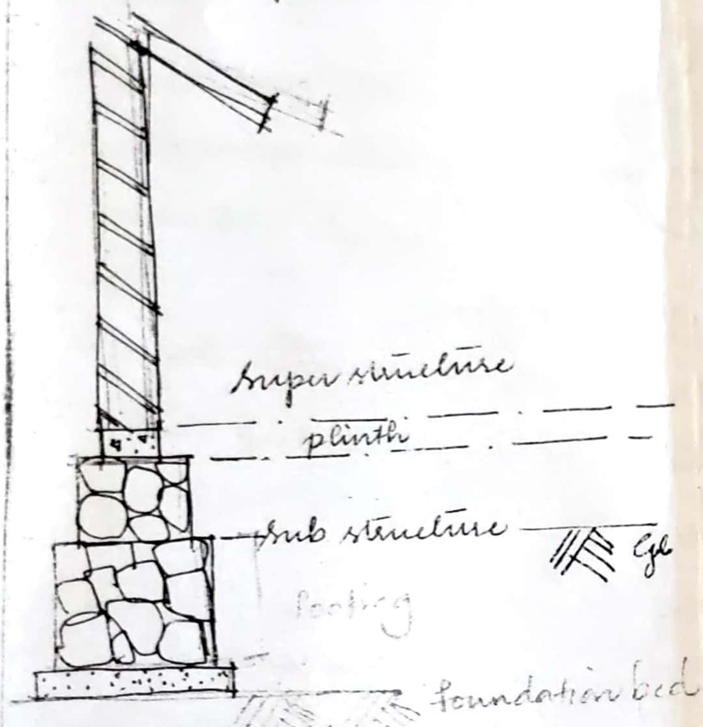
MODULE - IV

FOUNDATIONS.

Building - anything that is built with a wall and Roof.

Every structure can be divided into three parts.



Sub structure / Foundation:

* lowest artificially prepared part of a ~~forst~~ structure which is in direct contact with the ground.
* the solid bed on which foundations rest - foundation bed / foundation soil. it
* bears load and interacts with the foundation of the ...

\+ Inverted a...

* The lowermost portion of the foundation which is in direct contact with the subsoil - footing

Super structure:

part of the structure seen above the ground level.

plinth:

part of the super structure b/n the ground level and floor level

Functions of Foundations

* the most imp. part of a structure that remains below the ground.
* not available for inspection
* requires extreme care and attention in construction and design of foundations to avoid any failures in future as the failures are not noticed until the structure is seriously affected.

FUNCTIONS:

* to distribute the total load coming on the structure on a larger area so as to bring

down the intensity of load at its base below the safe bearing capacity of the soil.

* to support the structure
* to give enough lateral stability to the structure against various disturbing horizontal forces like wind, rain, earth quake etc.
* to prepare a level and hard surface for concreting and other masonry works.
* to Transmit non-uniform load of the super structure evenly to the sub soil.
* to prevent or minimise cracks due to movement of moisture in case of weak or poor soils.

* Load Bearing
* An anchor against changing Natural forces.
* Prevent ground Moisture rising

TYPES OF FOUNDATIONS.

Foundations can be broadly classified into two.

* Shallow foundations
* deep foundation.

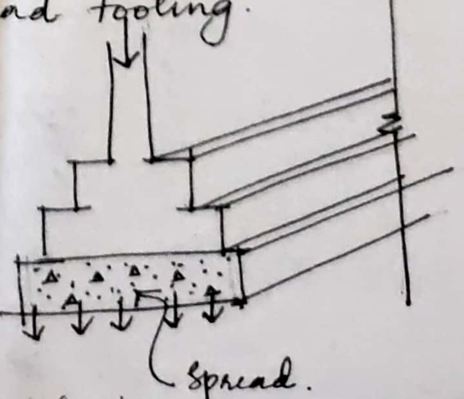
- based on the depth of the soil at which the foundation is placed.

Generally If the width of the foundation is greater than the depth then it is called shallow ~~footing~~ foundation.

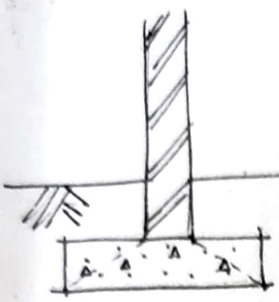
If the width is smaller than the depth it is called deep foundation.

Shallow foundation :

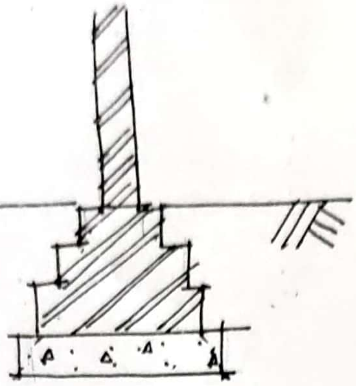
+ In such cases a spread is given under the base of the wall or column called footing and the foundation is called spread footing.



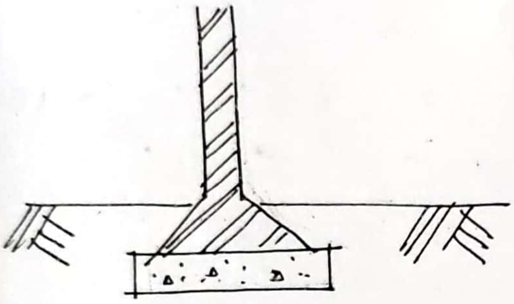
... footing for masonry walls.



simple footing



Stepped footing



Slopped footing

fig: ~~Masonry wall for~~ Foundation for Masonry Pier

Deep foundations:

piles are used to transfer load of the structure to the soil.

TYPES OF SHALLOW FOUNDATION

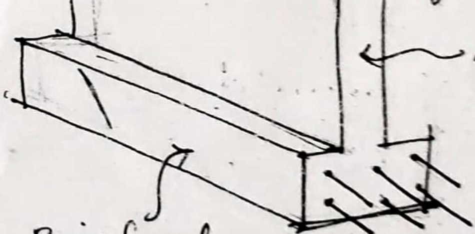
① WALL FOOTING / STRIP FOOTING.

* used to distribute loads of structural load bearing walls to the ground.
* wall foundation runs along the direction of the wall
* width of the wall foundation is generally 2-3 times the width of the wall.
* wall footing is a continuous RC slab strip along the length of the wall
* stone brick, reinforced concrete etc. is used for the construction of wall foundations.

Wall footing is economical when

→ Loads to be transmitted are of small magnitudes

→ The footing is placed on dense sand or gravel.



Reinforced concrete strip footing

→ The continuous strip of concrete is spread in trenches that have been excavated down to an undisturbed level of compact soil.

→ the ~~thickness~~ strip of the concrete may well need to be no wider than the thickness of the wall but in practise ... wider than walls for convenience. aced for a wide enough level base for the laying of bricks below ground.

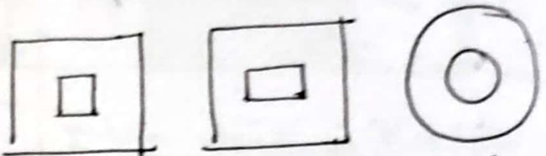
→ economic for small buildings on compact soil.

→ Ensure that trees are not planted close to shallow foundations as they will reduce moisture content in the soil causing clay to contract and the foundation to settle as the soil shrinks.

→ the greater the bearing capacity of the soil, the less the width of the foundation.

ISOLATED FOUNDATION

- most popular and simplest type of foundation used
- used to support a single column.
- independent footings provided for each columns.
- columns are not closely spaced
- Loads on footings are less
- The safe bearing capacity of soil is generally high
- essentially consists of a bottom slab
  - (i) Pad footing (with uniform thickness)
  - (ii) Stepped footing (with non uniform thickness)
  - (iii) Slopped footing (trapezoidal section)
- Isolated footing can have diff shapes in plan generally, it depends upon the shape of cross section of the column



square footing   Rectangulor   Circular

- used to carry and spread concentrated loads.
- can consist of either reinforced or non-reinforced materials
  - ↳ for non reinforced footing the hight of the footing has to be bigger inorder to provide the necessary spreading of load
- used only for firm grounds should ensure that differential settlement will not happen.

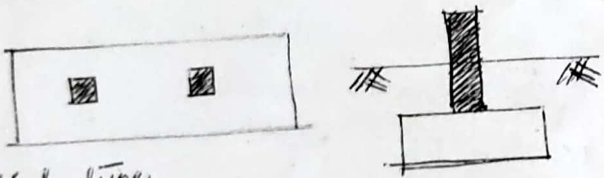
Brick size 22 x 11 x 7

— Continuous footing. \ Stepped | — Caissons

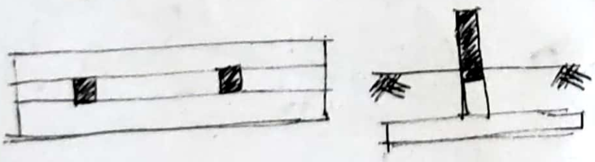
③ COMBINED FOUNDATION

- a common footing for two or more columns.
- used when two or more columns are close enough and their isolated footing overlap each other
- when exterior column is situated near to the boundary line and it is not possible to project its footing symmetrically on both sides
- combination of isolated footing but their structural design differs
- ~~shape of the footing is rectangular and is used when loads from the structure is carried by columns.~~
- used when the bearing capacity of soil is low.

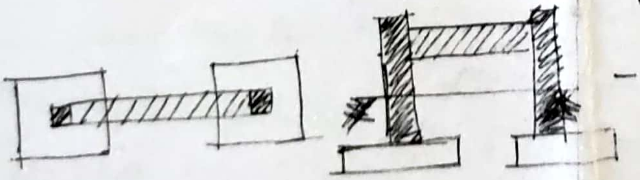
Types of combined footing



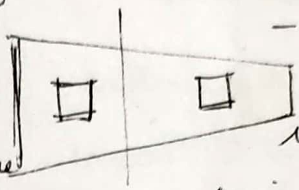
i) Slab type



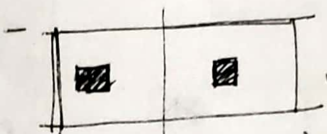
ii)



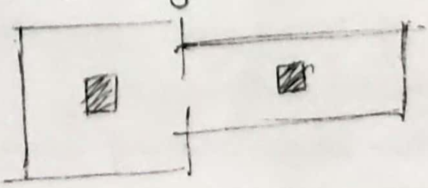
- may be rectangular, trapezoidal or Tee shaped in plan
- the geometric proportions and shape are so fixed that the ~~centroid~~ centroid ~~centre of gravity~~ of the footing area coincides (center of gravity) with the resultant of the column loads. This results in uniform pressure below the entire area of footing.



- Trapezoidal column load is used when one column load is much more than the other.



- Rectangular footing is provided when one of the projections of the footing is restricted or the width of the footing is restricted.
- this type of foundations are normally used in cases when an exterior column is situated near the boundary line of the plot and it is not possible to project its footing symmetrically on both sides.
- usually treated as an inverted floor supported by columns and loaded by earth reactions.

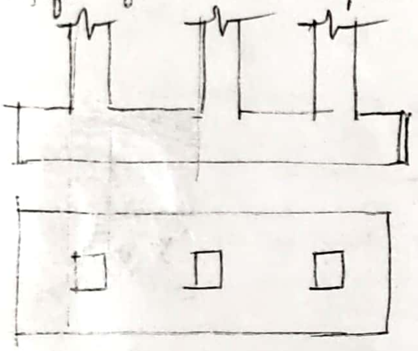


(iv) CONTINUOUS FOOTING

- in this type of construction, the footings of two or three adjacent columns are made continuous by providing beams b/w the successive columns.

- adopted to avoid differential settlements / uneven settlement

- to make the structure safe from earthquake



(V) RAFT FOUNDATIONS

- a thick reinforced concrete slab which spreads over a large area of soil and provides support for several columns and load bearing walls.

- also called as Mat foundation

Types of Raft foundations

(i) Flat plate type :-

- consists of Reinforced concrete slab of uniform thickness covering the whole bearing area

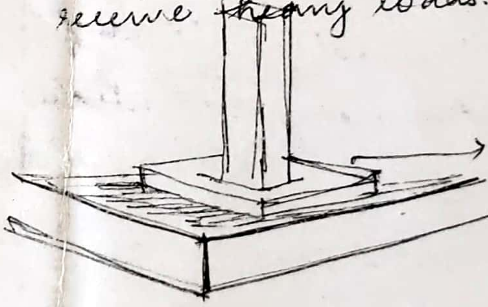
- This is suitable when the columns are placed with uniform space b/w them and carrying equal and small load.

- max. thickness of the concrete slab is 300 mm.

ii) Thickened Flat plate type

- used when column loads are heavy - to make it suitable slab thickness must be increased.

- provision of pedestals under the column without increasing slab thickness also helps to receive ~~heavy~~ loads.



iii) Beam and slab type

- beams are laid in ⊥r directions - all of those beams are connected by raft slabs.

- columns are provided exactly at the point of intersection of.

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walls.

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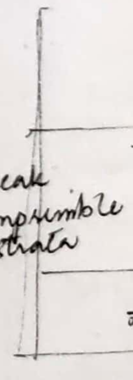

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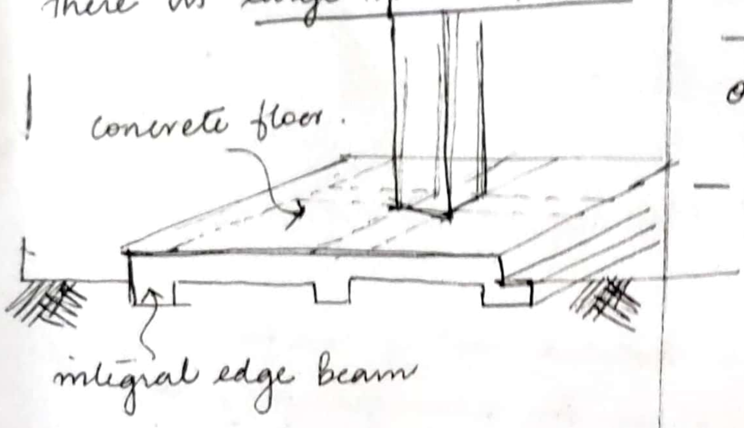
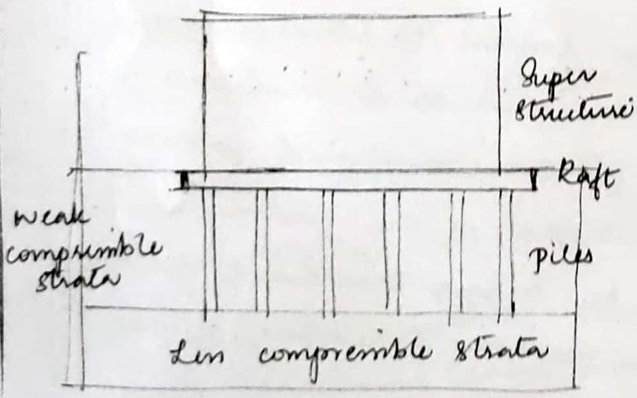
beams
- used when columns are carrying unequal loads and there is large space b/n them.



(4) Piled Raft foundation

- raft slab is supported by piles in soil.
- used in soil of high water table and high compressibility
- well suitable for high rise buildings

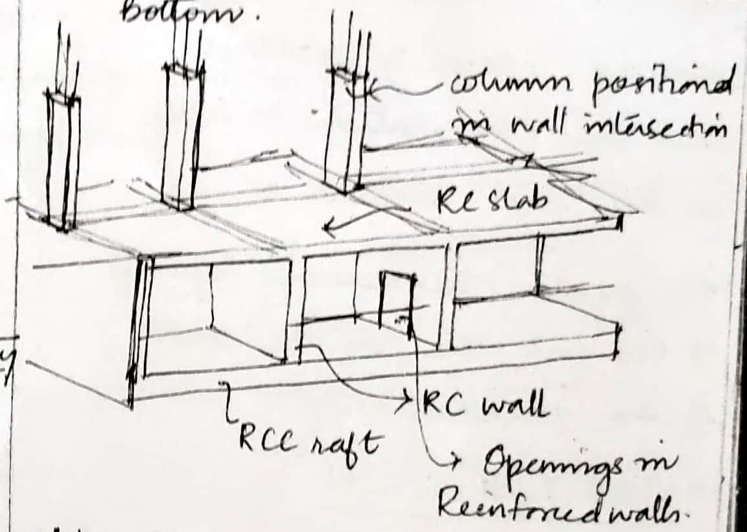


- provision of piles under raft reduces the ~~possibility of~~ amount of settlement and also controls effect of Buoyancy

- ultimate load capacity of foundations also increases.

(5) Cellular Raft foundations

- also known as box type Raft or rigid frame raft foundation
- Boxes like structures are formed where the walls of each box acts as beams and these are connected by slabs at top and bottom.



Advantages:

- used in shallow depth hence requires less excavation
- suitable in soils of Low Bearing Capacity
- Loads of Superstructure is distributed over a larger area
- reduces differential settlement

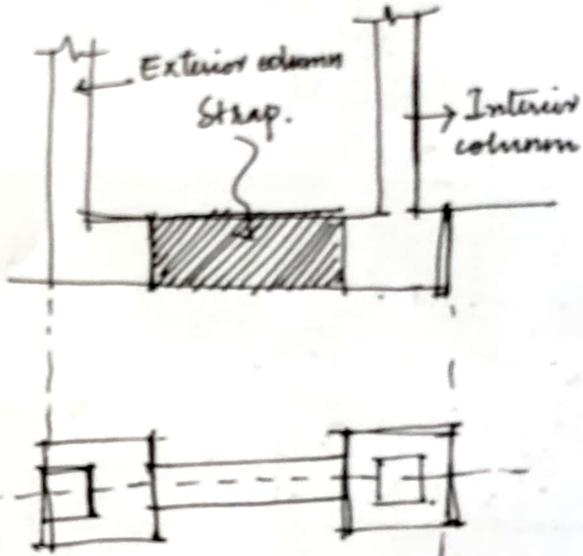
Disadvantages:

- in some cases large amount of reinforcement will be required which will increase the construction cost.
- Special attention should be given incase of concentrated loads.
- chances of edge erosion if not treated properly
- requirement of skilled labourers.

~~Deep DEEP FOUNDATIONS~~:

⑥ CANTILEVER / STRAP FOOTING

* similar to combined footing
* footings under columns are built individually and are connected by strap beam. in order to balance an asymmetrically imposed load
* consists of an eccentric footing for the exterior column and concentric footing for the interior column
* the strap joining these two columns need not touch ground or rest on the ground
* If it is not possible to provide an interior column a suitable anchorage should be provided in the form of a huge concrete block or a tension pile.
* can be constructed either in RCC or steel.



Cantilever footing

DEEP FOUNDATIONS

① PILE FOUNDATION

* Common type & used to reduce cost
* pile is a slender member with a small cross sectional area compared to its length
* used to transmit the load to a deeper soil or rock

— Continuous footing. \ Stepped | — Caissons.

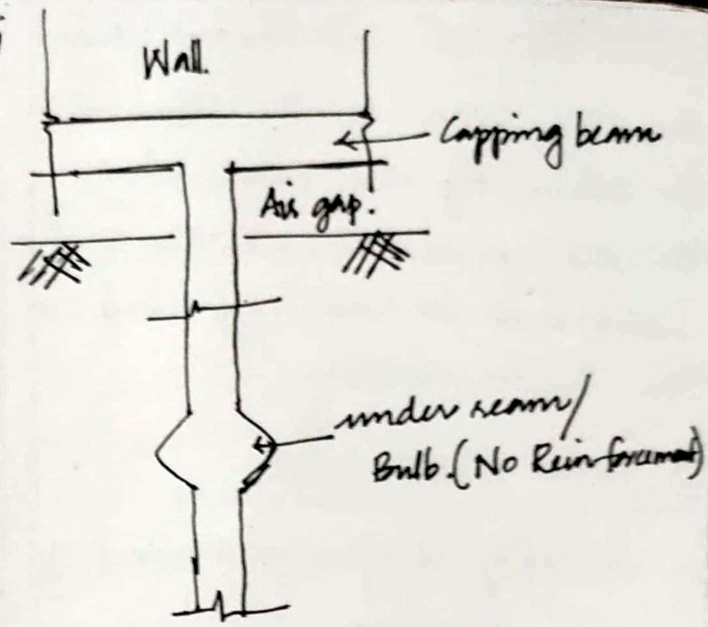
strata when the bearing capacity of soil is relatively low near the surface.

* used to give stability to structures against uplift, lateral and overturning forces.

* Pile foundations are economic when:
  - soil with great bearing capacity is at a greater depth.
  - when there are chances of construction of irrigation canals in the nearby area
  - when it is expensive to provide raft / grillage foundations.
  - when foundation is subjected to heavy concentrated loads.
  - In Marshy places.
  - when the top layer is compressive in nature

UNDER REAMED PILES:

Cast in Situ concrete piles having one or more bulbs or ...der reams at the lower part



- The load bearing capacity of underream piles can be increased by
  ↳ adopting piles of larger diameter
  ↳ extending the length of piles
  ↳ increasing no. of bulbs.

* Single under reamed ~~beam~~ pile has one bulb at the bottom
  Multi under-reamed pile has two or more bulbs.

* the Vertical spacing b/n bulbs ranges from 1.25 – 1.5 times the diameter of the bulbs.

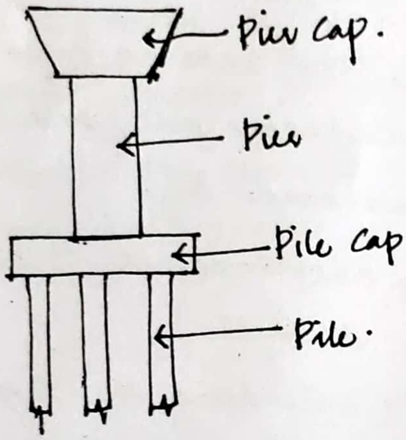
* the air gap is provided 80mm to 120mm to ensure that the soil from below does not

Scanned by CamScanner

heave against the beams and the full load of the structure is taken by the piles. thus the airgap accomodates the soil movement without affecting the super structure

② PIER FOUNDATION

- usually shallower than pile



-- cylinderical structural member that transfers heavy load from super structure to soil by end bearing.

- Pier foundation is economic when
  - ↳ sound rock strata lie under a decomposed rock layer at the top.
  - ↳ the top soil is stiff clay which resists driving the bearing pile
  - ↳ when heavy load is to be transferred

③ CAISSON FOUNDATION

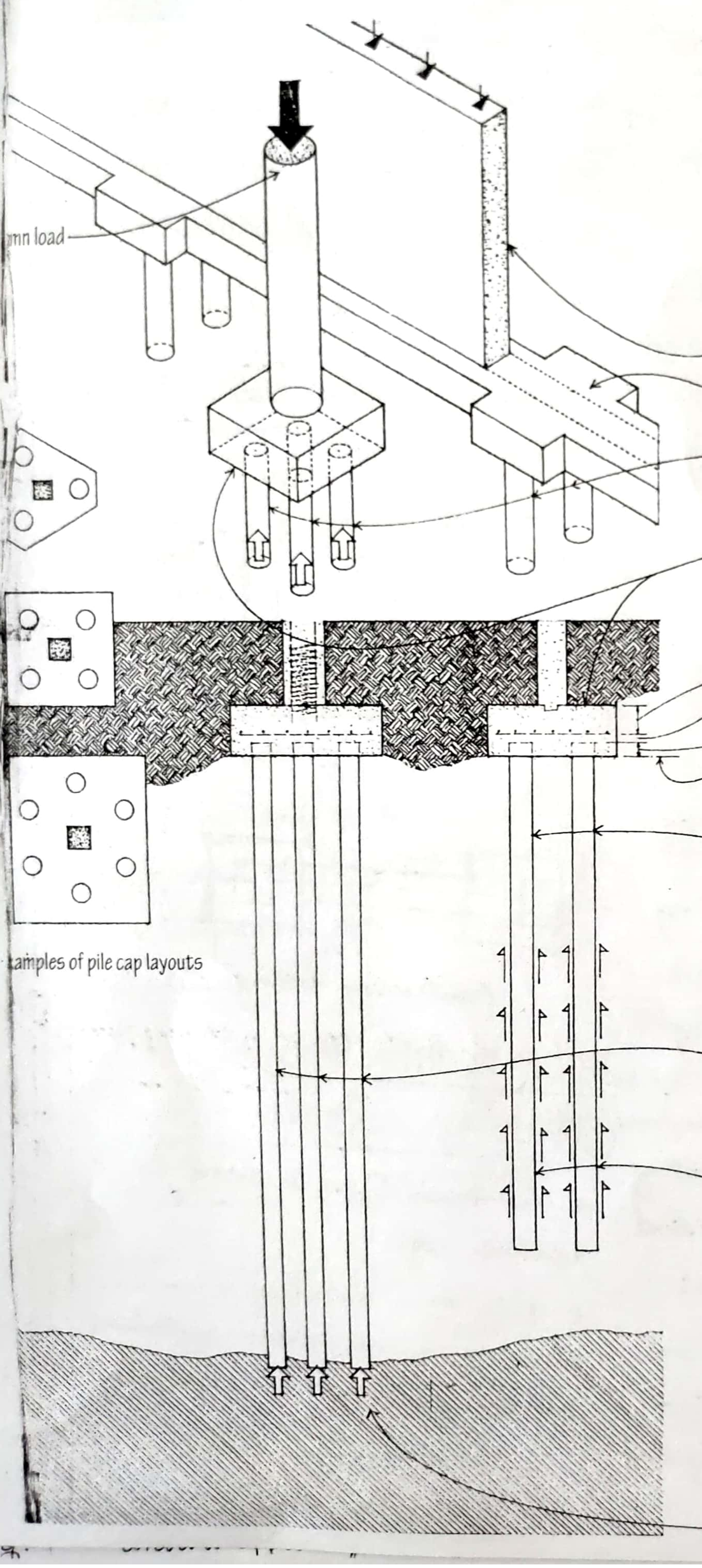
Caisson foundation is a wa tight retaining structure u as a bridge pier, constructi of dam etc.

- used when foundation is required below a river or similar water bodies
- for heavy foundation work at a depth of 12-15m belo the level of standing water surface

-

covering the whole bearing area

at the point of intersection of.



Deep foundations extend down through unsuitable or unstabl to transfer building loads to a more appropriate bearing stratum of rock or dense sands and gravels well below the superstructure. The two principal types of deep foundations are pile foundations and caisson foundations.

A pile foundation is a system of end-bearing or friction piles, pile caps, and tie beams for transferring building loads down to a suitable bearing stratum.

- Loadbearing wall
- Reinforced concrete grade or tie beam with integral pile caps
- Piles are usually driven in clusters of two or more, spaced 2'-6" to 4'-0" (760 to 1220) o.c.
- A reinforced concrete pile cap joins the heads of a cluster of piles in order to distribute the load from a column or grade bean equally among the piles.
- Varies with column load; 12" (305) minimum
- 3" (75)
- 6" (150)
- Place below frostline
- Piles may be of treated timber poles, but for large buildings, steel H-sections, concrete-filled pipes, or precast reinforced or prestressed concrete are more common.
- Piles are driven into the earth by a pile driver, composed of a ta framework supporting machinery for lifting the pile in position before driving, a driving hammer, and vertical rails or leads for guiding the hammer.
- End-bearing piles depend principally on the bearing resistance of soil or rock beneath their feet for support. The surrounding soil mass provides a degree of lateral stability for the long compression members.
- Friction piles depend principally on the frictional resistance of a surrounding earth mass for support. The skin friction develope between the sides of a pile and the soil into which the pile is driven is limited by the adhesion of soil to the pile sides and the shear strength of the surrounding soil mass.
- The allowable pile load is the maximum axial and lateral loads permitted on a pile, as determined by a dynamic pile formula, a static load test, or a geotechnical investigation of the foundation soil.
- Pile eccentricity, the deviation of a pile from its plan location o from the vertical, can result in a reduction of its allowable load
- Bearing stratum of soil or rock

...ECIAL FOUNDATIONS.

- Some engineering structures designed for heavy loads requires special treatment for foundations such as
  - (1) grillage foundations
  - (2) Raft foundations
  - (3) Inverted arches.

(i) GRILLAGE FOUNDATION

- depth is limited to 1-1.5m and width is increased considerably to bring the pressure on the soil within the permissible limits.
- the superstructure rests on one two or more tiers of steel beams, kept perpendicular to each other, superimposed on a layer of concrete so as to protect it from atmospheric actions.
- the concrete bed should be min 150mm and should never go less than 80mm
- the concrete filling does not carry any load but it maintains the beams in proper position and prevents them from corrosion
- Each steel beam (RSJ) should be designed to act independently.
- Steel beams/R.S joists can be replaced with reinforcement bars of steel of required dia. This is termed as mat foundation.
- economical and lighter solution for transferring concentrated loads to a soil weaker in bearing capacity and hence its used in bldgs such as theatres, factories, town halls etc.
- Temporary grillage foundations may be provided for timber columns or posts for supporting light buildings in soft soil or in permanently water logged areas.

(2) RAFT FOUNDATIONS.

- also called as Mat foundations
- used to increase bearing capacity of soil
- useful where uniform

— Continuous footing. \ Stepped ⊢ Caisson

BEARING CAPACITY OF SOIL

- maximum load per unit area which the soil will resist safely without displacement — also called as bearing power. (3)
- it is important to know the strength and behaviour of the soil on which the load of the building is coming. (1)

Safe Bearing capacity of soil (6)

$$= \frac{\text{Ultimate bearing power of soil}}{\text{Safety factor}}$$

minimum load which will cause failure to the foundation

Safe bearing capacity of soil differs for various soil conditions.

- the soil have a tendency to behave in a complex (2) manner when loaded and it gets deformed when stressed due to loading. The resistance of soil to such deformation will depend on various factors like bulk density, angle of internal friction, water content, manner of application of load on soil etc.

Points to be noted with bearing power of soil

MAX. SAFE BEARING CAPACITY OF SOIL

indicate the maximum pressure that a soil can bear without any risk of shear failure only irrespective of any settlement that may occur (4)

ALLOWABLE BEARING PRESSURE ON SOIL :

(5)

The maximum pressure which can be exerted on a soil while taking into account shear failure, settlement and the ability of the structure to resist settlement

- the value depends on the nature of ground and type of building

max safe bearing power > Allowable bearing pressure

NET PRESSURE INTENSITY

Indicate the excess pressure or the difference in the intensities of the gross pressure after the construction of the structure and the original overburden pressure

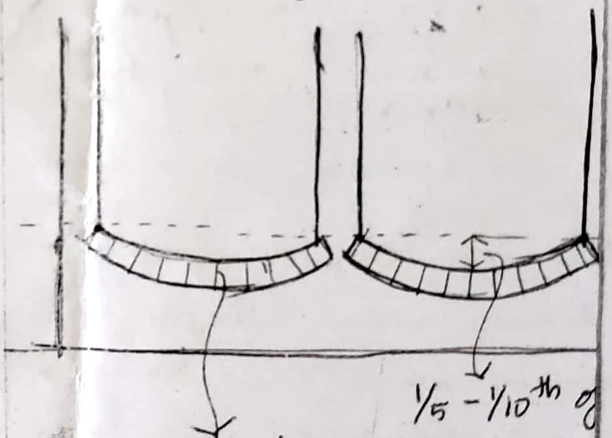
- used when the soil is soft or reclaimed.
- Refer the types of Rafts in Previous pages.
- Sometimes the design of the raft is so adjusted that the weight of the excavated earth is just equal to the total load of the building. Thus the loading on the soil remains practically same after the construction of the building. This is known as floating foundations and in such case settlement is reduced to a minimum extend.
- the design of raft is carefully done - so shaped and proportioned that the center of gravity of the imposed loads is vertically under the centre of area of the bearing ground.
- holes are provided in raft foundation if there is a chance of ground water pressure to damage the foundation. holes reduce the water pressure
- Raft foundations are useful for public bldgs, schools etc office bldgs, residential quarters etc.

ECIAL TY

RAFT FOU

(3) INVERTED ARCHES.

- method consists in constructing inverted arches b/w piers.
- used in early days for multi storeyed structures but with the advent of RCC construction practise inverted arch footing is rarely used



- IA should be set in cem mortar
- the end pier should be specially strengthened by buttress to avoid the outw pressure caused by arch action
- arches can be either along

at the top

soil is stiff clay

SPECIAL TYPE FOUNDATIONS

RAFT FOUNDATION.

or in both direction depending upon the bearing capacity of soil and the type of load.

- depth of foundation can be considerably reduced and proves economical in soft soil
- suitable for bridges, reservoirs, supports for drainage lines, tanks etc.

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Safe Bearing = U

minimum load which will cause failure to the foundation

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pressure.

③ In case of non cohesive soil such as sand & gravel, 50% reduction in allowable bearing pressure is applied, if water table is above or near the bearing surface of soil.

- If the water table is located below the bearing surface of the soil at a depth equal to the width of the foundation trench no such reduction should be applied.

- For intermediate depths of water table proportionate percentage reduction is applied

④ The bearing capacity of the reclaimed soil or ground, shrinkable soil etc. is likely to differ from site to site and it is therefore absolutely necessary to have detailed site explorations before deciding the safe bearing capacity for

- In the absence of such data safe bearing capacity is assumed as 50 KN/m^2

METHODS FOR TESTING THE BEARING CAPACITY OF SOIL

5 Methods

1. Method of Loading.
2. Plate Load test
3. Penetration test / Method of dropping a weight.
4. Analytical methods.
5. Presumptive values of bearing capacity of soils.

① **Method of Loading**:

Materials Required:-

→ A square steel plate
size - 3000 mm^2 - 7500 m
thickness not less than 25mm

→ A suitable platform
↳ a wooden table having 4 legs and a top plank board.
↳ two blocks of wooden beams are placed on the top plank board in a well balanced position

- Continuous footing. Stepped | Caisson

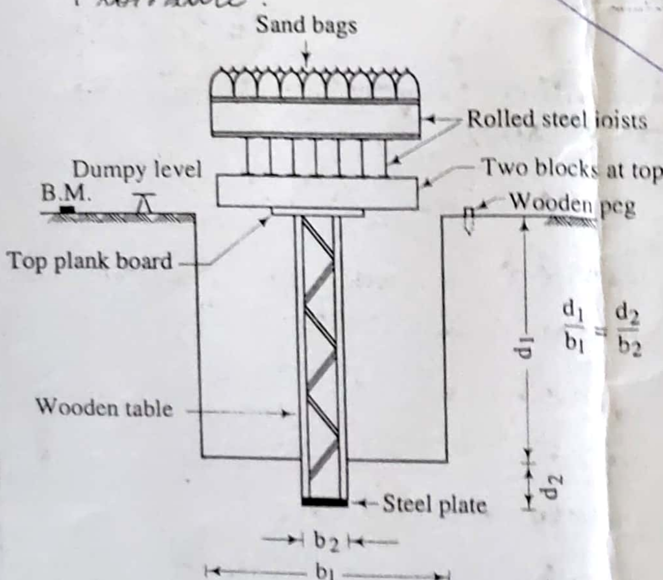
Wooden pegs: wooden pegs project out about 25mm-50mm above GL
↳ used to maintain line and level of bench mark.

Dumpy level with staff
levelling instrument
used to note the settlement of steel plate

Rolled steel Sections:
available in standard size & Weight
Arranged in two layers over a platform to take the load of Sand bags.

Sand bags:
used for loading.

Procedure:



Method of loading

① A square pit of required size is excavated upto required depth – the side of the pit is 5 times the side of steel plate.

② At the centre of the pit a square hole is dug of size equal to steel plate.

③ The bottom of the hole should correspond to the foundation level and the depth to breadth of the pit should be made equal to the ratio of depth to breadth of hole.

④ bottom of the hole is made level by scraping and is well protected against disturbing forces before and during the test.

⑤ the steel plate is kept in the hole and then the platform is prepared

⑥ The amount of initial load is decided according to the type of soil to be tested.

⑦ the weight of steel plate, wooden table and wooden

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+ Inverted arch

beams should be carefully worked out.

(8) A dumpy level is planted to note the settling of steel plate with reference to permanent bench mark.

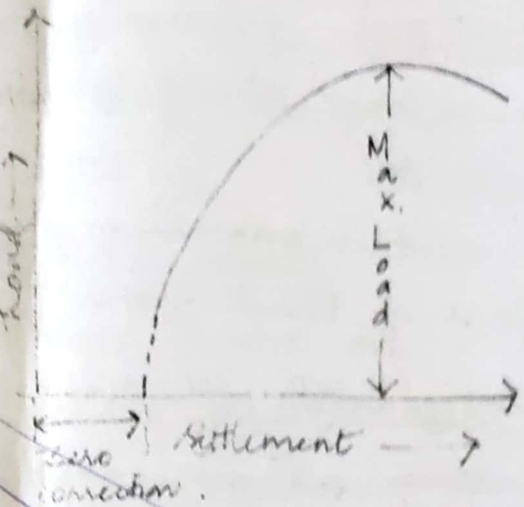
(9) The load is kept on the platform till the settlement of the ground stops.

(10) Load is increased by a suitable amount usually by 5 kN and the procedure is continued.

(11) Readings are noted in the format :

Date & Time	Load	Increase in Settlement	Total Settlement	Remarks.

(12) The settlement of ground will be fairly in proportion to the load upto a certain limit when the bearing power of soil is ~~high~~ exceeded the settlement will be out of proportion This can be easily noted by plotting a curve



The bearing capacity of soil is calculated as, (in kN/m^2)

$$= \frac{\text{maximum load}}{\text{area of steel plate}}$$

Safe bearing capacity of soil in kN/m^2 $= \dfrac{\text{bearing capacity of soil}}{\text{Factor of Safety}}$

Zero correction : There is some settlement at zero loading. This is due to the adjustment of soil particles under the action of Loading. This is known as zero correction and it is obtained from the Load Settlement curve.

$$\boxed{\text{Actual Settlement} = \text{Observed Settlements} - \text{Zero correction}}$$

The bearing capacity of sandy soil and gravelly soils is ...ted to the extend of 50%

by the presence of water table. If the water table is above the foundation level, the water should be pumped out before placing the steel plate. If water is met with a depth of 1m below the level of foundation level, the load test should be carried out at that level.

DRAWBACKS.

1. The arrangement gets disturbed during the incremental loading.
2. The entire system seems to be crude and not refined.
3. The settlements are not measured upto the desired accuracy.
4. The tilting of the loading platform may lead to serious accidents

2. Plate Load Test.

- Improved and refined method
- widely used for civil engineering structures.

PROCEDURE

1. the test pit and square hole for the steel plate are made as in the previous method.
2. the plate is firmly sea[ted in] the hole. If the ground is slightly uneven a thin laye[r] of sand is placed below the plate
3. the loading to the test plate is applied with the help of a hydraulic jack which is preferably provided with a remote control pumping unit.
4. The reaction of the hydraulic jack is borne either by the gravity loading method or by reaction truss method.

gravity loading method :- a platform is constructed on a vertical column resting on the platform. The loading is done by Sandbags, stones or concrete blocks.

Truss method : Truss made of mild steel sections is held to the ground through soil anchors. The lateral stability of the truss is obtained by ~~[illegible]~~ guy ropes

MODULE-4

FOOTINGS

Types

Any structure is considered to have two main portions.

i) Super structure

ii) Sub structure → transmits the loads to the soil → termed as foundation.

→ Footing is that portion of the foundation which ultimately delivers the load to the soil.

→ The object of providing footing is to distribute the load to the soil in such a way that maximum pressure on the soil does not exceed its permissible bearing value and the settlement is within the permissible limit.

Types of footing.

- shallow foundation
  - Wall footing
  - Combined footing
  - Isolated footing
    - Pad
    - Stepped
    - Slopped
  - Continuous footing.
  - Cantilever / Strap
- deep foundation
  - Pile foundation
  - Pier foundation
  - Caissons
- Special foundation
  - grillage
  - Raft
  - Inverted arch

ISOLATED FOOTING FOR AXIALLY LOADED COLUMNS :

Isolated footing of uniform depth for RCC column :

1) Design an isolated footing of uniform thickness of a RCC column bearing a vertical load of 600kN and having a base of size 500mm x 500mm. The safe bearing capacity of soil is 120kN/m². Use M_{20} Concrete & Fe 415 steel.

Given

$W = 600kN$

Column $\begin{cases} B = 500mm \\ D = 500mm \end{cases}$

$f_{ck} = 20N/mm^2$

$f_y = 415N/mm^2$

B_c or $q_o = 120kN/m^2$

STEP:1 : DIMENSIONS OF FOUNDATION

Bc, $\text{Pressure} = \frac{\text{load}}{\text{Area}}$

Let w' be the self weight of the footing and it is equal 10% of the super imposed load.

$w' = 10\% \, W$

$= \frac{10}{100} \times 600 = 60kN$

$\text{Total load} = 60 + 600 = 660kN$

$\text{Area} = \frac{\text{load}}{\text{Pressure}} = \frac{660}{120}$

$= 5.5m^2$

$\therefore B^2 = 5.5$

$\therefore B = \sqrt{5.5}$

$= 2.34 \simeq 2.4$

$\therefore$ provide a square footing of 2.4x2.4m.

$\therefore$ Net upward pressure $= \frac{600}{2.4 \times 2.4} \rightarrow \left[\frac{\text{Actual } \cancel{\text{pressure}} \text{ Load}}{\text{Area provided}}\right]$

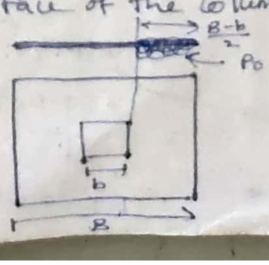
$= 104.17kN/m^2$

STEP:2

Design of section

Depth on the basis of bending compression

The maximum bending moment act at the face of the column and its magnitude is given by



$BM = M = P_o B \left(\frac{B-b}{2}\right)\left(\frac{B-b}{4}\right)$

$= \frac{P_o B}{8}(B-b)^2$

$= \frac{104.17 \times 2.4}{8} (2.4 - 0.5)^2$

$= 112.816\ kNm$

$M_u = 1.5 \times M$

$= 1.5 \times 112.816$

$= 169.224\ kNm$

$= 169.224 \times 10^6\ Nmm$

Calculate 'd'

$M_{u\,lim} = 0.36 \frac{x_{umax}}{d} \left(1 - 0.42 \frac{x_{umax}}{d}\right) \times bd^2 f_{ck}$

$169.224 \times 10^6 = 0.36 \times 0.48 (1 - 0.42 \times 0.48) \times 2400 \times d^2 \times 20$

$d^2 = 25550.266$

$d = 159.84$

$\approx 160mm$

Overal depth $= 160 + C + \phi/2$

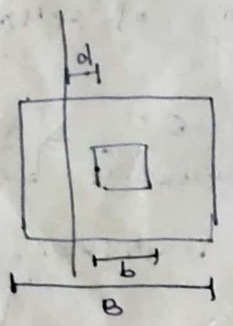
$= 160 + 50 + \frac{20}{2}$

$= 160 + 60$

$= 220mm$

Depth on the basis of one way shear.

For one way shear, the critical section is located at a distance 'd' from the face of the column.



$V = P_0 B \times \left(\frac{(B - b)}{2} - d\right)$

$= 104.17 \times 2.4 \times \left[\left(\frac{2.4 - 0.5}{2}\right) - \frac{d}{10^3}\right]$

$= 237.5076 - 0.250008d$

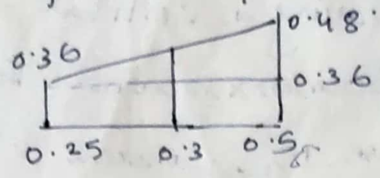
$V_u = V \times 1.5$

$= 356.2614 - 0.375012d.$

Nominal shear stress is equated the permissible shear stress ($k\tau_c$) [Table 4.9 of page 73].

$\frac{V_u}{Bd} = k\tau_c$

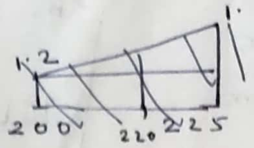
Assume $p_t = 0.3\%$ for M_{20} concrete.

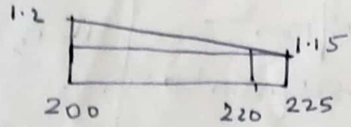


$\frac{0.25}{0.05} = \frac{0.12}{x}$, $x = 0.024$

$\tau_c = 0.36 + 0.024$

$= 0.384\ N/mm^2$





$\frac{25}{205} = \frac{0.05}{x}$

$= 0.01$

$K = 0.01 + 1.15$

$= 1.16$

$\frac{(356.2614 - 0.375012d) 10^3}{2400d} = 0.384 \times 1.16$

~~356 2614 − 0.375012d = 1069.056d~~

~~d = 40.333~~

$356261.4 - 375.012d = 1069.056d$

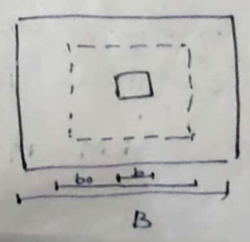
$d = 246.7$

$\approx 250mm$

Depth for two way shear

$d = 250mm$ [larger from both cases]

For two way shear (punching shear) the section lies at $\frac{d}{2}$ from the column face all round.



$b_o = b + d$

$b_0 = 500 + 250 = 750\,mm$.

Also shear force around the section.

$$F = P_0 \left[B^2 - b_0^2\right]$$
$$= P_0 \left[B^2 - (b+d)^2\right]$$
$$= 104.17 \left[2.4^2 - (0.75)^2\right]$$
$$F = 541.424\,kN$$
$$F_u = 1.5 \times F$$
$$= 1.5 \times 541.424$$
$$= 812.136\,kN$$
$$= 812136\,N$$

Shear stress, $\tau = \frac{load}{Area} = \frac{F_u}{Area}$

$$= \frac{F_u}{4 b_0 d}$$
$$= \frac{812136}{4 \times [750] \times 250}$$
$$= 1.083\,N/mm^2$$

[cl 31.6.3.1 of IS 456:2000]

permissible shear stress, $k_s \tau_c$

$$k_s = (0.5 + \beta_c)$$

β_c = Ratio of longer side to shorter side.

$$\therefore \beta_c = 1$$
$$k_s = 0.5 + 1 = 1.5$$

Subjected to a max of 1.

$$\therefore k_s = 1$$
$$\tau = 0.25\sqrt{f_{ck}}$$
$$= 0.25\sqrt{20} = 1.118\,N/mm^2.$$
$$k_s \tau_c = \cancel{1.5}\ 1 \times 1.118$$
$$= 1.118\,N/mm^2.$$
$$\tau_v < k_s \tau_c$$

Hence safe in two-way shear.

Provide eff cover 60mm.

$$\therefore D = 250 + 60 = 310\,mm \approx 330\,mm$$

$d = 330 - 60 = 270$ in one direction

Assume 12mm ϕ bars in other direction

$$= 270 - 12 = 258\,mm$$

Design of steel Reinforcement

Since the actual depth provided is greater than the depth required for bending compression, it is an under reinforced s/n.

$$M_u = 0.87 f_y A_{st} d \left[1 - \frac{A_{st} f_y}{b d f_{ck}}\right]$$

$$169.224 \times 10^6 = 0.87 \times 415 \times 258\, A_{st} \left[1 - \frac{A_{st} \times 415}{2400 \times 258 \times 20}\right]$$

~~$3.1274 A_{st}^2 = 931520.29 A_{st} + 169$~~

$$1816.665 = A_{st} - 3.35 \times 10^{-5} A_{st}^2$$
$$A_{st} = 1943.156\,mm^2$$

no. of bar $= \frac{1943.156}{\frac{\pi}{4} \times 12^2}$

$$= 17.18 \approx 18\ Nos$$

Check for development length

Min development length, $L_d = 47 \times \phi$

$$\therefore L_d = 47 \times 12$$
$$= 564\,mm.$$

Providing 60mm eff cover.

length of bars $= \frac{[B-b]}{2} - 60$

$$= 890\,mm > L_d$$

Hence safe.

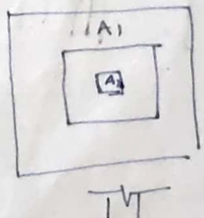
Transfer of load at column base

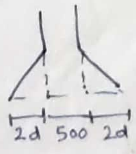
[cl 34.4]

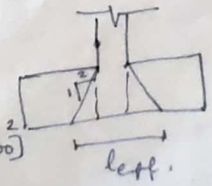
A_2 = loaded area of column.

$$A_2 = 500 \times 500$$
$$= 250000\,mm^2$$

Supporting area for bearing of footing.







$$A_1 = [500 + 2 \times 330 + 2 \times 300]^2$$
$$= 1820^2 = 3312400\,mm^2$$

$$\sqrt{\frac{A_1}{A_2}} = \sqrt{\frac{3312400}{250000}}$$

$$= \cancel{13.24}$$

$$= 3.63$$

Adopt max value $\sqrt{\frac{A_1}{A_2}} = 2$

permissible stress $= 0.45 f_{ck} \sqrt{\frac{A_1}{A_2}}$

$$= 0.45 \times 20 \times 2$$

$$= 18 \text{ N/mm}^2$$

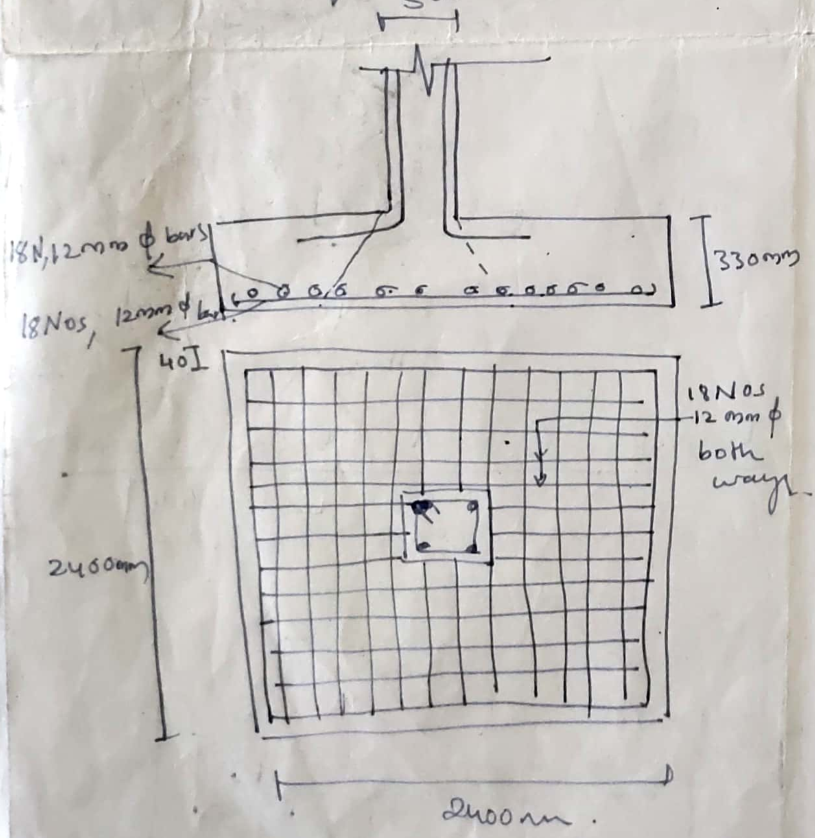
Actual bearing pressure,

$$= \frac{\text{factor of safety} \times \text{load}}{\text{Area}}$$

$$= \frac{1.5 \times 600 \times 10^3}{500 \times 500}$$

$$= 3.6 \text{ N/mm}^2$$

Hence safe. No separate bars are required to transfer load.



ISOLATED SQUARE SLOPED FOOTING

Design an isolated square slopped footing for a column 500mm x 500mm, transmitting an axial load of 1200kN. The column is reinforced with 8 bars of 20mm diameter. The safe bearing capacity of it is 12 tonnes/m^2. Use M_{20} Concrete and Fe 415 steel.

given

$b = 500$, $d = 500$ } column

$W_P = 1200kN$

$A_{SC} = 8$, 20mm ϕ bars.

$q_0 = 12$ tonnes/m^2

$= 12 \times 1000$ kg/m^2

$= 12 \times 1000 \times 10$ N/m^2

$= 12 \times 10$ kN/m^2

$= 120$ kN/m^2

$f_{ck} = 20 N/mm^2$

$f_y = 415 N/mm^2$

Step 1

DIMENSIONS OF FOUNDATION

Let w' be the selfwght of footing.

$w' = 10\% \, W$

$= \frac{10}{100} \times 1200 = 120 kN$

Total Load $= w + w'$

$= 1200 + 120 = 1320 kN$

Area $= \frac{load}{pressure}$

$= \frac{1320}{120} = 11 m^2$

$B^2 = 11 m^2$

$\therefore B = 3.31 \approx 3.4m$

$\therefore$ provide a footing of $3.4 \times 3.4m$.

Net upward pressure $= \frac{1200}{3.4 \times 3.4}$

$= 103.80 kN/m^2$

Step: 2

Design of section

Depth on the basis of bending compression

The max B.M occurs at the face of the column and its magnitude,

$$M = P_0 B \times \frac{(B-b)}{2} \left(\frac{B-b}{4}\right)$$

$$= \frac{P_0 B}{8} (B-b)^2$$

$$= \frac{103.8 \times 3.4}{8} (3.4 - 0.5)^2$$

$= 371.007$ kNm, $M_u = 371.007 \times 1.5$

$= 556.510$ kNm

$$M_{u\,lim} = 0.36 \frac{x_{umax}}{d}\left[1 - 0.42\frac{x_{umax}}{d}\right] \times bd^2 f_{ck}$$

$$556.5\times10^6 = 0.36\times0.48\left[1 - \overset{0.42}{\wedge}0.48\right]\times 500\times d^2\times 20$$

$= 635\text{mm}$ ~~[illegible]~~

~~Assume [illegible] cover 50mm~~

~~[illegible]~~

~~[illegible]~~

$=$ ~~[illegible]~~

$=$ ~~[illegible]~~

Fix overall depth = 760mm.

Assume a eff cover = 60mm.

eff depth for the lower layer

$= 760 - 60 = 700\text{mm}.$

eff depth for the upper layer

$= 700 - 12 = 688\text{mm}.$

provide ~~effective~~ overall depth at the end = 200mm.

effective depth available at lower part = 200 − 60

$= 140\text{mm}.$

effective depth for upper part $= 140 - 12 = 128$

Check for shear.

a) One-way / beam shear.

the critical section is at a distance 700mm from the face of the column.

$$V = P_0 B\left[\frac{1}{2}(B-b) - d\right]$$

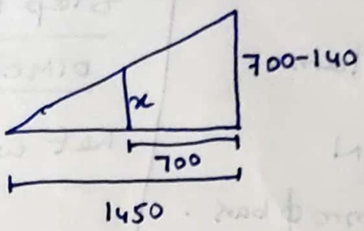
$$= 103.8\times 3.4\left[\left[\frac{3.4-0.5}{2}\right] - 0.7\right]$$

$$= 264.69$$

$V_u = 39\ldots$

Effective depth of the section at the location,

$$d' = 140 + x$$



$$\frac{700-140}{1450} = \frac{x}{1450-700}$$

$= 289.6$

$\therefore d' = 140 + 289.6$

$= 429.6$

$= 430\text{mm}.$

Top width of the section = 500 + 700 + 700

$= 1900\text{mm}.$

$\frac{x_{umax}}{d} = 0.48$ [For balanced section]

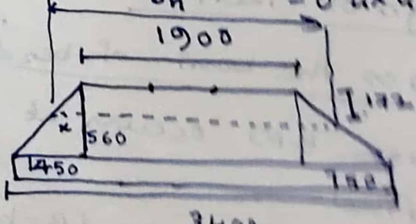
For under reinforced s/n,

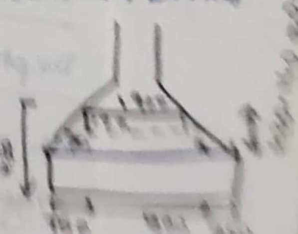
$$\frac{x_u}{d} < \frac{x_{umax}}{d}$$

Adopt $\frac{x_u}{d} = 0.4$

$\therefore x_u = 0.4\times d'$

b_n $= 0.4\times430 = 172\text{mm}$

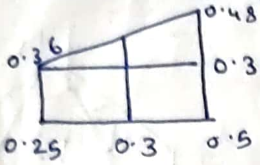




width b_n at the N.A =

$$\tau_v = \frac{V_u}{b_o d'} = \frac{397.035\times10^3}{2790\times 430} = 0.33\,N/mm^2$$

Assume 0.3% of percentage tensile reinforcement.



$$\frac{0.25}{0.05} = \frac{0.12}{x}$$

$\therefore x = 0.024$

$$\tau_c = 0.36 + 0.024 = 0.384\,N/mm^2$$

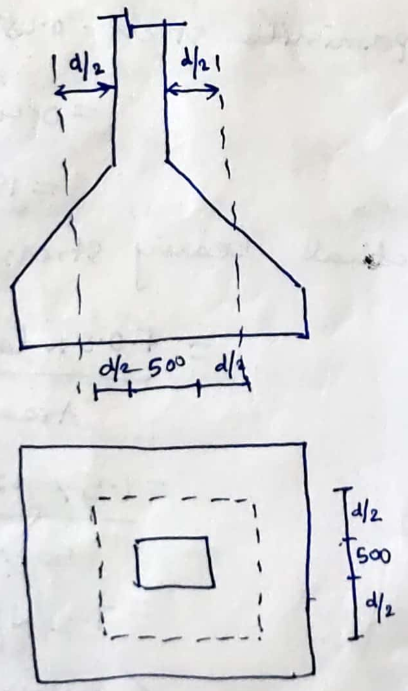
$k = 1$

$$k\tau_c = 0.384\times1 = 0.384$$

$\tau_v < k\tau_c$

Hence safe.

b) Two-way / Punching shear.



For two way shear (punching shear) the section lies at $\frac{d}{2}$ from the column face all round.

perimeter = 4 × side

$= 4\times[500 + d/2 + \frac{d}{2}]$

$= 4\times[500 + 700]$

$= 4800\,mm$.

$F = P_o[B^2 - b_o^2]$

Area $= 1200^2$

$= 1440000\,mm^2$

$= 1.44\,m^2$

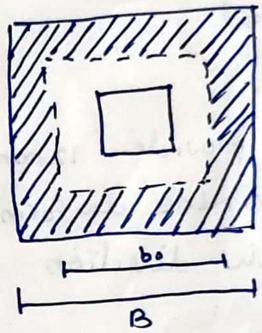
$B^2 - b_o^2$

Punching shear $= 103.8\,[3.4\times3.4 - 1.44]$

$= 1050.458\,kN$

$F_u = 1.5\times1050.458$

$= 1575.687\,kN$



τ_v, stress $= \frac{load}{Area} = \frac{F_u}{4800\times700} = \frac{F_u}{4b_o d}$

$4\times[500+\ldots]$ perimeter

$$= \frac{1575.687\times10^3}{4800\times700}$$

$= 0.468\,N/mm^2$

allowable shear stress,

$\tau_c = 0.25\sqrt{f_{ck}}$

$= 0.25\sqrt{20} = 1.118\,N/mm^2$

$k_s = 0.5 + \beta_c$

$\beta_c = \frac{500}{500} = 1$

$k_s = 1.5$

Subjected to maximum 1

$k_s = 1$

$k_s\tau_c = 1.118\,N/mm^2$.

$\tau_v < k_s\tau_c$

Hence safe.

Design of steel Reinforcement

$M_u = 0.87 f_y A_{st} d \left[1 - \frac{A_{st} f_y}{b d f_{ck}}\right]$

556.5

$558 \times 10^6 = 0.87 \times 415 \times A_{st} \times 700 \left[1 - \frac{A_{st} \times 415}{500 \times 700}\right]$

$\times 415$

$2201.91 = A_{st} - 2.857 \times 10^{-6} A_{st}^2$

$A_{st} = 2215.938 \, mm^2$

provide 12mm ϕ bars $= \frac{2215.938}{\frac{\pi}{4} \times 12^2}$

$= 19.59$

≈ 20 Nos.

Hence provide 12mm ϕ bars, of 20 Nos uniformly spaced in each direction

Check for development length

$L_d = 47 \times \phi$

$= 47 \times 12$

$= 564$ mm.

Length available

$= \frac{1}{2}(B - b) - c$

$= \frac{1}{2}(3400 - 500) - 60$

$= 1390 > L_d$

Hence safe.

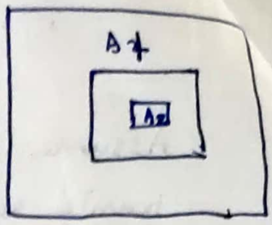
Transfer of load at Column base [Cl 34.4]

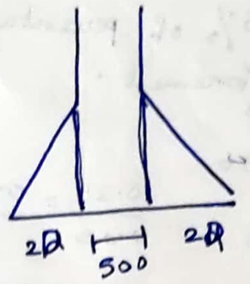
$A_2 =$ Loaded Area of the column.

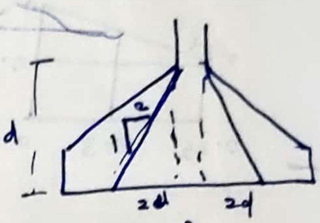
$A_2 = 500 \times 500$

$= 250000 \, mm^2$

Supporting area for bearing footing.







$A_1 = [500 + 2d + 2 \times d]^2$

$= [500 + 2 \times 760 + 2 \times 760]^2$

12531600

$= \cancel{10810000} \, mm^2$

$\sqrt{\frac{A_1}{A_2}} = \sqrt{\frac{12531600}{250000}}$

$= 7.08$

max value $= 2$.

$\therefore \sqrt{\frac{A_1}{A_2}} = 2$

permissible stress $= 0.45 f_{ck} \sqrt{\frac{A_1}{A_2}}$

$= 0.45 \times 20 \times 2$

$= 18 \, N/mm^2$.

Actual bearing stress/pressure,

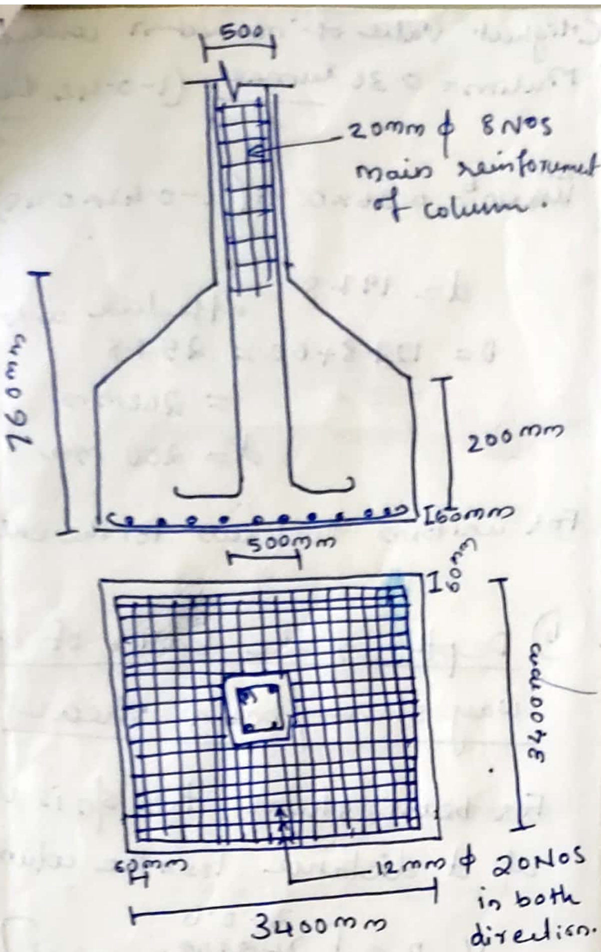
$= \frac{F.O.S \times load}{Area}$

$= \frac{1.5 \times 1200 \times 10^3}{500 \times 500}$

$= 7.2 \, N/mm^2$.

< permissible bearing stress.

Hence safe.



ISOLATED RECTANGULAR FOOTING OF UNIFORM THICKNESS FOR REINFORCED CONCRETE COLUMN

3) Design a Rectangular isolated footing of uniform thickness for R.C column bearing a vertical load of 600kN and having a base size of 400x600mm. The S.B.C of soil is taken as 120kN/m². Use M_{25} concrete & Fe 415 steel.

GIVEN

$W = 600\,kN$

Size of column $= 400 \times 600$

$q_0 = 120\,kN/m^2$

$f_{ck} = 20\,N/mm^2$

$f_y = 415\,N/mm^2$

STEP: 1

DIMENSIONS OF FOOTING.

$W' = 10\%$ of W

$= \frac{10}{100} \times 600 = 60\,kN$

Total load $= 600 + 60$

$= 660\,kN$

$\text{Area} = \frac{\text{load}}{\text{pressure}}$

$= \frac{660}{120} = 5.5\,m^2$.

Ratio of B to L $= \frac{40}{60} = \frac{2}{3}$

$\frac{2}{3} L \times L = 5.5$

$L = 2.9m$

$B = \frac{2}{3} L = \frac{2}{3} \times 29$

$= 1.93$

Hence provide a footing of size $= 2m \times 3m$

Net upward pressure, $= \frac{600}{2 \times 3}$

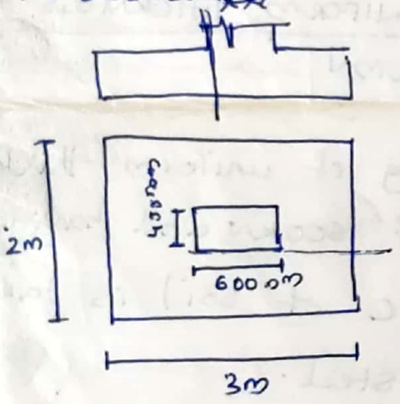
$= 100 KN/m^2$

STEP: 2

DESIGN OF SECTION

Depth on the basis of bending compression.

~~BM about xx~~



BM about xx axis,

$= P_o \times 2 \times \frac{(3-0.6)}{2} \times \frac{(3-0.6)}{4}$

$= 100 \times 2 \frac{(3-0.6)^2}{8}$

$= 144 KNm$

$M_u = 144 \times 1.5 = 216 KNm$

BM about YY axis,

$= P_o \times 3 \times \frac{(2-0.4)}{2} \frac{(2-0.4)}{4}$

$= 100 \times 3 \times \frac{(2-0.4)^2}{8}$

$= 96 kNm$

$M_u = 96 \times 1.5 = 144 KNm$

(Highest value of moment is co

$M_{ulim} = 0.36 \frac{x_{umax}}{d} (1 - 0.42 x$

$216 \times 10^6 = 0.36 \times 0.48 (1 - 0.42 \times 0.48) \times 2$
$d^2 \times 20$

$d = 197.8$ effective cover $= 60mm$

$D = 197.8 + 60 = 257.8$

$= 260mm$

$d = 200 mm$

For uniform thickness for the entire footing.

b) Depth on the basis of one way shear/beam shear

For beam shear the s/n is considered at d distance from the column phase.

$V = P_o B \left[\frac{3-0.6}{2} - d \times 10^{-3} \right]$

$= 100 \times 2 \left[\frac{3-0.6}{2} - 0.001d \right]$

$= [240 - 0.2d] KN$

$V_u = 1.5 [240 - 0.2d]$

$= (360 - 0.3d) KN$

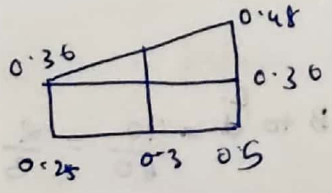
$\tau_v = \frac{V_u}{Bd} = \frac{(360 - 0.3d) \times 10^3}{2000 \times d}$

$= \frac{360000 - 300d}{2000d}$

Nominal shear stress = permissible shear stress

$\tau_v = k \tau_c$

Assume $p_t = 0.3\%$ of M_{20} concrete. [Table 19 page 73]



Scanned by CamScanner

$$\frac{0.25}{0.05} = \frac{0.12}{x}$$

$x = 0.024$

$\tau_c = 0.36 + 0.024$

$= 0.384\,N/mm^2$

$K = 1.2$ for depth ~~greater than 300~~ 200

$K\tau_c = 1.2 \times 0.384$

$= 0.4608\,N/mm^2$

$K\tau_c = \tau_v$

$$0.4608 = \frac{360000 - 300d}{2000d}$$

$0.4608 \times 2000d = 360000 - 300d$

$d = 294.6 \approx 300mm$

~~D = 294.6 + 60~~

~~= 354~~

d in other direction $= 300 - 12$

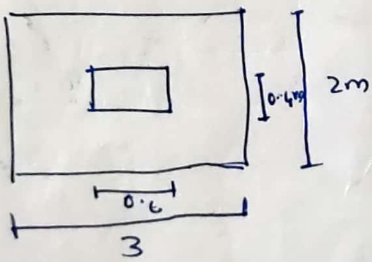
$= 288 mm.$

~~Depth for two~~

c) check for two way shear.

Adopt $d = 300mm.$

The section lies at $\frac{d}{2}$ distance from the face of the column for two way shear.



~~perimeter~~ $b_0 = 0.6 + 0.3 = 0.9$

$l_0 = 0.4 + 0.3 = 0.7$

$V_u = P_0 \times$ Area

$= P_0 [l \times b - l_0 b_0]$

$= P_0 [2 \times 3 - 0.9 \times 0.7]$

$= 100 [2 \times 3 - 0.9 \times 0.7]$

$= 537\,kN$

$V_u = 537 \times 1.5$

$= 805.5\,kN$

$$\tau_v = \frac{V_u}{2[(l_0 + 300) + (b_0 + 300)] \times d}$$

$$= \frac{805.5 \times 10^3}{2[(700 + 300) + (900 + 300)] \times 300}$$

$= 0.6102\,N/mm^2$

Allowable stress,

$\tau_c = 0.25\sqrt{f_{ck}}$

$= 0.25\sqrt{20}$

$= 1.11\,N/mm^2$

$k_s = 0.5 + \beta_c$

$= \left(0.5 + \frac{0.4}{0.6}\right) = 1.17$

Adopt max 1

$k_s = 1$

$k_s \tau_c = 1.11$

$\tau_v < k_s \tau_c$

Hence safe.

Effective depth 300 mm is o.k.

~~Adoptable~~

Overall depth = 360

Eff depth in one direct = 300

other d_{r}^{n} = 300-12

= 288 mm.

3) Design for Reinforcement

∵ Actual depth is more than the depth required in bending compression it is under reinforced sfn.

$$M_u = 0.87 f_y A_{st} d \left(1 - \frac{A_{st} f_y}{b d f_{ck}}\right)$$

$$216\times10^6 = 0.87\times415\times A_{st_1}\times 300 \left(1 - \frac{A_{st_1}\times415}{2000\times300\times20}\right)$$

$$1994 = A_{st_1} - 3.45\times10^{-5} A_{st_1}^2$$

$$A_{st_1} = 2154\,mm^2$$

$$\text{No: of bars} = \frac{2154}{\frac{\pi}{4}\times12^2}$$

$$= 19.04 = 20\,Nos.$$

$$M_u = 0.87\times f_y A_{st} d \left(1 - \frac{A_{st} f_y}{b d f_{ck}}\right)$$

$$144\times10^6 = 0.87\times415 A_{st_2}\times 288 \left[1 - \frac{A_{st_2}\times415}{3000\times288\times20}\right]$$

$$1384 = A_{st_2} - 2.401\times10^{-5} A_{st_2}^2$$

$$A_{st_2} = 1433.32\,mm^2$$

$$\text{No: of bars} = \frac{1433.32}{\frac{\pi}{4}\times12^2}$$

$$= 12.6$$

$$\approx 13\,Nos$$