PILE FOUNDATION

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٢٠١٣

- سوپاسی هەمیشەیی بۆ خوای پەروەردگار کە تەمەن وزانستی پێدایین تا گەشتینە ئەم پلە زانستیە . . .

- سوپاسی باوك ودایكی خۆشەویستمان ئەكەین كە تەمەنی خۆیانیان بەخشیوە لە پەروەردە كردن و پێگەیاند نمان . . .

- سوپاسی هەمیشەیی بۆ هەموو ئەو مامۆستا بەرێزانەی كە ئیمەیان سود مەند كردووە بە زانست وفێر كردن . .

سوریە میر حسن

PILE FOUNDATION

A pile is a slender , structural member installed in the ground to transfer the structural loads to soils at some significant depth below the base of the structure . Structural loads include axial loads , lateral loads and moments .

PILE FOUNDATION ARE USED WHEN :

- The soil near the surface does not have sufficient bearing capacity to support the structural loads .
- The estimated settlement of the soil exceeds tolerable limits (i.e., settlement greater than the serviceability limit state) .
- Differential settlement due to soil variability or non uniform structural loads is excessive .
- The structural loads consist of lateral loads and / or uplift forces .
- Excavations to construct a shallow foundation on a firm soil layer are difficult or expensive .

The ultimate object of the designer of piled foundations is the determination of the safe loads which can be carried by individual piles or by groups of piles . The total load to be supported must be carried in such a way that the distribution of load over the area of subsoil is regulated to suit the properties of the supporting stratum . Such estimation , though of necessity based on empirical findings , is considerably assisted by application of the principles of soil mechanics

SITE INVESTIGATION

Before the correct type of foundation can be determined a full and careful investigation of the site should be made . Tests on soil samples and careful mapping of surface and under ground conditions show whether a piled foundation is really necessary , or whether the properties of the various strata permit of a more economic solution by the use of rafts or isolated footings . Such a decision is usually made after examination of soil mechanics .

TYPE OF PILES

Piles are made from concrete or steel or timber . The selection of the type of pile required for a project depends on what type is readily available , the magnitude of the loading , the soil type , and the environment in which the pile will be installed , for example , a corrosive environment or a marine environment .

١. CONCRETE PILE :

There are several types of concrete piles that are commonly used . These include cast-in-place concrete piles , precast concrete piles , and drilled shafts . Cast-in-place concrete piles are formed by driving a cylindrical steel shell into the ground to the desired depth and then filling the cavity of the shell with fluid concrete .

Precast concrete piles usually have square or circular or octagonal cross sections and are fabricated in a construction yard from reinforced or pre stressed concrete . A very popular type of precast concrete pile is the Raymond cylindrical pre stressed pile .

٢. STEEL PILES :

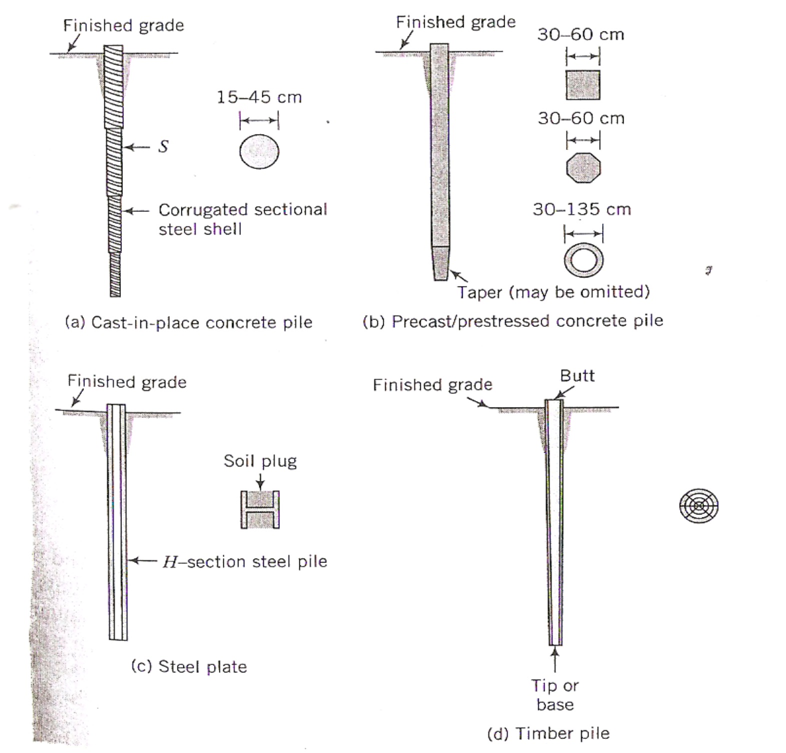
Steel piles come in various shapes and sizes and include cylindrical , tapered , and H-piles . Steel H – piles are rolled steel sections and are called non displacement piles . Steel pipe piles are seamless pipes that can be welded to yield lengths up to ٧٠m . They are usually driven with open ends into the soil .

٣. TIMBER PILES :

Timber piles have been used since ancient times . The lengths of timber piles depend on the types of trees used to harvest the piles , but common length are about ١٢m .

TABLE 10.1 Comparisons of Different Piles

Pile type	Section (m)	Common lengths (m)	Average load (kN)	Allowable stress (MPa)	Advantages	Disadvantages
Cast-in-place concrete	0.15–0.45 (diameter)	≤35	600	4.5–8.5	Can sustain hard driving, resistant to marine organisms, easily inspected, length can be changed easily, easy to handle and ship	Concrete can arch during placement, can be damaged if adjacement piles are driven before concrete sets
Precast concrete	0.15–0.25 (width)	≤35	750	4.5–7	Economical for specified length, higher capacity than timber	Cutting and lengthening of piles can be expensive, handling is a problem, shipping long piles is expensive, may crack during driving
Raymond cylinder	0.6–2.3 (diameter)	<60	2000	40–70	Can ship in sections, high capacity, long length	Cost (expensive)
Steel pipe	0.2–1 (diameter)	<35	900	59–83	High axial and lateral capacity, can take hard driving, easy inspection and handling, length can be changed easily, resistant to deterioration	Needs treatment for corrosive environment
Concrete-filled pipe	0.2–1 (diameter)	<35	900	Concrete: 4.5–8.5 Steel: 62–83	Similar to steel pile	Similar to steel pile
Steel H-pile	Webs: 1–3 Flange: 0.2–0.35	<60	900	59–83	"Nondisplacement," can take hard driving, easy handling, high axial and lateral capacity, length can be changed easily	Needs treatment for corrosive environment
Timber	0.125–0.45 (diameter)	12–35	250	5.5–8.5	Low cost, availability	Low capacity, can deteriorate if not protected, cannot take hard driving, cannot be inspected after driving

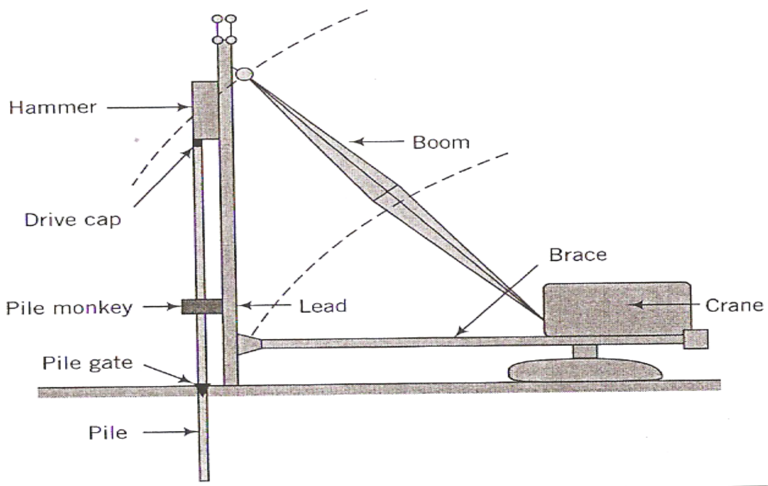


(a) Cast-in-place concrete pile (b) Precast/prestressed concrete pile

(c) Steel plate (d) Timber pile

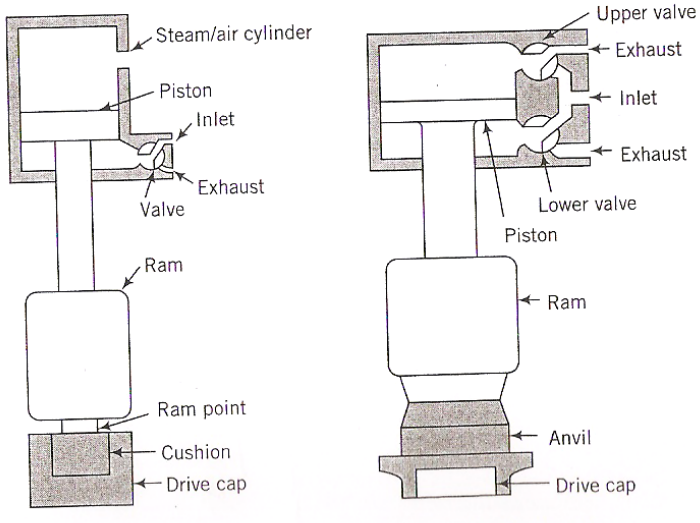
PILE INSTALLATION

Pile can either be driven into the ground (driven piles) or be installed in a predrilled hole (bored piles or drilled shafts) . A variety of driving equipment is used in pile installations . The key components are the leads and the hammer . The leads are used to align the hammer to strike the pile squarely . Hammers can be simple drop hammers of weights between ٢.٥ and ١٥ KN or modern steam / pneumatic hammers .



There are two popular types of hammer :

- Single – acting hammer utilizes steam or air to lift the ram and its accessories (cushion , drive caps , etc .) .
- Double – acting hammer is used to increase the number of blows / minute and utilizes steam / air to lift the ram and force it down .



(*a*) Single acting (*b*) Double acting

PILE – DRIVING FORMULÆ

The load which can be safely imposed on a single pile is often calculated from pile – driving formulae or from the results of test loadings . The numerous attempts which have been made to reduce to order the widely varying conditions encountered in constructing pile foundations have resulted in the production of many empirical expressions .

These have usually been constructed by equating the energy applied in driving the pile to the work done in causing penetration . Allowances are made for the losses of energy which are known to occur but whose magnitude can only be estimated . Such expressions are called (DYNAMIC FORMULÆ) , in which the properties of the soil are quite inadequately represented by the measured penetration or set of the pile under the hammer blow .

A " complete " formula is of the form :

Applied energy = Useful work + Loss in impact + Loss in pile cap + Loss in pile + Loss in soil

When the properties of the various foundation strata are examined by the methods of soil mechanics or used in an estimation of the possible resistance of a pile to long –continued static loading , the expressions which result are known as (STATIC FORMULÆ) .

The bearing capacity of the pile can thus be represented by the equation ;

Rd = rp A + f L

Where :

Rd = bearing capacity of pile

Rp = intensity of applied loading at level of tips of piles

A = cross – sectional area of pile

f = frictional or cohesive resistance per unit area

L = length of pile

p = perimeter of pile

It cannot be said that either of these methods is adequate or consistent in estimating the possible loading on a pile : wide variations and much uncertainty occur . A confirmation or check can be obtained from a direct loading test on a typical pile – a method which appears to give a sound answer to the problem . Even the results of such a test must , however , be treated with caution and experience , especially in extrapolation to groups of piles and in application to cohesive foundation material .

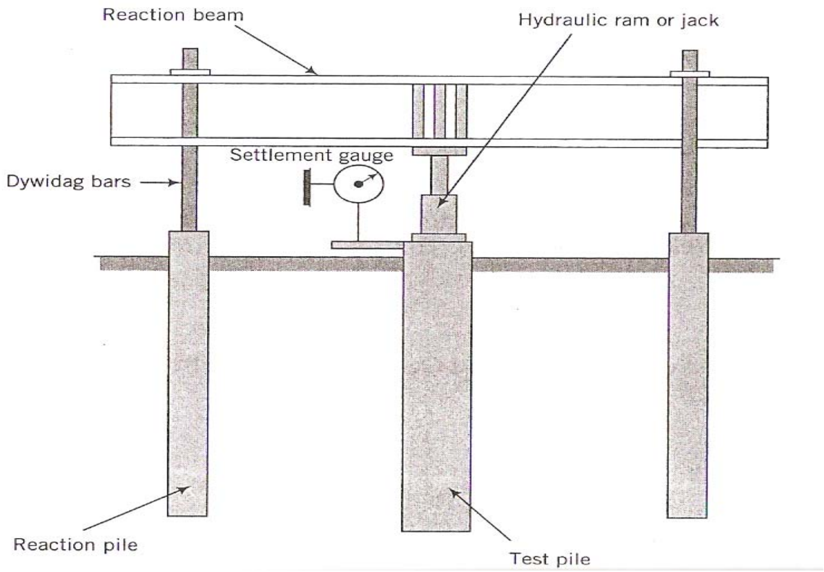
LOADING TESTS

The purposes of a pile load test are :

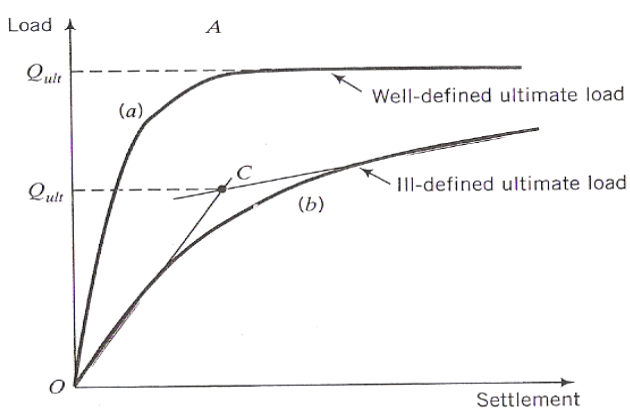
- To determine the axial load capacity of a single pile
- To determine the settlement of a single pile at working loads .
- To verify estimated axial load capacity
- To obtain information on load transfer in skin friction and end bearing .

In a typical pile load test , the test pile is driven to the desired depth , loads are applied incrementally , and the settlement of the pile is recorded . The axial loads can be applied by stacking sand bags on a loading frame attached to the pile or , more popularly , by jacking against a reaction beam and reaction piles (shown in fig.) . If load transfer information is required , the pile must be instrumented to ascertain the internal load of the pile shaft .

The interpretation of the load capacity depends on the method of the loading . Two loading methods are popular . In one method , called the constant rate of penetration (CRP) test , the load is applied at a constant rate of penetration of ٠.٧٥ mm/min in fine – grained soils and ١.٥ mm/min in coarse – grained soils . In the other method , called the quick maintained load (QML) , increments of load , about ١٥% of the design load , are applied at intervals of about ٢.٥min . At the end of each load increment , the load and settlement are recorded . Schematic variations of pile load test plots are shown in (fig.) .



The ultimate load is not always well defined . Load – settlement curve (a) in (fig.) shows a well – defined ultimate load while curve (b) does not . To obtain the ultimate load from curve (b) various empirical procedures have been suggested . One simple method is to find the intersection of the tangents of the two parts of the curve . The value at the ordinate of the intersection (c in fig.) is Qult . The allowable load capacity is found by dividing the ultimate load by a factor of safety , usually ٢ . An alternative criterion is to determine the allowable pile load capacity for a desired serviceability limit state , for example , a settlement of ١٠% of the pile diameter . The settlement at the allowable (working) load capacity is readily determined from the load – settlement plot (fig.)



PILE GROUPS

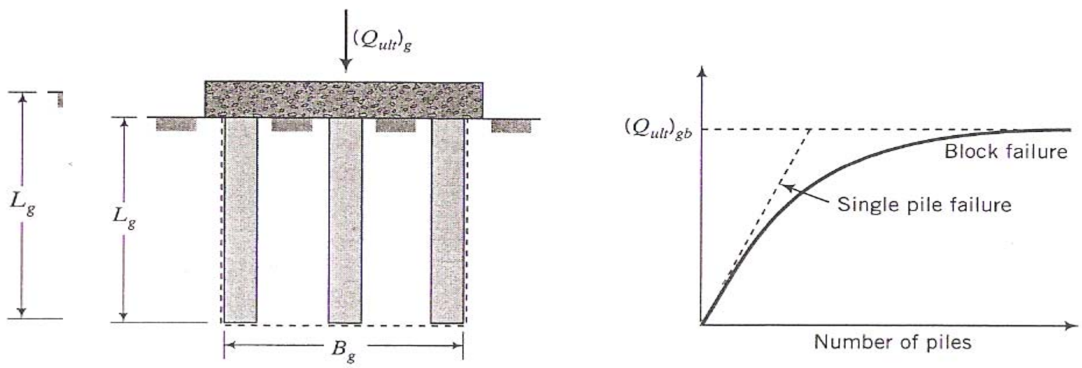
In most practical situations , piles are used in groups . They are arranged in geometric patterns (squares , rectangles , circles , and octagons)at a spacing , s (center to center distance) , not less than ٢D (where D is the diameter or width of the pile) . The piles are connected at their heads by a concrete pile cap , which may or may not be in contact with the ground (fig.) . If the pile cap is in contact with the ground , part of the load will be transferred directly to the soil .

The load capacity for a pile group is not necessarily the load capacity of a single pile multiplied by the number of piles . In fine – grained soils , the outer piles tend to carry more leads than the piles in the center of the group . In coarse – grained soils , the piles in the center take more loads than the outer piles .

The ratio of the load capacity of a pile group , (Qult)g , to the total load capacity of the piles acting as individual piles (n Qult) is called the efficiency factor , ne ; that is ,

$$ne = \frac{(Qult)_g}{n\, Qult}$$

Where (n) is the number of piles in the group and (Qult) is the ultimate load capacity of a single pile . the efficiency factor is usually less than ١ . However , piles driven into a loose , coarse – grained soil tend to densify the soil around the piles and ne could exceed ١ .



Two modes of soil failure are normally investigated to determine the load capacity of a pile group . One mode , called block failure (shown in fig.) , may occur when the spacing of the piles is small enough to cause the pile group to fail as a unit . The group load capacity for block failure mode is

E S A

$$(Q\ ult\ )gb\ = \sum_{i=1}^{j} \left\{ i \begin{pmatrix} 1 \\ z \end{pmatrix} i * (perimeter)ig * Li \right\} + Nq \begin{pmatrix} 1 \\ z \end{pmatrix} b(Ab)g$$

T S A

$$(Q\ ult\ )gb\ = \sum_{i=1}^{j} \{(u)i\ (Su)i * (perimeter)ig * Li\} + Nc(\mathrm{Su})b(Ab)g$$

Where the subscript (gb) denotes block mode of failure for the group .

To other failure mode is failure of individual piles called single pile failure mode or punching failure mode . The key assumption in the single pile failure mode is that each pile mobilizes its full load capacity (efficiency = ١) . Thus , the group load capacity is

(Qult)g = n Qult

The group efficiency in fine –grained soils is defined as

e = (Qult)gb [(Qult)^{٢}gb + (n Qult)^{٢}]$^{-١/٢}$

The values of (p) to use in determining Nq in Janbu's equation on the s/D ratio and the friction angle . Janbu (١٩٧٦) showed that

s/D = ١ + ٢ sin P (tan' +√ ١+ tan$^{٢'}$) exp (p tan')

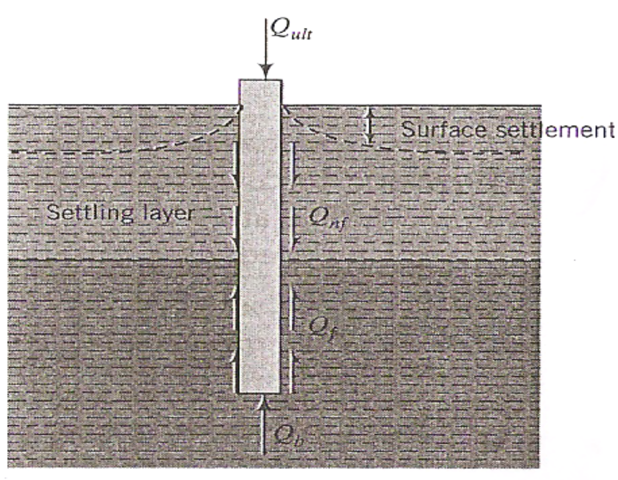
The value of (p) is not significantly affected by s/D ≤ ٢.٥ .

PILES SUBJECTED TO NEGATIVE SKIN FRICTION

Piles located in setting soil layers (e.g. , soft clays or fills) are subjected to negative skin friction called down drag (shown in fig.) . The settlement of the soil layer causes the friction forces to act in the same direction as the loading on the pile . Rather than providing resistance , the negative friction imposes additional loads on the pile . The net effect is that the pile load capacity is reduced and pile settlement increases . The allowable load capacity is given , with reference to (shown in fig.) , as

$$Qa = \frac{Qb+Qf}{FS} - Qnf$$

For a soft , normally consolidated soil , the negative skin friction is usually calculated over one – half its thickness . Negative skin friction should be computed for long – term condition ; that is , you should use an E S A .



LATERALLY LOADED PILES

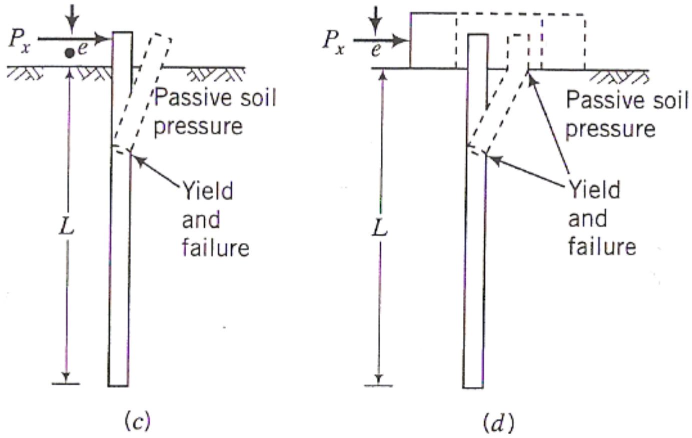
Structures founded on piles are often subjected to lateral loads and moments in addition to vertical loads . Lateral loads may come from wind , traffic , seismic events , waves ,docking ships , and earth pressures .

Moments may come from the eccentricity of the vertical force , fixity of the super structure to the piles , and the location of the lateral forces on the pile with reference to the ground surface .

When a pile is subjected to lateral forces and moments , the pile tends to bend or deflect . The deflection of the pile causes strains in the soil mass . To satisfy equilibrium , the soil must provide reactions along the length of the pile to balance the applied loads and moments .

Because soil is a nonlinear material , the soil reaction is not linearly related to the pile deflection . Consequently at every point along the length of the pile , a nonlinear relationship between soil resistance and pile deflection .

In designing laterally loaded piles , we need to know the pile deflection , to satisfy serviceability requirement and the bending moments for sizing the pile . The pile head deflection depends on soil type , pile installation , pile flexibility (or pile stiffness) , loading condition , and on how the pile is attached to the super structure and pile cap . A pile that is attached to the pile cap such that no rotation occurs is called a fixed head pile . A pile that is attached to the pile cap such that rotation is unrestricted is called a free head pile .

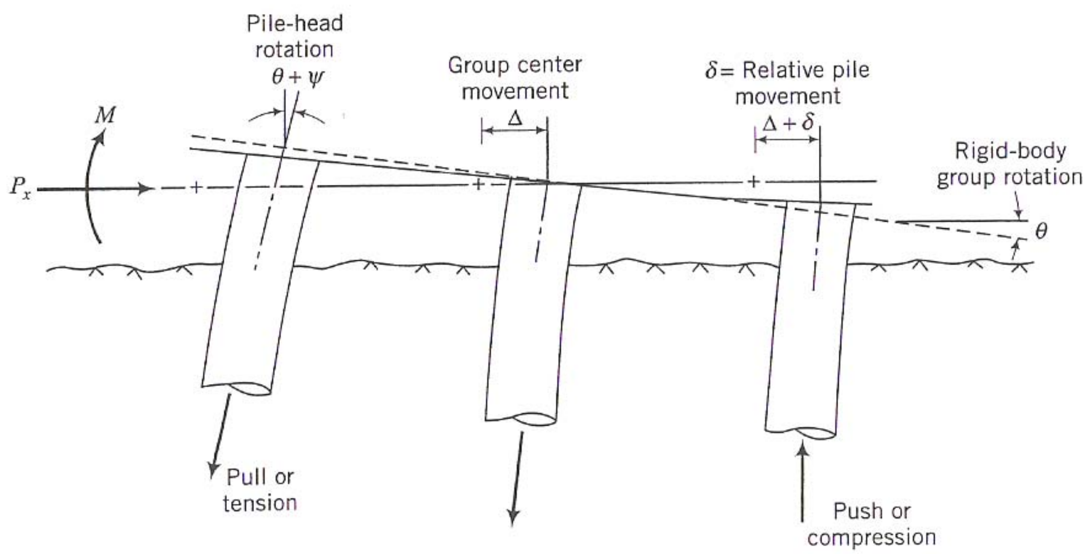


The mechanism of failure depends on the length to diameter or width ratio , soil type , and the fixity of the pile head .

Free head piles tend to fail by rotation . Lateral loads and moments applied to a free head pile are initially resisted by the soil near ground level . For very small pile deflections , the soil behaves elastically and as the deflection increases the soil yields and then permanent soil displacement occurs . The soil resistance is shifted to the lower part of the pile as yielding progressively occurs from the top to the bottom of the pile . Fixed head piles tend to fail by translation . Piles in general are neither fixed head nor free head . They have undermined fixity somewhere between free head and fixed head conditions . You can view fixed head and free head as two limiting conditions in which piles in practice will respond somewhere within these limits .

Laterally loaded piles , particularly group piles , are difficult to analyze mainly because of the complexity of the soil – structure (pile) interaction . The displacements and rotations are in the directions of the resultant lateral load and resultant moment . Outer piles in a group are subjected to uplift (pull) and compressive (push) forces while the piles in the center translate at the level of the super structure connection . The response of a pile group to lateral loads and moments is influenced by

- Geometry of the pile
- Pile – soil interaction
- Stiffness or flexibility of the piles
- Load conditions
- Individual pile response
- Pile group response resulting from individual pile responses



Summary

Piles are used to support structural loads that can not be supported on shallow foundations . The predominant types of pile material are steel , concrete , and timber . The selection of a particular type of pile depends on availability , environmental conditions , pile installation methods , and cost . Pile load capacity can not be determined accurately because the method of installation invariably changes the soil properties near the pile . We do not know the extent of these changes . The equations for pile load capacities and settlement are , at best , estimates . Load capacities from pile load tests are preferred but these tests are expensive and may only be cost effective for large projects .

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