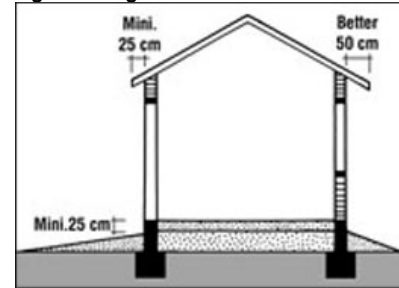# DESIGN AND MASONRY

BASIC DESIGN GUIDELINES FOR CSEB

General principles for a good design

- **"Good boots and a good hat".**

  That means built a good basement:
  (Minimum 25-cm high)

  And good overhangs:
  (Minimum 25 cm wide or better 50 cm)

Plinth and roof protection

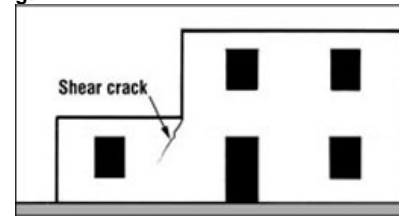### Compressive strength for earthquake resistant CSEB

- Design the walls (thickness + stability) according to the load bearing capacity of **wet CSEB.**
- The minimum admissible crushing load of HI CSEB should be 25 Kg/cm^2 under wet conditions. (After 3 days immersion)
- Keep at least a safety factor of 10 from the wet crushing strength (σ_c) for HI CSEB.

Example:

A Hollow Interlocking CSEB has a σ_c wet of 25/kg/cm^2: the maximum load bearing for the basement will be: 25/10= 2.5 kg/cm^2

Shear strength

- Avoid any major difference of load bearing in CSEB walls: especially with a different floor height.

Shear crack due to different load

Water absorption and erosion

- Avoid any concentration or accumulation of water in any part or surrounding of the building.
- Avoid any run off of water on any part of the building (i.e. leakage)
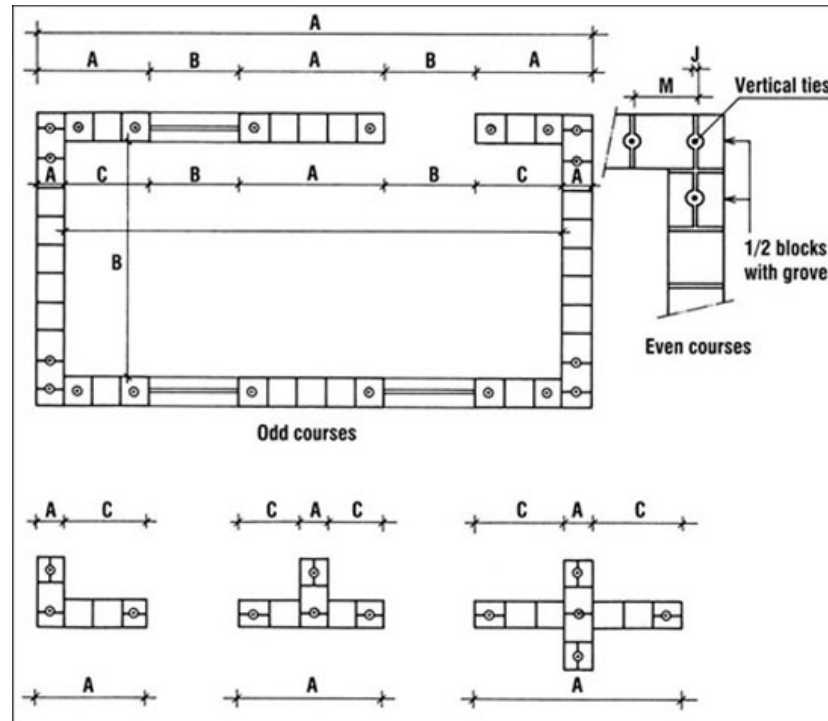
Dimensioning a building

A strong and clean block-work must follow the block module. The module of the block is its nominal size + the mortar thickness. The dimension of the building should fit with the block module theory:

A	=	Outside to Outside	= (X . M) - J	= (X . module) - 0.5 cm
B	=	Inside to Inside	= (X . M) + J	= (X . module) + 0.5 cm
C	=	Outside to Inside	= (X . M)	= (X . module)

Where:

M= module of the block = the block dimensions + the mortar joint thickness.

J = joint thickness = 5 mm, which is the optimum joint thickness for interlocking blocks.
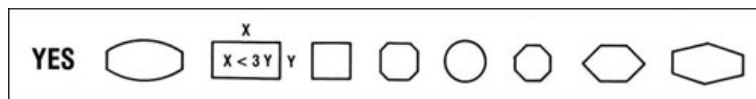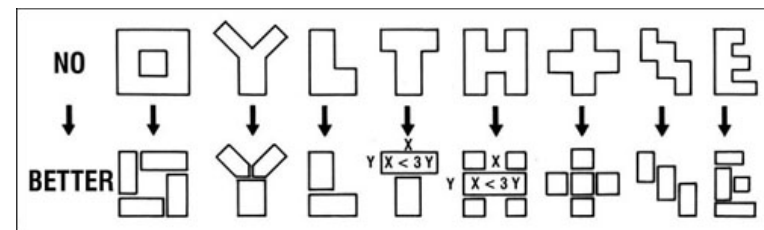
Dimensioning a building

BASIC DESIGN GUIDELINES FOR EARTHQUAKE RESISTANCE

Building shapes

The best shapes for earthquake resistant buildings are regular shapes and preferably with two symmetry axes. In this case the centres of gravity and rigidity will be the same or close to each other and therefore there will not be any torsion in the building. Round buildings behaved particularly well during the 2001 earthquake of Gujarat, especially those that were built in adobe bricks. When it is not possible to have regular shapes, it is possible to improve the earthquake resistance by dividing the building in several parts.

Good shapes

Deficient shapes and improvement

Separation gap

Buildings with irregular and asymmetrical shapes are more fragile than simple ones. Hence they should be split into simpler shapes like shown above. These various parts will vibrate at a different frequency and amplitude under the reversible ground shakings. Therefore they will hit each other and will be mutually damaged. A gap should be kept between them to avoid collision.
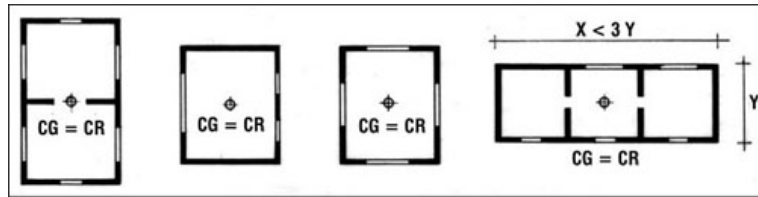
This gap can be filled with a crumbly material, which will be crushed under the shocks, or it can be left empty. In both cases, care should be taken for the waterproofing of the joint with a system that does not link again both parts. The separation gap must be minimum 25 mm for ground floor buildings and for higher ones the gap should be increased by 10 mm per storey more. (Ref. Indian Standards 4326: 1993)
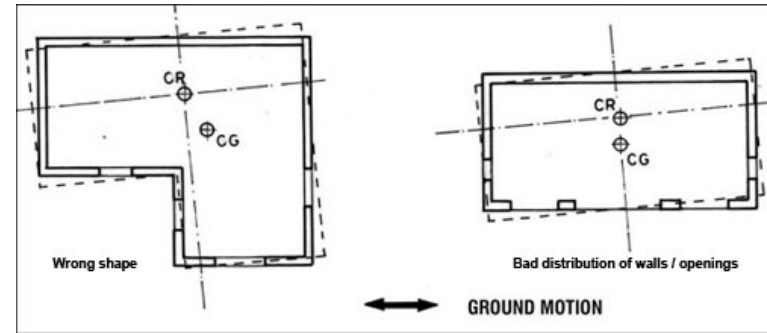
Ductility

Masonry components are most of the time brittle ones. Some reinforcements can be added to make a structure more ductile with these brittle materials. Wood and bamboo can be advantageously used. Reinforced cement concrete members are always more efficient, when they are well done and well distributed. Ring beams at various levels, which are linked together with vertical ties, will reinforce the structure very well and make it ductile.

Rigidity distribution

The centre of gravity of the plan should also preferably be the centre of rigidity of the vertical masses. This would avoid torsion of the building.

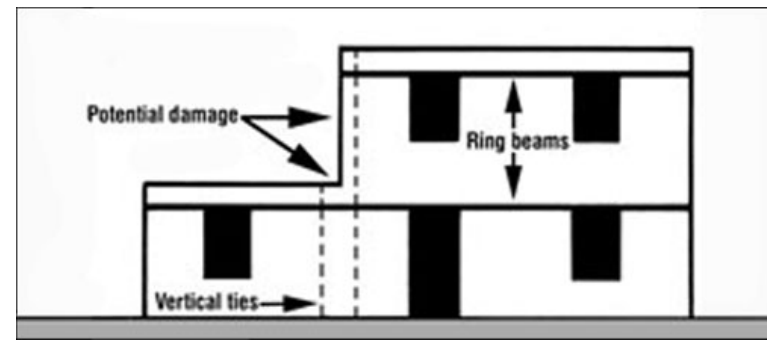*Proper distribution of walls and openings*

Torsion due to bad design

The vertical rigidity of the building should also be well distributed.

Change in the structural system from one floor to another or different building height would increase the damage potential.

Vertical ties should link the various floors and ring beams.

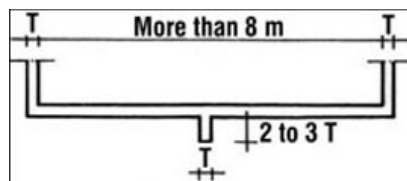*Vertical rigidity and vertical ties*

Simplicity

Simplicity in the ornamentation is the best approach. Large cornices, vertical or horizontal cantilevered projections, cladding materials, etc. are dangerous during earthquakes. They should be avoided.
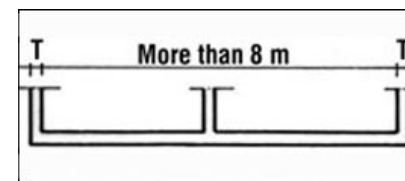
Foundations

Certain types of foundations are more susceptible to damage than others. Isolated footing of columns can easily be subjected to differential settlement, particularly when they rest on soft soils. Mixed foundations in the same building are also not suitable. What are working the best in most of cases are trench foundations.

Long walls

They should be designed as shear walls to resist the ground motion in the plane of the wall. To resist the bending moment occurred by the ground motion perpendicular to the wall, they should be braced 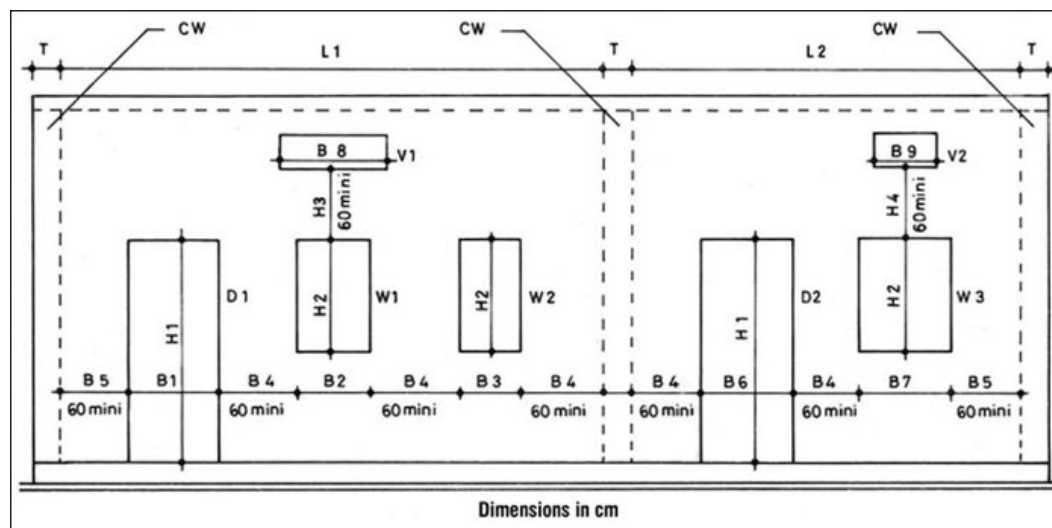either by a buttress or by a cross wall. Any opening in a wall should follow the specifications mentioned in the next paragraph.

Buttress in the centre

Cross wall near the centre

Openings

Doors and windows reduce the lateral resistance of walls to shear. Hence, they should preferably be small and rather centrally located. When a specific design cannot follow this basic specification, the specifications mentioned below (Indian Standards IS 4326: 1993) must be followed.

Various cases of openings

Where:
D_1, D_2 = Doors – W_1, W_2, W_3 = Windows – V_1, V_2 = Ventilators – CW = Cross walls – T = Thickness of cross walls
B_8 is wider than B_2 - B_7 is wider than B_9

	1 STOREY	2 STOREY	3 STOREY
B_1 +B_2 + B_3	$\leq 0.5\ L_1$	$\leq 0.42\ L_1$	$\leq 0.33\ L_1$
B_6 +B_7	$\leq 0.5\ L_2$	$\leq 0.42\ L_2$	$\leq 0.33\ L_2$
B_4	$\geqslant 0.5\ H_2$ (But not less than 60 cm)		
B_5	$\geqslant 0.25\ H_1$ (But not less than 60 cm)		
H_3	$\geqslant 0.5\ B_8$ (But not less than 60 cm)		
H_4	$\geqslant 0.5\ B_7$ (But not less than 60 cm)		
Notes: - H_3 is calculated from B_8, which is wider than B_2 - H_4 is calculated from B_7, which is wider than B_9			

DESIGN GUIDELINES FOR HOLLOW INTERLOCKING BLOCKS (HI CSEB)

Hollow interlocking compressed stabilised earth blocks must be bound by cement sand mortar, in order to get a homogeneous and cohesive masonry. The blocks should not be dry stacked. The design for these blocks should follow the basic design guidelines mentioned above. The following specifications should be added to increase the masonry strength. Note that the specifications hereafter are for the Auram blocks 245 and 295. Therefore, they might not apply for other types of interlocking blocks produced by other manufacturers, elsewhere in the world.

Trench Foundations and plinth

Any appropriate material can be used for the foundations. Stabilised rammed earth will be a very appropriate solution if the natural ground is suitable. Stabilised rammed earth foundations normally have a square section: i.e. 50 x 50 cm for a ground floor structure. Note that isolated foundations, like footings of columns, are not adapted.

On coastal areas, which are tsunami prone, buildings should have deeper foundations. Its minimum depth should be double the width: i.e. 50 cm wide x 100 cm deep. This will avoid the bearing ground of the foundations to be excavated by the flow.
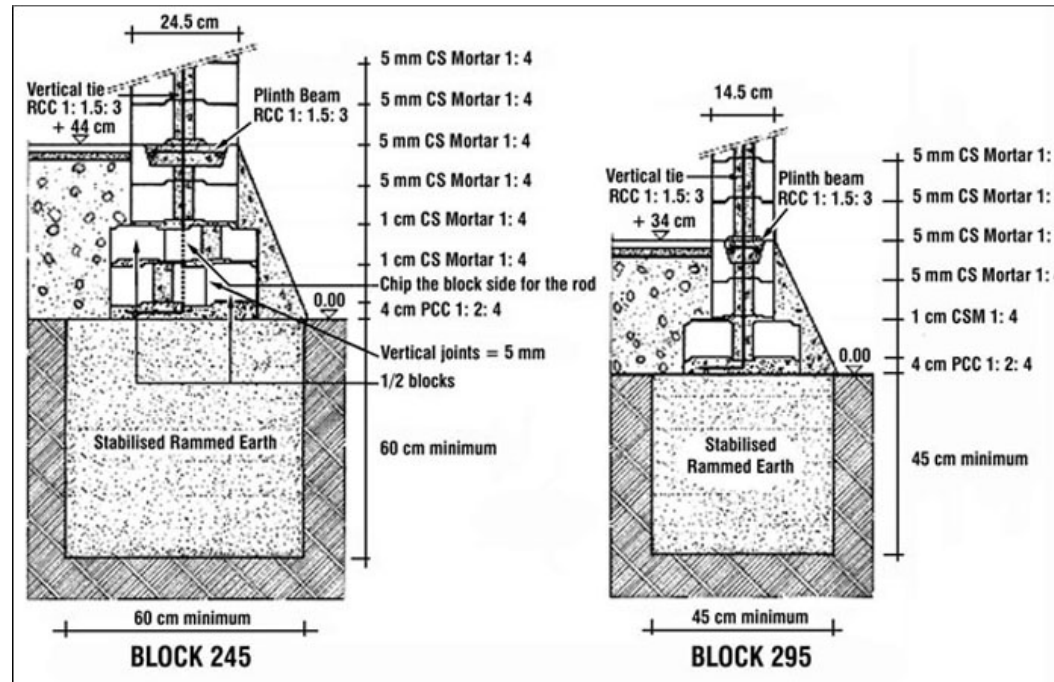If reinforced concrete foundation are to be used it is essential that the vertical ties are inserted very accurately from the bottom of the foundation.

Basement

It can be done with various materials, by steps or like a monolithic plinth. Note that the height of the basement varies with local conditions. The example shown below is the minimum height. A RCC ring beam is embedded at the top of the foundation and a plinth beam at the floor level should always be cast:

- At the top of the foundation (unless RCC foundations are used) is laid a first a reinforced concrete ring beam, 1 cement: 1.5 sand: 3 gravel, in which are anchored the vertical ties.
- It is essential to locate very accurately the vertical ties in the first reinforced concrete ring beam.
- Above it starts the step plinth and its height depends of the local conditions. The minimum height will be two blocks above the first concrete ring beam, as shown below.
- A plinth beam is laid on the basement and its top level will be the floor level. This plinth beam is cast in U blocks with 1cement: 1.5sand: 3gravel.
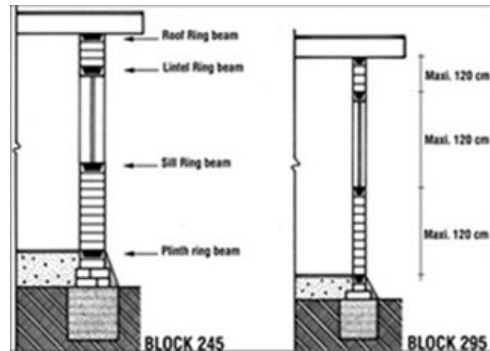
All courses of the step basement are laid in stabilised earth mortar, SEM: 1cement: 1 soil: 3 sand. The mortar thickness is everywhere 5 mm thick, for the horizontal and vertical joints. Note that on top of the plinth beam will be laid a damp-proof course of 1 cm thick with CS 1: 2 and waterproofing compound.
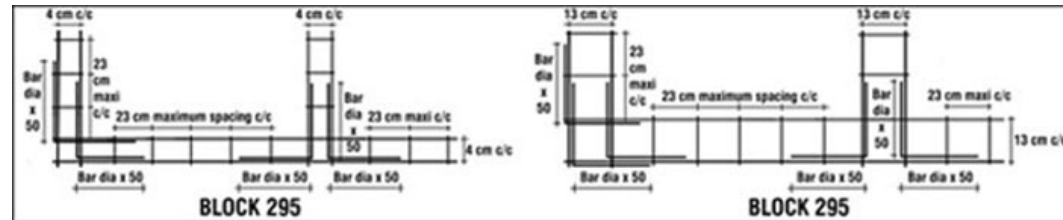

Stabilised rammed earth foundations

Ring beams

They should be regularly placed to tie horizontally the building. It must have 5 ring beams: The maximum vertical spacing between them should be 120 cm. Reinforcements are made with 2 bars of Ø 10 Tor Steel (TS) and stirrups Ø 6 Mild Steel (MS) @ 25 cm c/c maximum. Angles should be reinforced with angle bars of Ø 10 TS (50 cm side), distributed as follow:
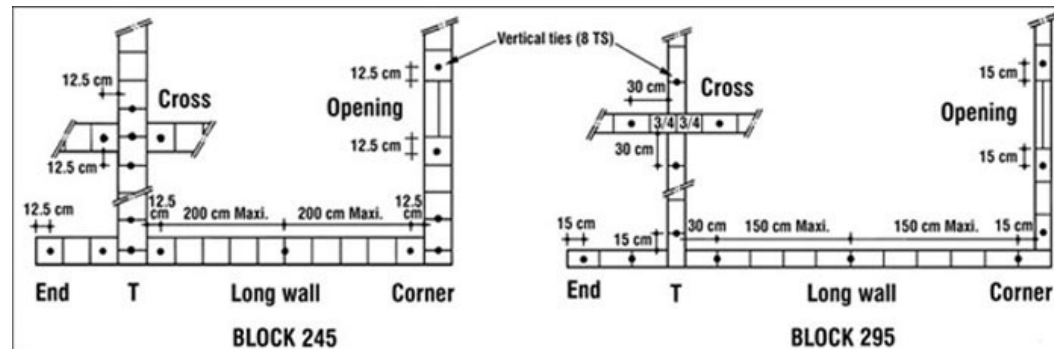
Section on vertical ring beams

Position of reinforcement with angle bars

Vertical ties

The four ring beams are tied together with vertical ties (Ø 10 TS), so as to create reinforcement net. The vertical ties are laid on the foundation and anchored in a PCC 1: 1.5: 3, just below the first course of the plinth. The bars should be bend 30 cm in the PCC and their height will not exceed 150 cm, so as to slide down the blocks. The overlap of the extension rod will be 50 times the bar diameter (50 cm for Ø 10 TS).
They should follow these spacing:

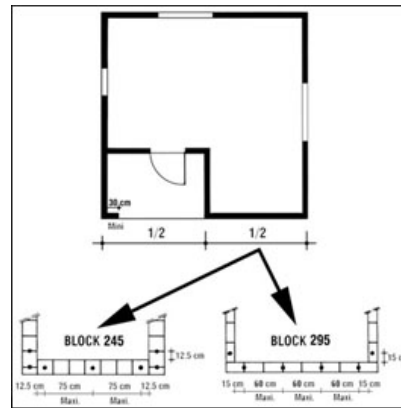|	BLOCK 245	BLOCK 295
Long walls	Maximum every 200 cm	Maximum every 150 cm
Openings	1 bar, on either side, in the first hole, (At 12.5 cm)	1 bar on either side, in the first hole, (At 15cm)
L Corner walls	1 bar on either side, in the first hole from the inside corner (At 12.5 cm) 1 bar centred in the L	1 bar on either side, in the first hole from the inside corner (At 15 cm)
T Cross walls	1 bar on 3 sides, in the first hole from the inside corner (At 12.5 cm) 1 bar centred in the T	1 bar on 3 sides, in the first hole from the inside corner (2 bars at 30 cm, on the length and 1 bar at 15cm on the T)
X Cross walls	1 bar on 4 sides, in the first hole from the inside corner (At 12.5 cm) 1 bar centred in the X	1 bar on 4 sides, in the first hole from the inside corner (At 30 cm)

Location of the vertical ties

Large opening

In case of a large opening in a facade (i.e. veranda), it must have a shear wall at least on one side, or several smaller shear walls. The total length of these small shear walls will not be less than the half of the front facade. This (these) shear wall(s) will be more reinforced:

Vertical ties ($\varnothing$ 10 TS) will be placed in the first hole close to the end or corner and at maximum spacing between them of 60 cm (block 295) or 75 cm (block 245).

In the case of a veranda, the sidewall will be reinforced with a buttress, not less than 30 cm, from the inside corner.

Vertical ties for a large opening

Binders

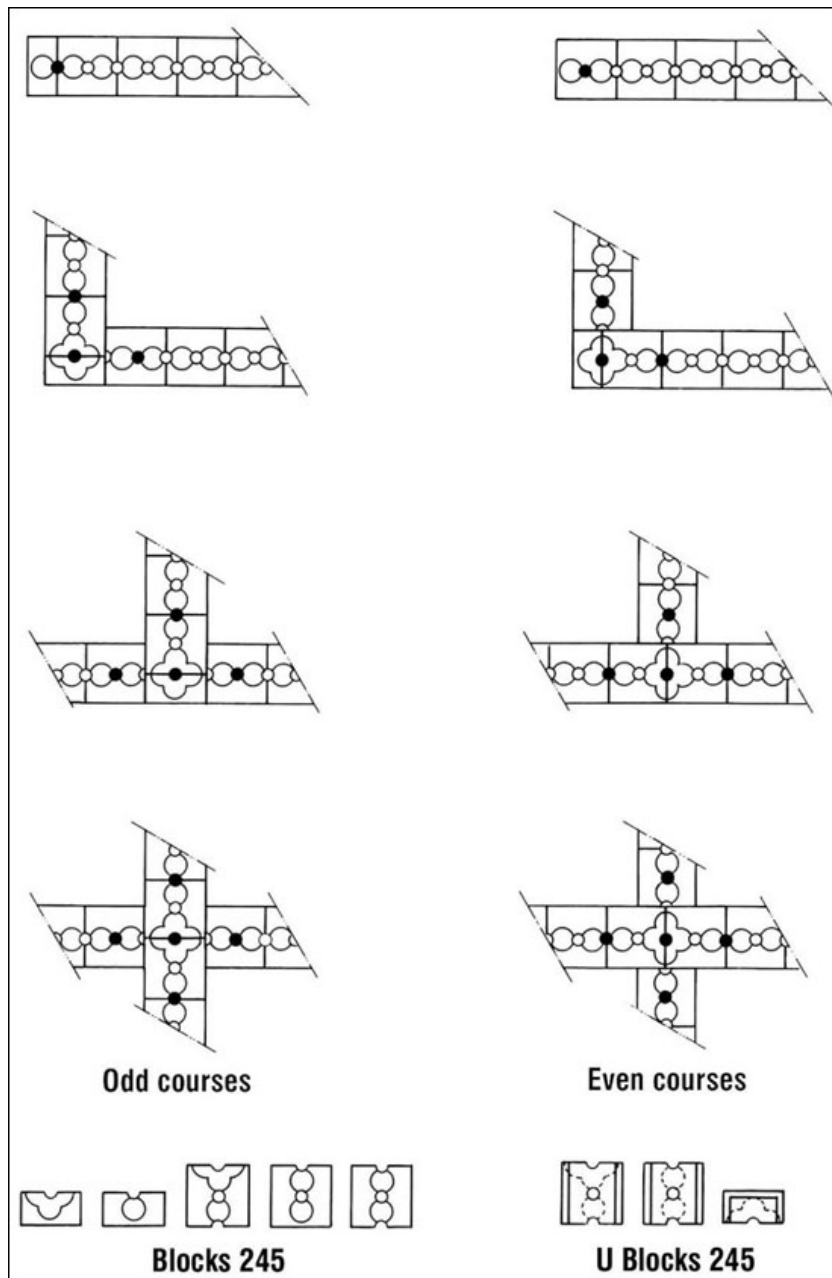- **Cement Earth Sand Mortar – SEM 1: 1: 3**
  All courses should be bound by cement stabilised earth mortar 1 cement: 1 soil: 3 sand. It should be plastic and not too liquid. The soil should not have more than 20-25 % of clay. All joints, horizontally and vertically, are 5 mm thick.

  All joints, horizontally and vertically, are 5 mm thick. Note a cement sand mortar (i.e. 1: 4) will have a very low workability as the mortar thickness is only 5mm.
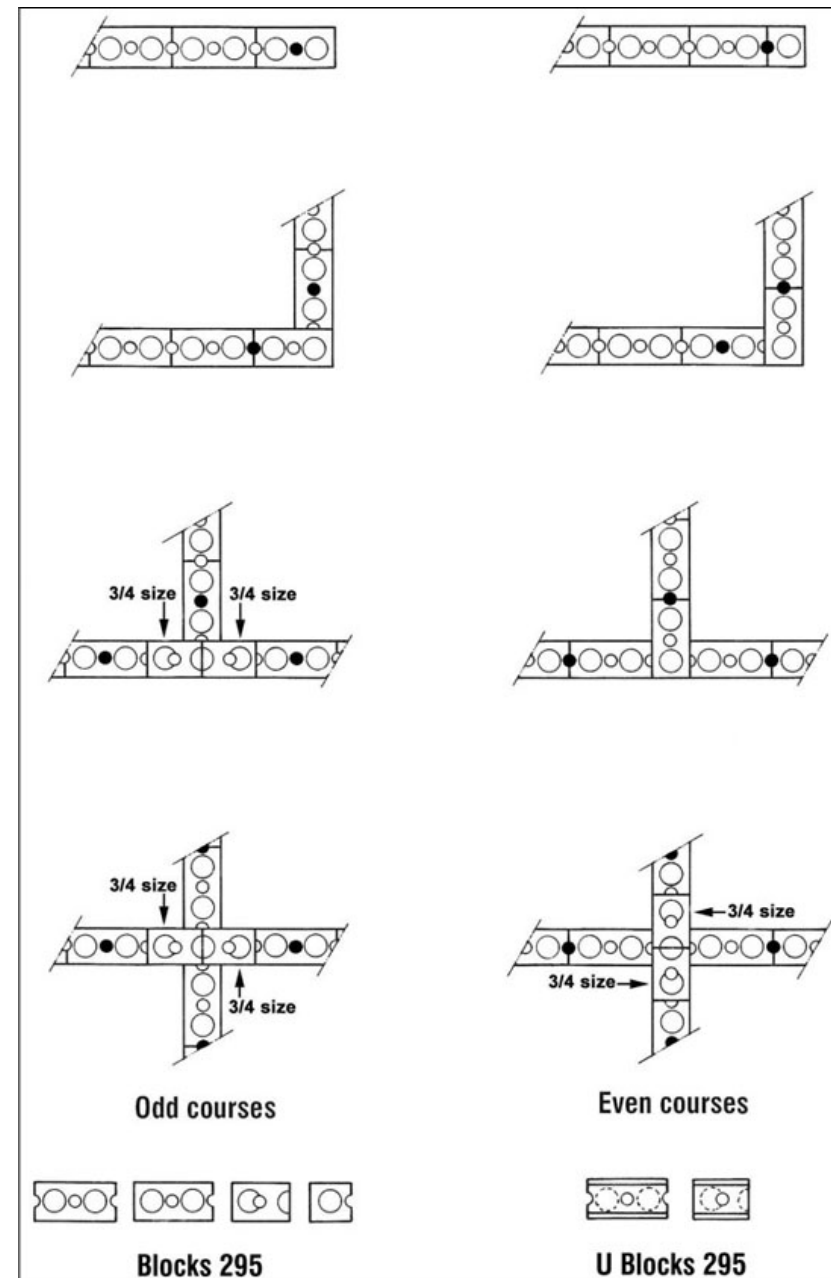
  Note for all courses: The blocks must be soaked before being laid and a well-laid block is impossible to remove with one hand because it sticks well to the cement sand mortar.

- **Plain Cement Concrete – PCC 1: 1.5: 3**
  All the holes, with or without reinforcement, are filled with plain cement concrete 1: 1.5: 3. The plasticity of the concrete is rather fluid, but not liquid. It should flow well in the holes without being a soup. It is essential to compress very well the concrete with a steel rod.

Odd courses   Even courses

Blocks 245   U Blocks 245

Bonds with the blocks 245

3/4 size   3/4 size

3/4 size

3/4 size

3/4 size

3/4 size

Odd courses   Even courses

Blocks 295   U Blocks 295

Bonds with the blocks 295