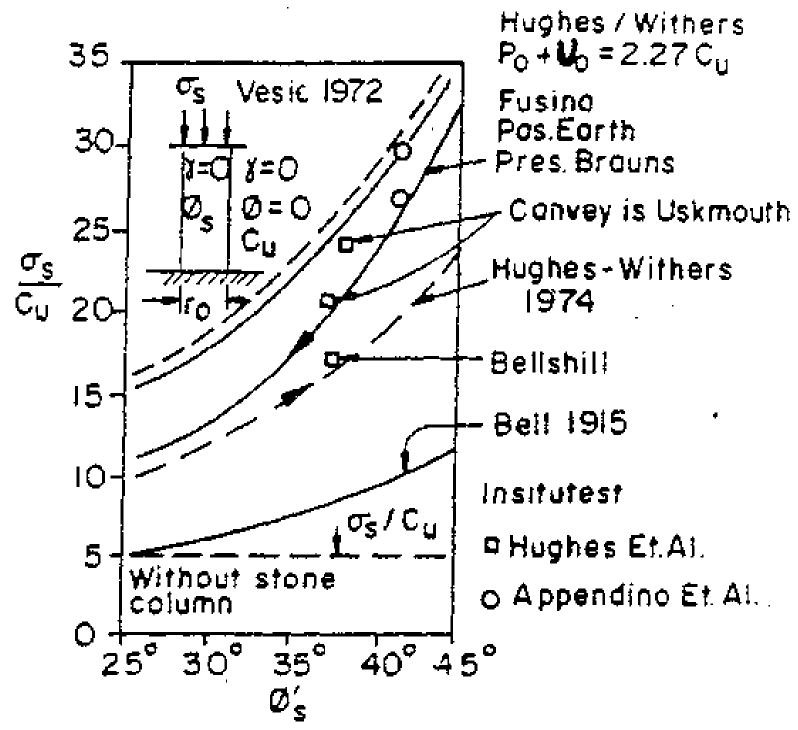
$\Phi_{avg} = \tan^{-1}(0.5*0.5*\tan 40) = 11.8^o$

$\beta = 50.9^o$

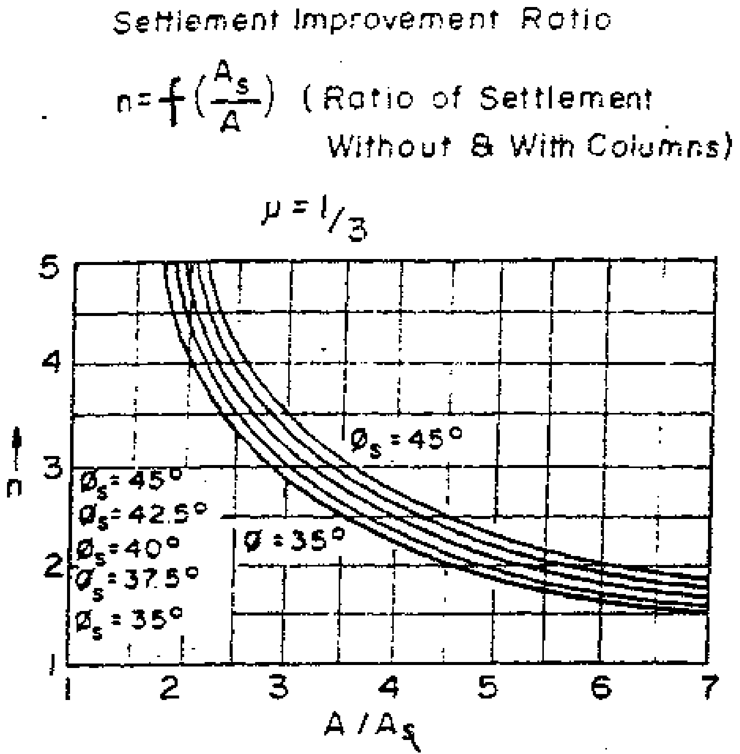
$\sigma_3 = ((20*10*\tan 40)/2) + (2*30) = 143.9kPa$

$C_{avg} = (1-a_s)C = 0.5*30 = 15kPa$

$q_{ult} = 143.9 + \tan^2 50.9 + (2*15*\tan 50.9) = 254.8kPa$



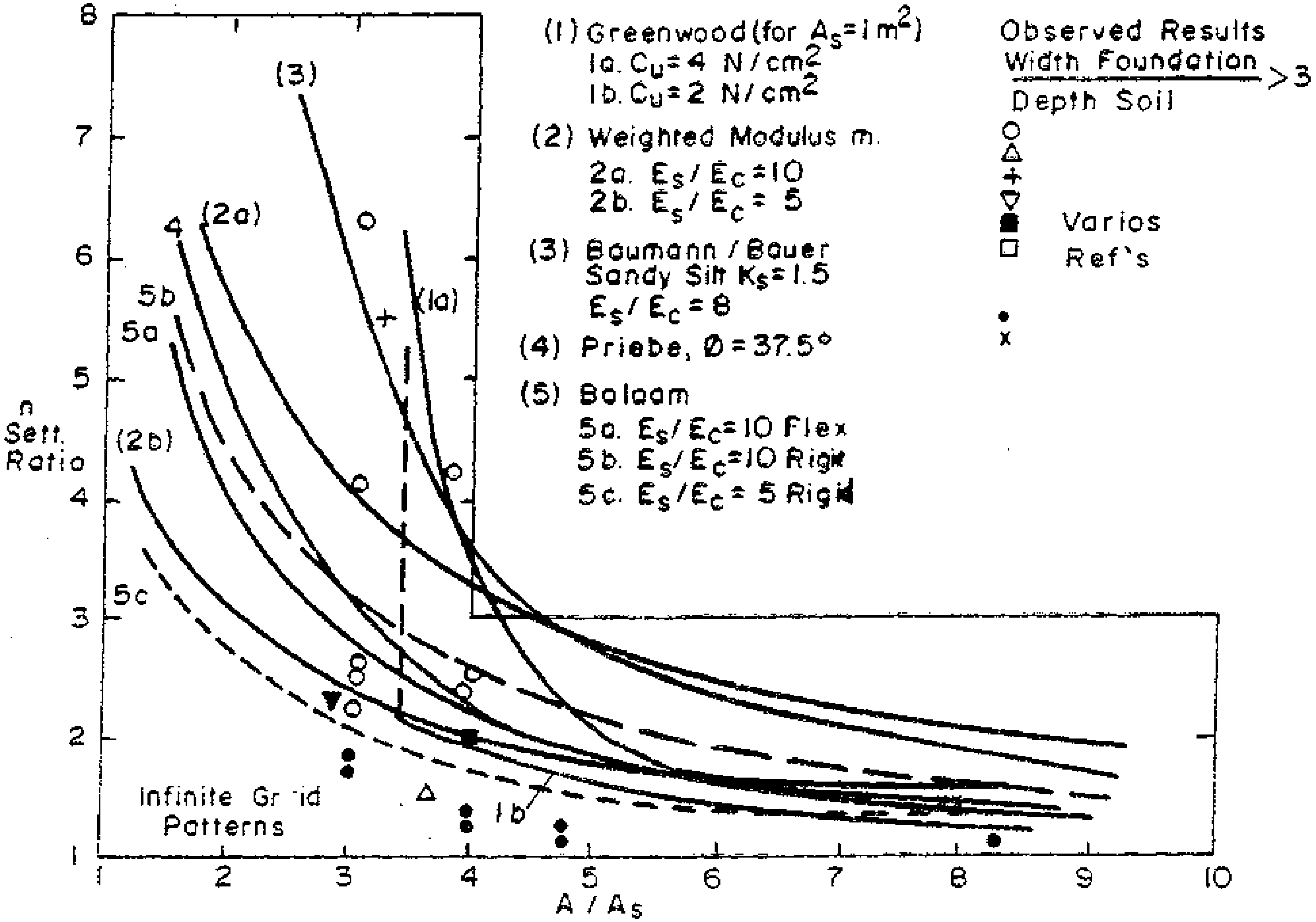
Ult. Cap. of Stone Columns



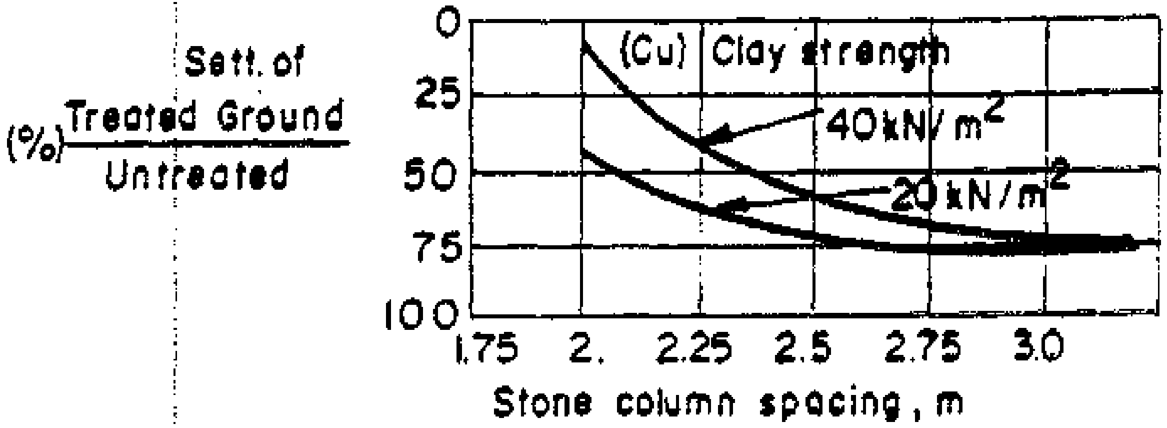
Settlement Improvement Ratio

$n = f\left(\frac{A_s}{A}\right)$ (Ratio of Settlement Without & With Columns)

Priebe's Design Curves



Comparison of Elastic Theorics & Field Observations

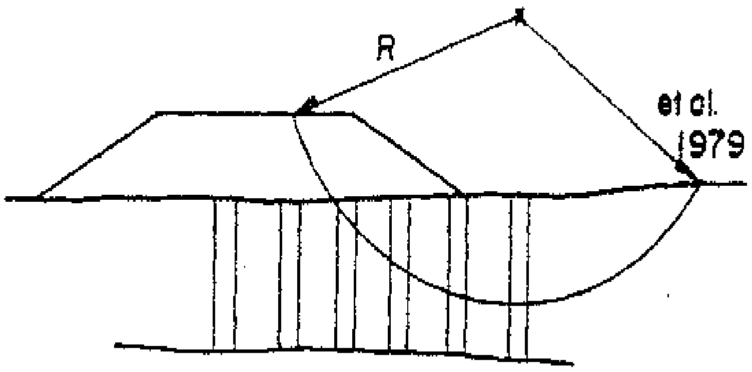


Coulmns Assumed resting on firm ground S_i & shear disp. are neglected..

GREENWOOD (1970)
(+ sett of underlying strata)

Figure 4.6 Spacing versus Ratio of Treated to Untreated Ground Settlement

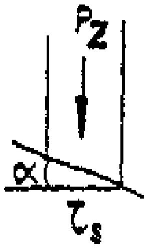
- Stone columns are sometimes used also for stability increase in slope stability.



$\tau_s = P_z \tan \phi_s \cos \alpha$

$P_z = \sigma'_{vo} + \Delta\sigma_z$

$\tau = (1-a_s)\,\tau_\chi + a_s\ \tau_s \cos \alpha$



Priebe (1978) presents graphs

Failure Mechanisms of Stone Columns suggested in IS code

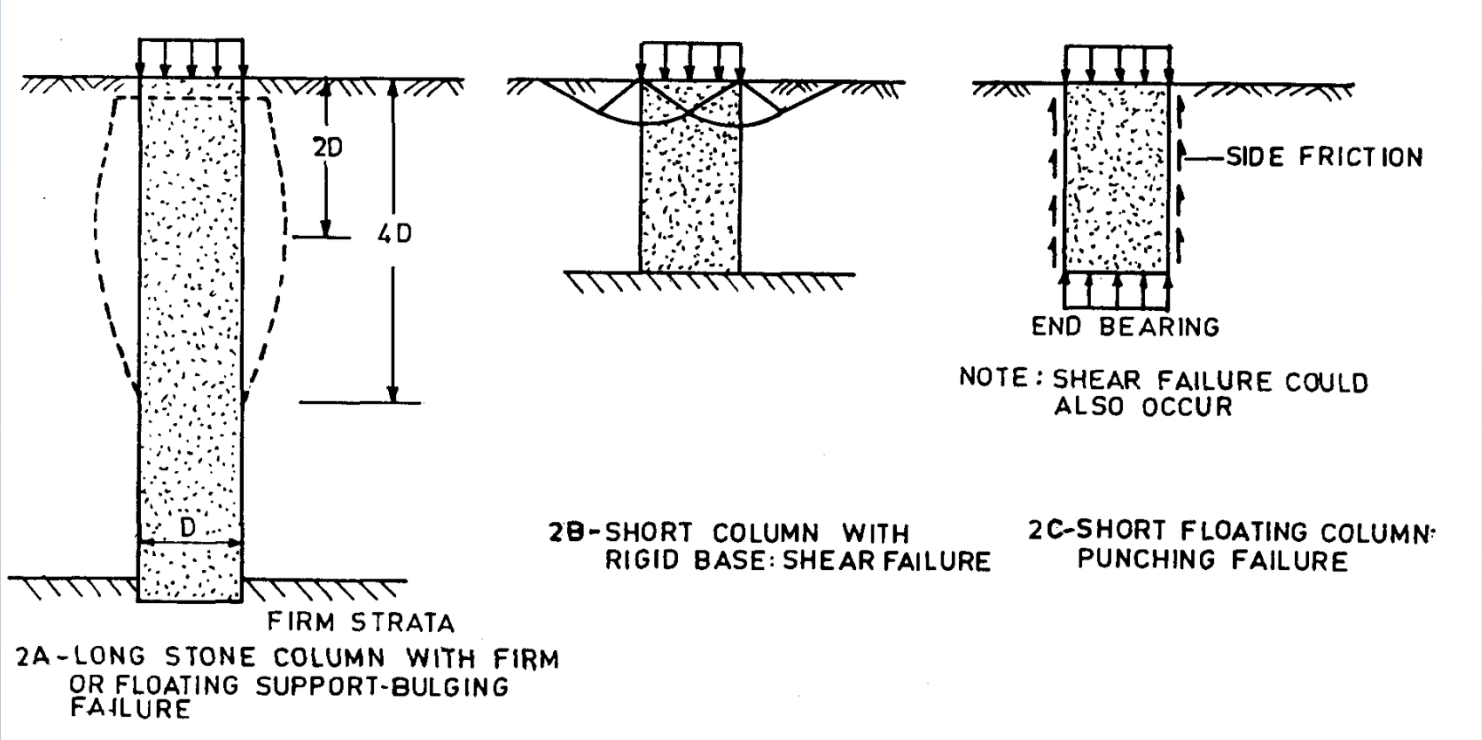


Fig1(a): Failure Mechanism of Single Stone Column in a Homogenous Soft Layer.

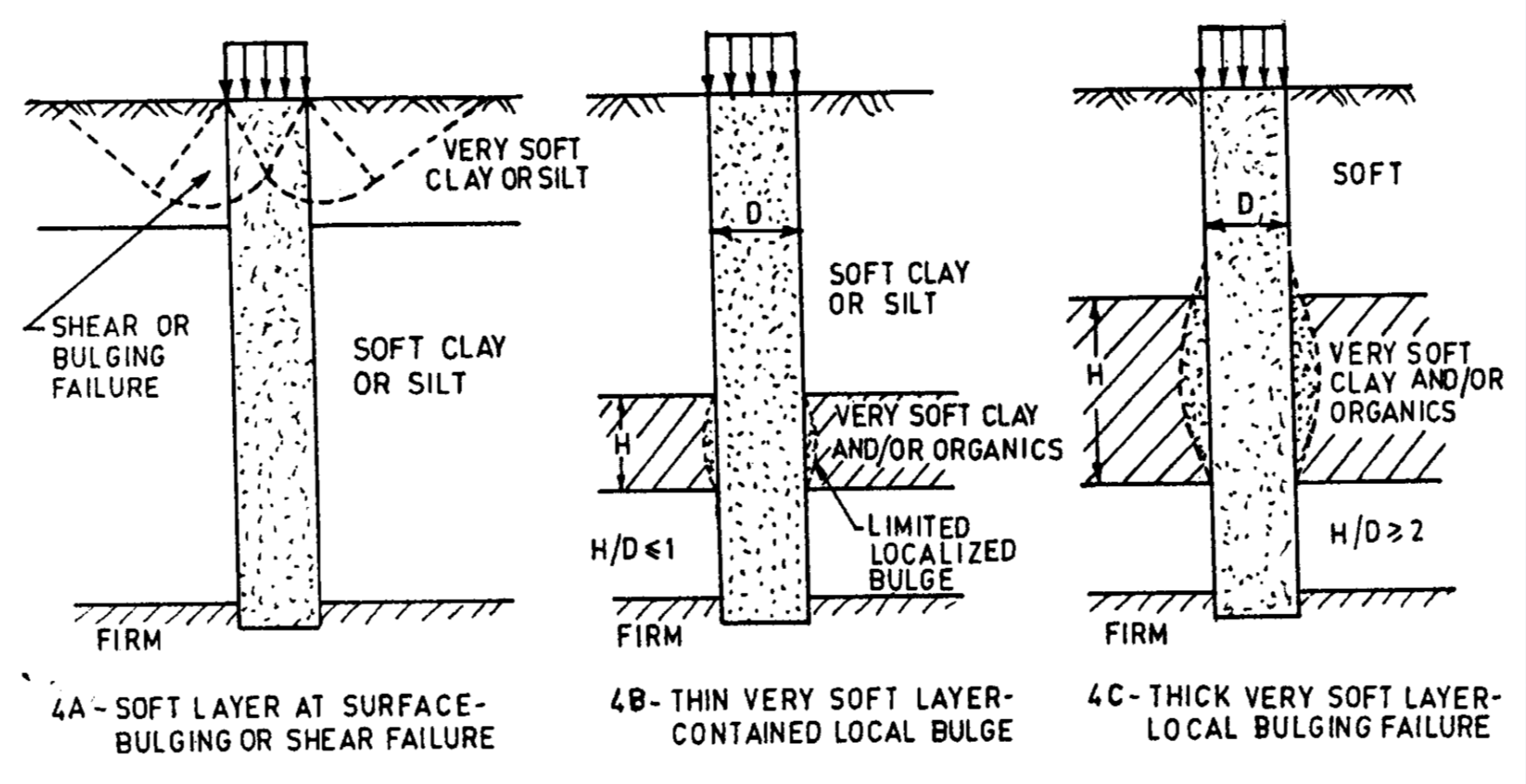


Fig1(b): Failure Mechanism of Single Stone Column in a Non-Homogenous Soft Layer.

Type of loading:

- In the case as shown in the fig1(b). where the loaded area is more than that of Stone columns experiences less bulging leading to ultimate load bearing capacity and reduced settlements since the load is carried by both soil and the stone columns.

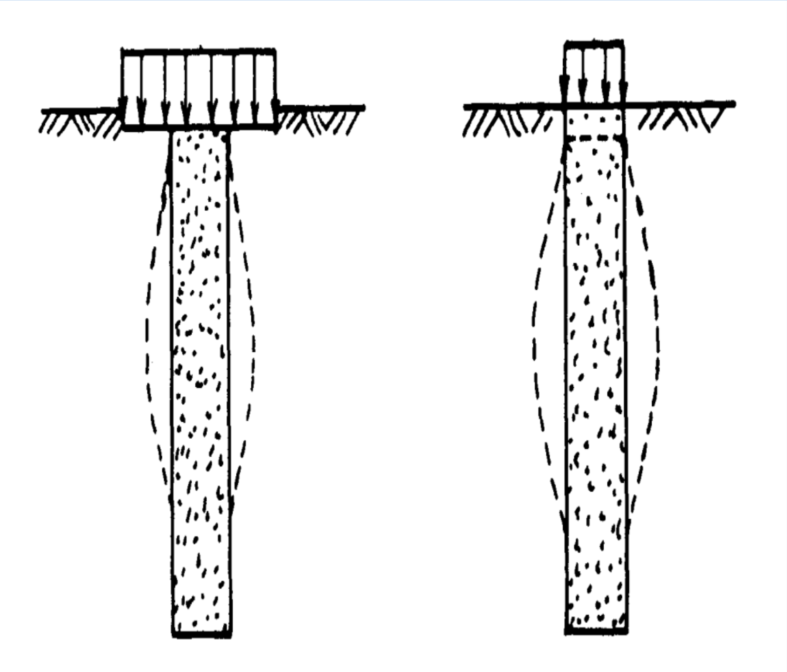


Fig1(c): Different types of loadings applied on Stone Columns.

Load Tests:

- From the Load test we can determine the ultimate load bearing capacity and settlement of single column with reasonable accuracy.
- A good experience with foundations on similar structures & calculations on the basis of principals of soil mechanics shall be made before final design.

Factor of Safety:

- The minimum Factor of safety against ultimate load capacity of column obtained from load test shall be **2.5**.

Installation Technique:

- The construction of stone columns involves creation of a hole In the ground which is later filled with granular fill / stone sand mixture and compacted to required strength.
- **Granular Blanket**: On the to top of stone columns a clean medium to coarse sand with 70-80% relative density is laid with a minimum thickness of 0.5m.
- This Layer should be exposed at its periphery to the atmosphere for easy dissipation of pore water pressure.

Field Tests:

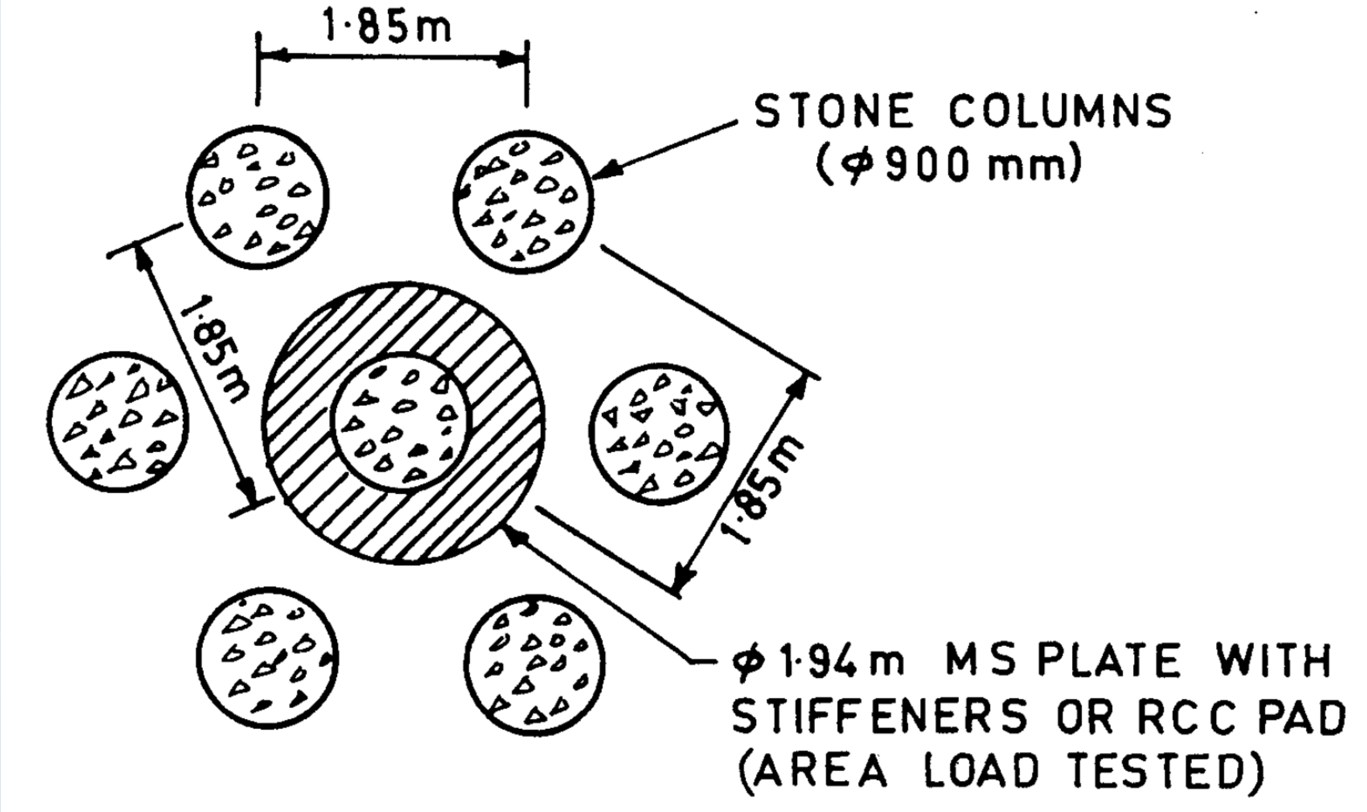


Fig1(d): Load test on single columns.

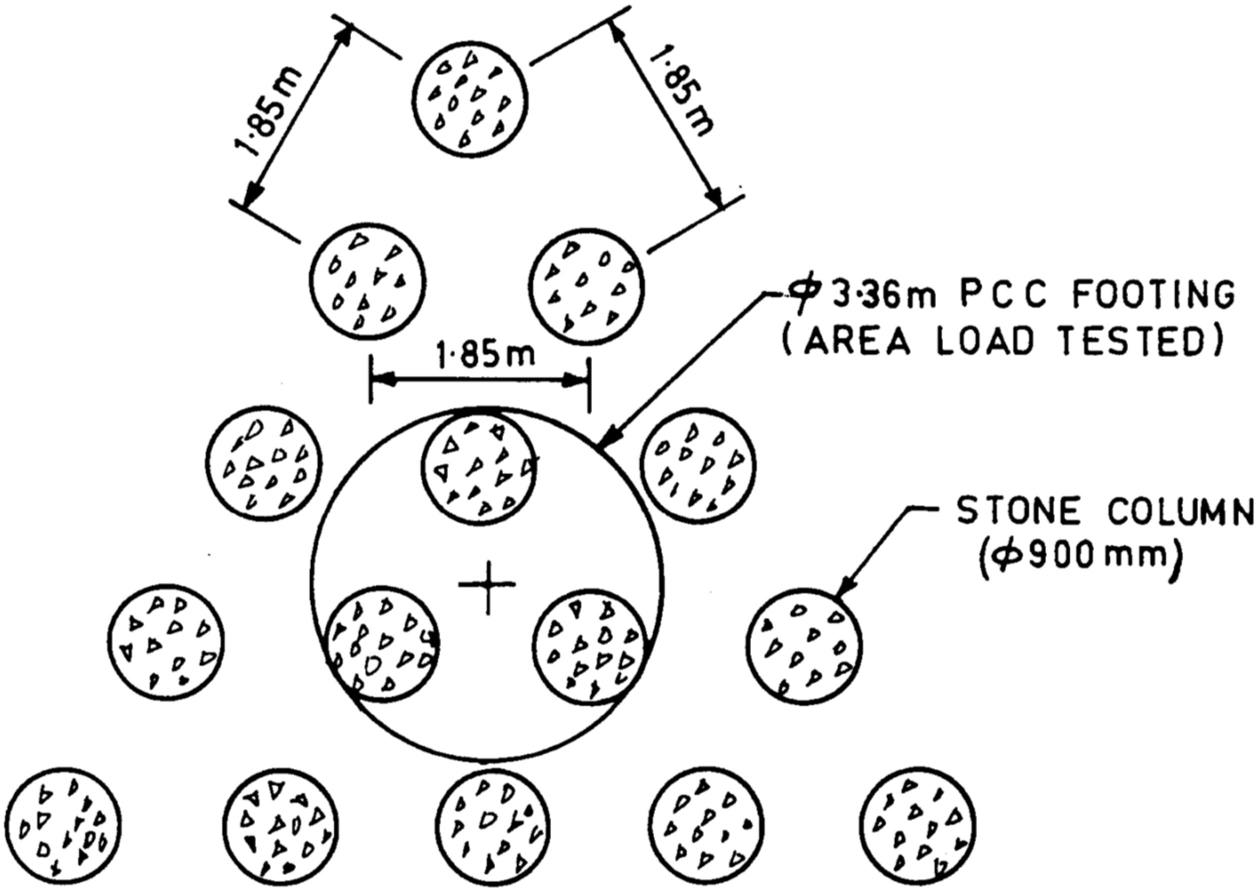


Fig1(d): Load test on Three columns(Group Test).

Design of Stone Columns Using Heinz J. Priebes Method

Contents

1. Introduction
2. Design of Stone Columns using Heinz J. Priebes method
3. Design example
4. Design using Stone C 3.3 Software

Introduction

- Vibro Replacement is an subsoil improvement method at which large-sized columns of coarse backfill material are installed in the soil by means of special depth vibrators.
- Vibro replacement improves non compactible cohesive soil by the installation of load bearing columns of well compacted, coarse grained backfill material contrary to vibro compaction used for cohesion less soils.
- The extent to which the density of compactible soil will be improved by vibro- compaction, depends not only on the parameters of the soil being difficult to determine, but also on the procedure adopted and the equipment provided.

Design of Stone Columns using Heinz J. Priebes method

Basic principle

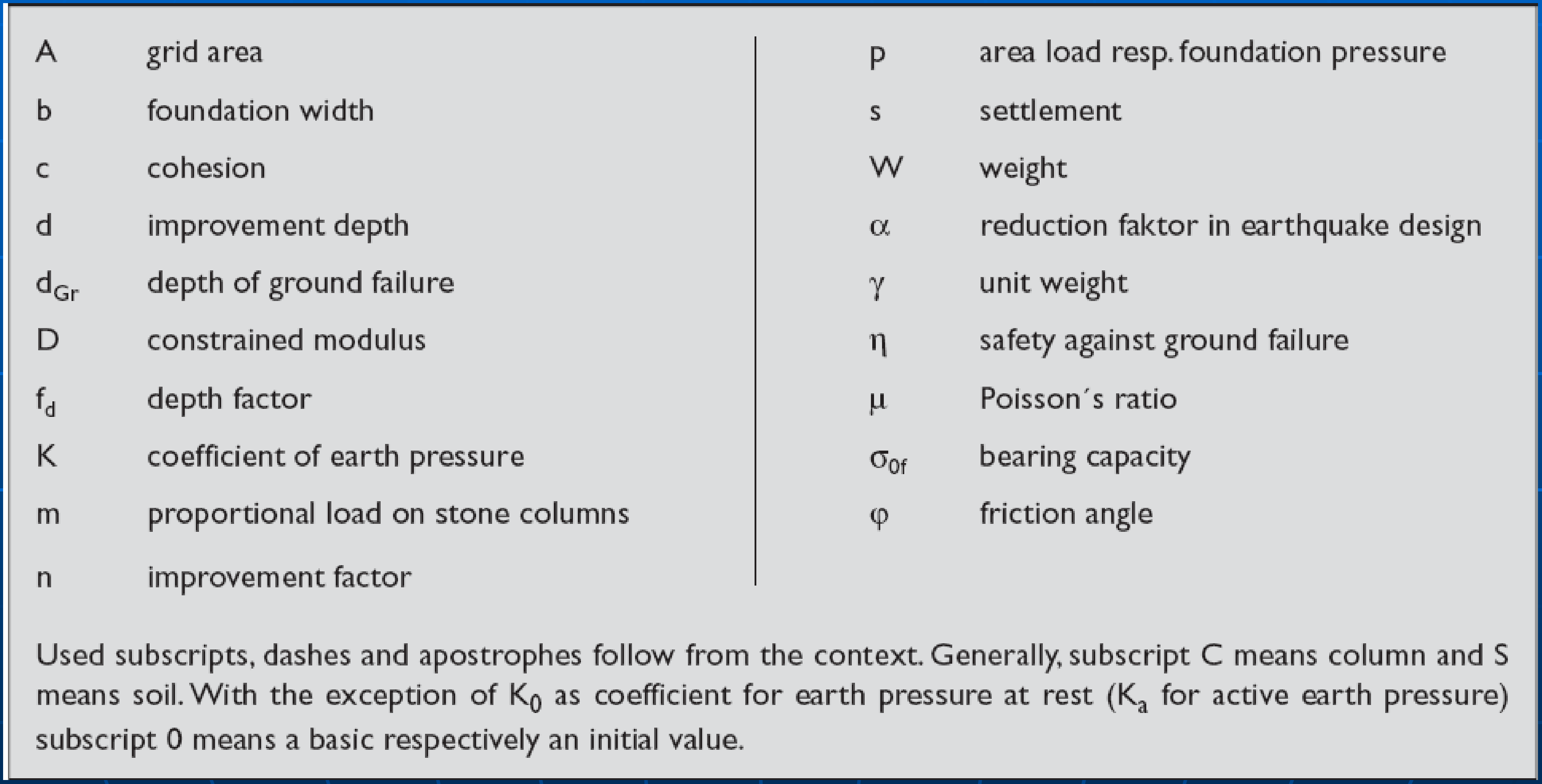
Load distribution and lateral support from the stone column & surrounding stiffened ground on an area basis are considered to give an improvement factor. The improvement factor indicates increase in compression modulus and the extent to which the settlement is reduced by the column ground improvement.

The design method refers to the improving effect of stone columns in a soil which is otherwise unaltered in comparison to the initial state. i.e. the installation of stone columns densifies the soil between.

The following idealized conditions are assumed in the design:

- The column is based on a rigid layer
- The column material is uncompressible
- The bulk density of column and soil is neglected. Hence, the column can not fail in end bearing and any settlement of the load area results in a bulging of the column which remains constant all over its length.

Notations Used

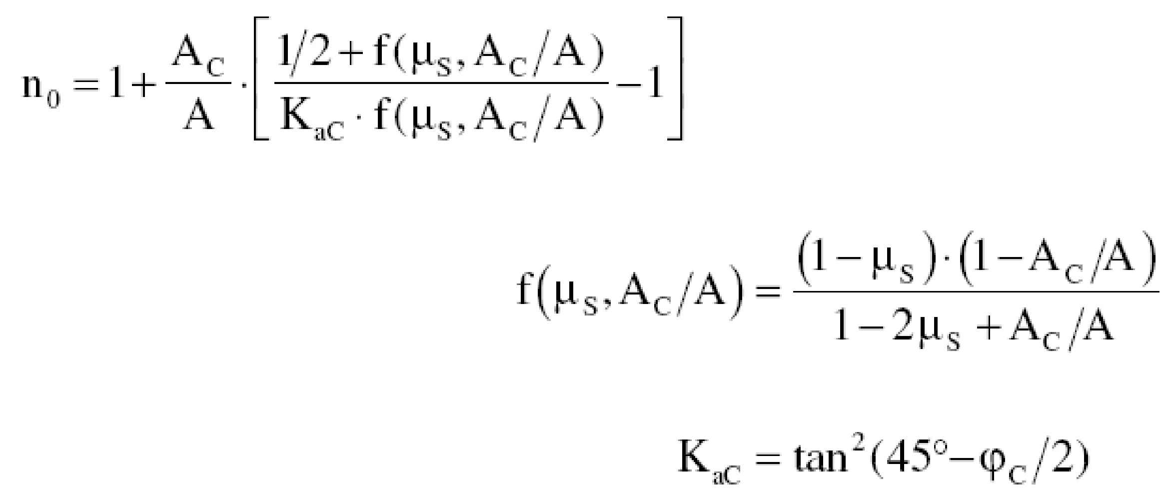


A	grid area	p	area load resp. foundation pressure
b	foundation width	s	settlement
c	cohesion	W	weight
d	improvement depth	α	reduction faktor in earthquake design
d_{Gr}	depth of ground failure	γ	unit weight
D	constrained modulus	η	safety against ground failure
f_d	depth factor	μ	Poisson´s ratio
K	coefficient of earth pressure	σ_{0f}	bearing capacity
m	proportional load on stone columns	φ	friction angle
n	improvement factor		

Used subscripts, dashes and apostrophes follow from the context. Generally, subscript C means column and S means soil. With the exception of K_0 as coefficient for earth pressure at rest (K_a for active earth pressure) subscript 0 means a basic respectively an initial value.

Determination of the Basic Improvement Factor, n_o

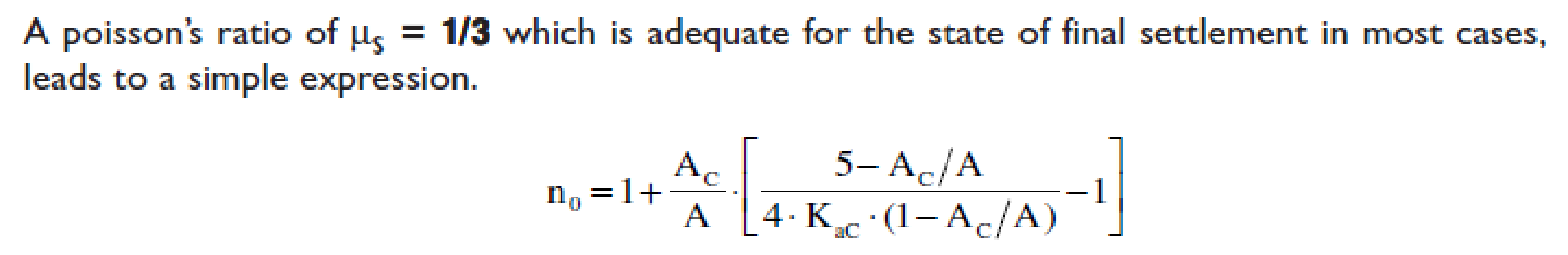
In a first step, the Basic improvement factor is calculated by using the following equation, n_o . A is the unit cell area and A_c is the area of column.



$$n_0 = 1 + \frac{A_C}{A} \cdot \left[\frac{1/2 + f(\mu_S, A_C/A)}{K_{aC} \cdot f(\mu_S, A_C/A)} - 1 \right]$$

$$f(\mu_S, A_C/A) = \frac{(1-\mu_S)\cdot(1-A_C/A)}{1-2\mu_S + A_C/A}$$

$$K_{aC} = \tan^2(45° - \varphi_C/2)$$



A poisson's ratio of μ_S = **1/3** which is adequate for the state of final settlement in most cases, leads to a simple expression.

$$n_0 = 1 + \frac{A_C}{A} \cdot \left[\frac{5 - A_C/A}{4 \cdot K_{aC} \cdot (1 - A_C/A)} - 1 \right]$$

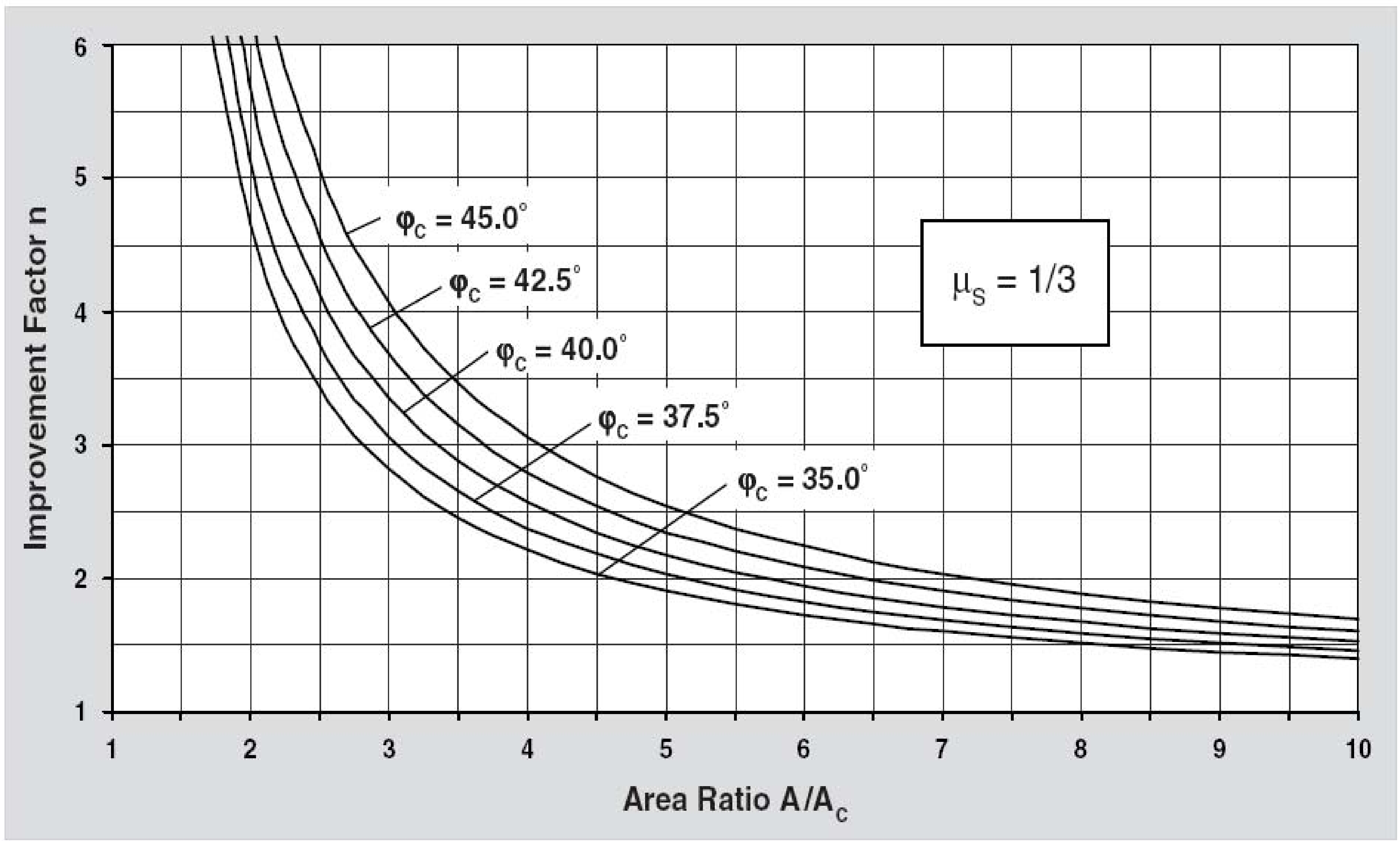


Fig1(a): Relation between the improvement factor n_0, the reciprocal area ratio A/A_C and the friction angle of the backfill material, ϕ_c.

Consideration of Column Compressibility

The compressibility of the column material can be considered in using a reduced improvement factor n_1 which results from the formula developed for the basic improvement factor, n_0 when the given reciprocal area ratio A/AC is increased by an additional amount of Δ(A/AC).The Reduced Improvement Factor is calculated by using the following equation, n_1

$$n_1 = 1 + \frac{\overline{A_C}}{A} \cdot \left[\frac{1/2 + f(\mu_S, \overline{A_C/A})}{K_{aC} \cdot f(\mu_S, \overline{A_C/A})} - 1 \right]$$

$$\frac{\overline{A_C}}{A} = \frac{1}{A/A_C + \Delta(A/A_C)}$$

$$\Delta(A/A_C) = \frac{1}{(A_C/A)_1} - 1$$

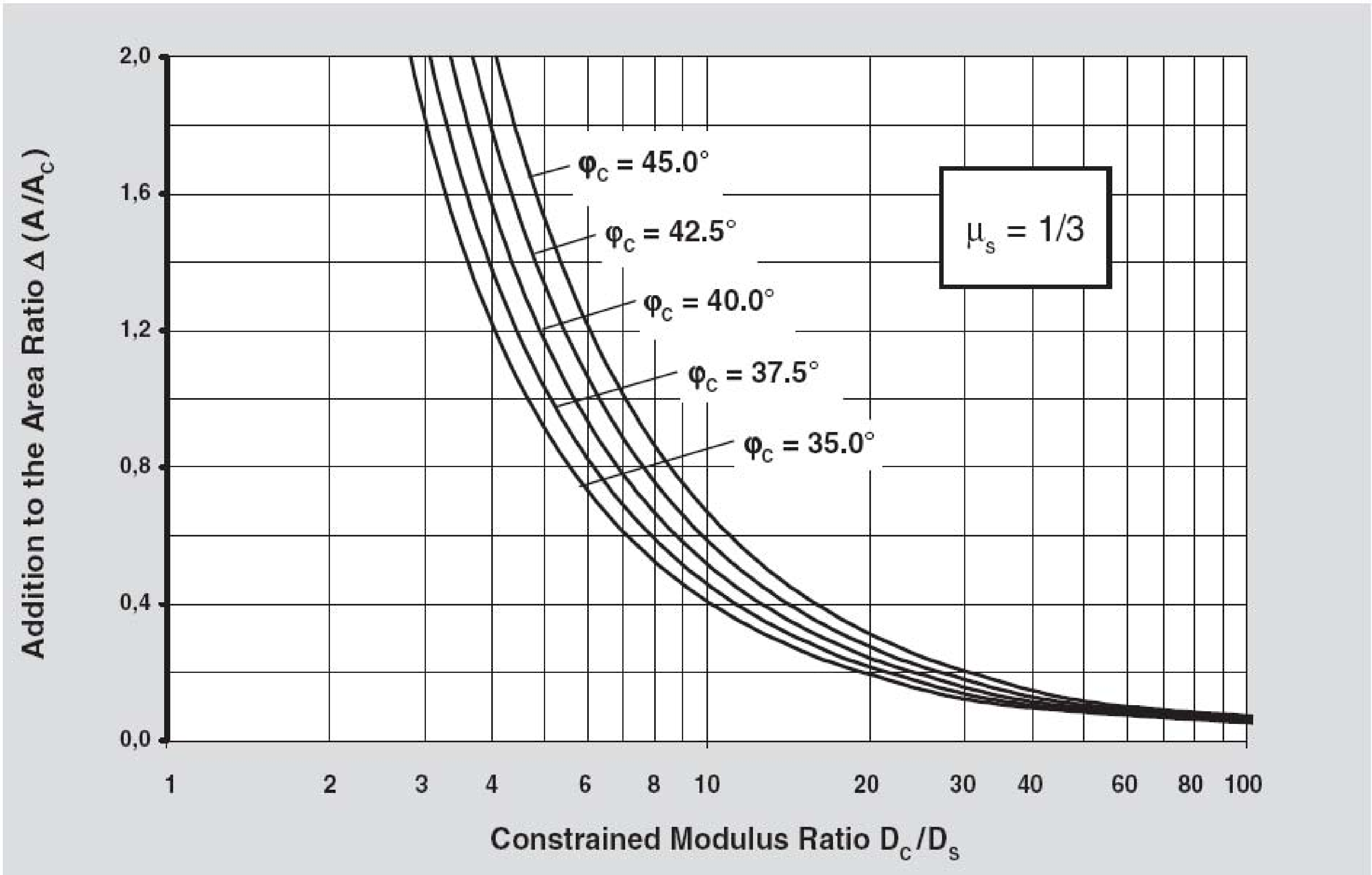


Fig1(b): Variation of Additional amount on the area ratio Δ(A/AC) with the ratio of the constrained moduli D_C/D_S.

Consideration of the Overburden

1)The neglect of the bulk densities of columns and soil means that the initial pressure difference between the columns and the soil which creates bulging, depends solely on the distribution of the foundation load p on columns and soil, and that it is constant all over the column length.

2)The consideration of external loads the weights of the columns WC and of the soil WS which possibly exceed the external loads considerably decreases the pr. difference and the bulging is reduced.

3)The pressure difference is a linear parameter in the derivations of the improvement factor, the ratio of the initial pressure difference and the one depending on depth- expressed as depth factor fd - delivers a value by which the improvement factor n1 increases to the final improvement factor $\mathbf{n_2 = fd \times n_1}$.

The depth factor fd can be determined from the following equations:

$$f_d = \frac{1}{1 + \frac{K_{0C} - W_S / W_C}{K_{0C}} \cdot \frac{W_C}{p_C}}$$

$$p_C = \frac{p}{\overline{\frac{A_C}{A}} + \frac{1 - \overline{A_C / A}}{p_C / p_S}}$$

$$\frac{p_C}{p_S} = \frac{1/2 + f(\mu_S, \overline{A_C / A})}{K_{aC} \cdot f(\mu_S, \overline{A_C / A})}$$

$$W_C = \Sigma(\gamma_C \cdot \Delta d), \qquad W_S = \Sigma(\gamma_S \cdot \Delta d)$$

$$K_{oC} = 1 - \sin \varphi_C$$

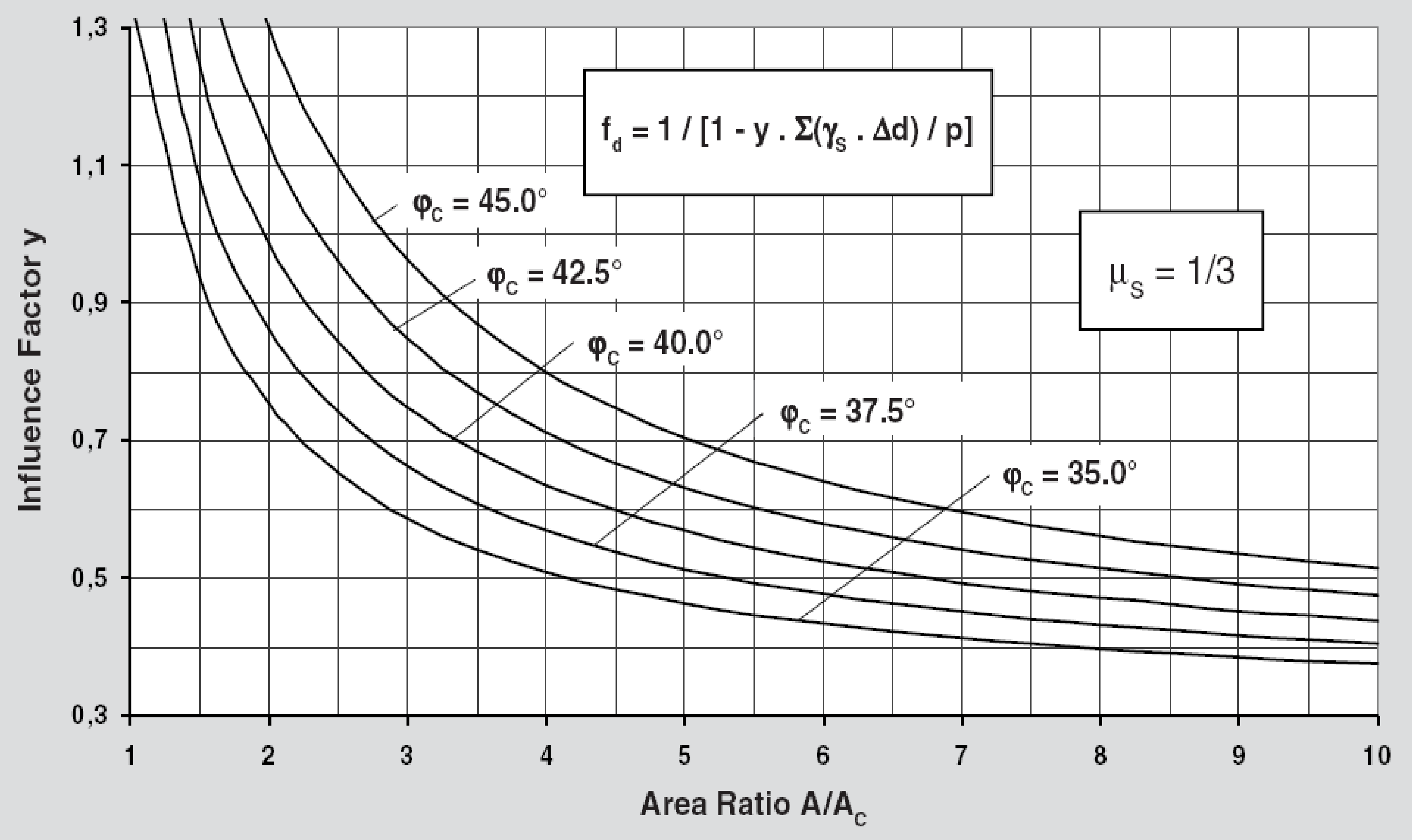


Fig 1(c): Variation of Influence factor, y for different values of friction angles.

Shear Values of Improved Ground

- The shear resistance from friction of the composite system can be determined by using the following equation:

$$\tan\overline{\varphi} = m'\cdot\tan\varphi_C + (1-m')\cdot\tan\varphi_S$$

$$m' = (n-1)/n$$

- The cohesion of the composite system depends on the proportional to the loads using the following equation.

$$c = (1-\overline{A_C/A})\cdot c_S$$

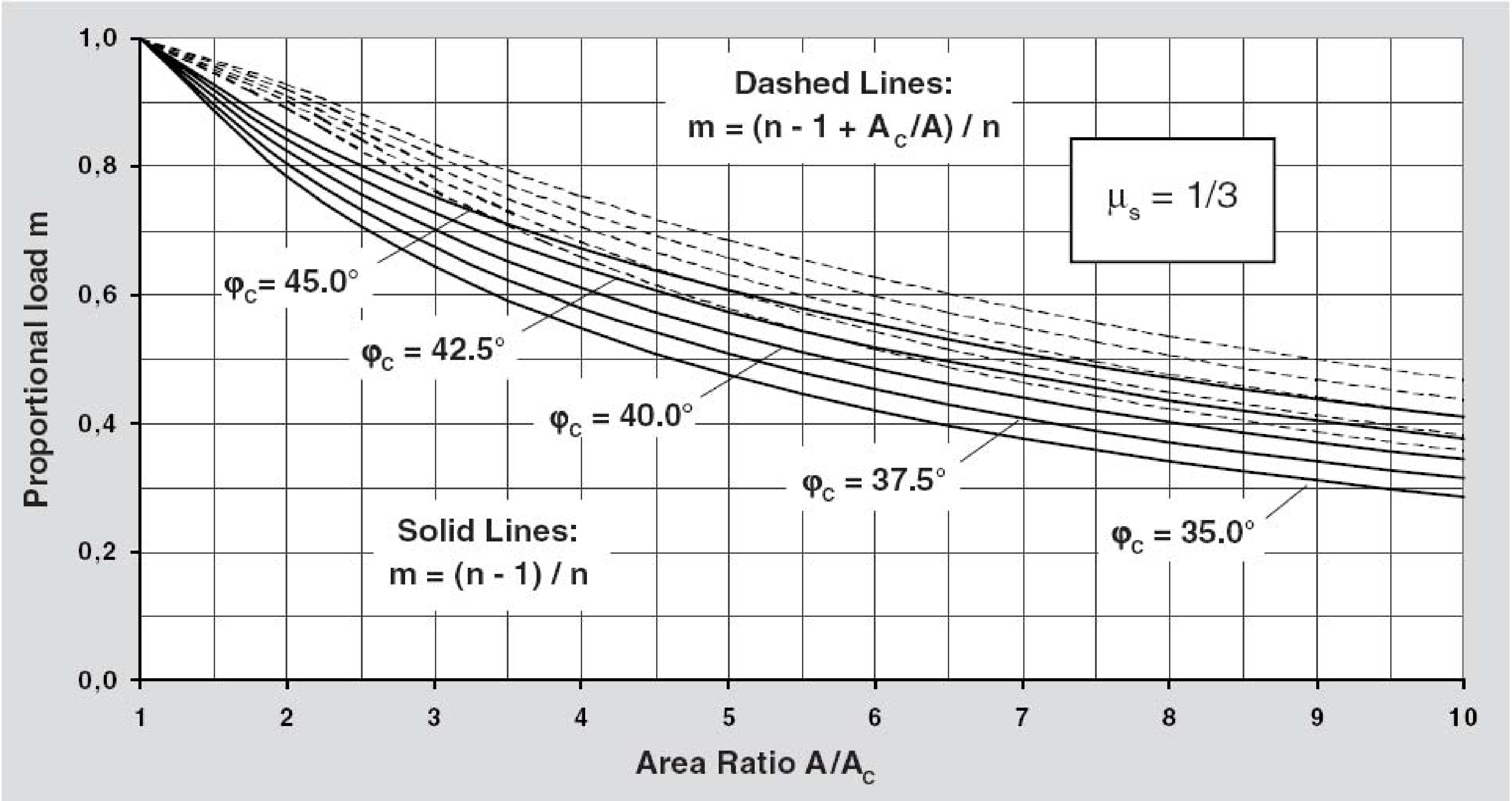


Fig1(d): Proportional Load on Stone Columns for different values of friction angles.

Settlement of improved Ground

- The design ensues from the performance of an unlimited column grid below an unlimited load area. The total settlement which results for this case at homogeneous conditions, is readily to determine on the basis of the foregoing description with n2 as an average value over the depth d is given by the following equation:

$$s_\infty = p \cdot \frac{d}{D_S \cdot n_2}$$

- The settlement of the ground with out improvement is 25.1cm which is more than that of settlement with improvement of 5.1cm.

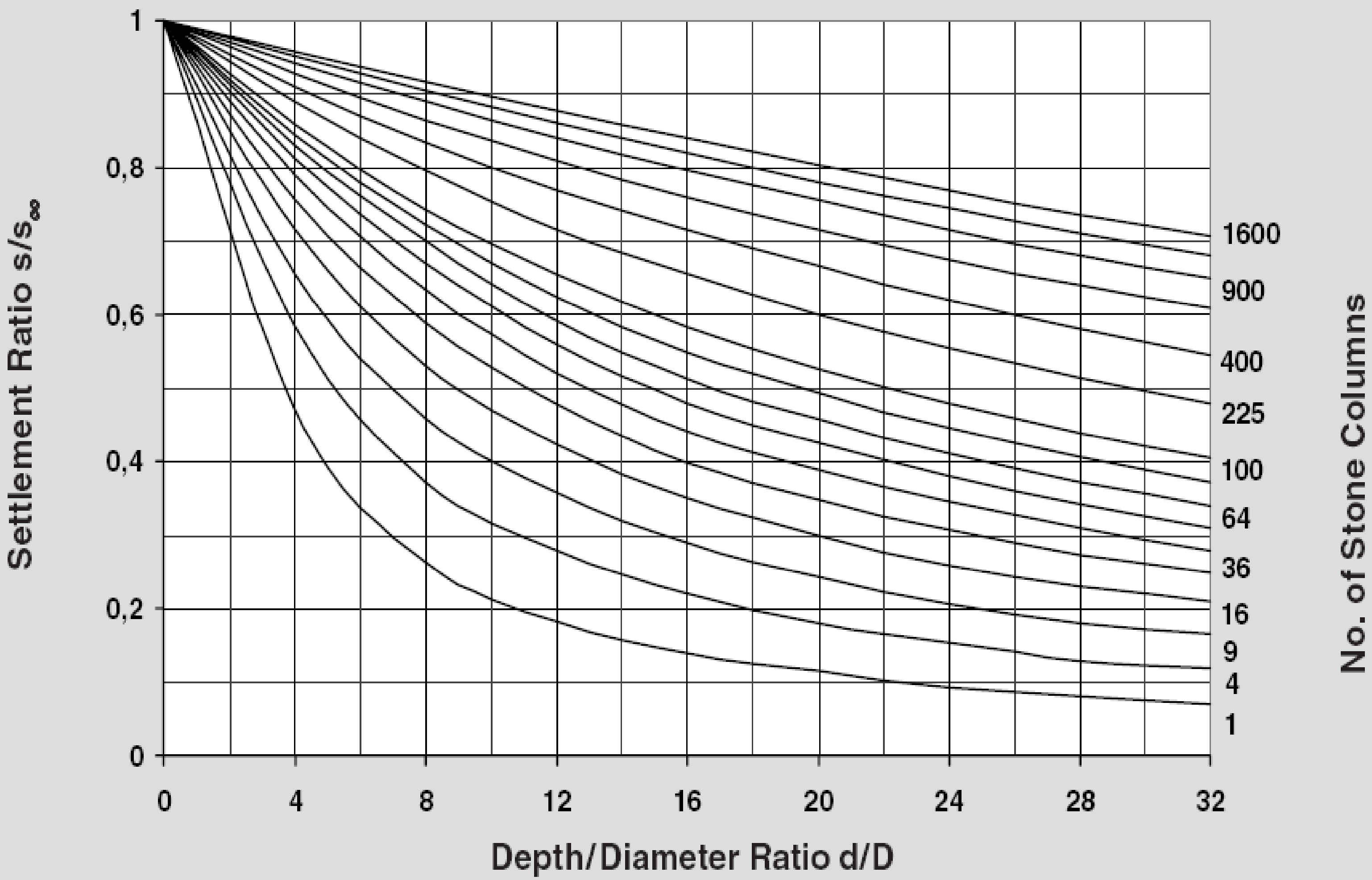


Fig1(e): Variation of settlement ratio with d/D ratio of Single Footing

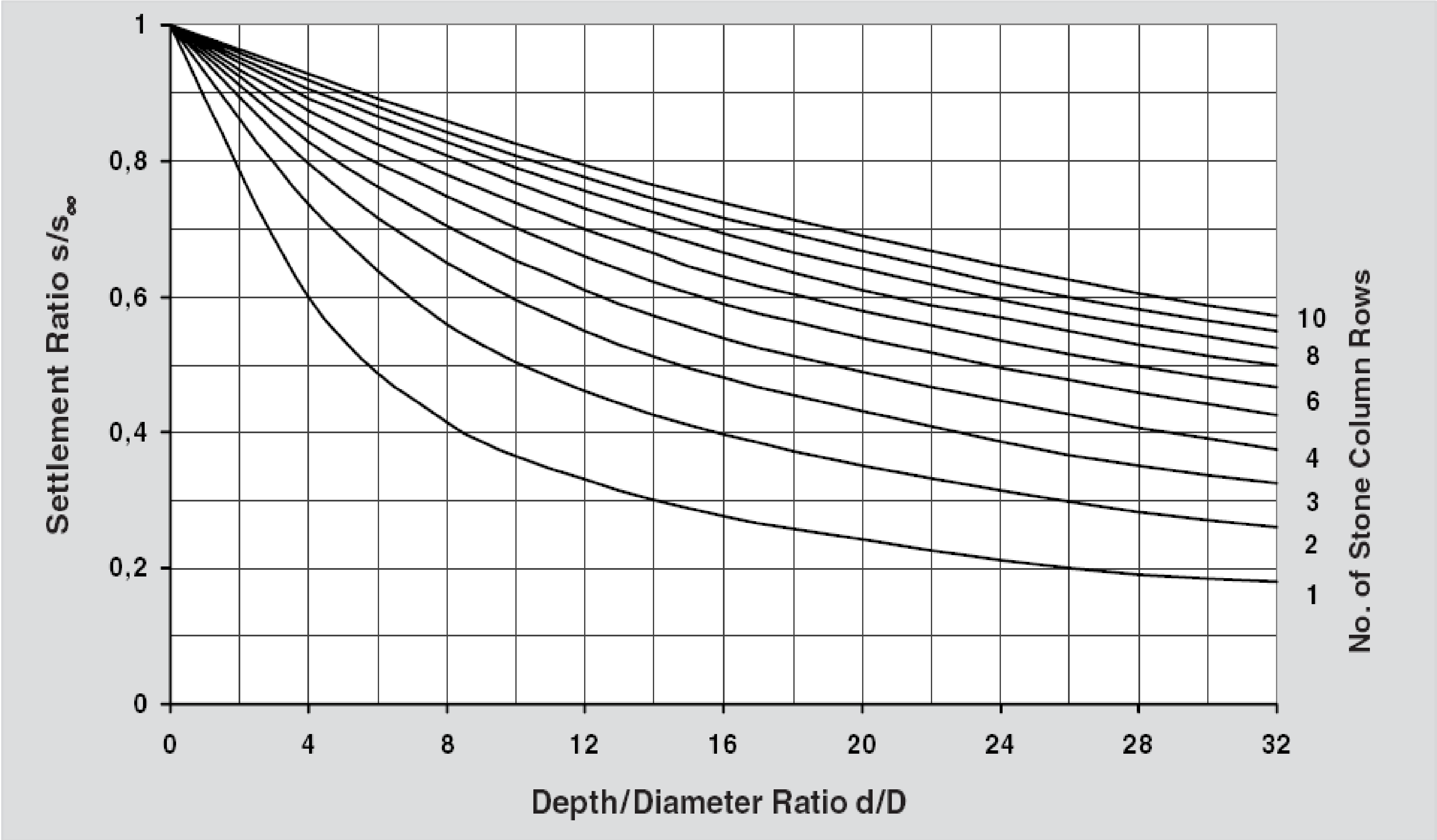


Fig1(f): Variation of settlement ratio with d/D ratio of Strip Footing

Bearing capacity of improved ground

Safety factor against bearing capacity of the soil can be determined using using the following equations:

$$\overline{\sigma_{0f}} = (c_S \cdot N_c \cdot \nu_c + q \cdot N_d \cdot \nu_d + \gamma_S \cdot \bar{b} \cdot N_b \cdot \nu_b) \cdot \bar{b}/b$$

Factor of Safety Against Bearing capacity= σ_{0f}/P

Design Example

- Design stone columns for an embankment with the following properties:

Top width of embankment= 5.0m with 1:1 slope on both sides. Surcharge on embankment=20kPa; Unit Wt. of embankment fill= 20KN/m^3 with depth of stone column= 6.0m. Given friction angle of column material= 40degrees; Cohesion=20kpa; Friction angle of soil= 0 degrees; μs=1/3; Column diameter=0.75m; Unit Wt. of Soil=16 KN/m^3.

Step1) Basic Improvement factor(no) given by:

$$n_0 = 1 + \frac{A_C}{A} \cdot \left[\frac{1/2 + f(\mu_S, A_C/A)}{K_{aC} \cdot f(\mu_S, A_C/A)} - 1 \right]$$

$$f(\mu_S, A_C/A) = \frac{(1-\mu_S)\cdot(1-A_C/A)}{1-2\mu_S + A_C/A}$$

$$K_{aC} = \tan^2(45° - \varphi_C/2)$$

$K_{ac} = \text{Tan}^2(45 - \varphi_c/2) = 0.217$

Area of Column, Ac= $0.785 * 0.75^2 = 0.441$

Area of unit Cell, A= 1.5*1.5=
2.25

$\mu_s = 0.33$

By substituting the above values in no, we get basic improvement factor as,

$n_o = 2.30$

Step2) Determine Reduced improvement factor(n_1)
The compressibility of the column material can be considered in using a reduced improvement factor n1 which results from the formula developed for the basic improvement factor n0 when the given reciprocal area ratio A/A_C is increased by an additional amount of $\Delta(A/A_C)$.

$$n_1 = 1 + \frac{\overline{A_C}}{A}\cdot\left[\frac{1/2 + f(\mu_S, \overline{A_C/A})}{K_{aC}\cdot f(\mu_S, \overline{A_C/A})} - 1\right]$$

$$\frac{\overline{A_C}}{A} = \frac{1}{A/A_C + \Delta(A/A_C)}$$

$$\Delta(A/A_C) = \frac{1}{(A_C/A)_1} - 1$$

$$\left(\frac{A_C}{A}\right)_1 = -\frac{4\cdot K_{aC}\cdot(n_0-2)+5}{2\cdot(4\cdot K_{aC}-1)} \pm \frac{1}{2}\cdot\sqrt{\left[\frac{4\cdot K_{aC}\cdot(n_0-2)+5}{4\cdot K_{aC}-1}\right]^2 + \frac{16\cdot K_{aC}\cdot(n_0-1)}{4\cdot K_{aC}-1}}$$

Assuming constrained modulus Ratio, $D_c/D_s=100$, we get $\Delta A/A_c=0.05$ and substituting, we get.

Reduced Improvement factor, $n_1=2.28$

Step3) The depth factor fd can be determined from the following equations:

$$f_d = \frac{1}{1 + \frac{K_{0C} - W_S/W_C}{K_{0C}} \cdot \frac{W_C}{p_C}}$$

$$p_C = \frac{p}{\frac{A_C}{A} + \frac{1 - A_C/A}{p_C/p_S}}$$

$$\frac{p_C}{p_S} = \frac{1/2 + f(\mu_S, \overline{A_C/A})}{K_{aC} \cdot f(\mu_S, \overline{A_C/A})}$$

$$W_C = \Sigma(\gamma_C \cdot \Delta d), \qquad W_S = \Sigma(\gamma_S \cdot \Delta d)$$

$$K_{oC} = 1 - \sin \varphi_C$$

$f_d = 2.01$.

f_d = Depth factor due to overburden.

n_2=improved factor (with overburden constraint)

$n_2 = f_d * n1$

$= 2.01*2.28$

$= 4.58$

Step4) Determine improved shear values

- The shear resistance from friction of the composite system can be determined by using

$$\tan\overline{\varphi} = m' \cdot \tan\varphi_c + (1 - m') \cdot \tan\varphi_s$$

m'=0.561;

$$Tan\overline{\varphi} = \left(2 * 0.578 * \tan 40 + \left(1 - 0.578\right) * Tan0\right)$$

$$\overline{\varphi} = 47 \deg rees$$

- The cohesion of the composite system depends on the proportional to the loads using the following equation.

$$c' = (1 - m') \cdot c_S$$

$$c' = (1 - 0.561) * 20$$

C′=8.44kPa

Step6) Determine the bearing capacity of the soil.

$$\sigma_{of} = \left(c_s.N_s.V_s + q.N_d.V_d + \gamma_s.\bar{b}.N_b.V_b\right).\frac{\bar{b}}{b}$$

$$\sigma of = \left(20*5.14*1.0+60*1.0*1.0+16*15*0*1.0\right)$$

$$\sigma 0 f = 104.22 Kpa$$

Factor of safety against bearing capacity=104.226/60.0=1.73

Introduction to Stone C Software

Main Characteristics

- Performs design calculations according to the method described by Priebe.
- Supports both rectangular and triangular stone columns grid installation patterns.
- Different stone columns diameters in every subsoil layer.
- Foundation type can be rectangular or circular.
- Performs settlements calculation using the basic theory of elasticity and according to Steinbrenner both for the treated and untreated soil.
- Performs bearing capacity calculations according to the method described by Priebe.
- Generates an extensive report of the results.

Steps to be followed for designing stone columns using Stone C Software

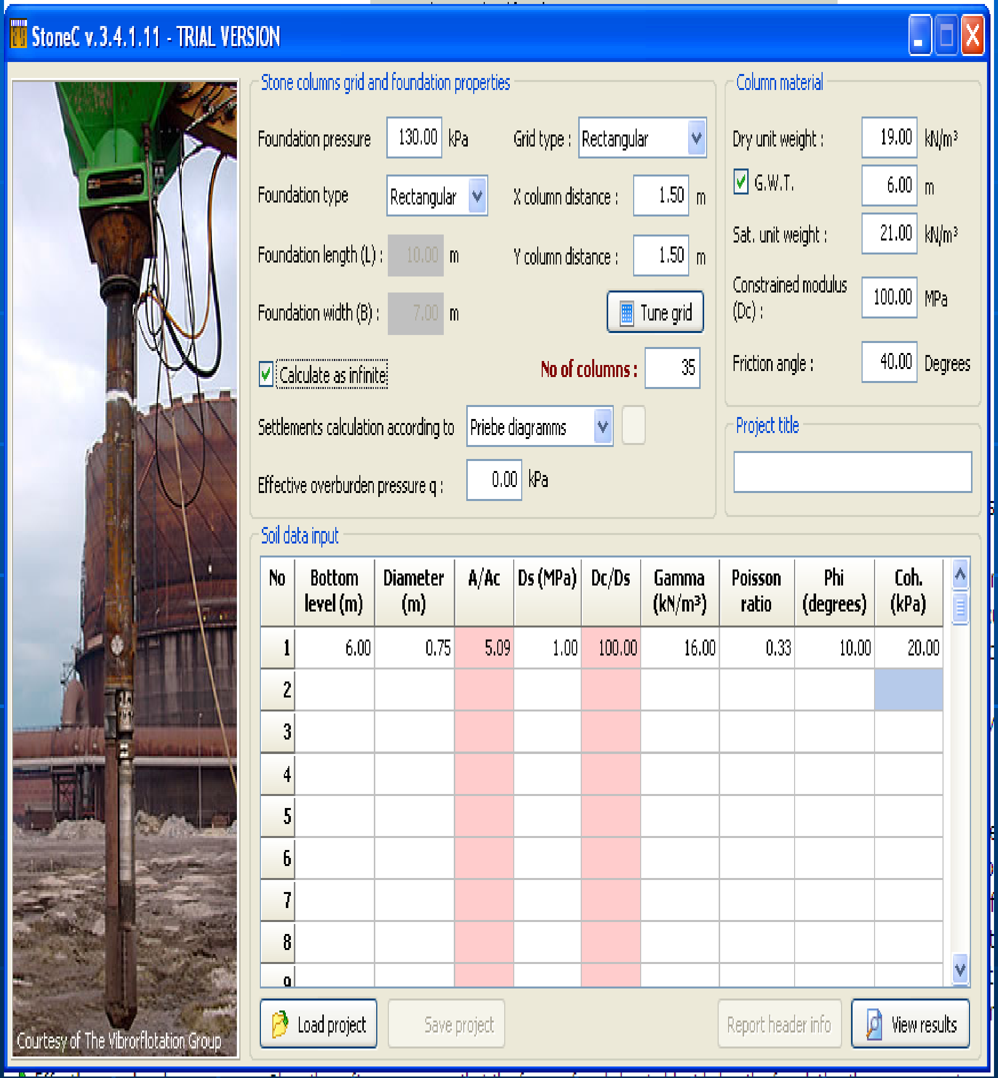
Step1) Input Stone columns grid & Foundation properties.

Step2) Input Column material properties.

Step3) Input Soil data.

Step4) Load project.

Step5) Click view results for the output values in a pdf document.



Stone columns grid and foundation properties

Foundation pressure 130.00 kPa

Grid type : Rectangular

Foundation type Rectangular

X column distance : 1.50 m

Foundation length (L) : 10.00 m

Y column distance : 1.50 m

Foundation width (B) : 7.00 m

☑ Calculate as infinite

No of columns : 35

Settlements calculation according to Priebe diagramms

Effective overburden pressure q : 0.00 kPa

Column material

Dry unit weight : 19.00 kN/m^3

☑ G.W.T. 6.00 m

Sat. unit weight : 21.00 kN/m^3

Constrained modulus (Dc) : 100.00 MPa

Friction angle : 40.00 Degrees

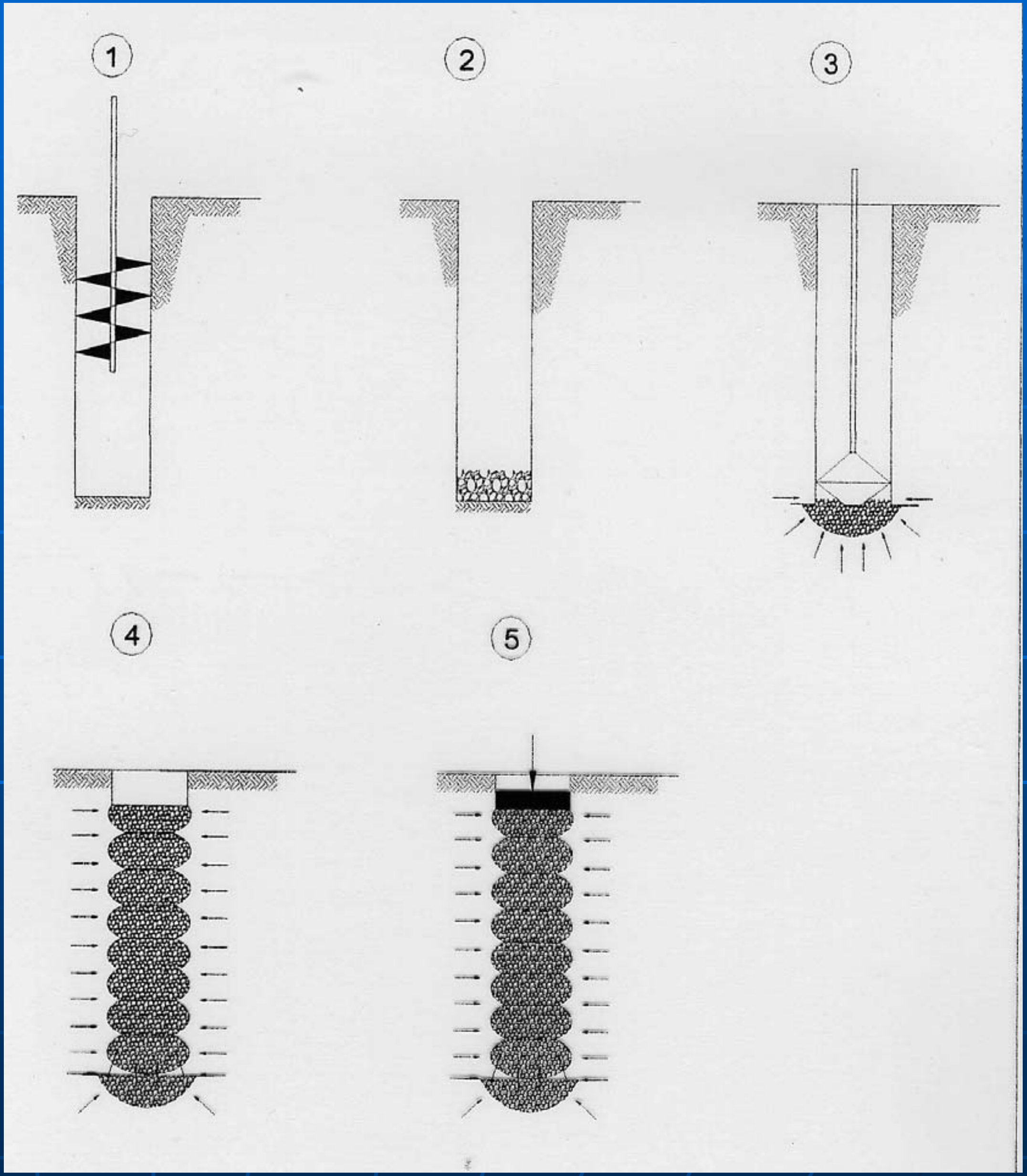
Project title

Soil data input

No	Bottom level (m)	Diameter (m)	A/Ac	Ds (MPa)	Dc/Ds	Gamma (kN/m^3)	Poisson ratio	Phi (degrees)	Coh. (kPa)
1	6.00	0.75	5.09	1.00	100.00	16.00	0.33	10.00	20.00
2									
3									
4									
5									
6									
7									
8									

Fig: Stone C software.

Fig. Step Construction procedure of aggregate pier element



1. drill cavity using augers, install casing if cave-ins occur.
2. place crushed stone at the bottom of cavity.
3. ram bottom stone with beveled tamper to produce bulb.
4. densify crushed stone in layers of 30 cm with tamper.
5. preload top of rap element.

Aggregate piers versus stone columns

	stone columns	aggregate piers
Typical length	5-15m	2-8m
Typical spacing	4d	2d
Thickness of lifts	1.5-3 m	20-30 cm
Allowable foundation pressure	25-150 kPa	250-300 kPa
Typical length diameter ratio	5-30	2-4
Construction equipment	6 m probe mounted crane	backhoe with 4 m long tamper & aces

Limitations of aggregate piers

Disadvantages associated with aggregate piers can be categorized into two consisting of economic limitations and performance limitations.

The requirement of a drilled cavity, and the fact that almost all the soils requiring improvement with aggregate piers, being very soft and compressible, cavity collapse is an inevitable issue. To prevent this, temporary casing is placed, and advanced once the backfilling stage onsets. this slows down the application rate and increases the cost per element. Additionally where treatment zone depths are required to be greater than say 8 m, aggregate piers shall not be considered as a solution because they give best performance when used in compressible strata as a floating pile to depths up to 8 m.

Conclusions

- Vibro- compaction and vibro- replacement techniques have been used to a considerable extent in ground improvement projects
- They have been very cost effective in infrastructure projects.
- Drainage function of the stone columns has been very useful in mitigation of damages due to liquefaction.