Unit - 4

PILES

DESIGN METHODOLOGY FOR PILES The detailed design methodology of piles is described in the following sections.

REQUIREMENT FOR DEEP FOUNDATIONS Generally for structures with load >10 t/m^2, we go for deep foundations. Deep foundations are used in the following cases:

- Huge vertical load with respect to soil capacity.
- Very weak soil or problematic soil.
- Huge lateral loads eg. Tower, chimneys.
- Scour depth criteria.
- For fills having very large depth.
- Uplift situations (expansive zones)
- Urban areas for future large and huge construction near the existing building.

CLASSIFICATION OF PILES 1. Based on material

- Timber piles
- Steel piles
- Concrete piles
- Composite piles (steel + concrete) 2. Based on method of installation
- Driven piles ----(i) precast (ii) cast-in-situ.
- Bored piles. 3. Based on the degree of disturbance
- Large displacement piles (occurs for driven piles)
- Small displacement piles (occurs for bored piles)

POINTS TO BE CONSIDERED FOR CHOOSING PILES

- Loose cohesion less soil develops much greater shaft bearing capacities if driven large displacement piles are used.
- Displacement effect enhanced by tapered shafts.
- Potential increased of shaft capacities is undesirable if negative friction is to be feared. (Negative friction is also called drag down force)
- High displacement piles are undesirable in stiff cohesive soils, otherwise excessive heaving takes place.
- Encountered with high artesian pressures on cased piles should be excluded. (Mainly for bridges and underwater construction)
- Driven piles are undesirable due to noise, damage caused by vibration, ground heaving.
- Heavy structures with large reactions require high capacity piles and small diameter cast-in-situ piles are inadequate.
- **PILE CLASSIFICATION**
- Friction piles.
- End bearing piles.
- Compaction piles.(Used for ground movement, not for load bearing)

- Tension piles/Anchored piles.(To resist upliftment)
- Butter piles (Inclined) --- +ve and –ve.

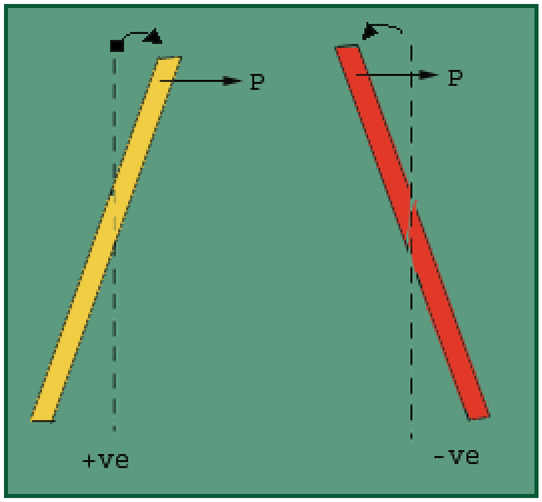


Fig. 5.1 Direction of load is same as the direction of batter. (Rotation of pile)

- Raymond piles. (Driven cast-in-situ piles, first tapered shell is driven and then cast)
- Franki Piles (Driven cast-in-situ piles, first casing is driven upto 2m depth, then cast a block within that casing and then drive the block. When it reaches the particular depth, take out the casing and cast the piles.)
- Underreamed piles (bored cast-in-situ piles, bulbs used, hence not possible to install in loose sand and very soft clays.)

PILES IN CLAY Zone of influence

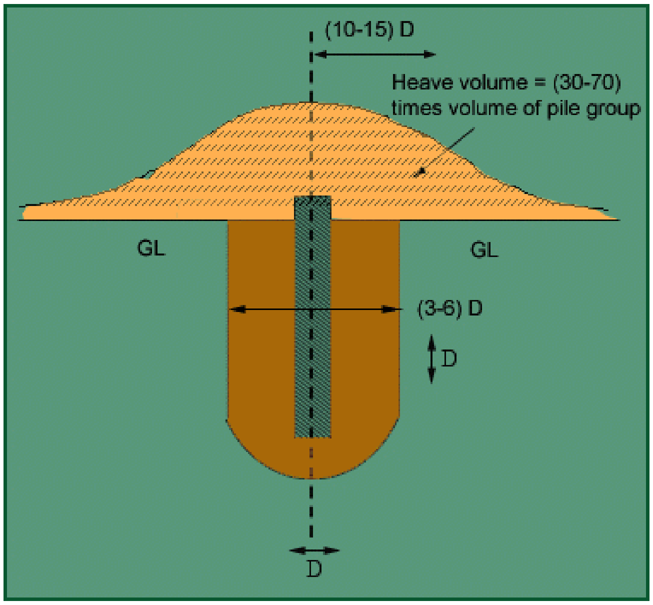
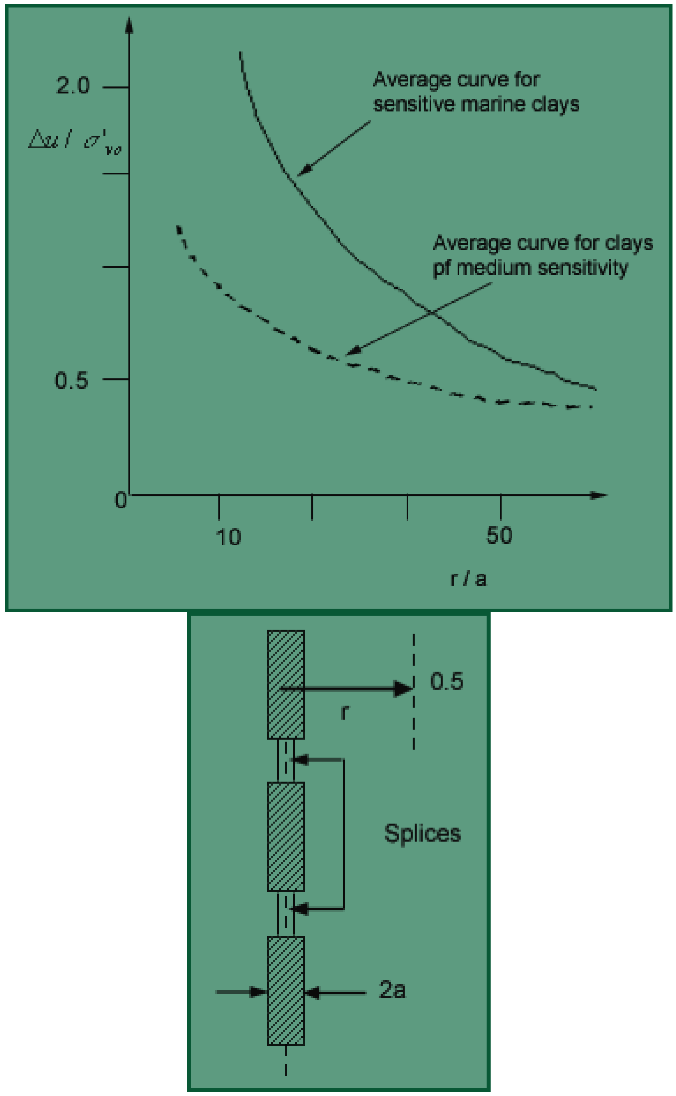


Fig.5.2 Driven piles in clay

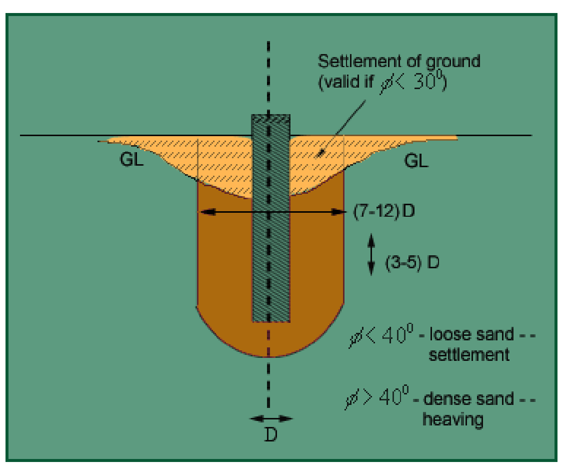
The heaving effect can be felt upto (10 –15) D from the centerline of the pile. Due to driving load, pressure is generated and as a result heaving occurs. Afterwards with time, the heaved part gets consolidated and strength gradually increases as the material regains shear strength within 3 – 6 months time after the installation of the pile. This regain of strength is called thixotrophy.

On the first day some part of the pile will be driven and on the second day some part of the pile may move up due to the gain of shear strength. This is known as the *wakening of the pile.* By the driving force, the extra pore pressure generated is (5 – 7) times the C_u of the soil. Bearing capacity of the pile is 9 C_u. Hence due to this property, maximum single length of the pile theoretically can be upto 25m but 10-12m is cast at a time. Then by splicing technique the required hired length of the pile is obtained. Special types of collars are used so that the splices become weak points. Concrete below the grade M20 is never used.

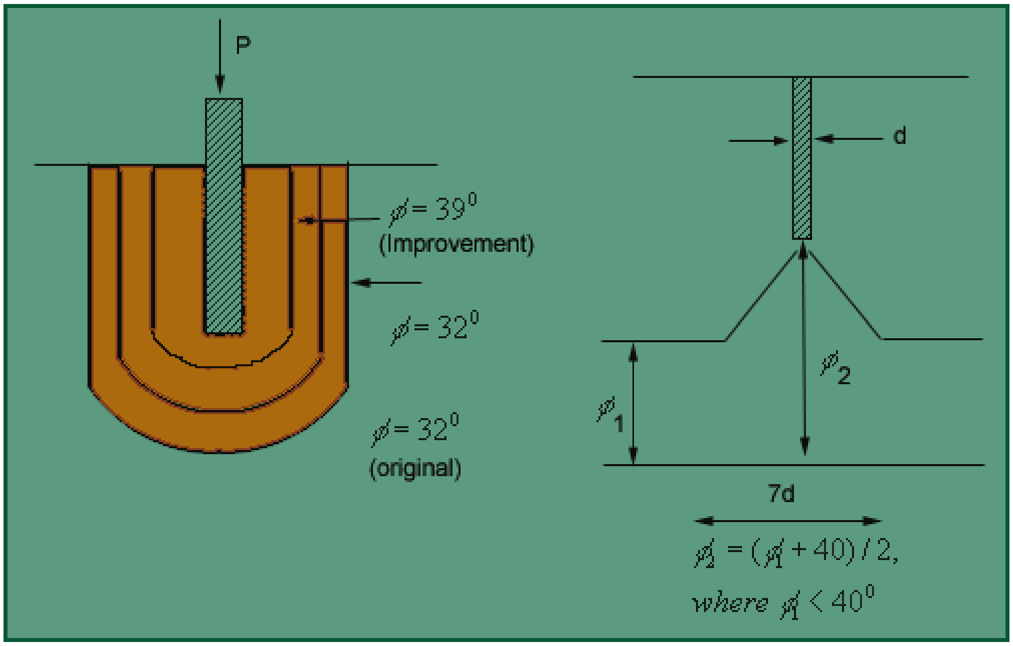
Pile Diameter	Maximum length (m)
250	12
300	15
350	18
400	21
450	25



PILES IN SAND



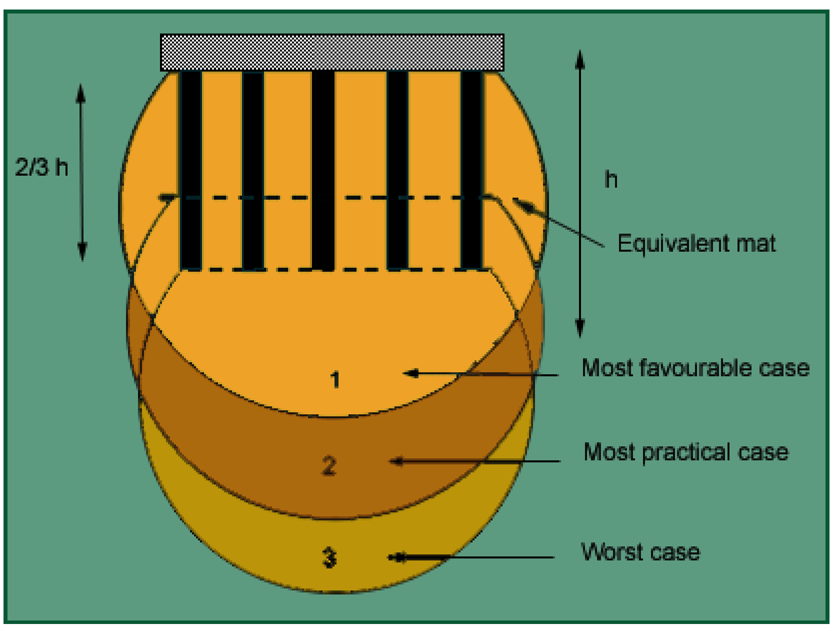
Driven piles in loose sand



Improvement in f due to pile driving

SETTLEMENT OF PILE GROUPS

Assume 2V:1H dispersion for settlement of pile groups.



Settlement of pile groups

CODAL PROVISION SAFE LOAD ON PILES/PILE GROUPS (Ref. IS: 2911 Part IV 1979)
Single pile: 1. Safe load = Least of the following loads obtained from routine tests on piles :

- 2/3 of the final load at which total settlement is 12mm.
- 50% of the final load at which settlement is 10% of the pile dia.(for uniform dia. piles) and 7.5% of bulb dia. (for Underreamed piles)
- 2/3 of the final load at which net settlement is 6mm.
- Consider pile as column and find the total compressive load depending on the grade of concrete and dimensions. Eg. Consider a 300mm dia pile made of M20 concrete. $\sigma_{cc} = 5N/mm^2$.

Therefore, ultimate load = $\frac{\pi}{4} \times 300^2 \times 5 = 353.4KN$.

Fig 5.40 Multiple Under Reamed Pile

Under reamed piles are bored cast-in-situ concrete piles having **one or more** number of **bulbs formed** by enlarging the pile stem. These piles are best suited in soils where considerable **ground** movements occur due to seasonal variations, filled up grounds or in soft soil strata. Provision of under reamed bulbs has the advantage of increasing the bearing and uplift capacities. It also provides better anchorage at greater depths. These piles are efficiently used in machine foundations, over bridges, electrical transmission tower foundation sand water tanks. Indian Standard IS 2911 (Part III) - 1980 covers the design and construction of under reamed piles having one or more bulbs. According to the code the diameter of under reamed bulbs may vary from 2 to 3 times the stem diameter depending upon the feasibility of construction and design requirements. The code suggests a spacing of 1.25 to 1.5 times the bulb diameter for the bulbs. An angle of 45 0 with horizontal is recommended for all under reamed bulbs. This code also gives Mathematical expressions for calculating the bearing and uplift capacities.

From the review of the studies pertaining to under reamed piles, it can be seen that ultimate bearing capacity of piles increases considerably on provision of under- reamed bulbs (Neumann and P&g, 1955, Subash Chandra and Kheppar, 1964, Patnakar, 1970 etc.). Pile load capacity was found to vary with the number of bulbs and with the spacing ratio S / D_u or S/d adopted (where S = distance between the piles, D_u = diameter of under reamed bulbs and d = diameter of piles). Table summarizes the various recommendations made for the selection of S / D_u and S/d for the optimum pile load capacity. It can be seen that some of these recommendations differ from those given in IS 2911 (Part III), 1980.

Table: 5.6 of recommendations for S / D_u and S/d for the optimum pile load capacity

Recommendations of S/ D_u & S/d values for under reamed piles			
s.no.	Reference	No. of Bulbs	Spacing
1.	Patnakar (1970)	Pile capacity for one bulb increases25 percent, for two bulbs 600 percent, and for three bulbs700 percent over simple	For optimum capacity two bulbs S / D_u = 6 or S/d = 15, far three

		pile.	bulbs, S / D_u = 5 or S/d = 12.
2	Agarwal and Jain (1971)	-	For optimum capacity S / D_u = 1.25 to 1.5
3	Sonapal and Thakkar (1977)	-	For optimum capacity S / D_u = 2.5
4	IS 2911(Part III 1980)	More than two bulbs are not advisable	S / D_u = 1.25 to 1.5
5	Ray and Raymond (1983)	-	Maximum value of S / D_u = 1.24 to 1.5

The choice of an under-reamed pile in unstable or water-bearing ground is generally to be avoided. There is a danger of collapse of the under-ream, either when personnel are down the hole, or during concreting.

Important Notes: On the basis of limited experimental studies conducted on model under reamed piles in cohesion less soil the following conclusions are drawn.

1. By providing under reamed bulbs the ultimate load capacities of piles increases significantly. 2. The ultimate load bearing capacities of the under reamed piles with angle of under reamed bulbs of *45* ^{0} *and* zero are almost same. 3. Three or more under reamed bulbs are advantageous only when the spacing ratio (S / D_u) is two or less, and when (S / D_u) is greater than two, multi-under reamed piles do not have specific advantages. 4. The ultimate load bearing capacities of piles are maximum when the spacing between two under reamed bulb is 2.5 times the diameter of the under reamed bulb. It appears that the spacing between two under reamed bulbs suggested in (1.25 to 1.5 times) IS 2911(1980) is not the optimum, 5. The expression suggested in IS 2911(1980) can be used for predicting the ultimate load carrying capacity of under reamed piles with spacing ratio (S / D_u) less than