# Bridge foundation

Bridges are defined as structures, which provide a connection or passage over a gap without blocking the opening or passage way beneath, they can be over streams, canals and rivers, creeks and valleys or road and railways passing beneath.
Bridges are now being provided across ocean bodies and for linking a number of islands as in japan.
The bridge Crossing Carrying a road or railway over another road or railways is called a grade separator or fly over.
The Bridge structure can be for passage /carriage of persons, cattle, vehicles, water or other material carried across in pipes or conveyors.
When they are used for carriage of water, they are called aqueducts. Even a jetty in the ports and harbors can be classified as a bridge. No other creation of a civil engineer has such a general appeal and fascination to the people as a bridge.

The bridge can be classified according to the type, purpose, shape and material made of,
The Table Show classification of Bridges:

| Sl. No. | Main classification | Sub classification |
|---|---|---|

١. Function foot; Road ;railway ; Road-cum-Railway;
Pipe line; Water conveying(aqueduct); jetty(port)

٢. Material Stone; Brick; timber; Steel; concrete; composite
Aluminum; Fiber.

٣. Form Slab; Beam; Arch; Truss; Suspension; Cable
Supported.

٤. Type of Support Simply supported; Continuous; Cantilever

٥. Position of floor/deckdeck ; Through: Semi Through

٦. Usage Temporary; permanent; Service (Army)

٧. With respect to Causeway; Submersible; High level( Normal case)
Water level

٨. Grade separators Road-Over; Road under(sub way); Fly over(Road
Over road)

٩. With respect to Pin jointed; riveted/bolted; Welded
Connections
(Type ofJointing)

And we have the most Important Elements of Bridge Structure,
Which is:(Pile, pile cap, Piers and Slab girder).
So like all the other Engineering structure a bridge needs, a strong and durable foundation to stay , since its more exposed to the load and weather effects,
To transfer the loads safely in to a strong strata and fixing the bridge foundation in its place we have to use piles.

**Types of bridge foundations(Types of pile):**

There are four types of foundations that can be provided for the piers and abutments of bridges. They are:

(١) Open foundation.

(٢) Pilefoundation.

(٣)Well foundation.

(٤)Block foundation.

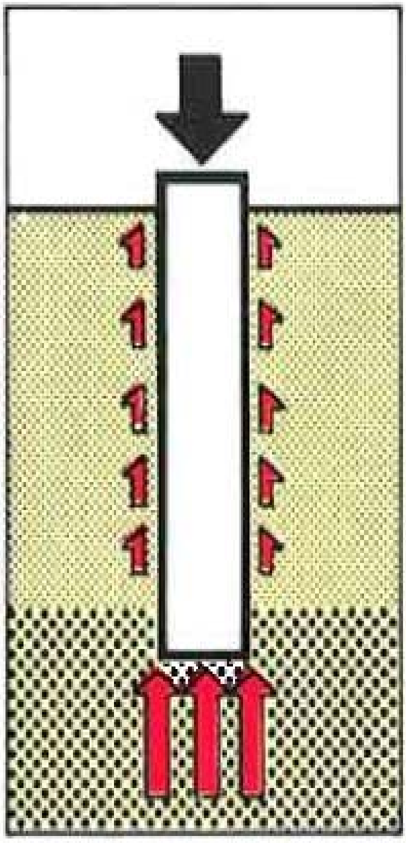
Foundation type (١& ٤) are grouped under (shallow foundation)
While type (٢&٣) are grouped under (deep foundations).

The choice of foundation depends up on the importance of the bridge:
Size, nature of soil and sub soil in the bed and velocity of water flow.

**A**-The pile foundation can be categorized in to different types based either on how the load is transferred or the type of construction of the pile foundations.

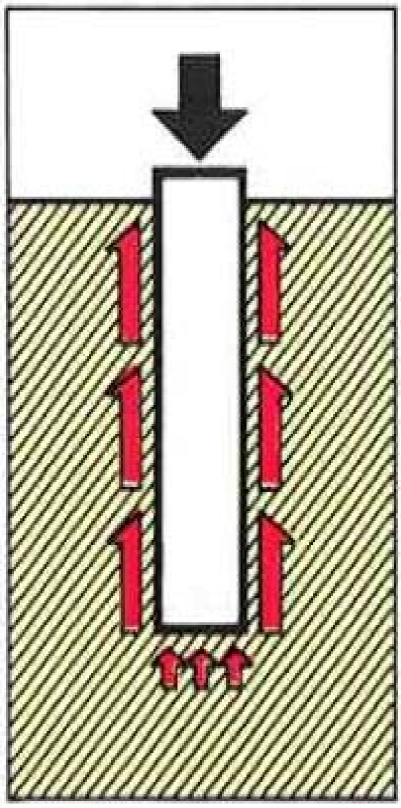
By the load classification, they are divided as follows:

١- **Bearing pile**:
The bearing Pile are designed as those which transmit the load to the foundation strata directly without taking in to account the frictional resistance offered by enclosing soil. The passive earth pressure resistance in the embedded portion of the pile is taken into consideration for the purpose of determining its resistance against the horizontal forces. Such bearing piles are generally taken up to or into the hard strata,such as soft or hard rock,hard consolidated sandy soil or gravelly soil.



Bearing Pile

٢- **Friction pile**:
Friction piles are those in which the load is transmitted by the pile through friction offered by the surrounding soil.
Such piles can be provided in cohesive soils not subjected to heavy scour

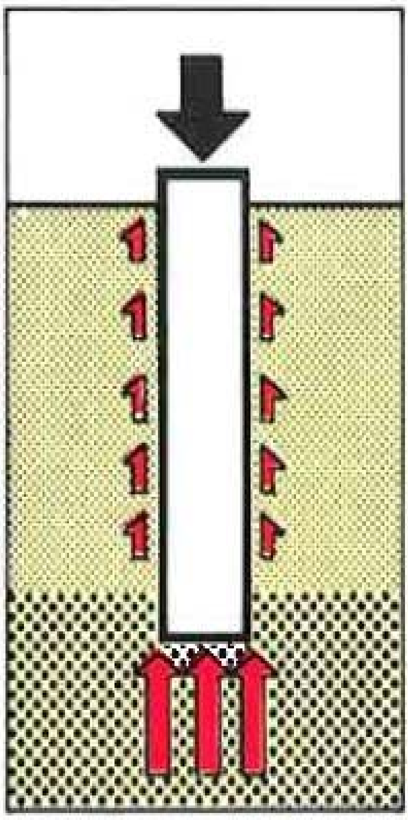


Friction Pile

**٣- Friction –cum – bearing pile**:

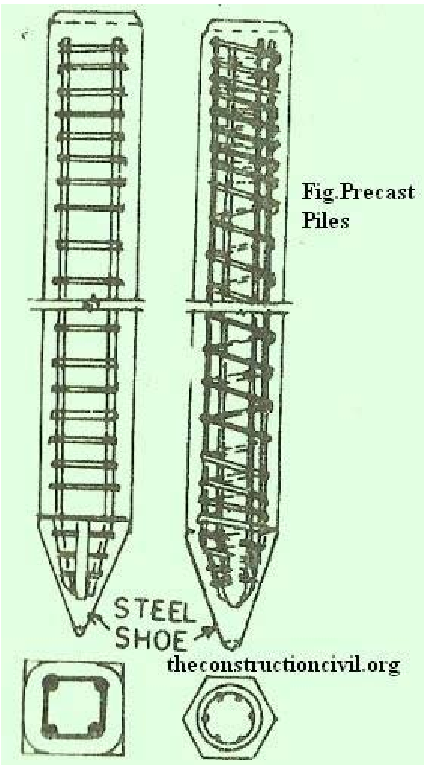
Friction-cum-bearing piles are designed in such a way that the load is transmitted both by the friction of the surrounding soil and the bearing resistance of the founding soil at the tip of the pile.These are used in mixed type of soils.

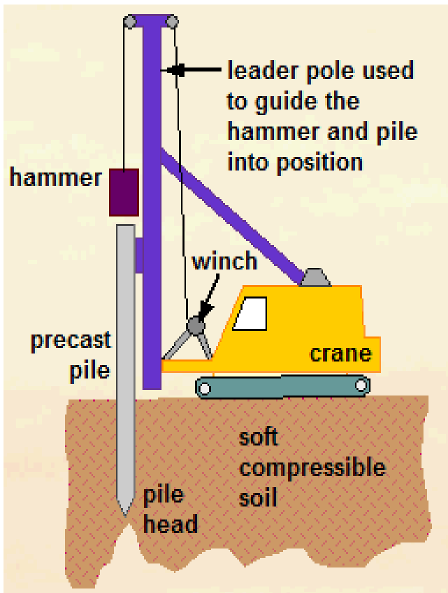
Friction & Bearing Pile



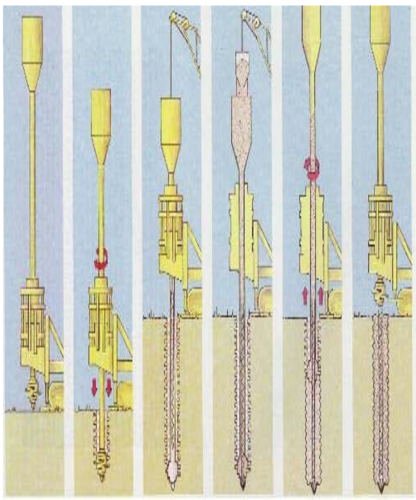
B-**Classification by Construction Method**
Depending upon the method of their construction, piles can be categorized as follows

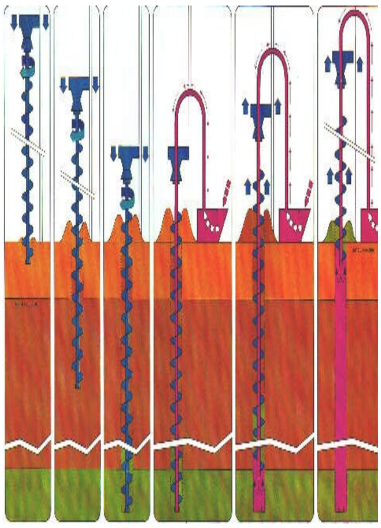
١- **Precast driven piles** :
these are usually of RCC or pre-stressed concrete and generally small in size for facility of handling .Their cross-sectional areas go up to ٩٠٠cm٢ and are square or circular in section, and their length do not exceed ٢٤m, the length depending upon the type of equipment that will have to be used for driving the pile.
The main advantage of this type of pile is that its quality, in terms of dimensions, use of reinforcement and strength of concrete, can be ensured as the piles are cast in a yard under controlled conditions .Thus, the structural capacity of the pile is ensured. However, care is needed while handling, transporting and driving the piles to avoid damage. Any crack developed reduces the strength and also accelerates the corrosion of steel owing to an atmospheric exposure.



**٢- Driven cast-in-situ piles:**
A steel casing pile with a shoe at the bottom is driven first to the required depth. Thereinforcement cage for the pile is then lowered inside the casing and the pile is concreted. If possible, the concrete is tamped and consolidated as it is poured, or a high slump concrete is poured through a tremie. As the concreting of the pile proceeds upwards, the casing is withdrawn keeping a suitable overlapping length. In this case, the main disadvantage is that good quality of the concrete cannot be ensured, andhence the structural strength of the pile cannot be guaranteed. When such piles are driven in soft soil and the tube is withdrawn while concreting, it affects resistance and changes the property of the soil and this also affects the capacity of individual piles, in a group of piles, the capacity of the individual pile can reduce to as low as ٥٠% of the calculated individual pile capacity.
These are not suitable for use in soft soils, in greater depths or where keying with the rock is required.





**٣- Bored cast in-situ piles:**

In the bored cast-in-situ process, a large diameter casing is used.
A casing of ٣ to ٤ m in length is provided on top of the bore hole which is driven with a help of a bailer.
Boring further below this casing is carried out by chiseling and the side walls are kept stable by circulating Bentonite slurry inside the bore hole.
The boring is continued up to the layer decided for founding the structure.
After reaching the desired founding level, the chisel is removed, bore holeflushed, reinforcement cage lowered in to the hole, and held in position by tack welding it to the support bars at the top of the casing.
After this, concreting is carried out by using 'tremie' keeping its end always below the top level of rising concrete.
The concreting is continued till a good quality concrete is seen at the top of the bore hole.
The tremie is removed and when the concrete has reached the top, the casing pipe on the top is also removed.
The Bentonite mix should be periodically checked for its specific gravity and change as, due to constant use, it can get mixed with the soil and deteriorate in quality. This type of pile can be used even where the pile is keyed in to the rock as chiseling in the rock can be carried out more easily.
These piles serve as bearing –cum – friction piles while driven cast-in-situ piles transfer load mainly by friction.
These types of piles have been very extensively used for even deep bridge foundations .The diameters of such piles are generally ٠.٩ m or more and can go up to ٣.٦m, They can be used singly or in group and are good replacements for well foundations required for bridge piers in rivers with clayey and mixed soils.


Casing process

Bentonite slurry Pumped inside the bore hole


Reinforcement cage lowered in to the hole


Concreting process

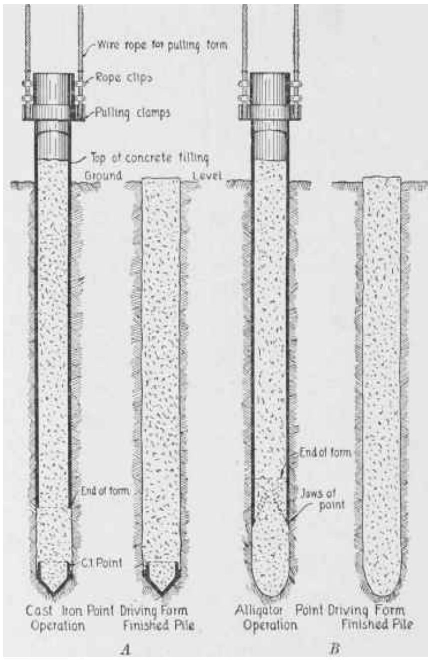
**٤- Bored pre- cast piles:**

In this case,as the name itself suggests, a hole is bored using a casing and a pre-cast pile is inserted into it.

After securing it in position, the casing is withdrawn. A particular process used for bored pre-cast piles is the Benito process which involves a steel tube being pushed in to the soil, turned and reversed using compressed air.

The tube is in the form of a casing and is driven for the entire depth after the soil is progressively grabbed from the tube. The process is continued till the tube reaches the pre-determined level.

Then the pre-cast pile is lowered inside and held in position. The tube is lifted gradually after filling the annular gap between the pre-cast pile and the soil by grouting.



**٥- Driven steel piles:**

Steel piles can becircular or in other structural shapes.

The circular ones are made in the form of either welded or seamless pipes.

Steel or cast iron piles used earlier for bridge structures are of longer diameter and screw type.

These were used in the past when loading was less.With the introduction of more powerful locomotives and change of traction to diesel and electric power, which introduce heavy horizontal forces on railways and heavier loads on highways, it has been found that these piles do not withstand such forces satisfactorily. In most cases, these are being replaced. Also, as the demand for such pile is small, no manufacture can produce these types of piles in small quantities and hence these piles are slowly becoming obsolete.

**٦- Driven timber piles:**

Timber piles have been extensively used in America;these have been used in India on the railways and high ways, for either temporary bridges or for bridges with lighter loading.

Timber piles are of hard wood. The timber may be used in the natural form with thin end cut or suitable sized.

They are used mostly as end-bearing piles in clusters. They are normally used in lengths of ١٢m and extended by splicing for use in deeper channels. They are not used for lengths exceeding ٢٠m. The Portion above bed/low water level is suitably braced in the cluster.

## The way and method of Drilling pile

Initial boring of about ١.٥ to ٢ m can be done using the bailer.
The temporary guide casing is then lowered in the bore holes after the drilling is done by dropping the chisel continuously and the broken pieces of the stones and mud are removed by the bailer.
The diameter of cutting tool (bailer or chisel) is ٧ to ٨ cm less than the outside diameter of casing (guide pipe).
The outside diameter of casing /guide pipe for each size of the pile is the same as nominal shaft diameter. The working level /ground level is kept at a minimum of ١.٥m above water table (pile cap) level.
As the drilling proceeds, the bore hole is filled with Bentonite slurry fed from Bentoniteinstallation with a liquid limit of not more than ٣٠٠% and sand content not exceeding ٧%.
The density of the solution is maintained at ١.٠٥ to ١.١٠.
The slurry is allowed to flow in to the guide casing so that the bore is filled with Bentonite slurry.
The slurry coming out is re-circulated after necessary reconditioning.

Some of the difficulties encountered during the sinking process are:

١- The casing is driven continuously along with the drilling /boring. The main drawback is that the casing could not be driven for the entire depth, so at a place where the casing is not available drilling becomes difficult job.
٢- Side collapse Occurs either due to the bouncing of chisel or owing to hollows in the strata and due to the layered and fissured nature of rock.
٣- Once the chisel/Cutting tool is inside and the side collapse occurs, it becomes difficult to remove it.
٤- In view of the hardness of strata of rock, the rate of drilling is slow. Also, chisels often break and require immediate replacement as repairs take considerable time.
٥- If any metal piece of the broken chisel remains in the excavated pile, further boring is not possible till this piece is removed by a mechanical grabber.
٦- Side collapse becomes more of a problem when drilling is done under water. Only for avoiding side collapse, continuous flow of Bentonite solution has to be maintained.

After the founding Strata is reached, bottom of bore is cleaned with the bailer. In the meantime, the reinforcement cage is prepared by tack welding the bars to rings at intervals to provide rigidity.
Roller cover blocks may be provided to the cage at approximately ٢m intervals and suitably staggered.
Each cage can be built for a height not more than ٩m and hence at least three laps are involved.
The maximum amount of steel used in each pile is ٧.٥ tones. This operation takes about ٤ to ٥ days.

The following precautions are necessary while lowering the cage:

١. While the cage lowering is done, it must be ensured that proper rolling cover blocks are fixed at ٢m intervals to ensure the cover required all round along the pile depth.
٢. Welding of overlaps must be perfect. Otherwise the complete cage below will fall down giving way at improper welding.
٣. Bending of rods in the cage should ensure proper clear space between the rods. One additional cage is required where these bent rods are in overlap.
٤. If proper care is not taken at overlap, it causes a problem by creating a cavity and Bentonite mixes with concrete while concrete build up is done.
٥. The bending of the rods which go into the pile cap for bond should have a mandrel size of ٦٠D as per IS Code ٢٥٠٢-١٩٦٣. If the bent is more, cracksare likely to develop in the bent bar.

Concreting is done using tremie, the tremie diameter being ٢٠٠mm. The slump for the concrete mix used is ١٥٠ to ١٨٠ mm and the maximum aggregate size used is ٢٠/٢٥mm.
In order to maintain the workability of the concrete, Cemoset ٠.٤% by weight of cement is used where necessary.
It is ensured that always the bottom of the tremie pipe is always ٢m below the surface to avoid mixing the fresh concrete with Bentonite slurry.
The concrete is to be filled up to approximately ٤٥٠ to ٦٠٠ mm above the cut-off level initially to ensure that the main length up to the cut off level bee of good concrete and any impurity overflows.
Where the cut off level of the pile is the same or above the top of the guide casing then the concrete is allowed to overflow till good concrete quality is visible.

Immediately after concreting, the temporary guide casing is withdrawn. Where the piles are taken through cavities to the rock below, it has been found advisable to leave the casing down throw the cavities to form a permanent part and provide protection to the pile.
The section of the casing has not been taken into consideration in the structural design.
The tolerance permitted in carrying out the work of center to center of the pile is within ٢٥mm to ٧٥mm radius of the predetermined center of the pile and the plumbing tolerance for the pile is ٠.٥ to ١% of height of pile.

# Drilling Method Procedure Explain by picture:

The drilling machine
(Bailer)

Initial boring (١.٥ to ٢) m

The temporary guide
Casing

Bentonite slurry pumping

Providing Roller Cover

Reinforcement Cage preparing


Steel Cage loweringConcreting Process Using tremie

**After Concreting, Temporary guide Casing is removed**

**cutting the Use less concrete of pile until the pile cup bed Elev.**

**Finally Ready for Pile cup works to start**

Rather than the other tests which we do it for the aggregate, steel bar ,cement to be used in making piles and at the time of casting concrete we do slump test and taking cube for determining the compressive strength of concrete mix which used in pile. We should make Load test on piles.

## **Load test on piles**

Testing of piles under actual load is the most reliable method of assessing their capacity.
All the national codes and bridge specifications make such testing obligatory.
Most common tests are the vertical load tests.
There are two kinds of tests prescribed viz., initial test and routine tests. The initial test is conducted on a pile installed before commencement of work at work site and routine tests are conducted during progress of work on a percentage of piles actually installed and proposed to form part of the foundation.
All these tests are conducted after the pile settles down, generally not earlier than ٢٨ days after installation of same.

Initial testing of the piles is aimed at the following:

١. To determine its suitability for the purpose and its safe load capacity
٢. To forecast settlement under working load
٣. To establish other criteria for installation of working piles at the selected site
Routine test are confirmatory tests on the strengths assumed for design and also on the quality of pile installed.
Whenever it is expected that the soil strata is likely to be different from that prevalent at the location where earlier tested piles exist, additional initial or routine test will have to be conducted.
Routine tests are conducted on ٢% of piles installed, selected at random by the engineer.
In case of failure, the pile may be rejected or accepted with lower load capacity and additional pile installed in the foundation block, as required.
Tests can be for assessing vertical load bearing capacity or for lateral resistance capacity of pile.
In addition, of late, integrity test of selected or a percentage of piles is done using ultra sonic methods (using a hand held hammer, transducer & a computer).
Such tests can reveal any discontinuities, neck formation in the pile installed.

## Vertical load test (Compression)

Vertical load (compression) tests can be conducted following two different viz. By preparing a platform and applying loads in form of kentledge or sand bags or jacking down the pile against a reaction frame or reaction slab held down by reaction piles or rock anchors installed around. The procedure is described below:

### a- preparation of pile head for test

The pile head is carefully chipped off to remove loose material till uniformly sound concrete is exposed. Any projecting reinforcement is cut off or bent and the top of pile finished level and square with plaster of pairs.

A bearing plate should be placed on the finished head for the jack to rest on.

### b- Preparation of platform

A pit is dug up around the pile head to be tested and a platform is prepared with a line of longitudinal and cross girders placed above the pile. Against which a hydraulic jack placed on top of the pile can be jacked up to transfer the reaction, Centers of jack and pile and center line of the load transfer girders should coincide and the center of gravity of the load on platform should be coaxial with the pile.

Platform loaded with Kent ledge or sand bags which will aggregate in weight to the final expected load plus at least ٢٥%.

The load is transferred to the pile by placing a hydraulic jack with well calibrated loading gauge and applying the load against the base plate placed below the line of cross girders over the jack.

Dial gauge (preferably three of ٠.٠٢mm sensitivity)shall be fixed on independent frames with indicators pointing against reference marks on the pile .they should be such that the observer can easily access them and read the dial gauges and load gauge fitted to the jack at different stages of loading.

In case of large diameter piles, the Kentledge loading arrangement may become too unwieldy in view of large load involved. In that case, the jacking is done against a reaction frame fixed to a set of two or more anchor piles (four preferably) or pre stressed anchors (if rock is available at lower levels) Placed around the test pile.

**c- Loading the pile**

Test loads are applied in stages and each stage loading is maintained for a minimum period till rate of settlement reaches a specified stage.

The incremental Stages of loading used is ٢٠% generally. Load and settlement are recorded for each stage. Each stage of loading is maintained till the rate of settlement is not more than ٠.١mm per hour in sandy soils and not more than ٠.٠٢mm per hour in case of clay soils or for a maximum of ٢ hours, whichever is longer.

Estimated safe load or design load should be maintained for ٢٤ hours and any settlement in this period should be recorded periodically.

Loading should be continued in case of initial tests up to twice the safe load (as determined by using static formula) or twice the design load or the load at which total displacement of pile top/cap reaches ١٠% of pile diameter or ٧.٥% of bulb diameter, whichever is earlier.

Loads will be removed gradually but in one continuous stage and the rebound is noted corresponding to stages used while loading and also after ٢ hours after release of jack.

The safe load according to IS Code on a single pile will be at least of the following:

١- Two thirds of the load at which the total settlement is ١٢mm unless a different settlement limit is specified in a given case on the basis of nature of soil strata and importance of structure , or

٢- Fifty percent of the load at which the total settlement is equal to ١٠% of the diameter of the pile in case of uniform diameter or ٧.٥ percent of bulb diameter in case of under reamed piles(normally under reamed piles are not used for bridges).

In some cases, like pile founded on rock or very dense sand, the deflection may be much lower even at twice or thrice the design load and in such cases, the loading should be stopped before the structural capacity of pile is reached, in consultation with the designer.



# Vertical Load Test

## Lateral Load test

Lateral load test is conducted to determine the resistance capacity of the pile in the horizontal direction.
It is conducted by applying load between two adjacent piles in a cluster.
Load will be applied in stages using a hydraulic jack fixed to a test frame between the pair of piles.
The horizontal displacement of each pile is measured through dial gauges (of ٠.٠١ mm sensitivity) bearing against parallel pair of datum bars placed on outer sides of the selected piles.
The load will be applied in increments of about ١/٨th of estimated safe load and horizontal displacement is about ٠.٠١ mm in ٣٠minutes.
The safe load as per IS Code will be the least of the following:
١- ٥٠% of the load at which the displacement of the pile is ١٢mm
٢- Final load at which the displacement is ٥mm
Load corresponding to any other specified displacement specified to suit the performance requirement of the system.

**Lateral Load test**