



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

EARTHQUAKE RESISTANT DESIGN OF FOUNDATIONS

Lecture 27: Introduction to Well Foundations

B.K. MAHESHWARI

Professor, Dept. of Earthquake Engineering, IIT Roorkee

E-mail: bk.maheshwari@eq.iitr.ac.in



ERD of Foundations - Modules

1. Introduction
2. Shallow Foundations
3. Pile Foundations
4. Well Foundations
5. SSI for Deep Foundations



Module - 4

Well Foundations



Module -4: Chapters

1. Introduction
2. Lateral Stability of Well Foundations
3. Construction and Sinking of a Well
4. Numerical Problems



Chapter -1: Introduction

- 1. Usage of Wells**
- 2. Types of Wells or Caissons**
- 3. Components of a Well Foundation**
- 4. Shapes of Wells**
- 5. Depth of a Well Foundation**
- 6. Forces acting on Well Foundation**

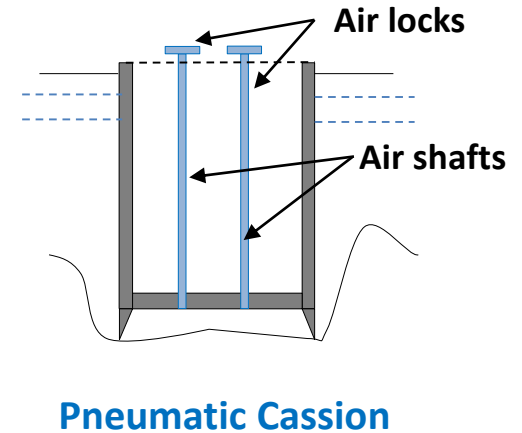
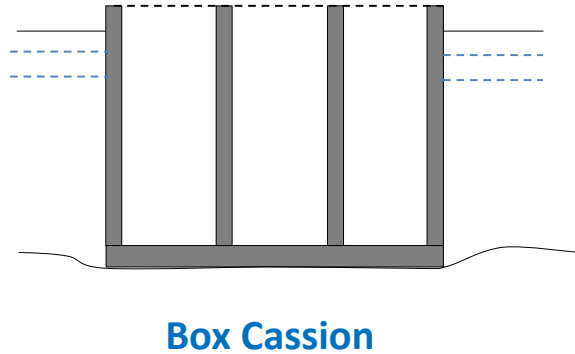
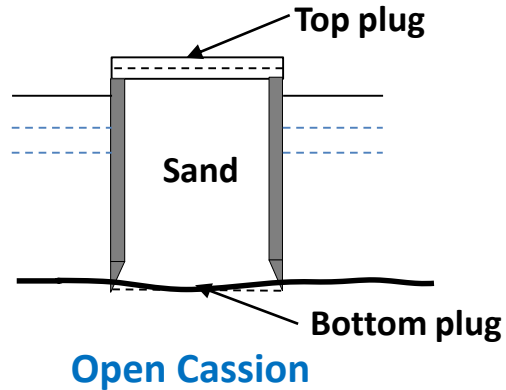
Usage of Wells

Wells are deep foundation which provide a solid and massive foundation for heavy loads and are useful in situations where the loads to be transferred to a soil stratum deep below i.e.

- In the case of bridge foundations, wells have been widely used in India as foundation for bridge piers and abutments, (equally popular in western country)**
- Well are also useful in situations when the uplift are large as in case of transmission line towers**
- Being a massive Sub-Structure, it is monolithic and relatively rigid in its structural behavior**

Types of Wells or Caissons

Three types: Open Caisson or Well, Box Caisson, Pneumatic Caisson



Types of Well Foundations

Open Caisson: The top and bottom of the caisson is open during construction. It may be of any shape in plan – circular, rectangular, oblong, etc. It has a cutting edge which is fabricated at the site and the first segment of shaft is built on it. The soil inside the shaft is dredged by suitable means and another segment added to it. The process of sinking is continued thus till it reaches the required depth. Then bottom is sealed with concrete and shaft is filled with sand.

Advantage: It can be constructed up to any depth and economical

Disadvantage: The progress of construction in boulder deposits is very slow, the concrete seal placed under water is not effective and also the bottom can not be inspected.

Types of Well Foundations

Box Caisson (also called floating caisson): Open at the top and closed at the bottom. First casted on land and then towed to the site where it is sunk onto a previously levelled foundation based. This is used where the loads are not very heavy and a bearing stratum is available at a shallow depth.

Disadvantage: Foundation bed has to be prepared in advance and the bearing capacity of the base has to be properly assessed. Also, care has to be taken to protect the foundation from scouring action.

Types of Well Foundations

Pneumatic Caisson: A pneumatic caisson has a working chamber at the bottom of the caisson which is kept dry by forcing out water under pressure, thus permitting excavation under dry conditions. Air locks are provided at the top. The caisson gradually sinks as excavation is made. On reaching the final depth, the working chamber is filled with concrete.

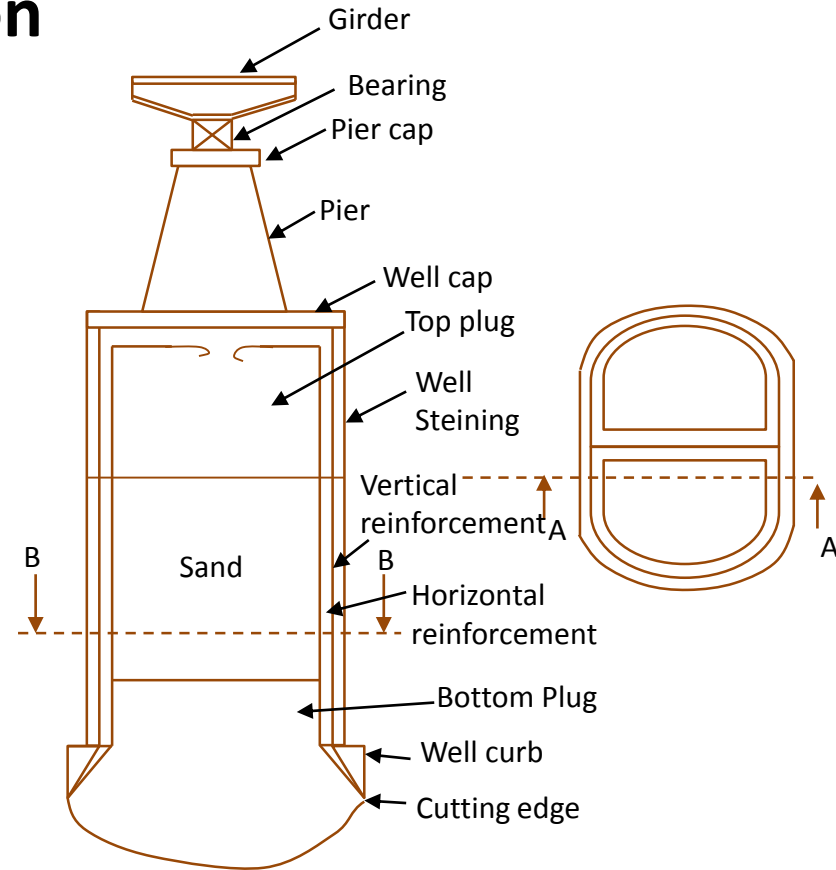
Advantage: Better control in sinking and supervision. Also, the bottom of the chamber can be sealed effectively with concrete, as it is placed under dry condition. Further, obstructions during sinking, e.g., boulders etc., can be removed quite easily.

Disadvantage: Very high cost and the limit on the depth of penetration below water level, of about 35m (a pressure of about 3.5kg/cm^2). Higher pressure are beyond the endurance limit of the human body.

Components of a Well foundation

The various components of a Well Foundation are briefly described:

Well Cap – RCC slab laid at the top of the well steining and is usually cast monolithically with the steining. It transmits the forces from pier to the body of well. The dimension of the well cap should be sufficient to accommodate the pier. The recommended minimum thickness is 0.75 m.



Steining – The wall of well which transfers the load to the subsoil. It also acts as a coffer dam during sinking and provides the weight for sinking. The thickness should be sufficient so as to overcome skin friction developed during sinking by its own weight. The minimum reinforcement in the well steining should be **5 to 6 kg/m³** of which 75 % is to be provided as vertical and 25 % as lateral ties or hoop rings. The minimum thickness is 0.45 m or 1/ 8 of the external dia. of well for brick masonry and 1/10 for wells with cement concrete.

Well Curb – The well curb supports the steining. The curb should be slightly projected from the steining to reduce the skin friction during sinking of well. It is made of RCC with steel cutting edge. The minimum reinforcement to be provided is **72 kg per cubic meter**. The inner portion of the steining should have a slope of 2:1 (V:H).

Cutting Edge –The cutting edge is either projected below the curb as a sharp edge or can also have flat bottom. The projected edge is likely to be damaged in strata of gravels and boulders. In such soils the flat bottom cutting edge is provided.

Bottom Plug –The bottom plug is made bowled shape in order to have an arch action. The bottom plug transmits load to soil below. When sunk to its final depth bottom part is concreted to seal the bottom completely. The thickness varies from $\frac{1}{2}$ to full inside diameter of the well so as to be able to resist uplift forces.

Sand Filling – After concreting the bottom plug, the sand is filled above the bottom plug and below top plug. Sand filling provide stability of well, reduce tensile stress produced by bending moment and distributes the load of super structure on to the bottom plug. Sand filling relieves load to steining to some extent.

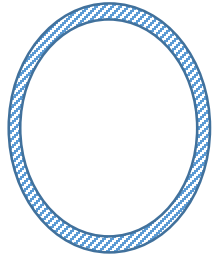
Top Plug –This is a plug at the top of the well below the well cap. This helps transferring the load through the granular material into the staining.

Shapes of Wells

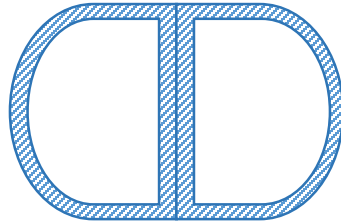
The most commonly adopted section of a well is the circular one. **This has the least perimeter for a given area of the base** and hence is the ideal section in terms of the effort needed during shaking. Also, as the distance of the cutting edge from the dredge hole is equal, sinking is more uniform. However, disadvantages lies in accommodating a large oblong pier which would require a large diameter well. In the case of large oblong piers, two or three independent, circular wells placed very closely to each other with a common well cap can be used. A combination of independent wells is easy to handle but they have a tendency to tilt towards each other during sinking.

Tied wells of different shapes are preferred in order to avoid relative tilt between wells. Usually, the neck portion is kept a minimum, keeping in view the dimensions of pier and the dredge hole. Double D and dumb-bell shapes are the commonly used shapes of wells.

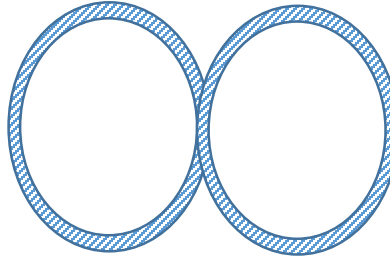
Different Shapes of Wells



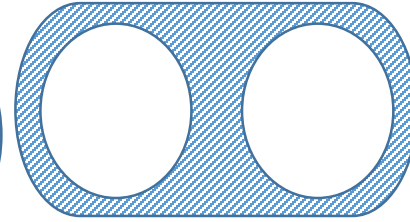
Circular Well



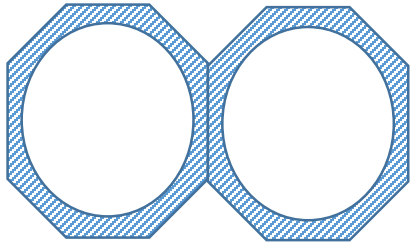
Double D-Well



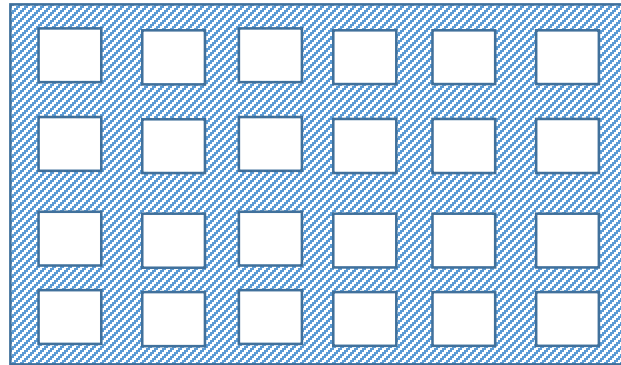
Dumb Well



**Broad necked twin Well
with circular dredge holes**



**Double octagonal
with circular dredge holes**



Multiple dredge hole well

IS:3955 (1967) has laid down the following requirements for the horizontal cross section of the well.

- a) The dredge hole should be large enough to permit dredging.
- b) The steining thickness should be sufficient to transmit the load and also provide necessary weight for sinking and adequate strength against forces acting on the steining, both during sinking of wells and service.
- c) It should accommodate the base of the structure and not cause undue obstruction to the flow of water.
- d) The overall size should be sufficient to transmit the loads to the soil.
- e) It should allow for the permissible tilt and shift of the well.

The code recommends that any shape that fulfils the above requirements be adopted. Also, when a group or group of wells sunk, the minimum spacing between them depends on the depth of the well. However, for general guidance in design, a spacing of about 1 m may be used.

Depth of a well foundation

The two important requirements that influence the depth of a well foundation are:

- a) Minimum grip length below the scour depth
- b) Base pressure to be within permissible limit

For natural streams in alluvial bed, the normal depth of scour, d (in m) below high flood level (HFL) for regime conditions in a stable channel is given by the following equation.

$$d = 0.473 \left(\frac{Q}{f} \right)^{\frac{1}{3}}$$

Where, Q is design discharge in cumecs, f is Lacey's silt factor ($=1.76\sqrt{m}$), m = Mean size of particle in mm

The values of silt factor f as recommended by IS:3955 (1967) are given in next slide

Silt factor f as recommended by IS:3955 (1967)

Sl No.	Type of bed soil	Size of particles (mm)	f
1	Coarse silt	0.04	0.35
2	Fine sand	0.08	0.50
		0.15	0.68
3	Medium sand	0.3	0.96
		0.5	1.24
4	Coarse sand	0.7	1.47
		1.0	1.76
		2.0	2.49
5	Gravel	5.0	3.89
		10.0	5.56
		20.0	7.88
6	Boulders	50.0	12.30
		75.0	15.20
		90.0	24.30

Recommendation for maximum scour depth

Section	Maximum depth of scour
In straight reach	$1.27d'$
At a moderate bend	$1.50d'$
At a severe bend	$1.75d'$
At a right angled bend or at nose of piers	$2.00d'$
At upstream noses of guide banks	$2.75d'$
In severe swirls	$2.50d'$

Grip length is taken as one third of the maximum scour depth. Thus as per IS: 3955 (1976), the depth of foundation should not be less than 1.33 times the deepest scour below HFL. The depth below the scour line should in no case be less than 2 m for piers and abutments with arches and 1.2 m for piers and abutments supporting other type of structures.

The maximum base pressure should be less than the allowable bearing pressure. This is important from the consideration of safety of well.

For wells in cohesionless soils, the allowable bearing pressure can be estimated from the standard penetration test data. As per IS: 3955 (1967), the allowable bearing pressure Q_a is given by

$$Q_a = 5.4N^2B + 16(100 + N^2)D$$

Where, Q_a is allowable bearing pressure in kg/m^2 , N is corrected SPT value, B is smaller dimension of well section in m, D is depth of foundation below scour level in m.

For wells in cohesive soils, consolidation and shear strength parameters should be obtained from test on undisturbed soil samples. The allowable bearing pressure is determined with the help of these parameters.

In case of rock, the allowable bearing pressure is estimated from the crushing strength of rock which can be determined from the test on rock mass.

References

1. Ranjan G. and Rao A S R (2016) “Basic and Applied Soil Mechanics” New Age International, New Delhi, India (Third Edition)
2. IS: 3955-1967 “Code of Practice for Design and Construction of Well Foundations” Bureau of Indian Standards, New Delhi, India.