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Various Types of Foundations Used for Civil Engineering Structure

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Abstract- This article describes various types of foundations used for civil engineering structures. Any civil engineering structures either building constructions or any types of road constructions needs foundation. In general, foundations of all types of structures are to take loads and transmit them to the subsoil foundation. Subsoil foundation is to carry the imposed loads (dead and live loads) safely during the designed life of the structures. There are two basic types of foundations that are usually used in foundation engineering; shallow and deep. Shallow foundations are the most commonly used types of foundations for usual building constructions. Shallow foundations have their bases either at ground level or close to the ground surface while deep foundations transfer the imposed loads from the structure to much deeper and in to a firm soil layer at any depth of the subsoil foundation. There are other types of foundations as well that are usually used in special cases where ever applicable or required that include; caissons, *micro-piles*, shell foundations, and sheet piles. Basically, types of foundations to be designed and used for a particular civil engineering project depend on several factors. The most significant of these factors are ; subsoil foundation conditions, load intensity and economical feasibilities.

Keywords- *Shallow and deep foundations, Single and strip footings, Mat foundation, Driven and in-place piles, Caissons and micro-piles, Shell foundations*

I. INTRODUCTION

Any structure which is to be built on the basis of civil engineering, safety factors need a safe and sound structural base to transfer the imposed load from the structure to the soil or bed rock. This structure is called foundation. It is possible to call the foundation of any structure as one of the most important part of any civil engineering structure. Foundations for structures are to transfer the structural loads safely to the soil (without failure or excessive settlements) in critical or worst possible conditions such as; earthquake, flooding, or high potential tornadoes.

II. BASIC TYPES OF FOUNDATIONS

There are two usual types of structural foundations:

a) Shallow
b) Deep

1) Shallow foundations

Shallow foundations are usually those types of foundations that are built either on or close to ground level (surface). Some geotechnical researchers consider a foundation to be shallow when its depth of foundation (D_f) is less than four times its width (4B) or when $D_f / B < 4$.

Depth of foundation is to be designed to protect the foundation from freezing environment and also scouring (soil materials being washed away around the foundation during various phenomena such as flooding).

Shallow foundations may be divided in to the following types;

a) Single footing
b) Strip footing
c) Mat foundation
d) Grid foundation

B. Single footing

Single footings are usually designed to transmit the imposed loads from a single column to a single footing. Single footings are usually connected to each other in order to protect the footings from possible lateral loads caused by earthquakes. Single footings can be designed in different geometric shapes such as circular, rectangular or square (Fig. 1).

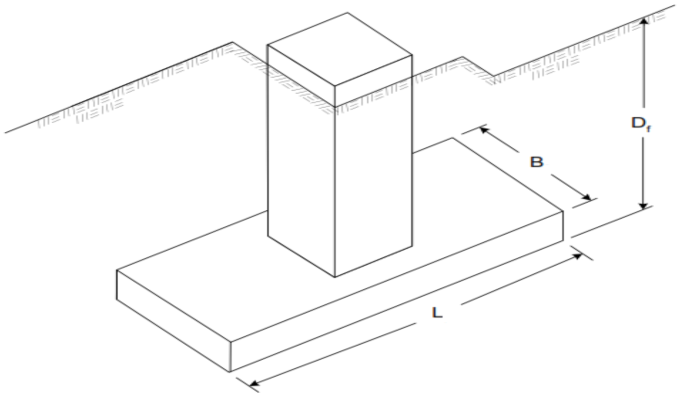

Figure 1. Rectangular single footing [1] *Df* (depth of footing), *B* (width of footing), *L*(length of footing)

C. *Strip footing*

Strip footings are long footings as their names indicate and with approximately L / B > 5. These types of footings are usually designed to support loads from several single columns as well as wall footings (Fig. 2).

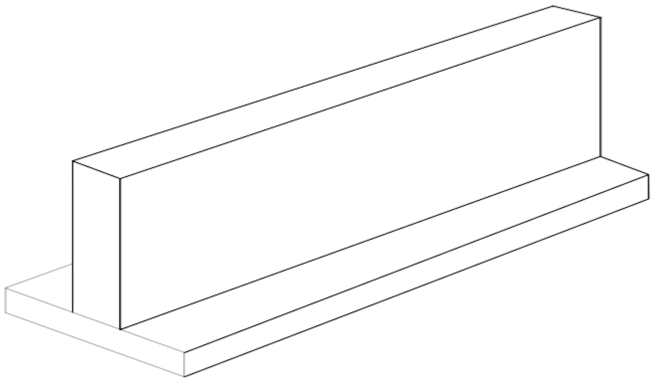

Figure 2. Strip (wall) footing [1]

D. *Mat foundation*

This type of foundation (footing) is used when there are several columns in either horizontal or vertical directions to support loads from structure. Mat foundations are often economical when spread footings would cover more than about 50 percent of the plan area of the structure's footprint [2]. A mat foundation typically supports a number of columns and/or walls in either direction or a uniformly distributed load such as that imposed by a storage tank. The principal advantage of a mat foundation is its ability to bridge over local soft spots, and to reduce differential movement.

Structures founded on relatively weak soils may be supported economically on mat foundations. Column and wall loads are transferred to the foundation soils through the mat foundation (Fig. 3).

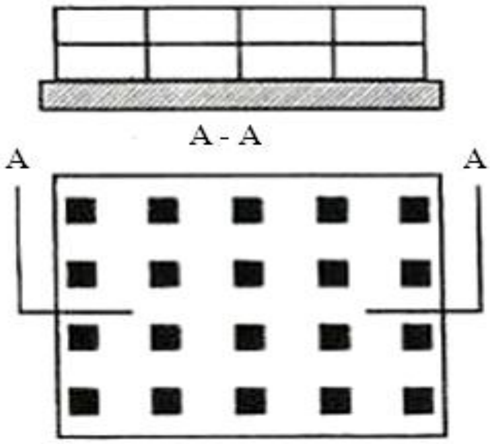

Figure 3. Mat foundation

Mat foundations distribute the loads over a large area, thus reducing the intensity of contact pressures. Mat foundations are designed with sufficient reinforcement and thickness to be rigid enough to distribute column and wall loads uniformly. Although differential settlements may be minimized by the use of mat foundations, greater uniform settlements may occur because the zone of influence of the applied stress may extend to considerable depth due to the larger dimensions of the mat. Often a mat also serves as the base floor level of building structures [3].

E. *Grid foundation*

Grid foundations may be substituted for mat foundations. A grid foundation is combination of several wall footings that are well connected to each other (Fig.4). The thickness of grid foundations is usually higher if compared with the replaced mat foundation. The spaces appearing within the grid foundations are usually filled with coarse gravels which serves two purposes. First, it makes a firm and grade level for the slab to be place in it, and second it prevents moistures to be transferred from the ground below to the immediate slab founded in the area.

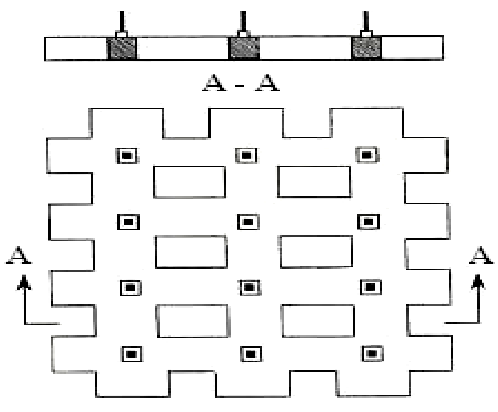

Figure 4. Grid foundation

2) Deep foundations

Deep foundations are usually considered when the subsoil foundation is not able to support the imposed loads from structures using shallow foundations. Therefore it may either fail through less bearing capacity or settles more than the permissible amount. Thus deep foundations transfer the loads to deeper ground, and where there is a strong and reliable layer of soil or rock exist.

Deep foundations or piles may be used to support various types of loads such as; vertical or lateral as well as uplift forces. Also, they can be placed in to the ground with various inclinations.

Piles usually carry loads through their end bearing, their surface area frictions, or a combination of both (Fig. 5). Common types of piles are either driven type or in - place as far as their placement into the ground is concerned.

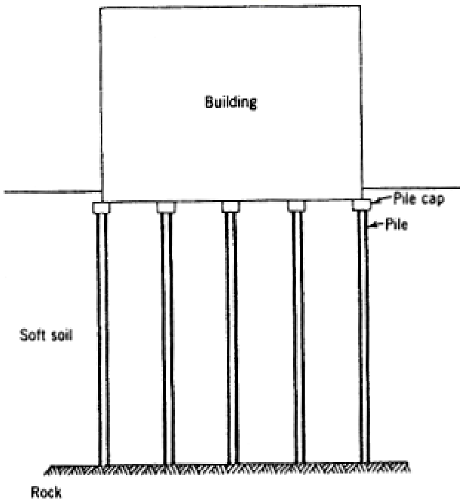

Figure 5. Building with pile foundation [4]

F. *Driven piles*

Driven piles are hammered in to the ground using various types of pile driving equipment that have different degrees of power driving potential. This type of piles usually have profiles such as; circular, square, H or I shape. They are usually made either from steel or concrete.

Driven piles may be either close or open ended. In offshore constructions, the steel piles (open or close end) are more commonly used. Applications of any types of piles onshore are easier than offshore. Very often, after piles are driven in to the ground, they are filled with reinforced concrete (especially open ended piles are used).

Also, as open ended piles are driven in to the ground, the soil materials are inserted in to them during the process. One possible alternative is to drill out the inserted soil materials from the piles and refill them with better materials (e.g. concrete). This process makes the piles to be structurally stronger to support loads and also, it helps them to be more resistive against different type of corrosive materials such as sodium chloride, and finally this process makes the piles to live longer. Figure 6 shows the application of various types of piles when used in either onshore or offshore constructions. Also, Fig. 7 shows various profiles for driven piles.

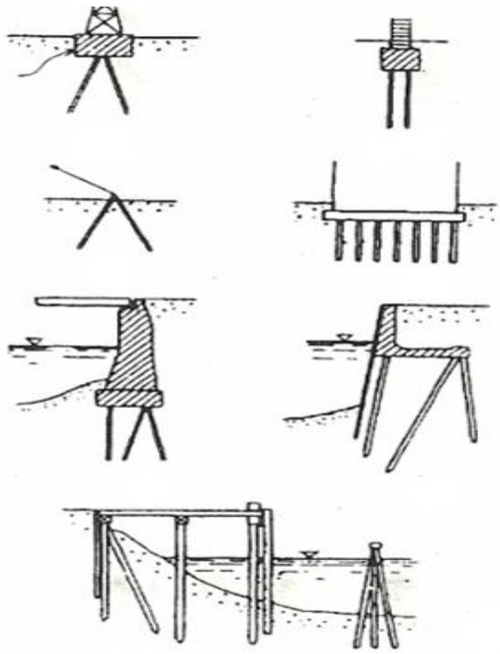

Figure 6. Examples of piles used in onshore and offshore constructions

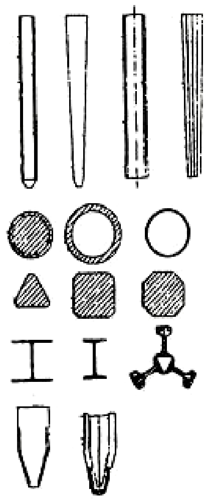

Figure 7. Profiles / cross sections used for driven piles

G. *In - place piles*

These types of piles are usually made at the construction site, and are also called piers as well. Actually, a distinctive difference between driven piles and piers is related to their diameter size. Usually, those piles whose diameters are more than 60 cm are called piers.

Because it is economically not feasible to carry these large and heavy piles which are usually made of reinforced concrete to the construction site and drive them in to the ground, they are made at their terminal place and this is the reason for them to be called in- place piles.

Their construction includes; predrilling (preboring) a hole or shaft, a designed and prepared reinforced bar cage is placed in the shaft, and finally shaft is filled with concrete using tremie. In order to make *in – place* piles to carry more loads, it is possible to make them belled type (belled pier) as shown in Fig. 8. The belled parts of piers are usually constructed in cohesive soils only, and are not applicable within cohesion less soils, because of their collapsing potential.

In cohesion less types of soils, it is also possible to make a shaft by using a casing or a hollow pipe throughout the drilled shaft to prevent the bored shaft to collapse. This hollow pipe or casing then can be pulled out with concreting the shaft simultaneously.

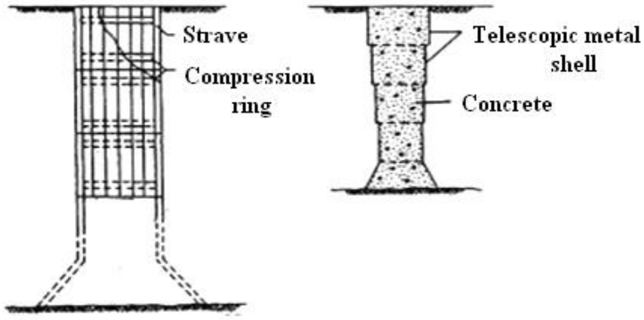

Figure 8. Examples of *in - place* or belled piers [5]

III. OTHER TYPES OF FOUNDATIONS

Some other type of foundations that are used in special civil engineering projects include;

a) Caisson foundations

b) *Micro-piles*

c) Semideep foundations

d) Shell foundations

e) Sheet piles

A. *Caisson foundations*

Wells, which are also known as caissons, have been in use for foundations of bridges and other important structures since the Roman period. There are three most common types of caissons that include; box caissons, open caissons, and pneumatic caissons (Fig. 9).

A box caisson is a prefabricated concrete box (it has sides and a bottom); it is set down on prepared bases. Once in place, it is filled with concrete to become part of the permanent works, such as the foundation for a bridge pier. Hollow concrete structures float, so a box caisson must be ballasted or anchored to prevent this phenomenon until it can be filled with concrete (indeed, elaborate anchoring systems may be required in tidal zones); adjustable anchoring systems, combined with a GPS (Global Positioning System) survey, allow engineers to position a box caisson with pinpoint accuracy.

An open caisson is similar to a box caisson, except that it does not have a bottom face. It is suitable for use in soft clays (e.g. in some river-beds), but not for where there may be large obstructions in the ground. An open caisson that is used in soft grounds or high water tables, where open trench excavations are impractical, can also be used to install deep manholes, pump stations and reception/launch pits for micro tunneling, pipe jacking and other operations.

A compressed-air caisson has the advantage of providing dry working conditions, which is better for placing concrete. It is also well suited for foundations for which other methods might cause settlement of adjacent structures.

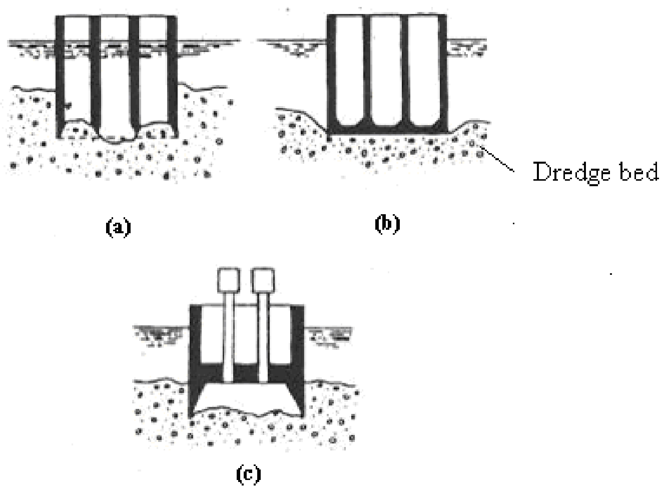

Figure 9. Various types of caisson foundations; a) open, b) box ,c) pneumatic

B. *Micro- piles*

Also known as mini piles, pin piles, needle piles or root piles, micro piles offer alternatives to conventional piling techniques, particularly in restricted access or low headroom situations. They involve increasing degrees of soil compaction where the soil is too weak to carry the loads of a convention press pile.

Micro piles have small diameter (60 to 200 mm or less than 300 mm) and can be installed in almost any type of ground where piles are required. They are termed “piles” because they involve driving a small diameter tube and forcing grout or concrete into it, as with large drilled piles.

Micro-piles are usually drilled and grouted reinforced piles typically used for structural support where conventional deep foundation elements cannot be installed due to project constraints such as limited work space or where heavy machinery cannot be used.

Micro-piles can be used in soil or bedrock. They can be installed for new construction or for existing foundation remediation. These piles work well as both tension and compression piles and can be installed on a rake or inclined angle to provide reticulated pile solutions as well (Figs. 10 and 11).

Figure 10. Slightly inclined micro- piles [6]

Figure 11. Typical cross section of an exhumed micro pile [7]

C. *Semideep foundations*

Semideep foundations are used to carry the imposed loads from the structures to a stronger ground layer which is not too deep from the ground level. This is done by using a bored shaft usually having diameter more than 100 cm (1 m) which is then filled by various sizes of cobbles and coarse aggregates to make an stone columns type of foundation. The rock materials are poured in to the bored shaft up close to the ground surface, and then a concrete single footing is constructed over it. Schematic diagram of a semideep foundation is shown in Fig. 12.

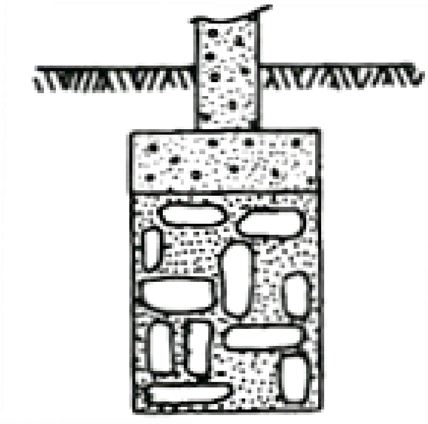

Figure 12. An example of semideep foundation

D. *Shell foundations*

The overriding virtue of the shell foundation is its capacity to distribute loads of considerable magnitude with low intensity of soil pressure, with an economy of materials and without introducing into the foundation structure excessive bending moments and shearing stresses. Design of shell foundations is more on the basis of shape of the structure rather than its masses. Some of the examples of shell foundations are shown in Fig. 13.

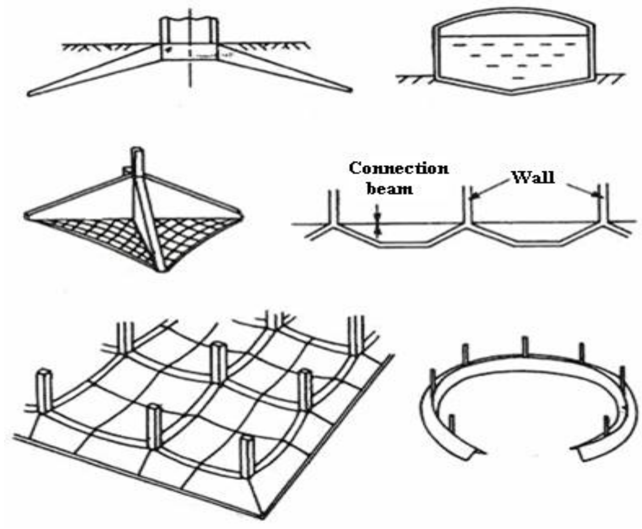

Figure 13. Examples of shell foundations

E. *Sheet piles*

Sheet piles are civil engineering supporting structures that widely used for both large and small waterfront structures (horizontal loading types) ranging from small pleasure – boat launching facilities to large dock structures for ocean going ships. Sheet piling is also used for beach erosion protection, to assist in stabilizing ground slopes, for shoring walls of trenches and other excavations, and for cofferdams.

Sheet piles are usually vibrated or hammered in to the ground. Figure 14 shows schematic diagram of two connected sheet piles. Also, Fig. 15 depicts some sheet piling structures.

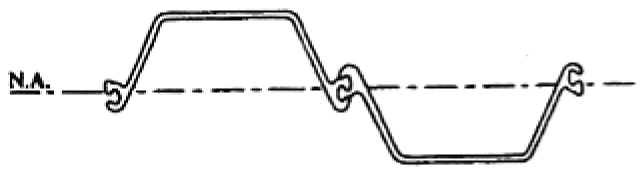

Figure 14. Cross section for one type of sheet pile connection

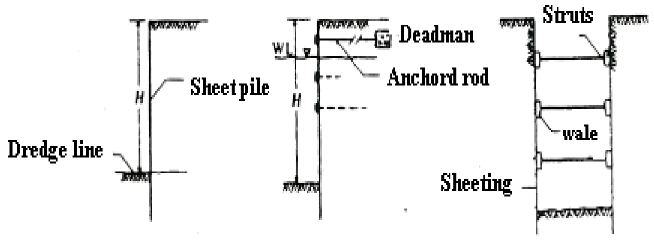

Figure 15. Examples of sheet piling structures [5]

IV. CONCLUSIONS

Any civil engineering structure needs foundation. A foundation is to take the structural loads and transfer or transmit them to the subsoil foundation. Subsoil foundation is to carry the imposed loads safely (without load bearing failure and/or excessive settlement) throughout the lifespan of the structure. Loads may be transmitted to the soil by means of shallow or deep foundations. Deep foundations are usually [8] used when the subsoil foundation at close to the ground surface cannot carry the imposed loads from the structures safely. It is also, in some cases both types of foundations may be used as grid or combined foundations if required.

There are other types of special foundations that are used in special cases where applicable and/or when required. These types of foundations include various types of caissons, micro-piles, semideep foundations, shell foundations, as well as sheet piles.

Among different types of foundations discussed in this article that may be used for civil and architectural engineering projects, the choice of choosing a foundation for a structure greatly depends on several factors. The most significant of these factors includes; subsoil foundation physical and mechanical properties or conditions, structural load intensity, ease of construction, area availability to build a foundation to support the imposed loads, and also economical feasibilities.

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