Lecture 3 - Footings

Footings

- Factors influencing footing type
- Design considerations
- Reinforced concrete properties
- Footing types

Design for structure
Actions – concentrated or distributed forces (direct actions) acting on a structure or deformation or forces constrained within it (indirect actions)

- Building life (N) (assumed to be 50 years)
- Permanent actions – dead load (G)
- Earthquake actions €
- Earth pressure (Fe)
- Ground water action (Fgw)
- Liquid pressure action (Fip)
- Ice and snow actions (Fice & Fsn)
- Imposed snow action (live load)
- Wind action (W)

Factors affecting choice of footing system (& structure)
Building typology

- Design (Seijmas point loads VS Diestas unformly distributed load)
- Use (e.g factory loading vs house)
- Materials (Seijmas lightweight vs Diestas mass)
- Building systems (Seijmas steel column system vs Diestas masonry)

Factors affecting choice of footing system

- Foundation properties
- Impact on adjacent properly or retaining wall conditions
- Below ground infrastructure and site features
- Soil stability
- Climatic effects
- Constructability
- Construction time and program
- Occupational health and safety

Summary

- Foundation conditions are the most important factor in design of footings
- BUT
- Design typology
    - Brief
    - Use
    - Cost
- Construction efficiency
    - Time
    - Safety

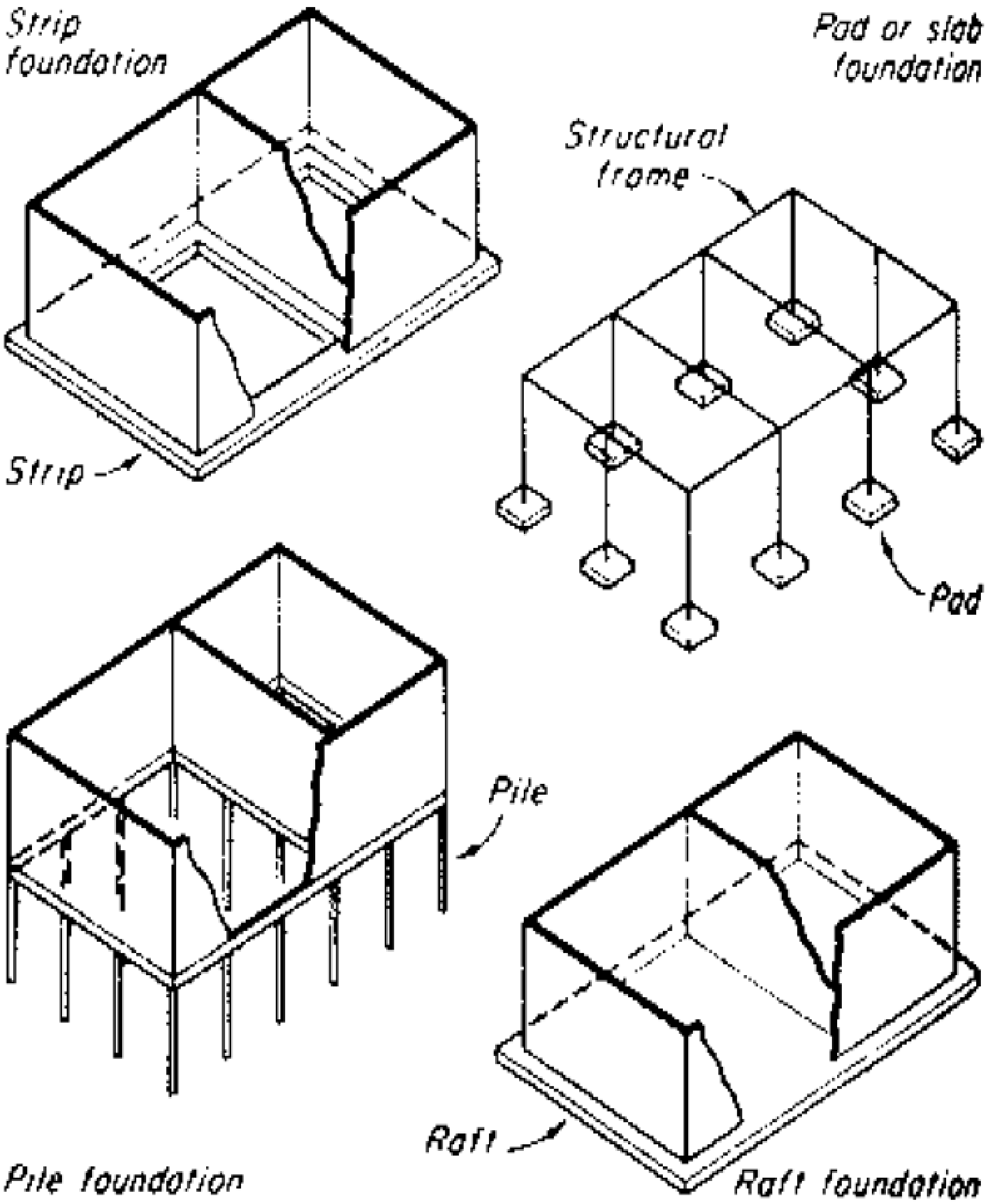
Footing types

Shallow footings

- Transference of load relatively close to main building or sub-structure due to foundation of adequate bearing capacity (raft pads tend to be shallow)

Deep footings

- Footing transfers load through soil of inadequate bearing pressure to deeper layers of soil having adequate bearing pressure or acts through friction between footing and surrounding soil

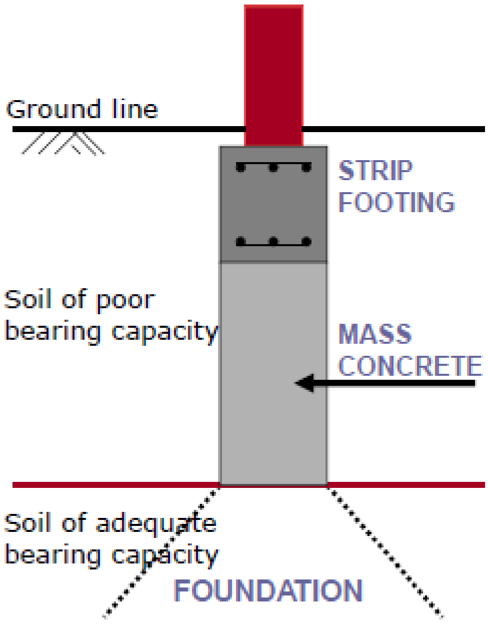


Blinding Concrete

- Blinding – layer of concrete between 50-100mm thick, put down on soil to seal the ground and provide a clean and even surface for construction work. Also assists to clean the base of the excavation if required as the base of excavation is sealed by the concrete
- Primarily used just to level the ground off

Mass concrete

- Unreinforced concrete, of a known compressive strength
- Used where
  - Soil conditions are poor – usually due to depth of a bearing
  - Bearing is at a depth where standard footing design is not achievable or uneconomical or where safety is an issue
  - To avoid load transference at a particular level, due to site conditions (trees, adjacent structures)
- Acts as a quasi-foundation/footing system in compression – no reinforcement used
- Replacement of poor soil with “good soil” (concrete of a known compressive strength)
  - Excavation is carried out and trench filled with lesser strength concrete
  - Standard footing design then poured over this mass concrete base
- Cheap and quick to do so builders like it

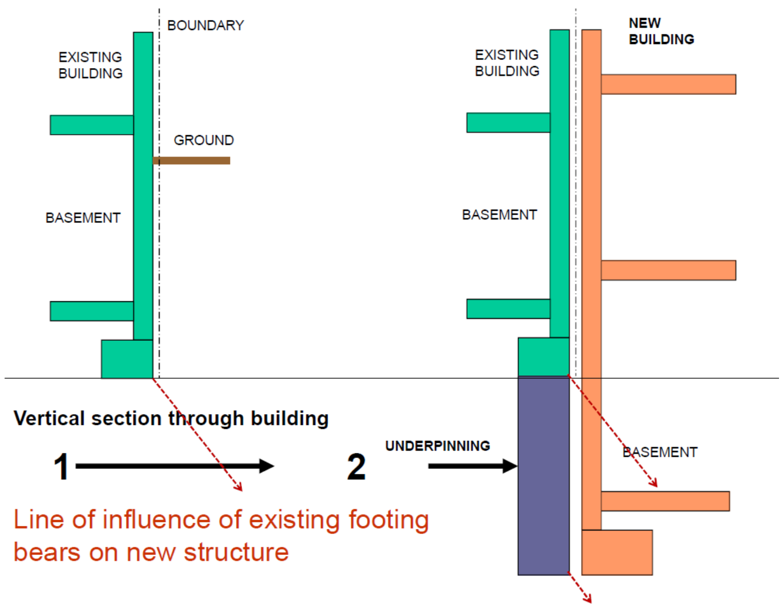


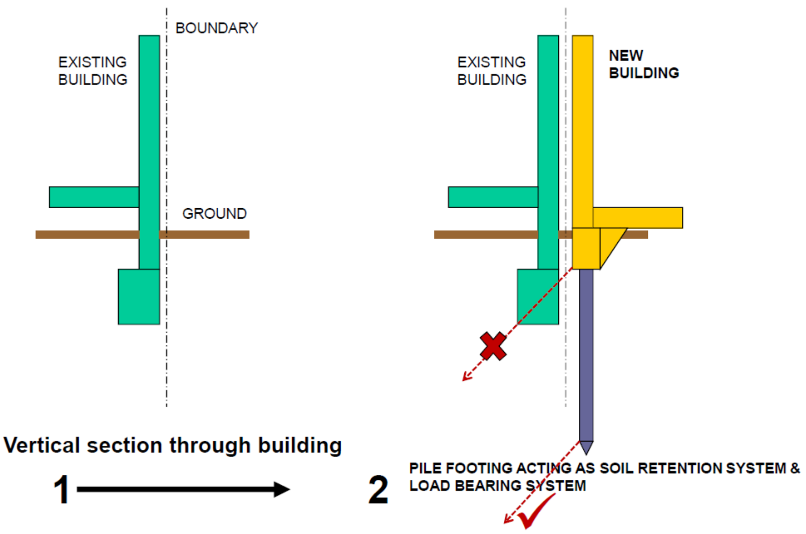
Underpinning

- New support structure underneath the existing footing without the removal of the superstructure
- Transfers load to a new bearing level at a lower depth
- Prevents collapse due to excessive or uneven settlement
- Allows additional loading of building
- Enables ground level inside or outside to be lowered

How to do underpinning

- Continuous strip footings – simplest method
- Removal of sections of soil at consistent intervals below footings
- Filing on of these sections with new footing system
- Sections allowed to set
- Remaining soil intervals removed and these provided with new footing





Line of influence of new footing bears on existing structure

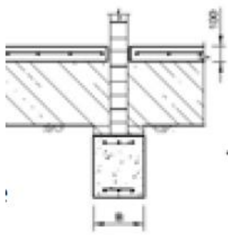
Spread footings

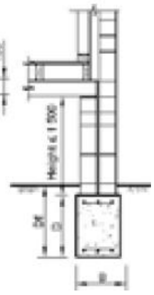
Types of shallow (spread footings

- Strip
    - Takes a continuously distributed load
    - Continuous footings
    - Stepped footing
- Pad
    - Takes a point or concentrated load
    - Isolated footing
- Raft
    - Can take either or both loads – concentrated or distributed
    - Thickened slab footing

Strip footings

- Supports a continuously distributed load
- In reactive soils they may act as beams, hence, need to be mindful of bending behaviour
- Generally rectangular in shape, with greater depth than width due to support requirement of wall above it
- Longitudinal bars control concrete shrinkage and cracking
- Reinforcement at bottom of footing is tensile resistance bending form above
- Reinforcement at top of fitting is tensile resistance bending from below



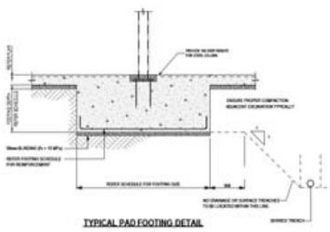


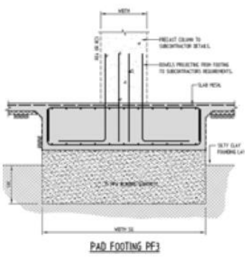
Site slope

- Sloping site topography may require footing to be stepped
- Structural continuity and integrity to be maintained
- Concrete and reinforcing overlapped

Pad footings

- Supports a point load – square or rectangular in plan, supporting a single column
- Area is a factor of the load and the bearing capacity
- Depth is a factor of shear (column cant punch through) and bending (dishing of side, tensile stress at the bottom)
- Reinforcement critical at base not at top, reaction of the ground acts upwards on all sides of the columns – counteracts the upward pressure exerted by the soil and downward pressure exerted by the column
- Greatest bending and shear is under the column





Raft footings

- Extends completely under the building footprint so as to spread weight over the entire foundation area
- Used when loads become so large that it is more economical to join up all the pad footings that would be required
    - Column grid say 8m x 8m – pads 3m x 3m (for 4 flootr) increase load (more floor levels) pads must be bigger (may end up touching) so easier to join up into a raft
- Used where ground conditions poor, raft required to distribute the loads over a larger area
- Very stiff footing good in dealing with settlement and differential movement
    - Better than individual footings which are more suspectible to local differential settlement
- Depth of raft
    - To deal with shear of columns
    - A factor of the large load from floors above
    - Often at least 1-1.5 metres deep
- Raft wants to bend between columns, so need to make it very stiff but using lots of reinforcement

Pile footings

- End bearing – taken through soil of poor bearing capacity to a level of good bearing capacity
- Friction piles – soil generally all poor so length of pile is determined by resistance generated by friction
- Bored piles – can be a combination of the above. In effect drilled holes, sometimes wide at bottom. Generally insitu reinforced concrete. Canst use them where soil is prone to collapse, like silt soils
- Driven piles – like nails, driven to refusal (can be concrete or steel, precast/prefabricated). Docklands driven to 25-30m – Coode island silt
- Designed as long columnds – reinforcement for driven piles robust enough for impact load, bored piles reinforcement deals with slenderness of column and buckling even though restrained by soil
- Generally have a pile capping beam to connect piles and distribute load across piles
- Uplift / shear can be generated by driven piles – the reinforcement design is important

Pile Footing Systems

- Driven Piles
    - A pile of steel, timber or precast concrete which is forced into the soil by blows from a pile hammer
- Bored piles
    - A pile, with or without steel casing, formed by excavating or boring a hole in the ground and sub sequentially filling it with plain or reinforced concrete

Reinforced concrete slabs

- There are a number of types
- Most common stiffened raft
    - Slab and beams poured at same time
    - Integrated system
    - Slab panel (relatively think 100mm +) is stiffened by introduction of edge beams and internal beams
    - Spacing of beams as a factor of spanning capacity of panel, loading condition and foundation
    - Beams need to be supported by foundation of adequate bearing
    - Panels need to be supported by ground or compacted fill

Summary

- Different footing systems respond to different design conditions
- Primary systems
    - Mass concrete (blinding not a footing)
    - Underpinning (lowering load transfer or increasing capacity)
    - Strip footings
    - Pad footings
    - Pile footings
- Reinforcement design is critical
    - Type
    - Configuration
    - Protection

Concrete composition

Air	**Portland cement**	**Coarse aggregate (gravel or crushed stone)**	**Fine aggregate (sand)**	**Water**
6%	11%	41%	26%	16%
Workability	Binder	Density, strength thermal conductivity, heat storage capacity, workability		Setting agent for binder

<u>Specifying and ordering concrete</u>

Concrete classes

- Normal class
- Special class

Ordering

- Strength - 30 MPa
- Aggregate size - 20mm
- Slump - 80mm

Testing

- Slump test
- Compaction test (7, 14, 28 days)

Reinforced Concrete

Concrete:

- High compressive strength but low tensile strength
- Low strength to weight ratio
- Tensile stresses develop under load, shrinkage or temperature change
- As low tensile strength it will fail suddenly and completely when first cracks forms – susceptible to cracking

Steel

- Steel – very high tensile strength and high compressive strength, but expensive
- High strength to weigh ratio
- Can take increased load when it enters an elastic stage and then fails when ultimate stress reached. Deformation occurs prior to failure

Reinforced concrete

- Combines high tensile strength of steel and relatively low-cost compressive strength of concrete

Reinforcement

Yield stress

- Max useable strength
- Point at which steel behaves plastically and is permanent deformed (reo steel 500 MPa)

Ductility

- Ability to undergo deformation and deflection when loaded
- Avoidance of brittle failure (L- low, N-normal, E-Seismic)

Reinforcement placement is critical – must be in correct plane for tensile resistance and must be projected by concrete cover

Mesh – Square and Rectangular (Slabs and Pads)

Configuration of bars	**Ductility Class**	**Size**	**Spacing**
S = Square R = Rectangular	L = low N = normal E = earthquake	Numerical value of the nominal diameter expressed in millimetres. 8/100; 6,7,8,9/200	Numerical value of the spacing of bars, expressed in millimetres, multiplied by 100.

Example: Square SL102 Square mesh, low ductility, 10mm diameter (nominal) bars, spaced at 200mm spacings.

NOTE: Rectangular mesh e.g. RL1218

Rectangular, low ductility, 12 mm diameter longitudinal bars, spaced at 100mm spacings and with 8mm diameter cross-bars. (Cross bars generally spaced at 200mm spacings)

Trench Mesh (Strip Footings)

- Ribbed bars
- 500 MPA
- Main wires and cross wires at 300mm centres
- Strip footings and slab beams

Ductility Class	**Size**	**Identifier**	**No. of wires**
L = low N = normal E = earthquake	Numerical value of the nominal diameter expressed in millimetres. 7, 9, 11, 13, 18, 22, 27mm diam.	Abbreviation of Trench Mesh – TM	3, 4 or 5 bars (wires) 3 – 200mm width 4 – 300mm width 5 – 400mm width

Example: L11TM3

Low ductility class, 11mm diameter, Trench Mesh, 3 bars (wires)

Reinforcing Bars

Shapes	**Strength grade**	**Durability class**	**Size**
R = Round D = Deformed ribbed I = Deformed indented	Numerical value of the lower characteristic yield stress expressed in magapascals	L = low N = normal E = earthquake	Numerical value of the nominal diameter expressed in millimetres.

Example: D500N16

Deformed ribbed bar, grade 500 MPa, normal ductility steel being 16mm diameter

Week 3 – Footings - Case Study Project

Bored piers

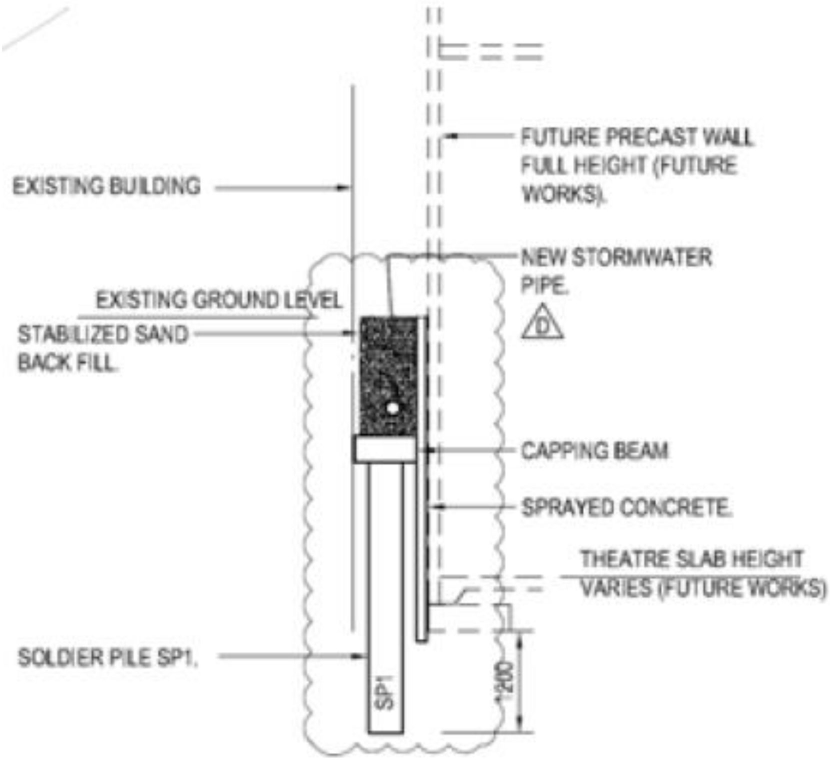
- Bored piers to be founded into highly to moderately weathered basalt at depths of minimum 4.6 metres below existing ground

Underpinning

- Underpinning adjacent structure
- Depth of underpinning determined by lowest depth of new footing system
- Existing footing spans across underpins

Soldier Piles

- Retaining (shoring) system to hold back soil to allow excavation on one side of the shoring members
- Can also be used as a support mechanism to transfer load from existing structures



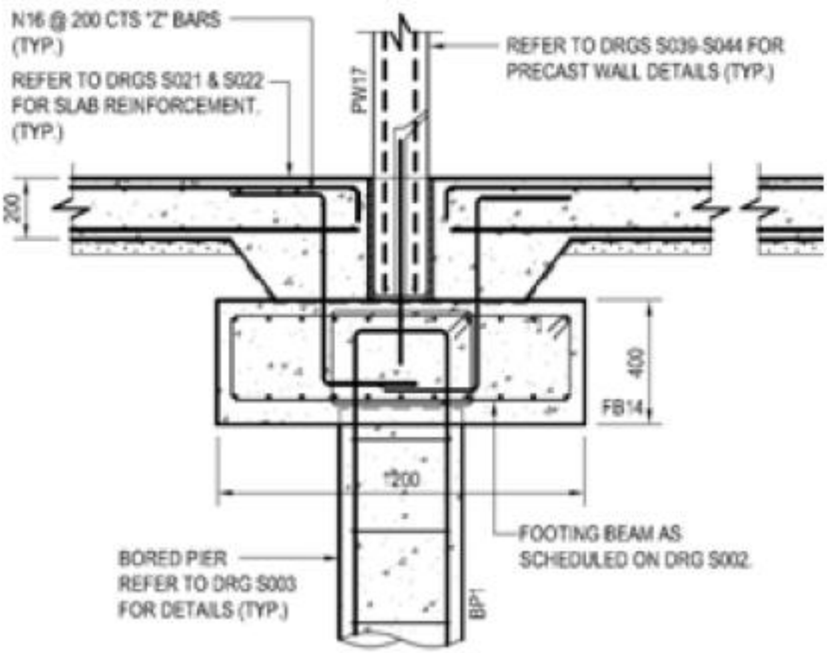
Capping beams

- Beams poured on top of piles
- Important structural component as they distribute load across a number of piles (in this sense they act like a footing)
- Can be designed to tie piles together and prevent lateral displacement (pile beams)
- Blinding concrete under the capping beam provides an even and level base

Footing beams

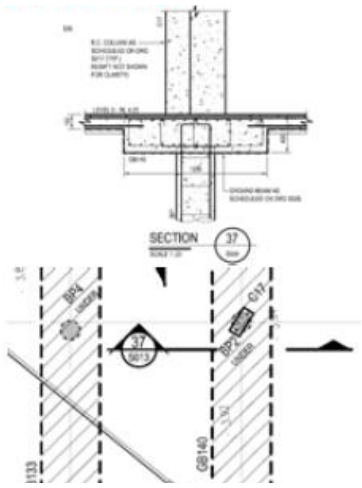
- Element is built directly onto this footing
- Not incorporated as part of the floor slab
- Precast wall bears directly onto footing (beam)

FB14	400 DEEP x1200 WIDE	11N24 TOP & BOTTOM 2/N12 @ 200 CTS LIGS	



Ground beams

- Integral to functioning of the slab
- Acts to stiffen the slab
- Slab panels span from integrated beam to integrated beam
- Slab and beam are poured together
- Critical as entire slab acts as if it is suspended – not reliant on ground for support
- Beams are supported by piles



Summary

- Different types of footings are suitable for different design conditions
- Primary issues are related to load and soil type
- Form that footing takes related to how loads are dealt with and how they are transferred into the foundation material