FOR HOUSE-HOLDS

TECHNICAL HANDBOOK ON

Design, Construction and Renovation of Typhoon-Resilient Low-Income Housing

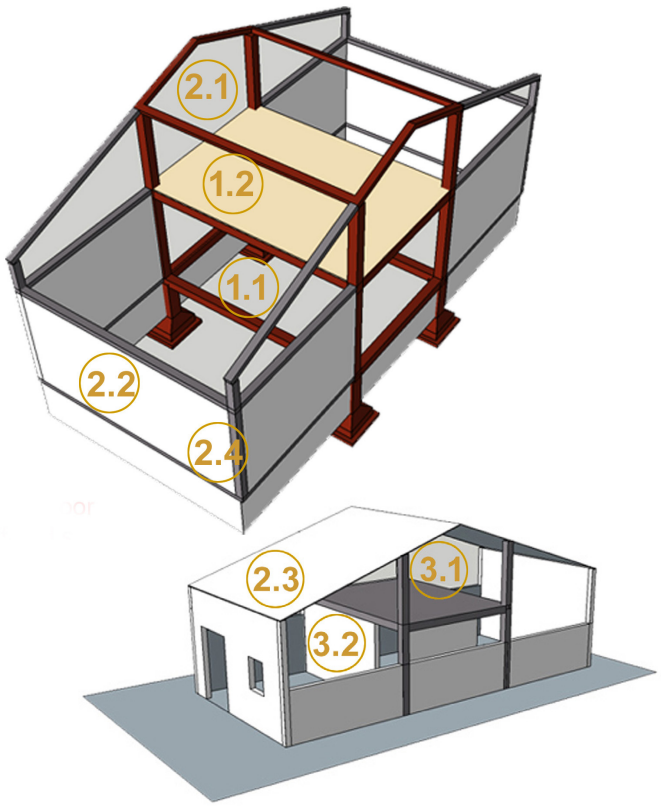
Typhoon-resilient houses can have different forms depending on the characteristics of the land and socio-economic conditions of each household. The principles for typhoon resilience recommended in this document, however, should be strictly followed in the housing design process.

1 ROBUSTNESS

Robustness anticipates the potential breakdown of systems and ensures failure is safe (called *safe failure*). Failures in one system can be compensated in another, thus avoiding severe impacts.

1.1 One room in the house is designed with a reinforced concrete (RC) frame combined with an RC slab to form a safe box where occupants can find refuge in case of a severe typhoon. This room protects occupants even if other parts of the house collapse.

1.2 The room on the second floor serves as shelter for occupants if the first floor is flooded.



2 REDUNDANCY

Redundancy refers to the spare capacity to absorb extreme pressures. Interacting components are composed of similar parts that can replace each other if one or many fail.

2.1 The main structure of resilient housing is designed to be stronger than that of traditional housing. All building parts are securely connected such that ring beams, concrete slabs and posts form a solid structure.

2.2 Simple rectangular building forms with gable roofs at a 30-45^0 angle reduce wind pressure placed on the structure.

2.3 Roof overhangs are protected to reduce wind impacts that damage the roof's structure.

2.4 The reinforced concrete posts and brick walls are securely connected by steel bars with a diameter of 8 millimeters (mm).

3 FLEXIBILITY

Flexibility refers to viable changes in response to varying circumstances. Assets and functions are distributed so they are not all affected by a given event at once, and provide multiple ways of meeting a need.

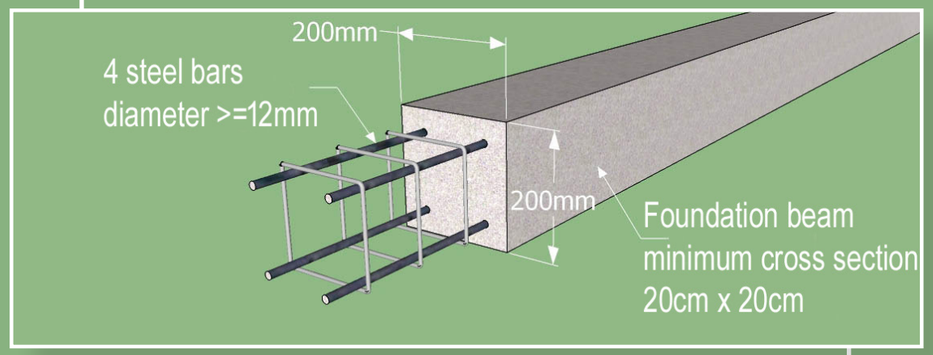
3.1 The function of each room is flexible. For example, the room on the second floor of the safe box can be used as a flood shelter, bedroom, study room, altar or storage.

3.2 All materials used for housing construction are locally available and technical designs are simple to apply.

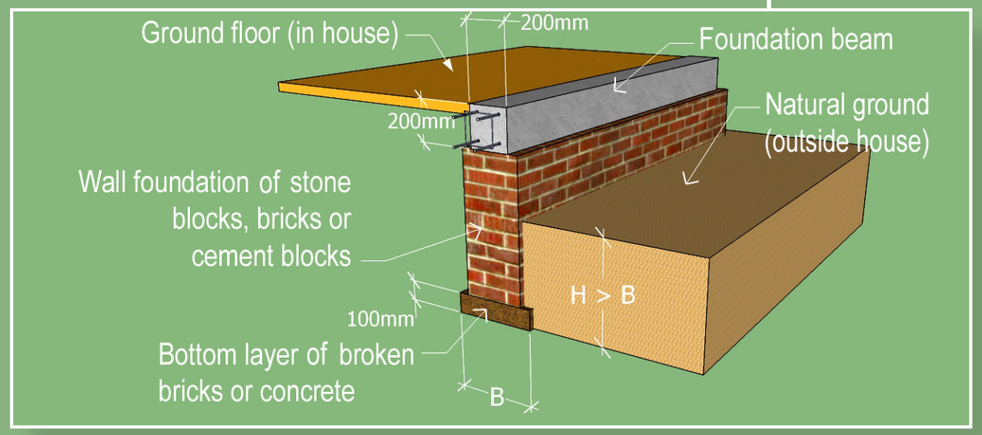
FOUNDATION

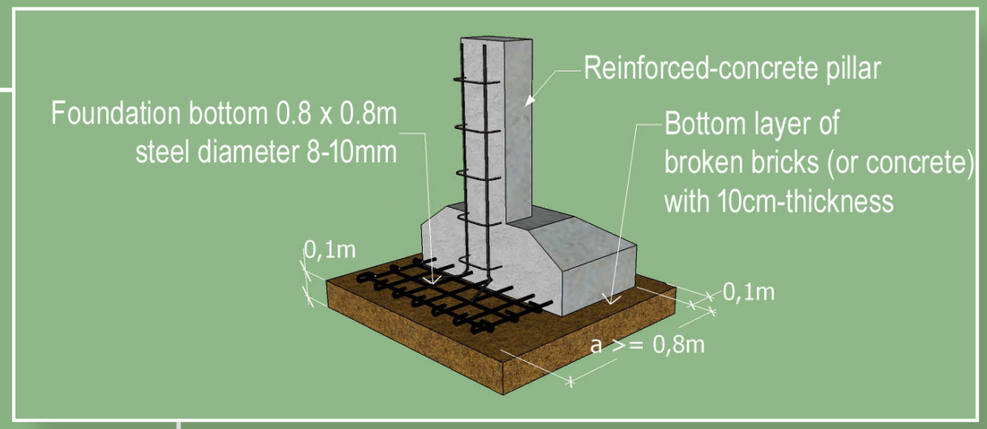
The ground floor should be above the annual average flood level (if in flooded area).

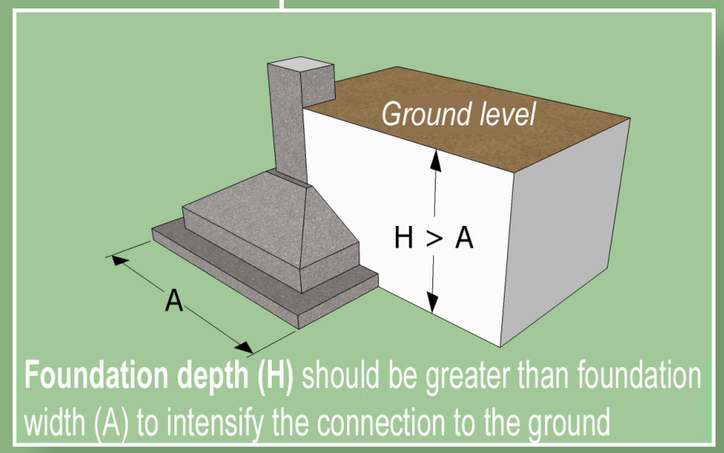
Steel bars at the bottom of the pillars should be perpendicular, diameter ≥ Φ10 mm.



The lower part of pillars, from the foundation bottom to the ground floor, should have a minimum cross section area of 20 cm x 20 cm.

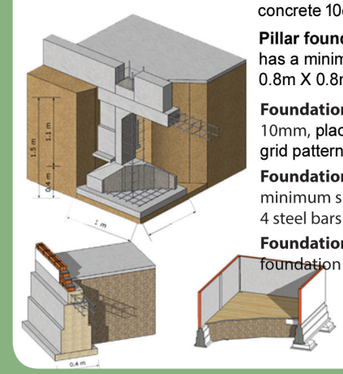






The foundation beam should be the same height as the ground floor, continuously going around the house. Minimum steel reinforcement: four steel bars Φ12 mm, steel wire Φ6 mm, 15 centimeter (cm) spacing.

FOUNDATION OF STORM SHELTER



Foundation bottom layer made of broken bricks or concrete 10cm-thick

Pillar foundation bottom has a minimum area of 0.8m X 0.8m

Foundation steel Φ ≥ 10mm, placed in a grid pattern

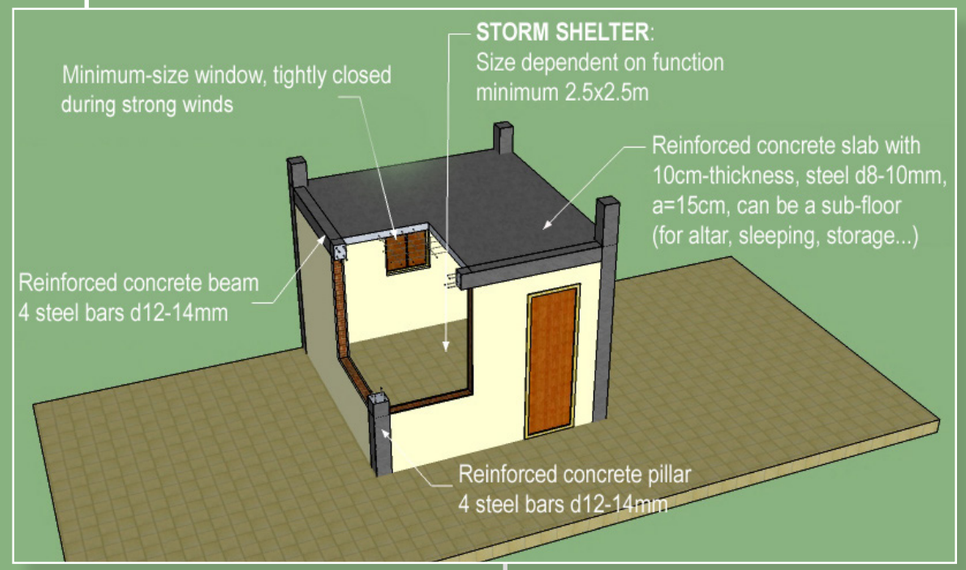
Foundation beam has a minimum size of 20x20cm, 4 steel bars Φ ≥ 12mm

Foundation depth ≥ foundation width

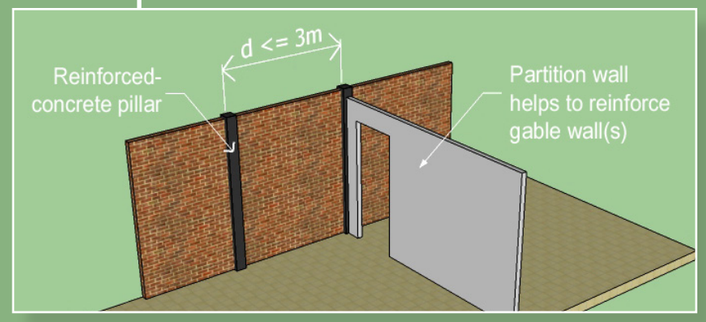
The area of the pillars' bottom should be at least 80 cm x 80 cm, with a 10 cm-thick layer of broken bricks or concrete underneath and extended outside the pillars' bottom, 10 cm per side.

The depth of the foundation should be greater than the width, usually at least 0.5 m (for normal ground). The foundation of the wall is made of stone blocks, cement blocks, or solid bricks with a width 5 cm greater than the foundation beam on each side.

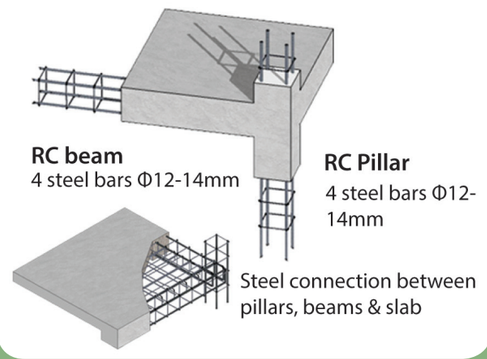
WALL



Foundation beam at the top of walls should have the same height reinforcement: four steel bars Φ10–12 mm, steel wire Φ6 mm, 15 cm spacing.



BEAM & PILLAR FOR STORM SHELTER

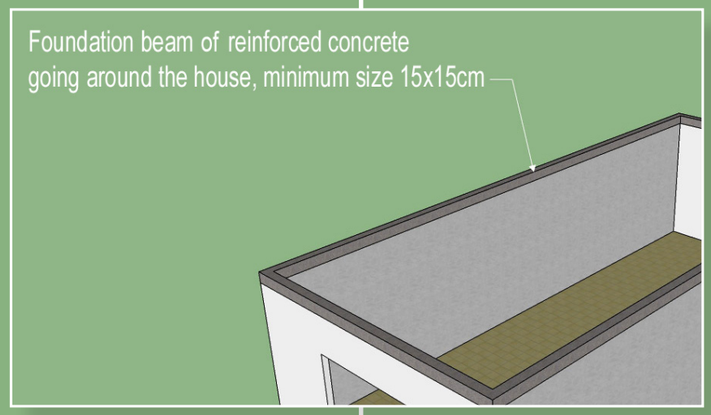


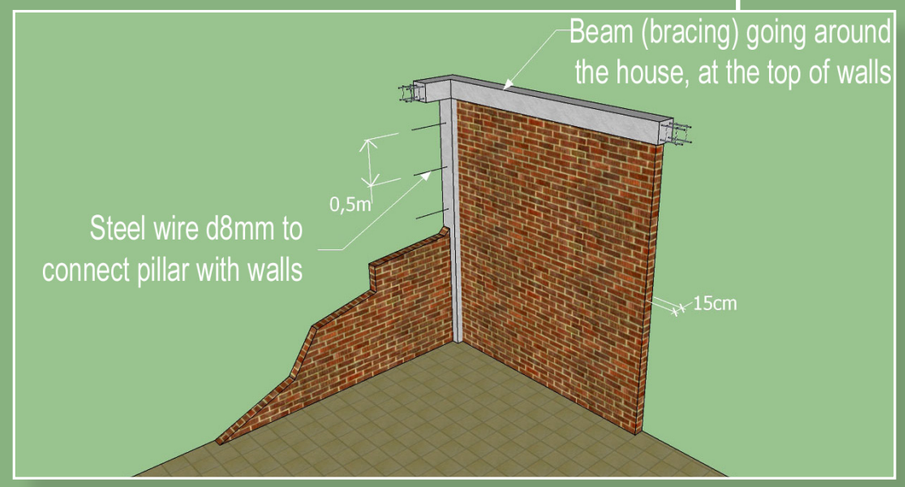
Reinforced concrete pillars are securely connected with the foundation beam and ring beam at the top of walls.

Place steel wire Φ6mm inside the reinforced concrete pillars when casting them, extending a minimum of 40cm horizontally into the wall space, 0.5m vertical spacing.

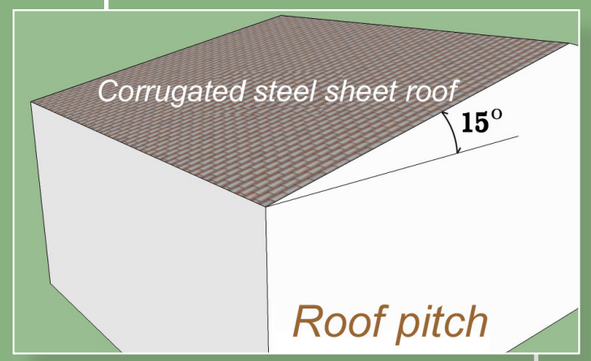
Walls are usually built with six-hole bricks:

- External (envelop) walls: lay bricks horizontally, with a wall thickness of at least 15cm.
- Internal (partition) walls: lay bricks so that wall thickness is at least 10cm.





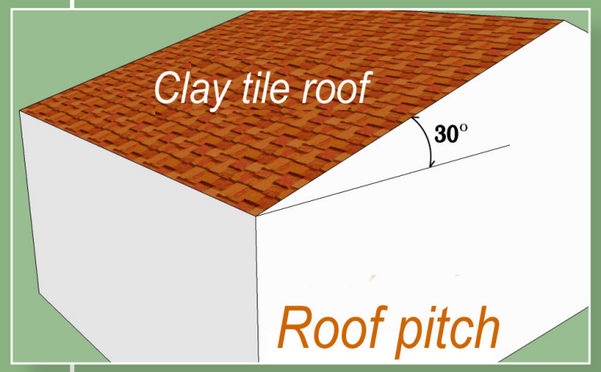
ROOF

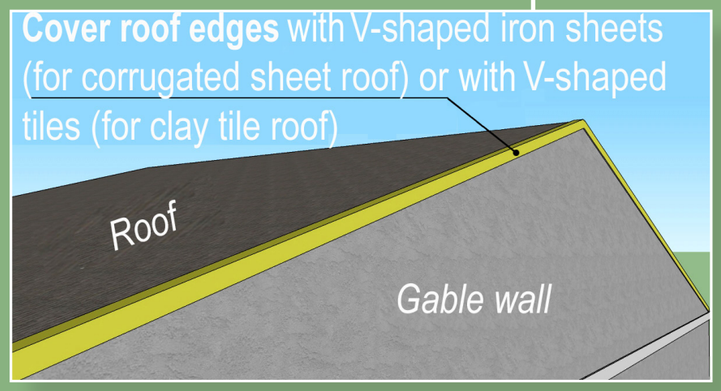


The veranda roof and the main house roof should be separated, including corrugated steel sheet and tile roofs.

The house should have a ceiling under the roof to reduce blowoff effects caused by storm wind. The distance from the floor to the ceiling should be from 3.6 m to 4.0 m.

Avoid extending the roof beyond the walls. Cover the roof edges with V-shaped steel sheets (for corrugated steel sheet roof) or with V-shaped tiles (for tile roof).

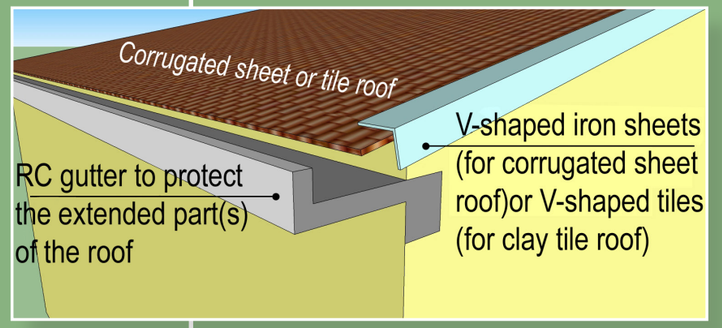


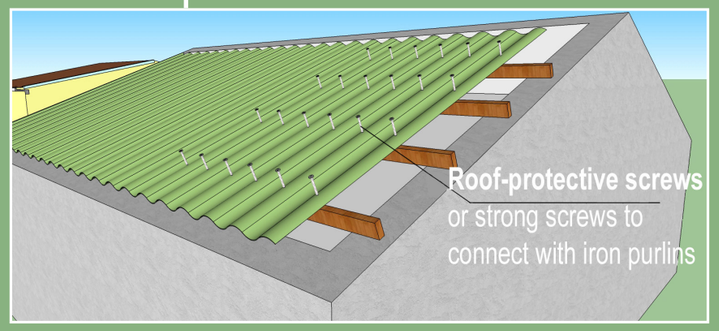


Use roof tiles with holes so tiles can be tightened to roof frame underneath. Tighten using plastic wire every two tiles.

For corrugated steel roofs, use sheets with a minimum thickness of 0.4mm. Use bracing bars on roof cover (V-shaped steel bars, wooden bars, or bamboo bars) tightly tied to roof purlins.

Do not use fibrocement sheets as roof cover for health safety reasons.





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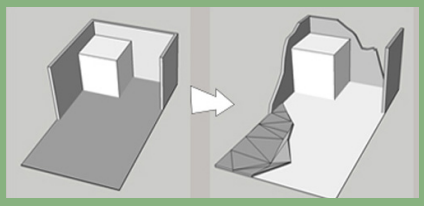
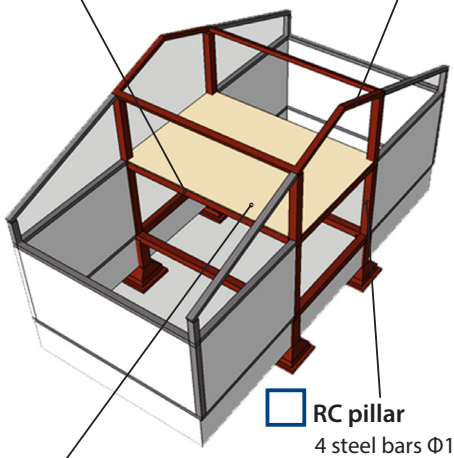
FOR HOUSE-HOLDS



STORM SHELTER: a safe place for storm risk reduction that has foundations, pillars, beams and slabs made of reinforced concrete (RC)

RC wall beam
4 steel bars Φ10-12 mm

RC beam
4 steel bars Φ12-14 mm



RC pillar
4 steel bars Φ12-14 mm

RC slab
Thickness ≥ 8 cm, steel net Φ ≥ 8 mm

FOUNDATION ON THE GOOD-CONDITION GROUND

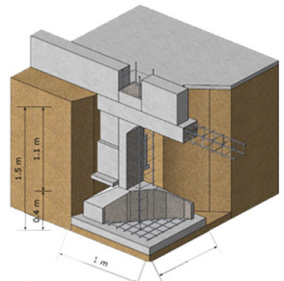
Foundation bottom layer made of broken bricks or concrete, 10 cm-thick

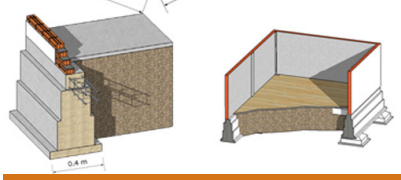
Pillar foundation bottom has a minimum area of 0.8 x 0.8 m

Foundation steel Φ ≥ 10 mm in grid pattern

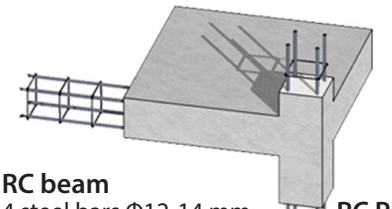
Foundation beam has a minimum size of 20 x 20 cm, 4 steel bars Φ ≥ 12 mm

Foundation depth ≥ foundation width



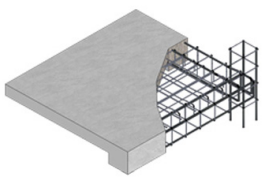


RC PILLAR & BEAM



RC beam
4 steel bars Φ12-14 mm

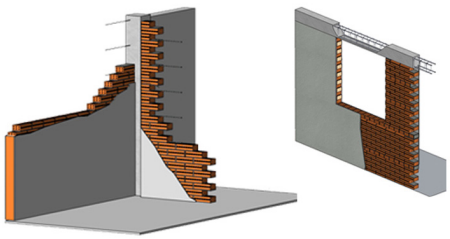
RC Pillar
4 steel bars Φ12-14 mm



Steel connection between pillars, beams and slab

WALL

Steel wire Φ6 mm to connect RC pillars with walls, distance between wires ≤ 0.5 m



Six-hole brick wall with minimum thickness of 15 cm for envelop walls (outside the house), 10 cm for partition walls (inside the house)

RC SLAB

RC Slab
Thickness ≥ 8 cm, steel Φ ≥ 8 mm, net spacing ≤ 20 cm