Lecture 29

BEARING CAPACITY IMPROVEMENT using geosynthetics in soft soils

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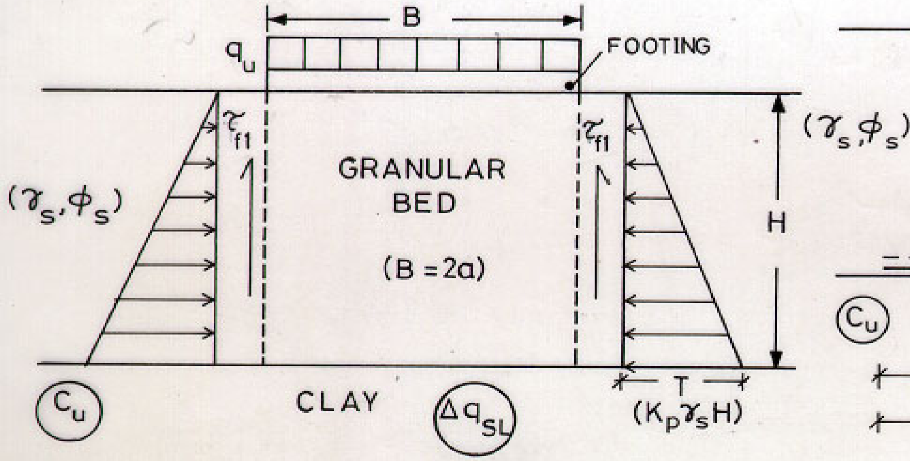
The ultimate bearing capacity of a footing resting on soft soil $q_u = C_u N_c$

Use of geosynthetics results in improvement of bearing capacity. The improvement is attributed to three effects

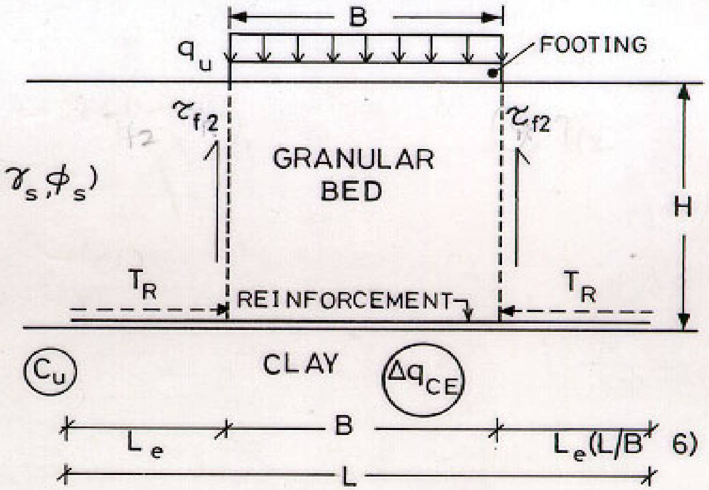
a) shear layer effect

b) confinement effect due to the interaction between sand and reinforcement in the sand layer and

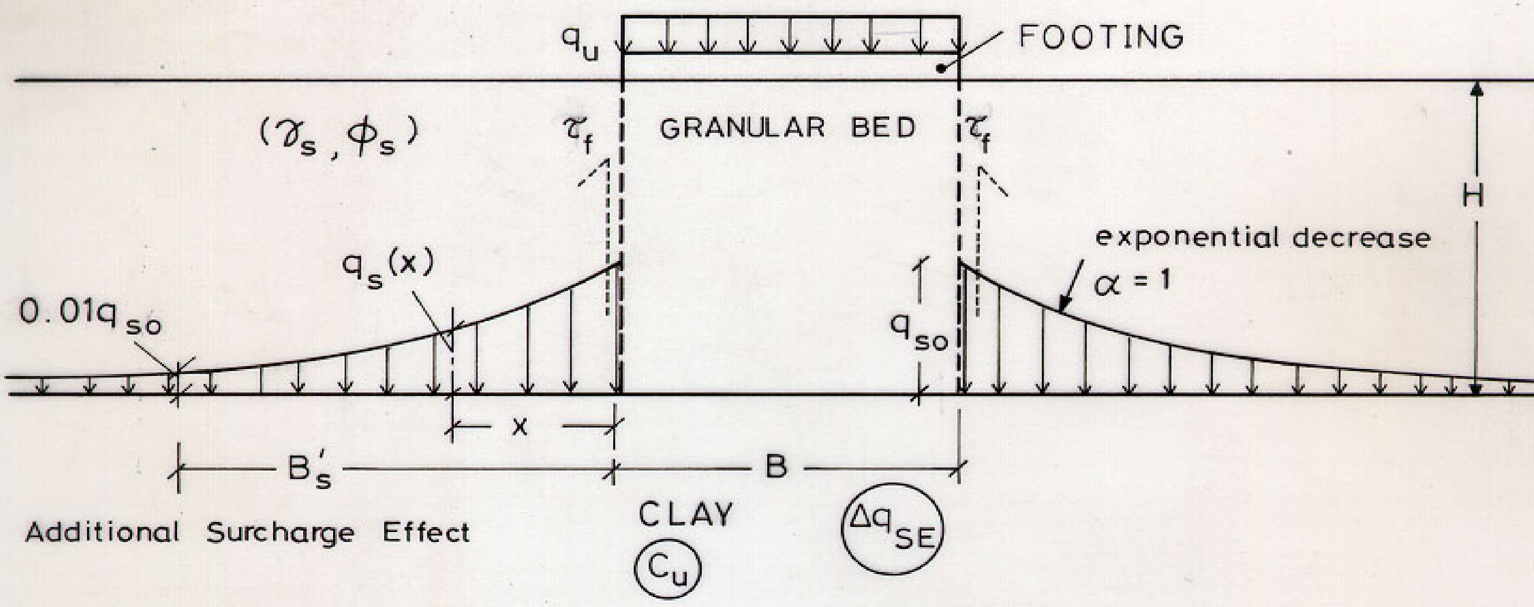
c) additional surcharge effects.



Shear Layer Effect



Confinement Effect



Additional Surcharge Effect

When a granular bed of thickness (H) of bulk density (γ_s) and friction angle (ϕ_s) with reinforcement is provided over soft soil, the bearing capacity of the footing resting on this foundation medium is increased. Frictional forces developed between the soil and the reinforcement induce tensile strains in the reinforcement. The tensile strains developed provide the confining effect. This will induce additional shearing resistance along the vertical plane at the edge and exponentially decrease with distance away from the edge of the footing. The three effects contribute to increase in bearing capacity, given as

$$q_u + \Delta q_R = C_u N_c + \Delta q_{SL} + \Delta q_{CE} + \Delta q_{SE}$$

T_{f1} =

Shear layer effect

The shearing stresses that are developed along the vertical plane at the edge of the footing is given by

$$T_{f1} = \frac{k_p \gamma_s H^2}{2} \tan \phi_s$$

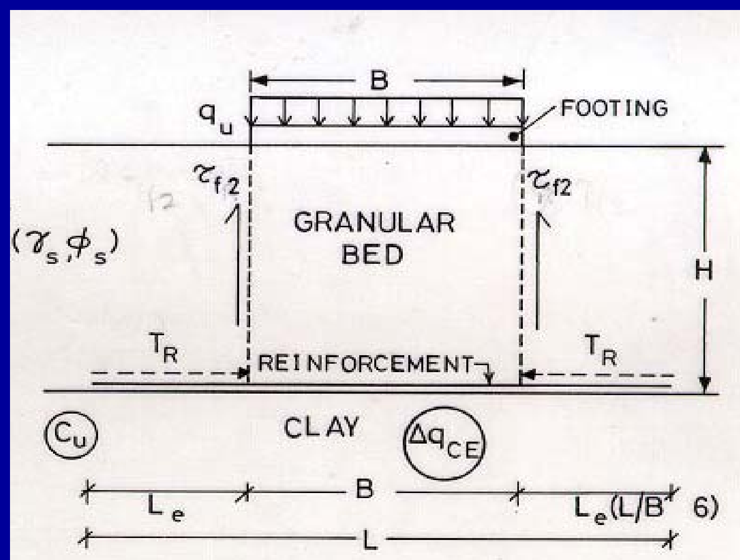
The improvement due to shear layer effect is given by Δq_{SL}

$$\frac{2T_{f1}}{B}$$

$$\Delta BCR_{SL} = \frac{2T_{f1}}{BN_c C_u}$$

Confinement effect

The tensile forces are generated in the reinforcement as a result of friction between the granular soil and the reinforcement. L_e is the effective length, ϕ_R is the friction angle between the reinforcement and granular soil, LDR is the linear density, ratio of reinforcement material (LDR = 1 for geosynthetics and 0.5 to 0.7 for metallic grids).



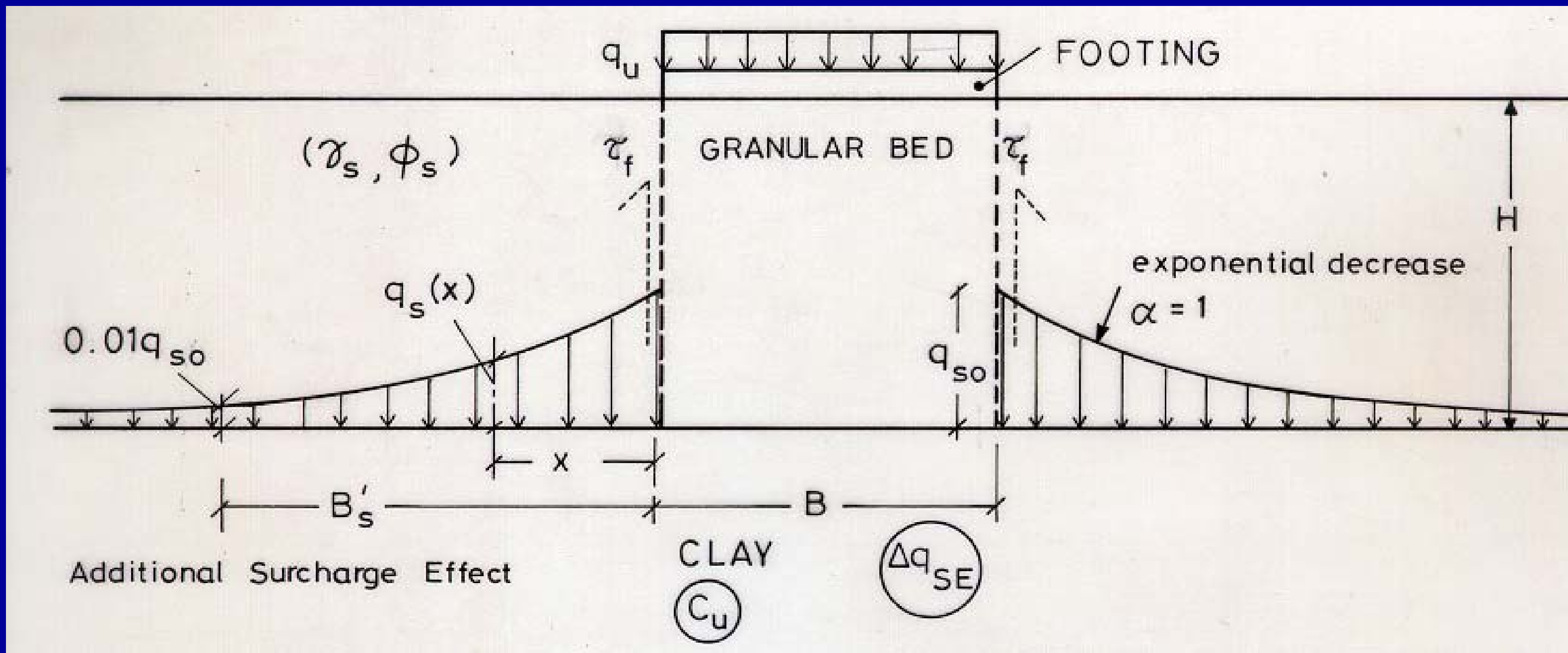
Confinement Effect

$$\Delta q_{CE} = \frac{2T_{f_2}}{B}$$

$$\Delta BCR_{CE} = \frac{2Tf_2}{BC_u N_c}$$

The reinforcement force (T_R) = (γ_sH) tanϕ_R.L_e(LDR). L_e can be taken as equal to 2.5B or greater. The frictional resistance (T_{f2}) developed at the edge of the footing due to the effect of reinforcement leading to confinement is given as

$$T_{f2} = T_R \tan\phi_s$$



The surcharge effect is calculated as follows.
Surcharge stress (q_{so}) at the edge of the footing is given as

$$q_{so} = 0.84\ (\Delta q_{SL} + \Delta q_{CE})$$

An example illustrating the application of the above formulation is given below.

Design a continuous foundation (B = 1m) that will carry a load of 480 kN/m that needs to be constructed on a soft soil and the undrained strength (C_u) of the soil is 10 kPa.

Solution

The ultimate bearing capacity of the soft soil

$$(q_u) = C_u N_c = 10 \times 5.14 = 51.4 \text{ kPa}$$

(i) A granular bed of 2m thick (design friction angle, φ_s = 30° and unit weight = 18 kN/m^3) to introduce shear layer effect is considered. The effect of the granular bed is given by

$$T_{f1} = \frac{k_p \gamma H^2}{2} \tan \phi_s$$

$$= \left(\frac{1 - \sin \phi}{1 + \sin \phi} \right) * \frac{18 * 2^2}{2} * \tan 30 = 62.35\, kN/m$$

Bearing capacity improvement due to shear layer effect

= (2*62.35)/1= 124.7 kN/m

ii) Consider that a geotextile layer is laid at the interface of the clay and sand bed.

The tensile forces are generated in the reinforcement s a result of friction between the granular soil and the reinforcement. If L_e is the effective length, ϕ_R is the friction angle between the reinforcement and granular soil, LDR is the linear density, ratio of reinforcement material (LDR = 1 for geosynthetics and 0.5 to 0.7 for metallic grids).

The reinforcement force (T_R) = $(\gamma_s H) \tan\phi_R . L_e (LDR)$

$$T_R = 18*2*\tan30*3*1 = 62.36$$

Bearing capacity due to confinement effect = 2 x 62.36 =124.70 kN/m

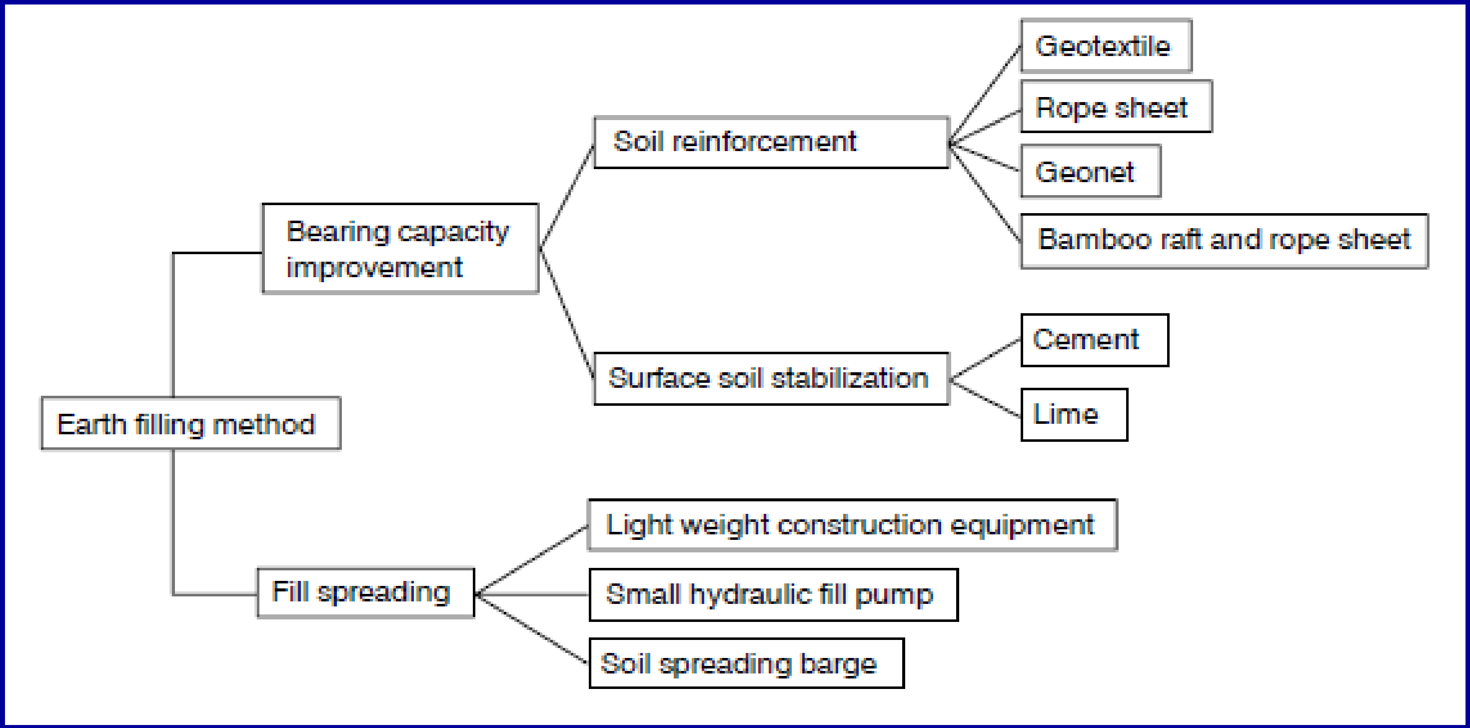
The contribution due to surcharge effect

= 0.84 (124.7+124.7) = 209.5 kN/m

Total improvement = 124.7+124.7+209.5 = 458.9 kN/m

Hence, it can be noted that the original ultimate bearing capacity of the soft soil is likely to increase from 51.4 kN/m to 458.9 kN/m, owing to the contribution in improvement of bearing capacity from shear layer effect, confining effect and surcharge effect. However, it is desirable that the improvement needs to be examined in relation to results that can be obtained from testing of a trial foundation.

Ground Reclamation methods In Japan



Ochiai, H.,Watari, Y. and Tsukamoto, Y., 1996, “Soil Reinforcement Practice for Fills Over Soft Ground in Japan”, *Geosynthetics International, Vol. 3,(*1), 31-48.

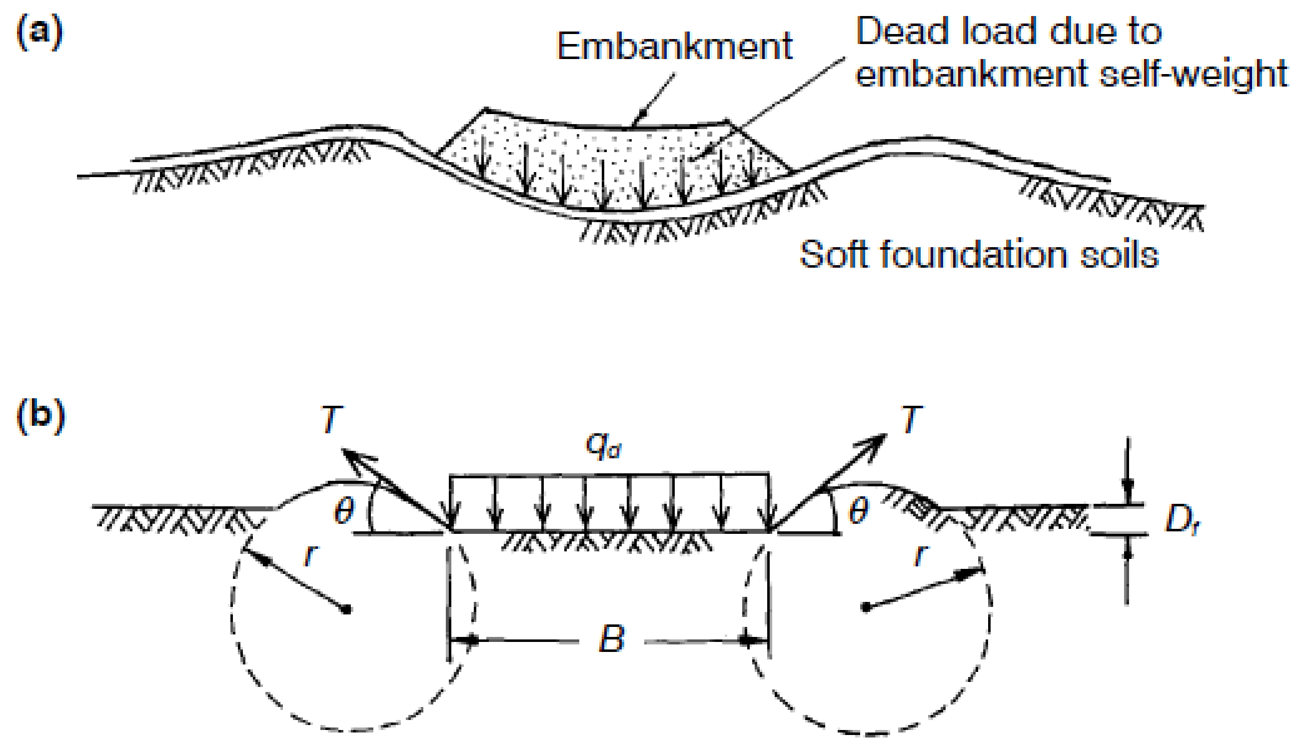


Figure 3. Design concept for embankment construction: (a) ground deformation under embankment; (b) modelling of ground deformation.

Design concept for bearing capacity

The ultimate bearing capacity of the foundation soil is assumed to comprise the following four components:

1. bearing capacity due to the shear strength of the existing ground, q_1 ;
2. *bearing capacity developed by the tensile forces generated* at both ends of the geotextile reinforcement, q_2 ;
3. *restraining effect of the geotextile on* ground deformation, q_3 *; and,*
4. *the surcharge effect due to settlement and heave,* q_4 .

These four components can be expressed as:

$q_1 = c_u N_c$
$q_2 = 2T \sin\theta / B$
$q_3 = T N_q / r$
$q_4 = \gamma D_f$

Ultimate bearing capacity, q_d is given by

$q_d = q_1 + q_2 + q_3 + q_4$

Design pressure = sum of the pressures due to the fill and the equipment:

$q = q_b + q_m$

Design pressure shall be less than the ultimate bearing capacity in terms of factor of safety (recommended value 1.5)

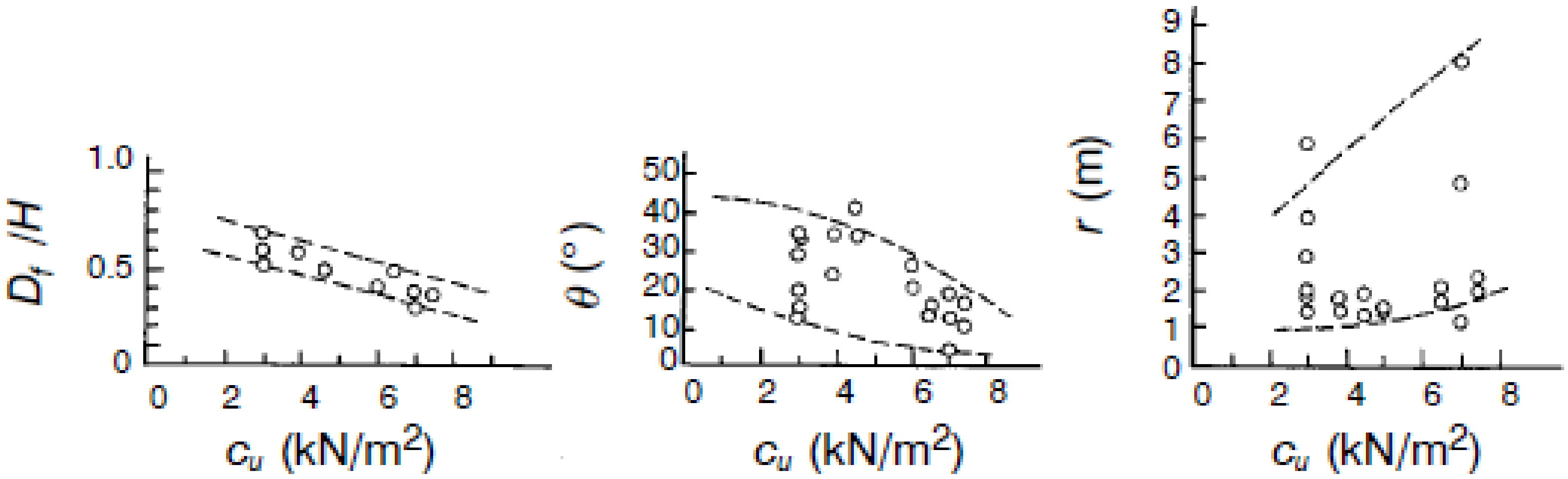
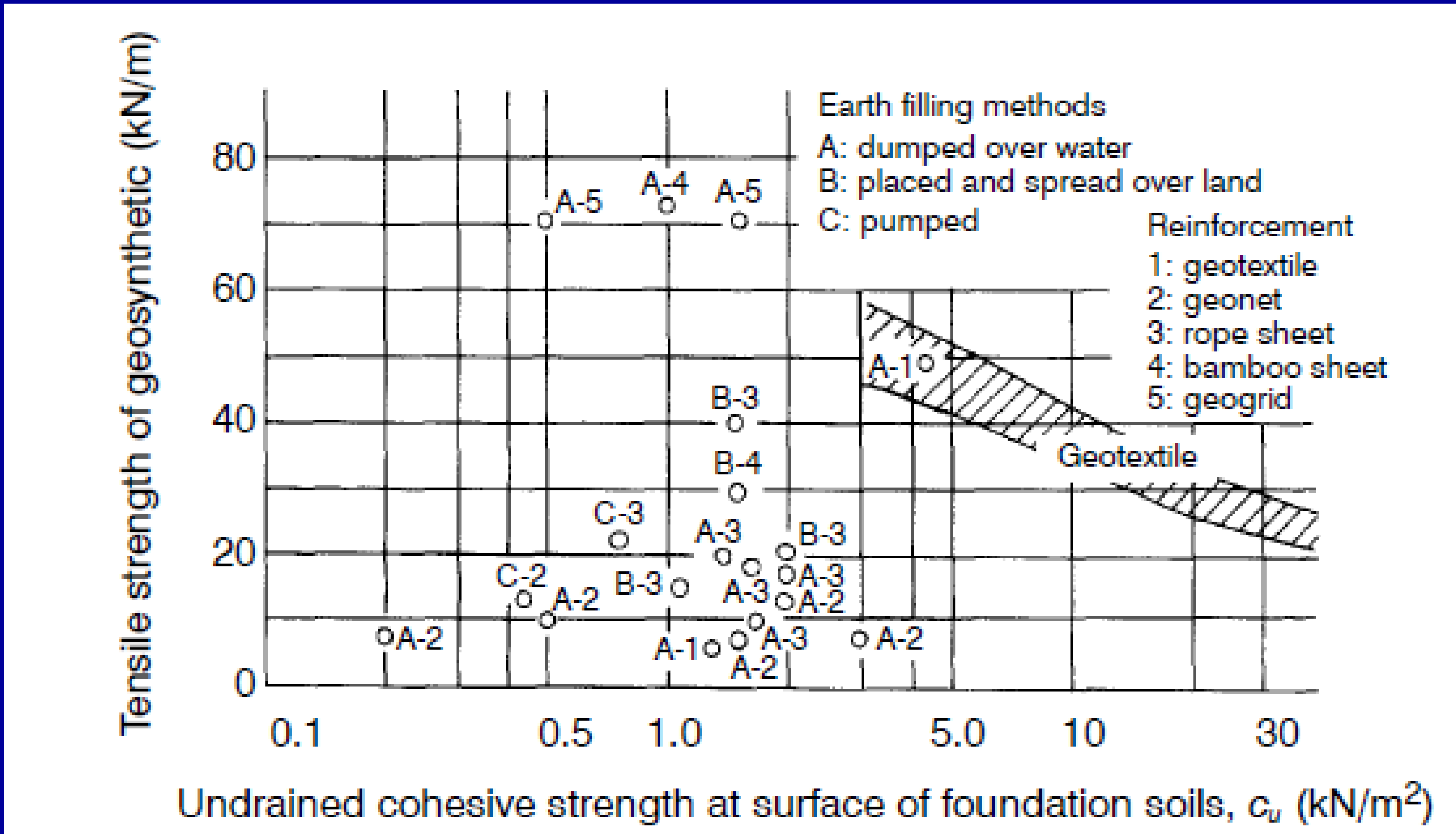


Figure 4. Parameters for calculation of ground bearing capacity (JSSMFE 1986).



Geosynthetic tensile strength versus soil strength and earth filling methods based on documentation.

Concluding Remarks

Use of geosynthetics is very useful in bearing capacity problems to increase bearing capacity and reduce settlements.
The technique has been implemented successfully in many problematic areas.
Research is continuing on the material development, design methodologies, construction influences, and guidelines,