2.2 Bearing capacity:

Bearing capacity: It is the load carrying capacity of the soil.

The bearing capacity of soil is defined as the capacity of the soil to bear the loads coming from the foundation. The pressure which the soil can easily withstand against load is called allowable bearing pressure.The bearing capacity of soil is the maximum average contact pressure between the foundation and the soil which should not produce shear failure in the soil. There are three modes of failure that limit bearing capacity: general shear failure, local shear failure, and punching shear failure. It depends upon the shear strength of soil as well as shape, size, depth and type of foundation.

Basic definitions:

1. Ultimate bearing capacity or Gross bearing capacity (q_u):

It is the least gross pressure which will cause shear failure of the supporting soil immediately below the footing.

2.Net ultimate bearing capacity (q_{nu}):

It is the net pressure that can be applied to the footing by external loads that will just initiate failure in the underlying soil. It is equal to ultimate bearing capacity minus the stress due to the weight of the footing and any soil or surcharge directly above it.

3.Safe bearing capacity:

It is the bearing capacity after applying the factor of safety (FS). These are of two types,

a. Safe net bearing capacity (q_{ns}) :

It is the net soil pressure which can be safety applied to the soil considering only shear failure.

(or)

Net ultimate bearing capacity is divided by certain factor of safety will give the net safe bearing capacity.

$$q_{ns} = q_{nu} / F$$

Where F = factor of safety = 3

b. Gross Safe bearing capacity (q_s):

It is the maximum gross pressure which the soil can carry safely without shear failure.

(or)

When ultimate bearing capacity is divided by factor of safety it will give gross safe bearing capacity.

$$qs = qu/F$$

4.Allowable Bearing Pressure(q_a):

It is the maximum soil pressure without any shear failure or settlement failure.

5. Net safe settlement pressure (q_{np})

The pressure with which the soil can carry without exceeding the allowable settlement is called net safe settlement pressure.

6. Net allowable bearing pressure (q_{na})

This is the pressure we can used for the design of foundations. This is equal tonet safe bearing pressure if $q_{np} > q_{ns}$. In the reverse case it is equal to net safe settlement pressure.

Methods of Improving the Bearing Capacity of soils:

The bearing capacity of a soil mainly depends on the closeness of its particles. The bearing capacity of a soil can be increased by the following methods:

1.By increasing the depth of foundation.

The compactness of the foil increases as we go below the ground level. As the bearing capacity directly depends on the compactness of the soil, it will go on increasing as the depth of foundation is increased.

2.By draining of the sub-soil under.

Water reduces the cohe•sive properties and hence reduces the bearing capacity of the soil. By draining off water from the sub-soil the bearing capacity of the soil is certainly increased.

3.By compacting the soil.

If the soil is compacted thoroughly, the voids are decreased and bearing capacity is increased.

4.By confining the soil and preventing it from spreading and lateral movement.

Spreading soils, if confined by sheet piling will resist more leads, that is, their bearing capacity will increase.

5.By increasing the width of foundation.

By increasing the width of foundations, the intensity of load is decreased and on the same soil more loads can be placed.

6.By hardening the soil by grouting, i.e. pumping in the cement -grout into the ground.

7. By grouting, the cohesive properties are in•creased and the soil will be able to take up more loads.

8.By solidifying the ground by chemical processes.

In this case also the soil is compacted by mixing certain chemicals such as ‘calcium chloride etc.

Factors influencing bearing capacity of soils

1. Soil Strength
2. Foundation Width
3. Foundation Depth
4. Soil Weight and Surcharge
5. Spacing Between Foundations
6. Earthquake and Dynamic Motion
7. Frost Action
8. Subsurface Voids
9. Expansive and Collapsible Soils
10. Potential Heave
11. Soil Reinforcement
12. Soil Erosion and Seepage

1.Soil Strength:

Bearing capacity of cohesionless soil and mixed soil increases unproportionally with the increase of in the effective friction angle. However, bearing capacity of cohesive soil varies linearly with the soil cohesion provided that the effective friction angle is zero.

2. Foundation Width

- Foundation width affects bearing capacity of cohesionless soil. The bearing capacity of a footing placed at the surface of cohesionless soil, where the soil shear strength is considerably dependent on internal friction, is proportional tothe width of the foundation. Bearing capacity of cohesive soil of constant shear strength and infinite depth is independent of foundation width.

3. Foundation Depth

- The greater the bearing capacity the deeper the foundation. This is specifically obvious in a uniform cohesionless soil. In contrary, if the foundation is carried down to a weak soil layer, then bearing capacity is declined.

- Foundations placed at depths where the structural weight equals the weight of displaced soil usually assures adequate bearing capacity apart from the case where the structure supported by under-consolidated soil and collapsible soil subject to wetting.

4. Soil Weight and Surcharge

The contribution of subsurface and surcharge soil, which are influenced by water table, to the bearing capacity cannot be ignored. The water table should not be above the base of the foundation to avoid construction, seepage, and uplift problems. If the water table is below the depth of the failure surface, then it has no influence on the bearing capacity.

5. Spacing between foundations

It is recommended to consider minimum spacing between footings, which 1.5 times foundation width, during the design of foundation in order to avoid reduction in bearing capacity.

6. Earthquake and Dynamic Motion

Repeated movements could increase pore pressure in foundation soil and consequently bearing capacity is decreased. Sources of cyclic movements are earthquakes, vibrating machinery, and other sources like vehicular traffic, blasting, and pile driving.

The foundation soil can liquify when pore pressures equal or exceed the soil confining stress. Liquefaction reduces effective stress to zero and causes gross differential settlement of structures and loss of bearing capacity.

7. Frost Action

Frost heave in certain soils in contact with water and subject to freezing temperatures or loss of strength of frozen soil upon thawing can alter bearing capacity over time. Low cohesion materials containing a high percentage of silt-sized particle are mostly susceptible to frost action.

8. Subsurface Voids

Bearing capacity of soil decreases due to subsurface voids which are within a critical depth beneath the foundation. The critical depth is that depth below which the influence of pressure in the soil from the foundation is negligible.

9. Expansive and Collapsible Soils

Collapsible and expansive soil can have large strength and bearing capacity when they are fairly dry. However, the volume of these soils changes due to changes in water content. This leads to total and differential foundation movements. Seasonal wetting and drying cycles may cause soil movements that often lead to excessive long-term deterioration of structures with substantial accumulative damage.

10. Potential Heave

The potential heave can be determined from results of consolidometer test which can be performed in accordance with ASTM D 4546. The results of this test is considered in determining preparation of foundation soils to reduce destructive differential movements and to provide a foundation of sufficient capacity to withstand or isolate the expected soil heave.

11. Soil Reinforcement

Bearing capacity of soft or weak soil can be increased greatly by installing various forms of reinforcement in the soil like metal ties, strips, or grids, geotextile fabrics, or granular materials.

12. Soil Erosion and Seepage

Erosion of soil around and under foundations and seepage can reduce bearing capacity and can cause foundation failure.

Types of shear failure of foundation soils:

Depending on the stiffness of foundation soil and depth of foundation, the following are the modes of shear failure experienced by the foundation soil.

- General shear failure (Fig.1(a))
- Local shear failure (Fig.1(b))
- Punching shear failure (Fig.1(c))

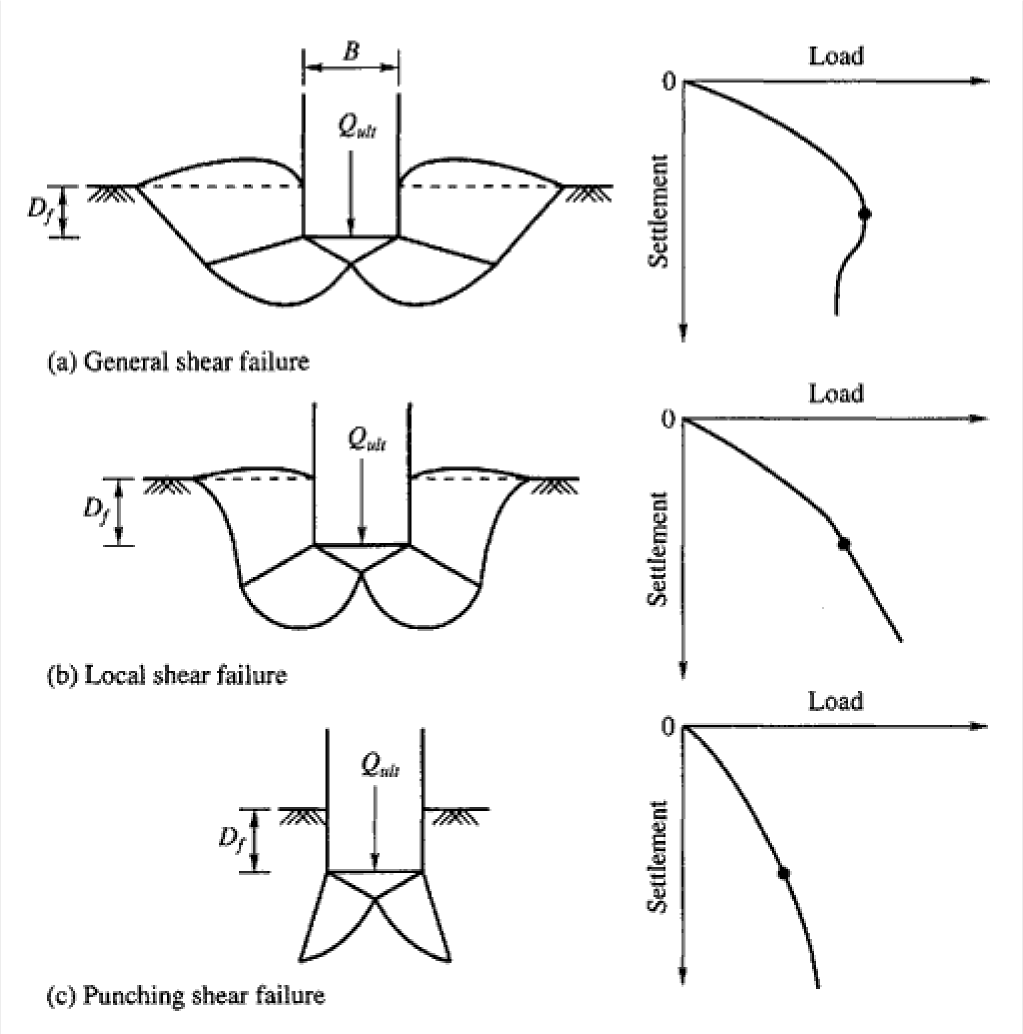

Fig 1 Different modes of failure

[Fig1 http://www.abuildersengineer.com/2012/11/types-of-failure-in-soil.html]

General Shear Failure:

- This type of failure is seen in dense and stiff soil. The following are some characteristics of general shear failure. Continuous, well defined and distinct failure surface develops between the edge of footing and ground surface.
- Dense or stiff soil that undergoes low compressibility experiences this failure.
- Continuous bulging of shear mass adjacent to footing is visible.
- Failure is accompanied by tilting of footing.
- Failure is sudden and catastrophic with pronounced peak in curve.
- The length of disturbance beyond the edge of footing is large.
- State of plastic equilibrium is reached initially at the footing edge and spreads gradually downwards and outwards.
- General shear failure is accompanied by low strain (<5%) in a soil with considerable (>36°) and large N (N > 30) having high relative density (I_D> 70%).

Local Shear Failure:

- This type of failure is seen in relatively loose and soft soil. The following are some characteristics of general shear failure. A significant compression of soil below the footing and partial development of plastic equilibrium is observed.
- Failure is not sudden and there is no tilting of footing.
- Failure surface does not reach the ground surface and slight bulging of soil around the footing is observed.
- Failure surface is not well defined.
- Failure is characterized by considerable settlement.
- Well defined peak is absent in curve.
- Local shear failure is accompanied by large strain (> 10 to 20%) in a soil with considerably low (<28^o) and low N (N < 5) having low relative density (I_D> 20%).

Punching Shear Failure of foundation soils:

- This type of failure is seen in loose and soft soil and at deeper elevations. The following are some characteristics of general shear failure. This type of failure occurs in a soil of very high compressibility.
- Failure pattern is not observed.
- Bulging of soil around the footing is absent.
- Failure is characterized by very large settlement.
- Continuous settlement with no increase in P is observed in p-Δ curve.

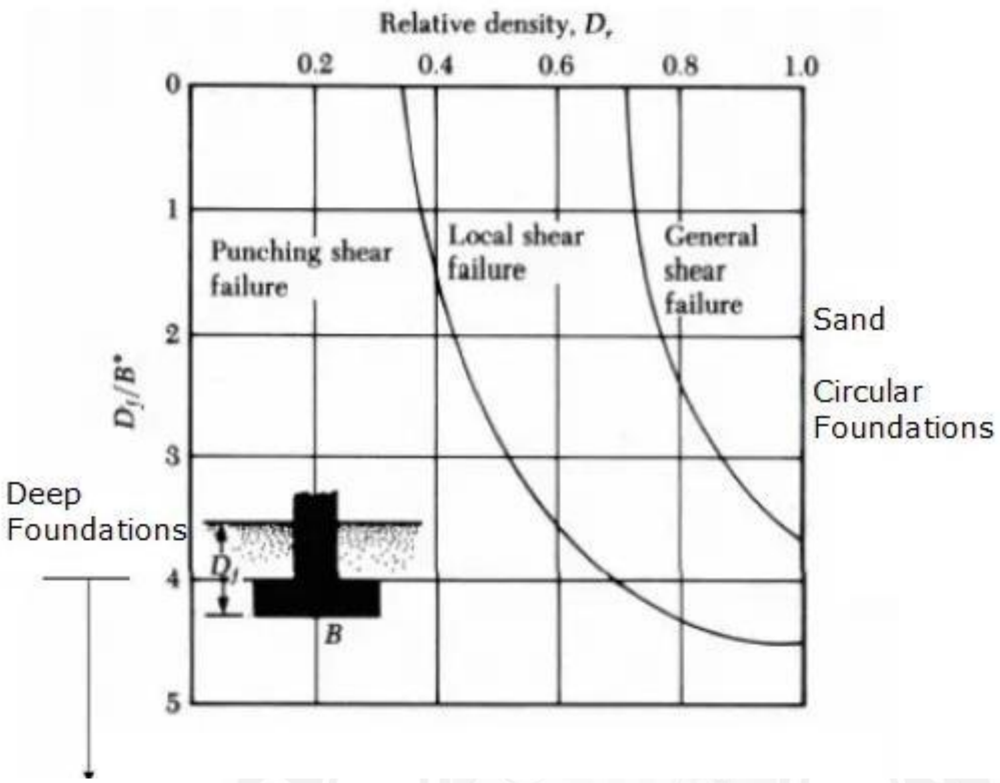

Fig. 2 presents the conditions for different failure modes in sandy soil carrying circular footing based on the contributions from Vesic (1963 & 1973)

[Fig 2 https://theconstructor.org/geotechnical/types-of-shear-failure-of-foundation-soils/7492/]