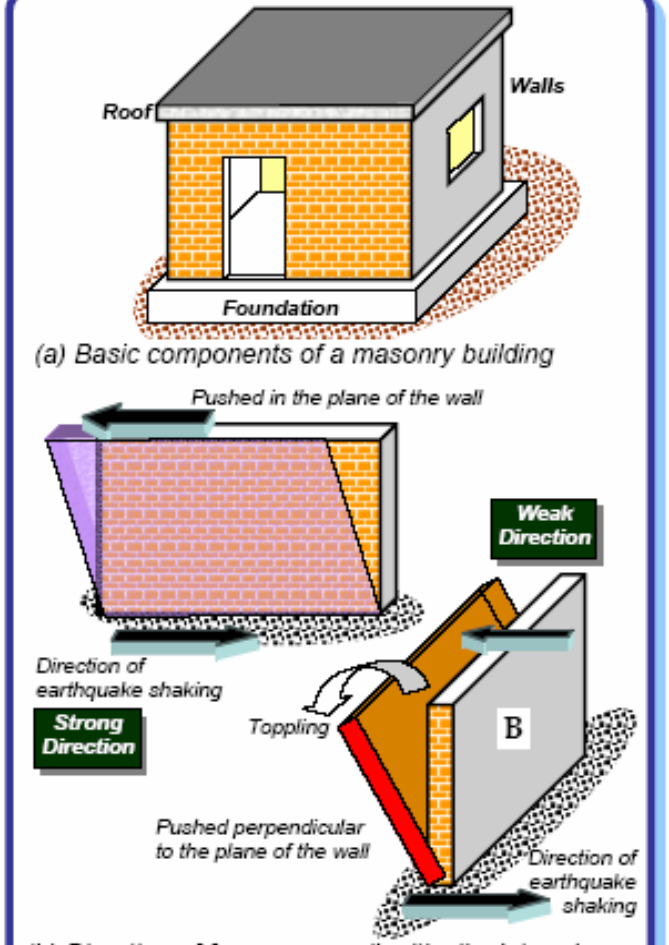
CONNECTIONS

Good connections are critical for good performance of confined masonry buildings in earthquakes. Unreinforced or unconfined masonry walls fail in earthquakes. Good connections are necessary between

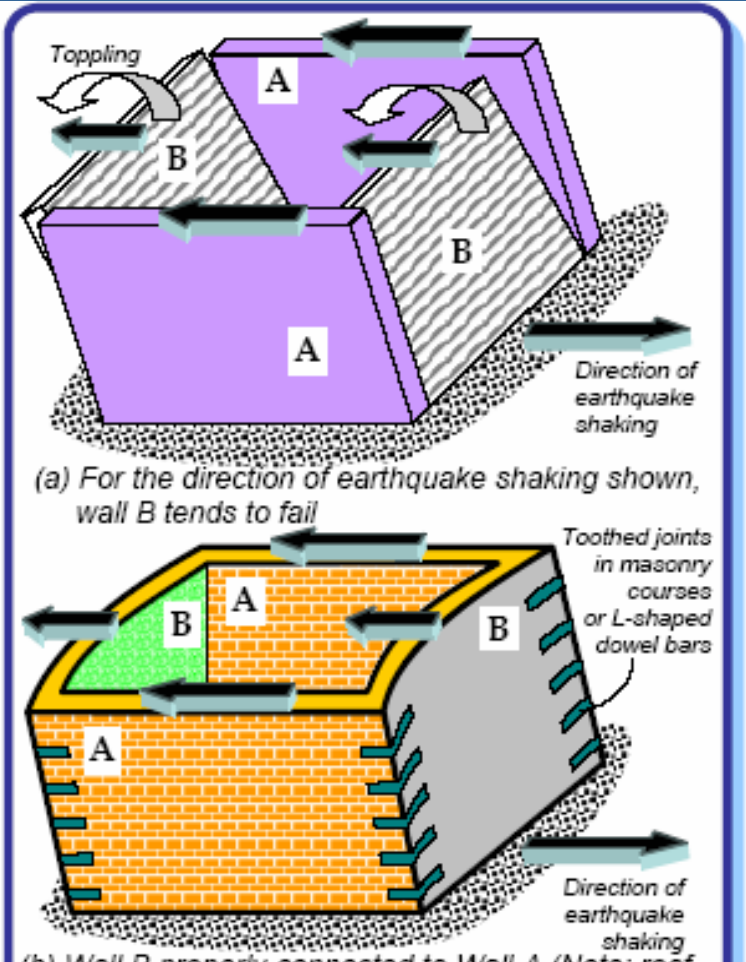
- All masonry walls
- All confining elements
- Foundation and walls
- Tie columns and walls
- Bond beam and walls
- Bond beams and tie columns
- Ring bond beam and roof



(a) Basic components of a masonry building

(b) Direction of force on a wall critically determines its earthquake performance

Figure 1: Basic components of a masonry building – *walls are sensitive to direction of earthquake forces.*



(a) For the direction of earthquake shaking shown, wall B tends to fail

(b) Wall B properly connected to Wall A (Note: roof is not shown): Walls A (loaded in strong direction) support Walls B (loaded in weak direction)

Figure 2: Advantage sharing between walls – *only possible if walls are well connected.*

from IITK-bmtpc Earthquake Tip #12

Function of Bond Beams (Sloof, Ring Balok)

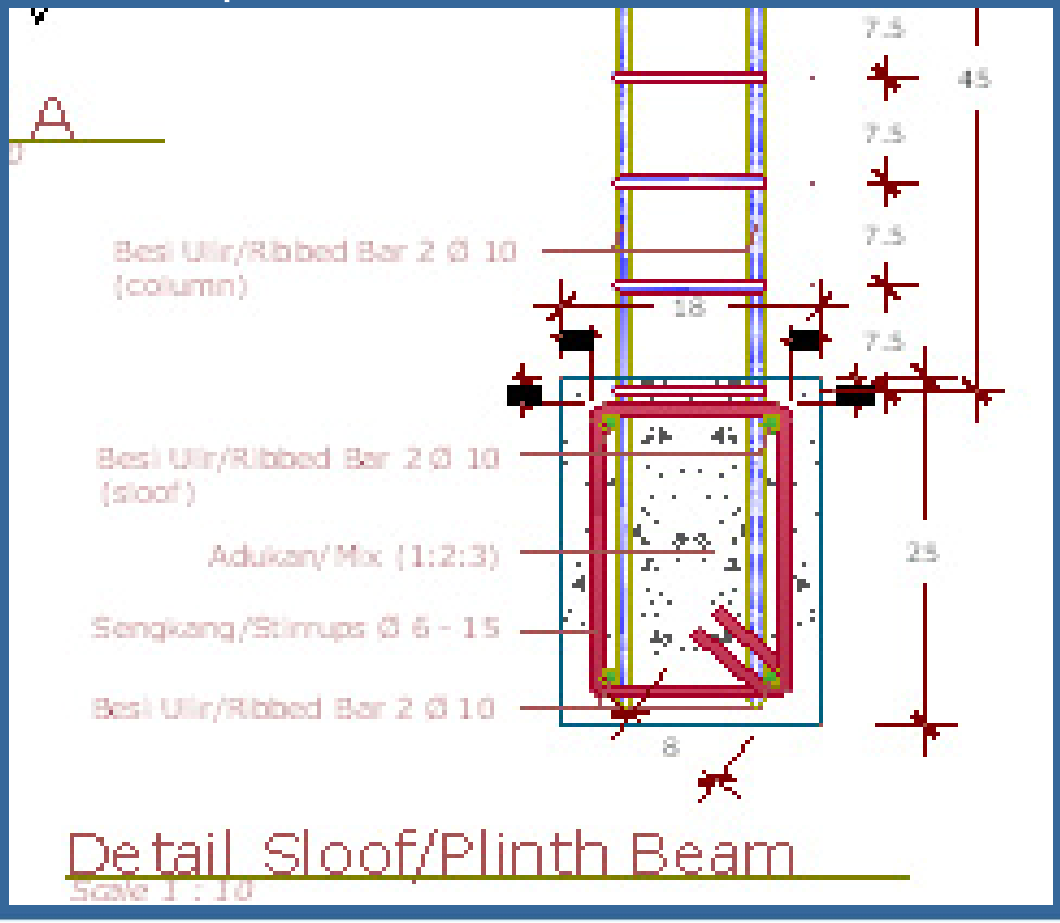
Bond Beams – required at foundation and on top of all structural walls. WHY:

- Tie the walls together at the roof and floor level
- Anchors the RC tie columns
- Ring beam confines the walls from vertical movement and makes it more difficult for wall to tip over or fail out-of-plane
- Confining action results in better initial stiffness, shear crack strength, and ultimate lateral load capacity of the wall

Design for Aceh: Plinth Tie Beam (Sloof)

	BRR	build change	Why We Deviate
Section	15 x 20	18 x 25	→ Uncertainty in soil conditions → Too difficult to fit 15 x 15 column with 15 x 20 plinth beam
Long bars	ϕ12mm smooth	ϕ10mm ribbed	→ Too difficult to cut and bend → Space for cover, confinement → Justified with engineering calcs
Stirrups	ϕ8mm	ϕ6mm 8cm long hook	→ Too difficult to BEND → Justified with engineering calcs
Stirrup spacing	15 cm	15 cm	→ Calcs indicate spacing could be increased to 30 cm away from joint
Cover	Not specified	2.5 cm	USE BETON TAHU (concrete spacer)

With a 15 x 20 sloof and a 15 x 15 column, it is very difficult to fit column steel inside beam steel and at the same time maintain sufficient cover over the concrete in the sloof, and at the same time maintain sufficient space between the long bars in the column, so as to be able to bend a stirrup that is square, not round!



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Smooth vs. Ribbed? 10mm vs. 12mm?

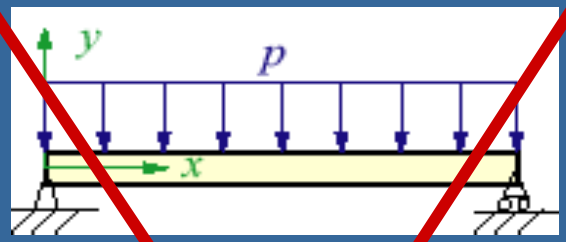
IN THEORY:

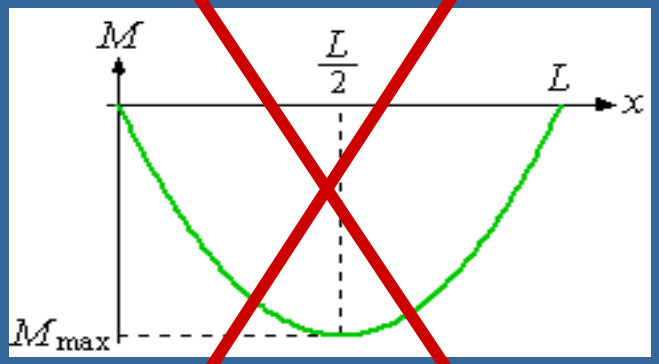
- 12mm bar provides greater strength in tension than a 10mm bar *if the steel is the same and both bars are properly developed and covered with sufficient concrete*
- Ribbed bar provides greater strength in tension than a smooth bar *if the steel is the same and both bars are properly developed and covered with sufficient concrete*

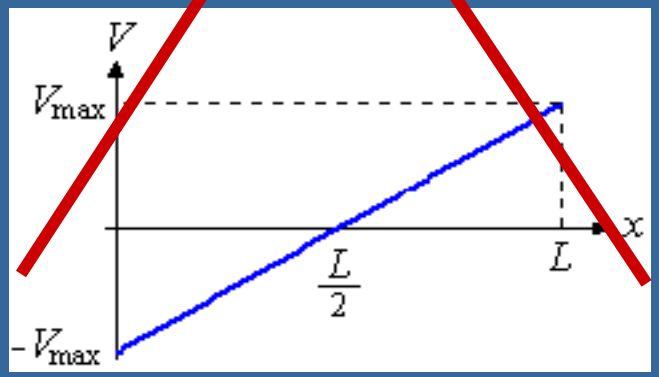
IN PRACTICE:

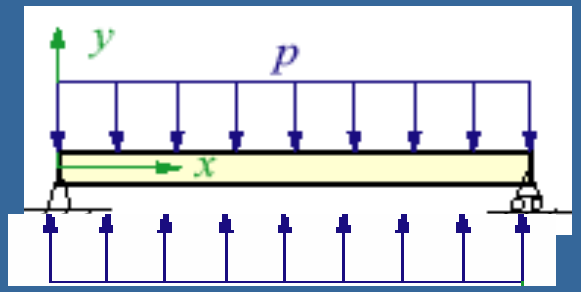
- (Our limited) test data does not show a significant difference in tensile strength between ribbed vs. smooth bars
- (Our limited) test data does not show a significant difference in tensile strength between 12mm vs. 10mm diameter bars
- (Our limited) test data indicates a significant variation in strength of steel on the market in Aceh
- (Our limited) test data indicates that actual bar diameter is 0.5 – 1mm smaller than claimed

“Tie Beams” are Not Beams – they are uniformly supported by strip footing or masonry wall

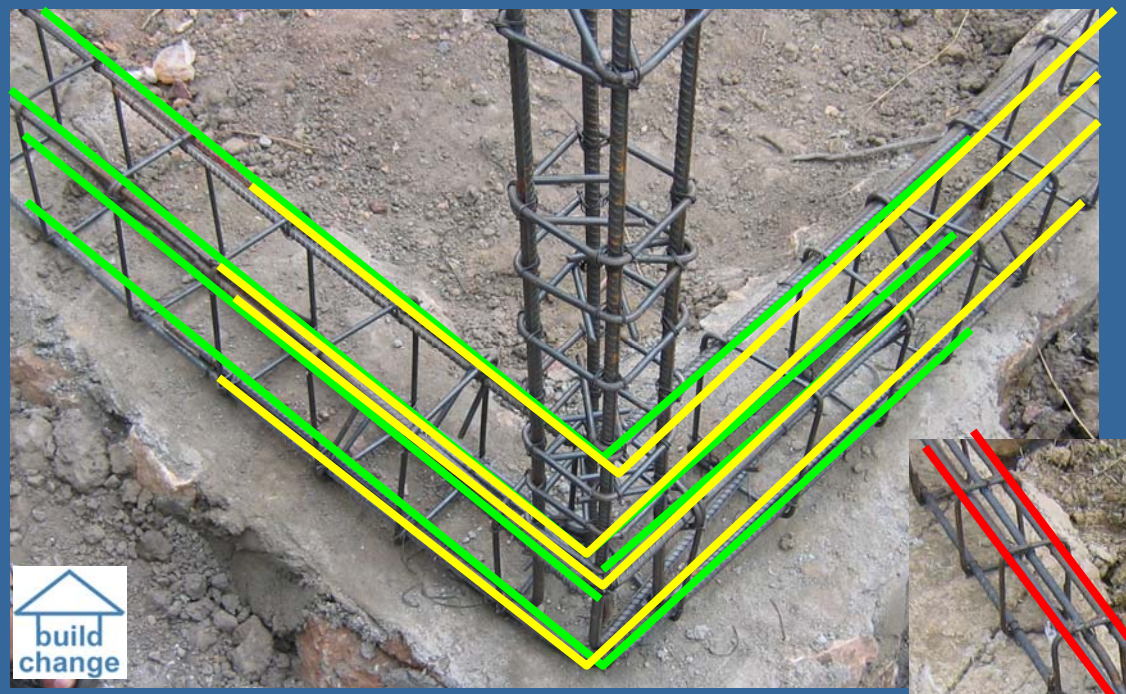








Connections, Laps are CRITICAL



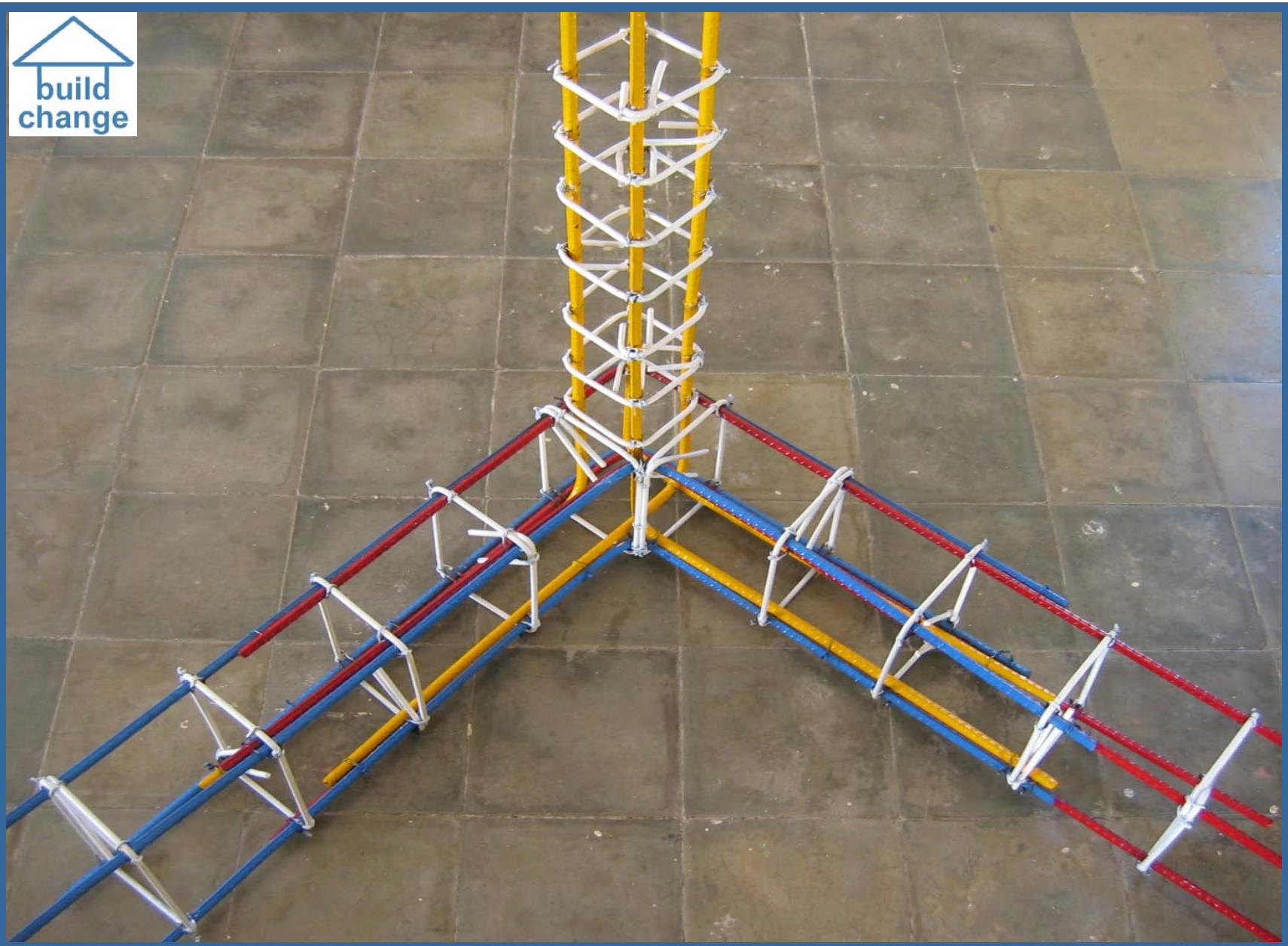
No matter what size bars you are using!!

Bad Practice (Buruk)

→ *Long bars terminate in the joint*

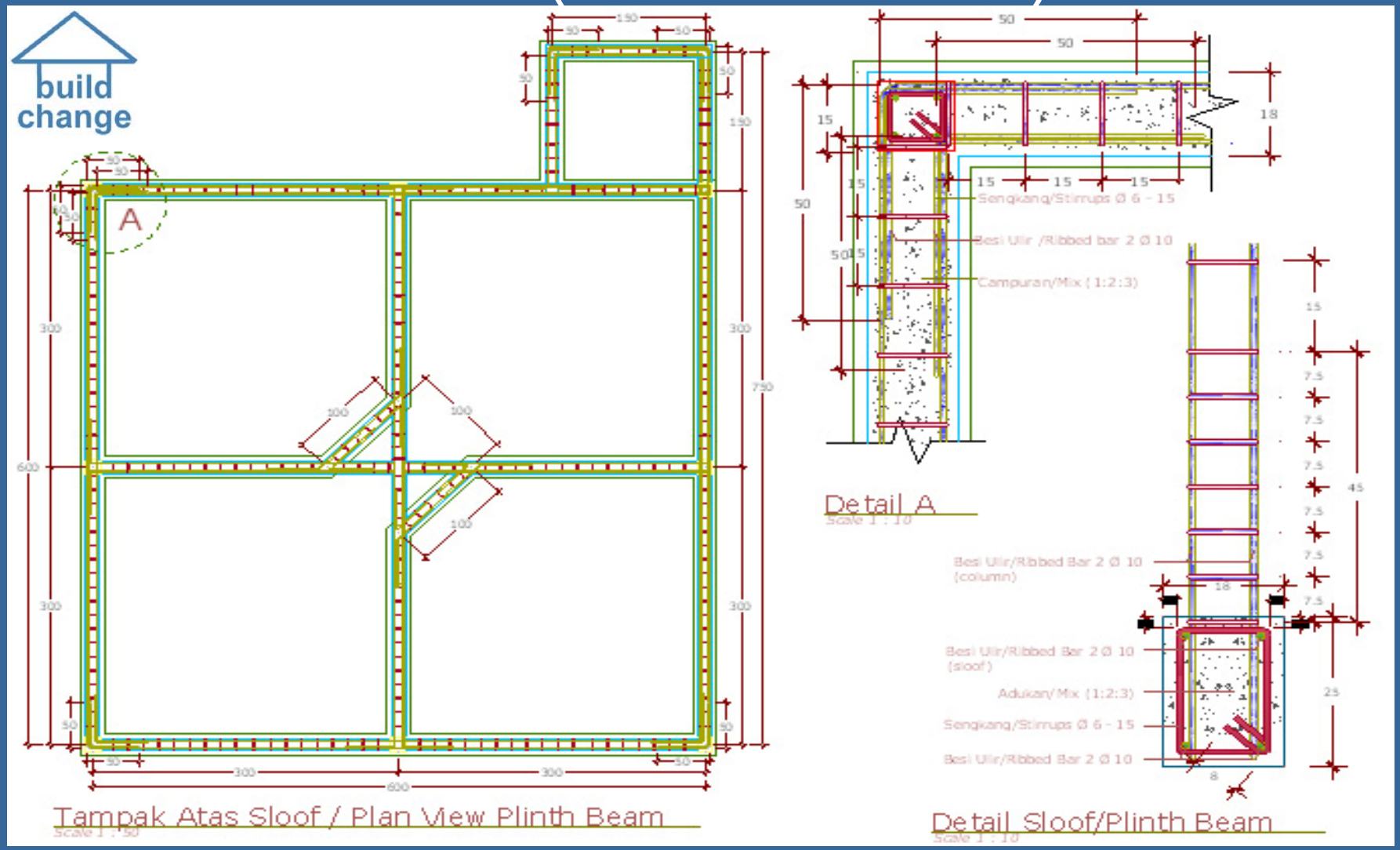
Good Practice (Baik)

→ *Long bars pass through corner and overlap 40-50 times diameter of rod for ribbed bars, twice that for smooth*



Build Earthquake Resistant Houses
Change Construction Practice Permanently

Overlaps of 40-50 Times Diameter of Rod at all Joints (for Ribbed Bars)



Build Earthquake Resistant Houses
Change Construction Practice Permanently

build change

Design for Aceh: Plinth Tie Beam (Sloof)

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Section	15 x 20	18 x 25	→ Uncertainty in soil conditions → Too difficult to fit 15 x 15 column with 15 x 20 plinth beam
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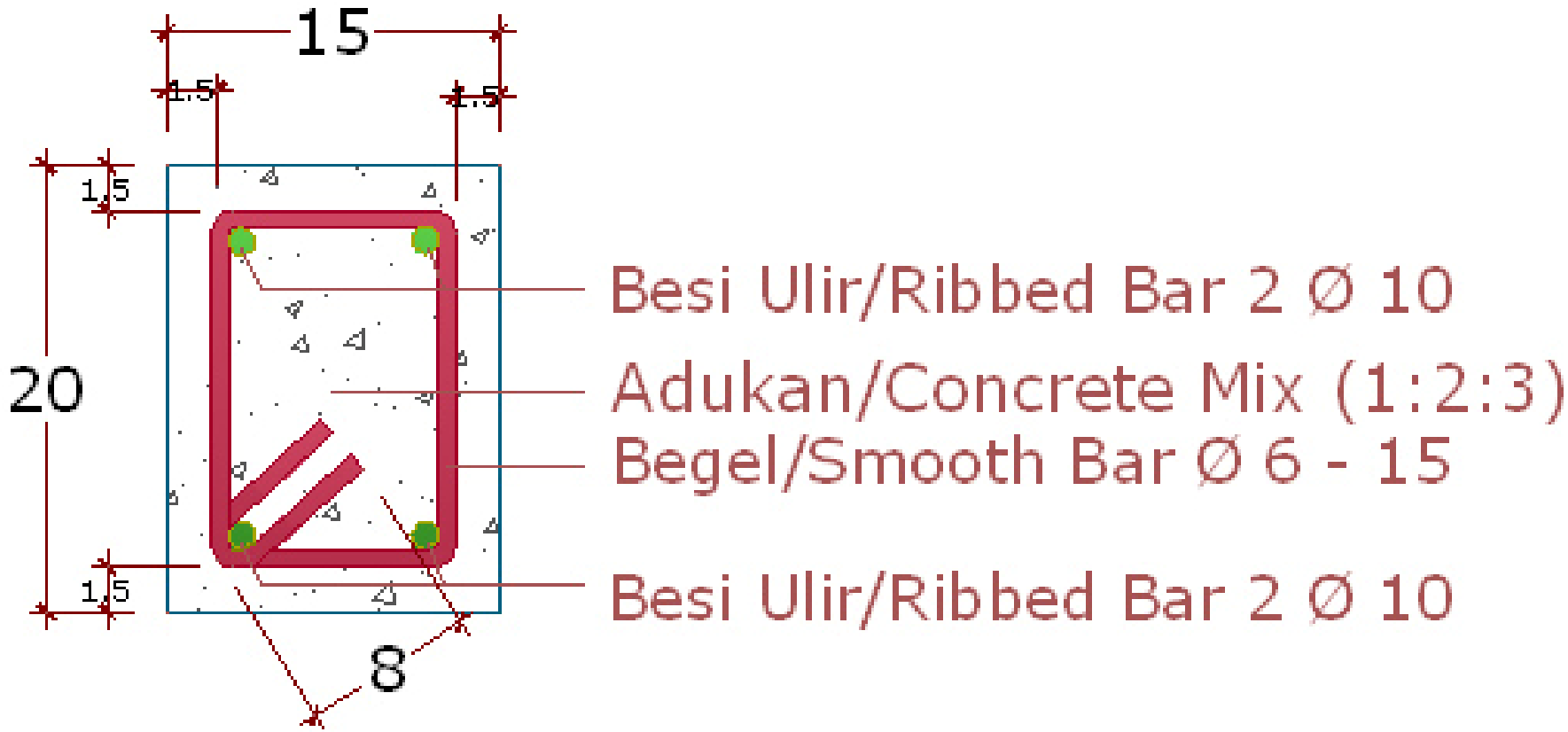
Stirrup spacing	15 cm	15 cm	→ Calcs indicate spacing could be increased to 30 cm away from joint
Cover		2.5 cm	USE BETON TAHU (concrete spacer)



Detail Ring Balk/Ring Beam

Scale 1 : 10

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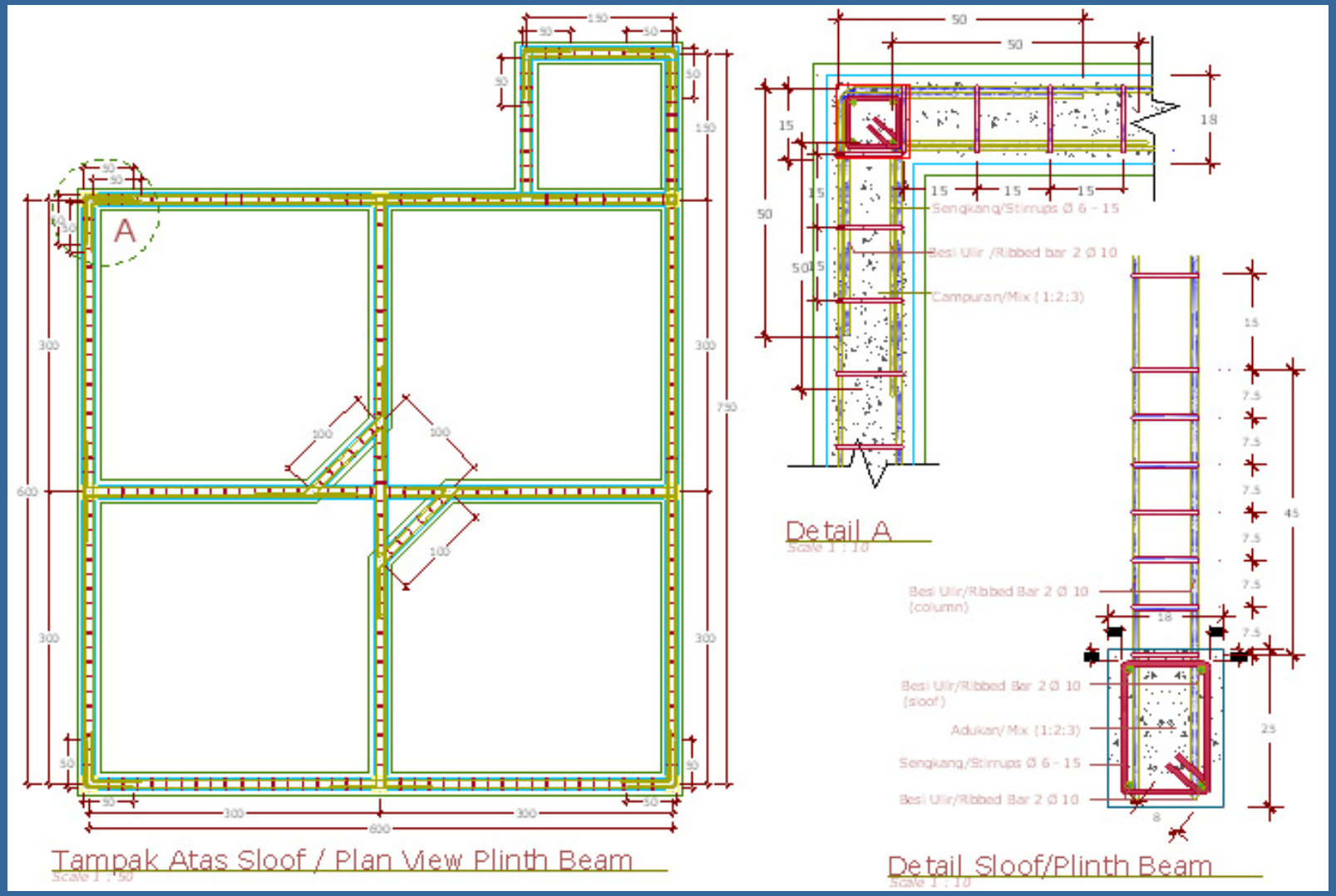
Stirrups	ϕ8mm	ϕ6mm 8cm long hook	→ Too difficult to BEND → Justified with engineering calcs
Stirrup spacing	15 cm	15 cm	→ Calcs indicate spacing could be increased to 30 cm away from joint
Cover	Not Specified	2.5 cm	USE BETON TAHU (concrete spacer)

Design for Aceh: Ring Bond Beam (Ring Balok)

	BRR	build change	Why We Deviate
Section	15 x 20	15 x 20	
Long bars	ϕ12mm smooth	ϕ10mm ribbed	→ Too difficult to cut and bend → Space for cover, confinement → Justified with engineering calcs
Stirrups	ϕ8mm	ϕ6mm 8cm long hook	→ Too difficult to BEND → Justified with engineering calcs
Stirrup spacing	15 cm	15 cm	→ Calcs indicate spacing could be increased to 30 cm away from joint
Cover		1.5 cm	USE BETON TAHU (concrete spacer)

Overlaps of 40-50 Times Diameter of Rod at all Joints (for Ribbed Bars



Build Earthquake Resistant Houses
Change Construction Practice Permanently

build change

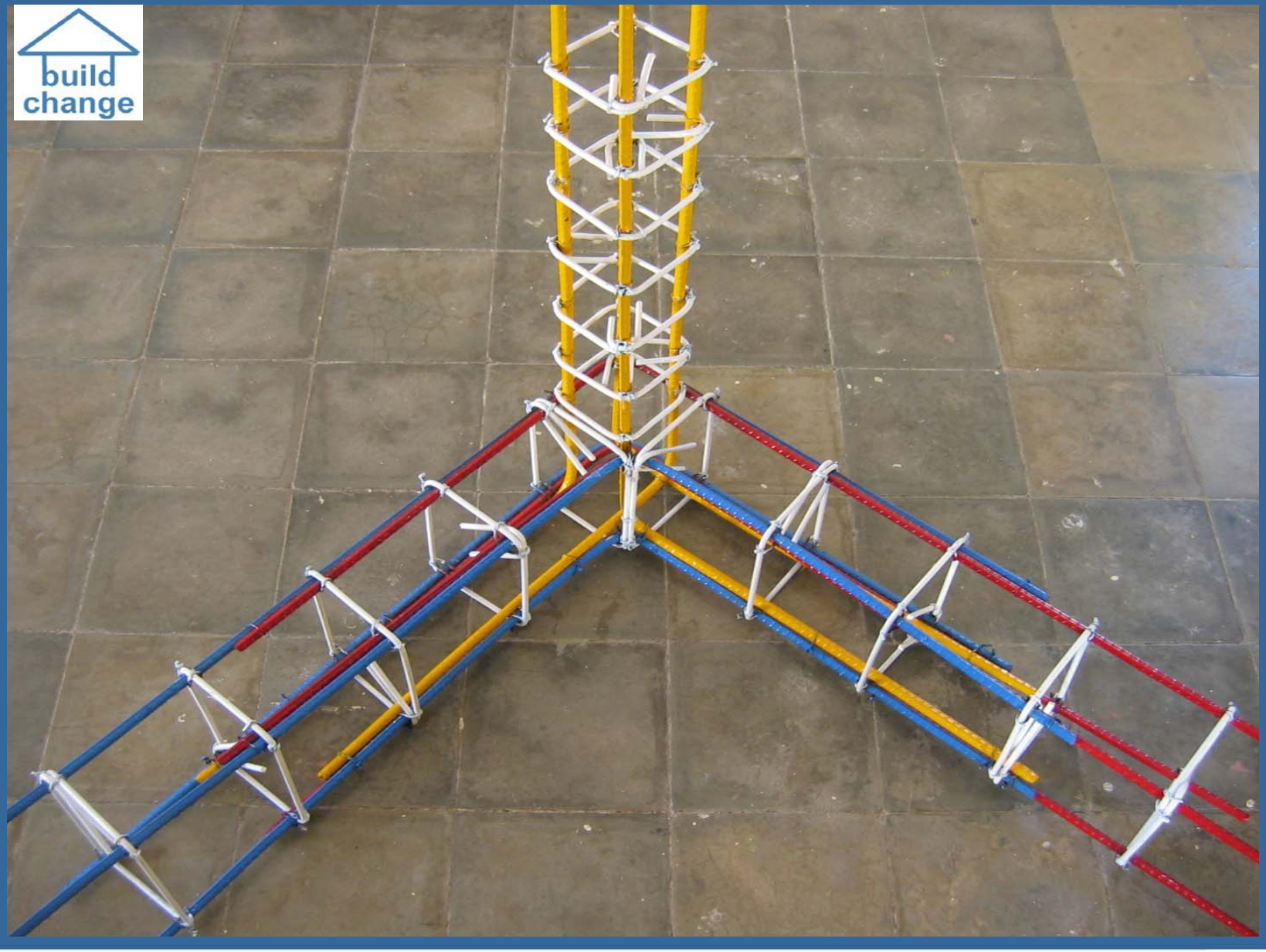
Connections, Laps are CRITICAL

Bad Practice (Buruk)

→ *Long bars terminate BEFORE the joint*

→ *Column bars not bent and lapped with ring beam bars*

→ *Missing stirrups at the joint*



Build Earthquake Resistant Houses
Change Construction Practice Permanently

Function of Tie Columns

Tie columns

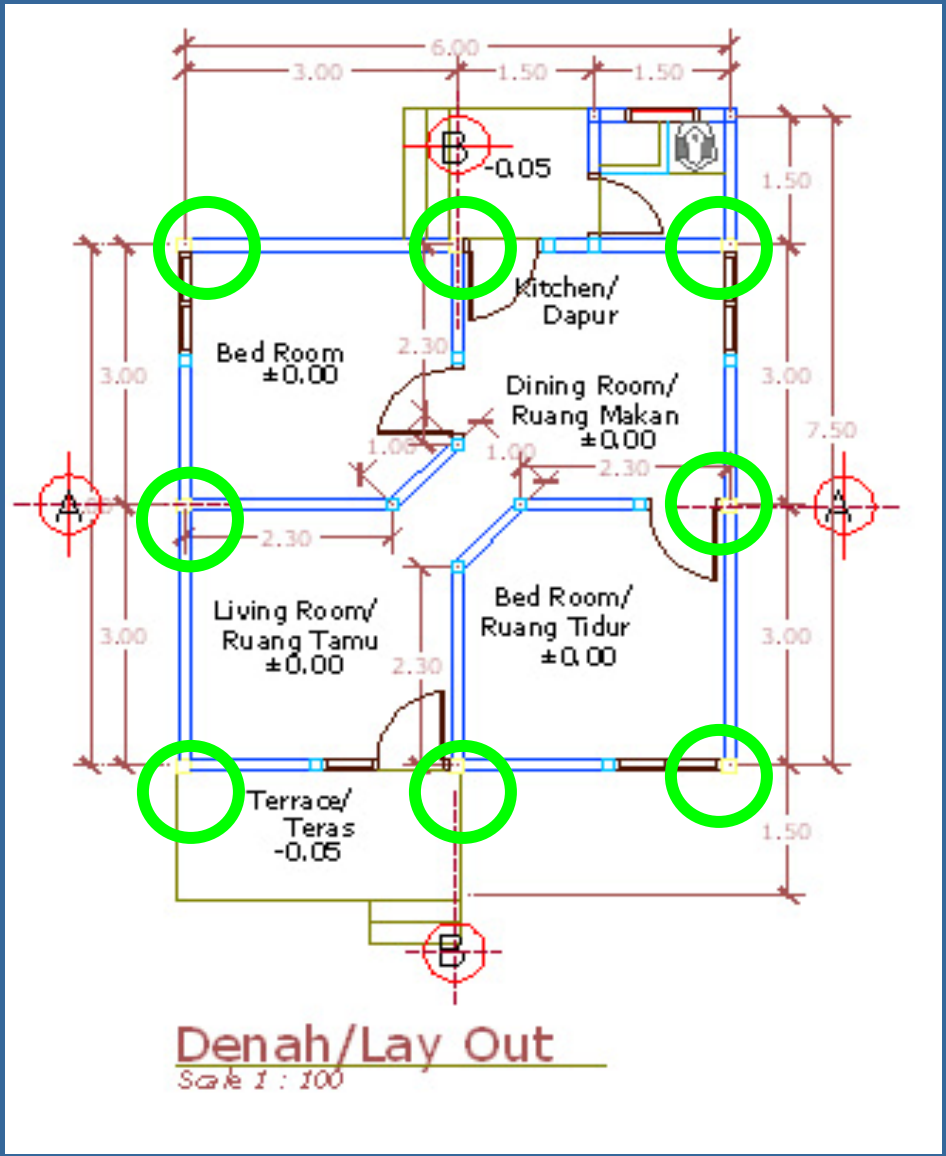
- Unreinforced or unconfined masonry walls will crack and may collapse in large earthquakes. Tie columns improve the ability of the wall to crack but not collapse.

Locations of Major Tie Columns

Major columns (kolom utama) should be used at

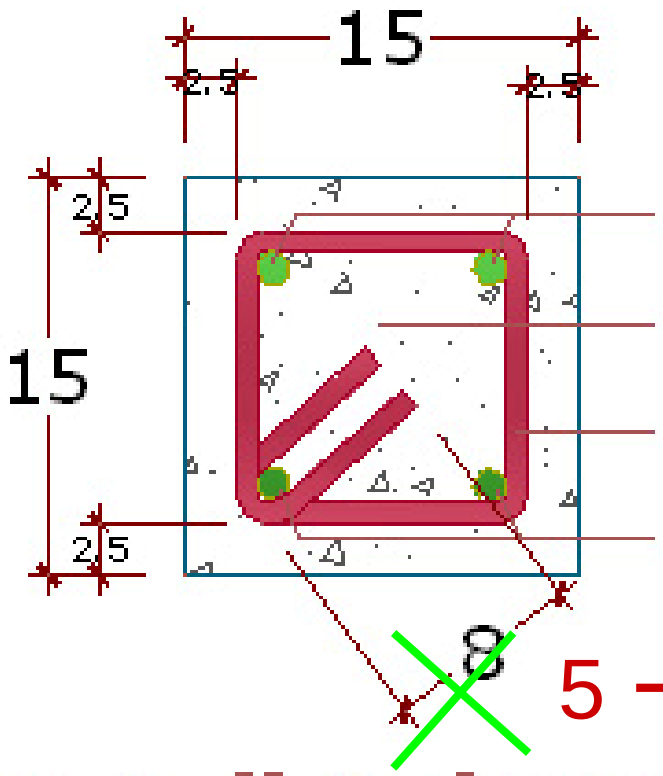
→ All major corners

→ All major joints and wall intersections



Design for Aceh: Major Columns (Kolom Utama)

	BRR	build change	Why We Deviate
Section	15 x 15	15 x 15	
Long bars	ϕ12mm smooth	ϕ10mm ribbed	→ Too difficult to cut and bend → Space for cover, confinement → Justified with engineering calcs
Stirrups	ϕ8mm	ϕ6mm 5cm long hook	→ Too difficult to BEND → Justified with engineering calcs
Stirrup spacing	15 cm	7.5 cm 15 cm	→ First 7 stirrups at joint → Away from joint
Cover		2.5 cm	USE BETON TAHU (concrete spacer)



Besi Ulir/Ribbed Bar 2 Ø 10

Adukan/Mix (1:2:3)

Begel/Smooth Bar Ø 6 - 15

Besi Ulir/Ribbed Bar 2 Ø 10

5 → 8 cm was too long (aggregate would get stuck)

Detail Column Utama (K1)

Scale 1 : 10

Good Practice (Baik)

→ *Stirrups have square corners, sufficient hook lengths, hooks alternating between long bars*

Bad Practice (Buruk)

→ *Stirrups have insufficient hook lengths*

Design for Aceh: Major Columns (Kolom Utama)

	BRR	build change	Why We Deviate
Section	15 x 15	15 x 15	
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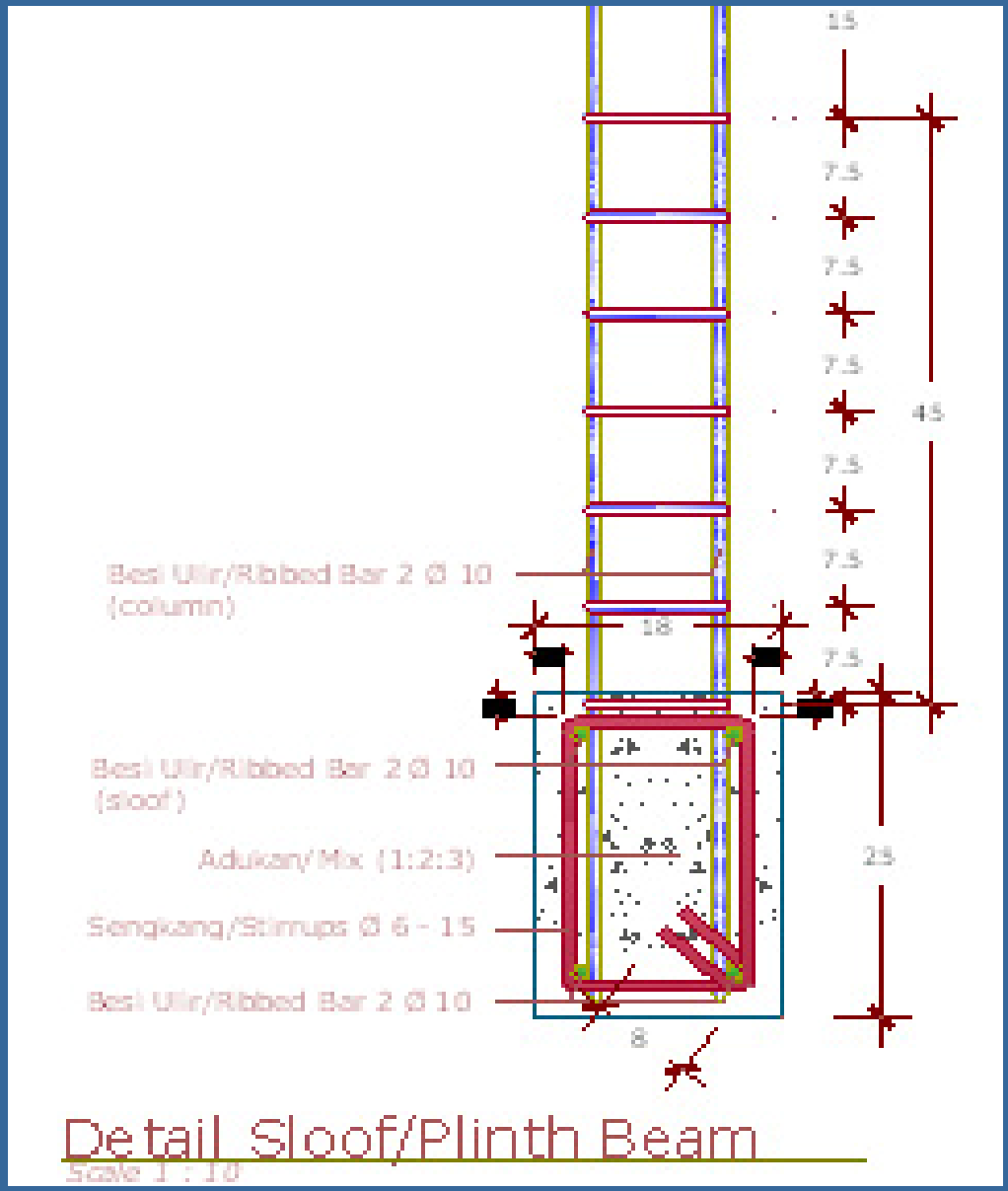
Cover		2.5 cm	USE BETON TAHU (concrete spacer)

How To Prevent Shear Failure in Columns

1. Increase size of the column
2. Increase number or size of long bars (doesn't have a big effect and expensive)
3. BEST → Increase the number of stirrups at the top and bottom of the joint in the columns.



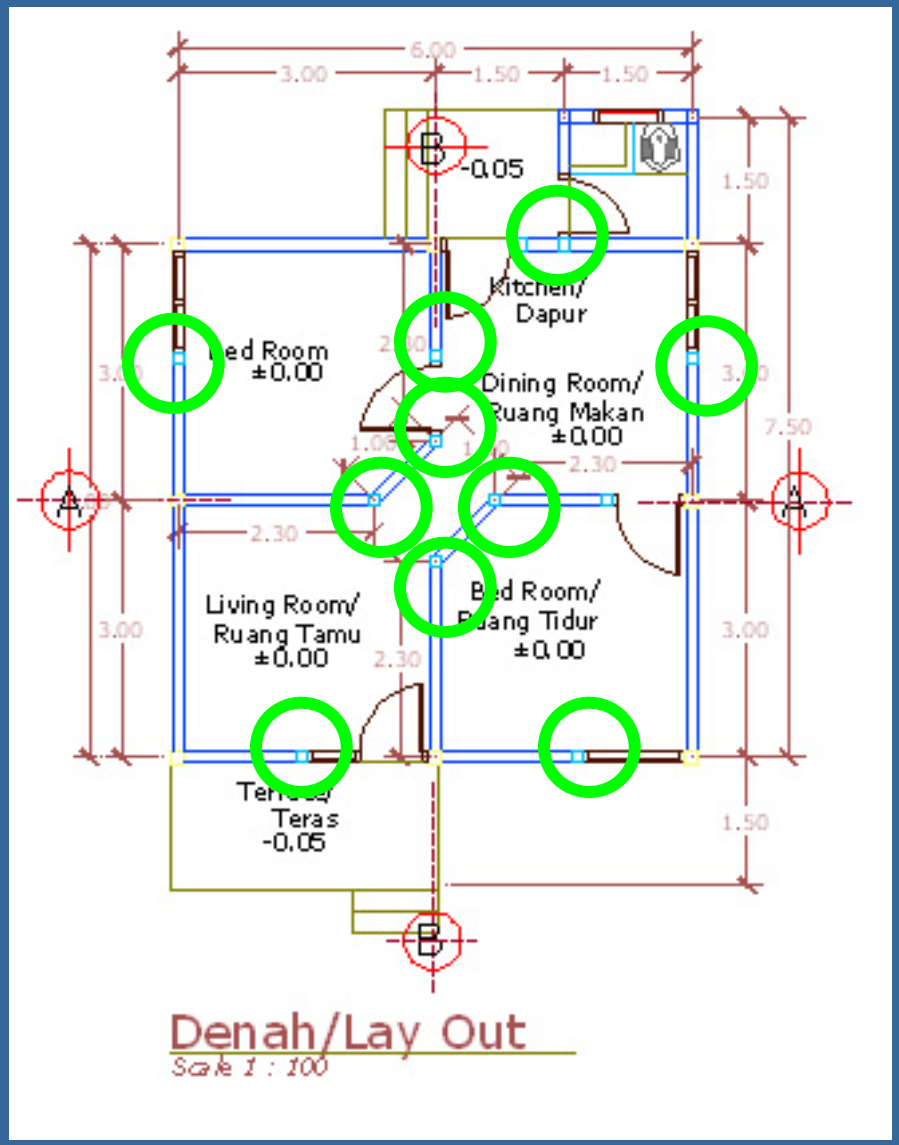
Build Earthquake Resistant Houses
Change Construction Practice Permanently

build change

Locations of Minor Tie Columns

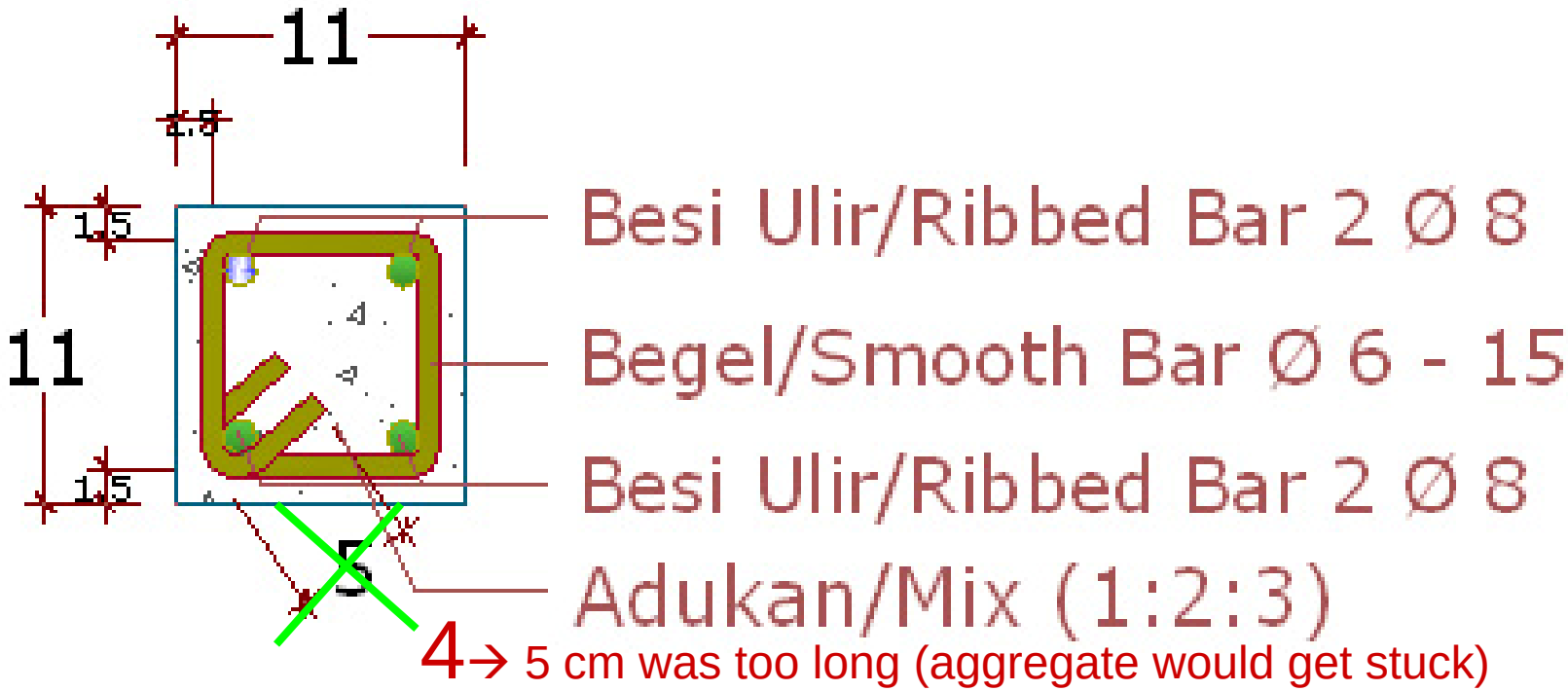
Minor columns (kolom praktis) should be used at

- All free ends of masonry walls
- All changes in wall contour
- Adjacent to any opening with area greater than 2.5m²
- All wall spans longer than 4m



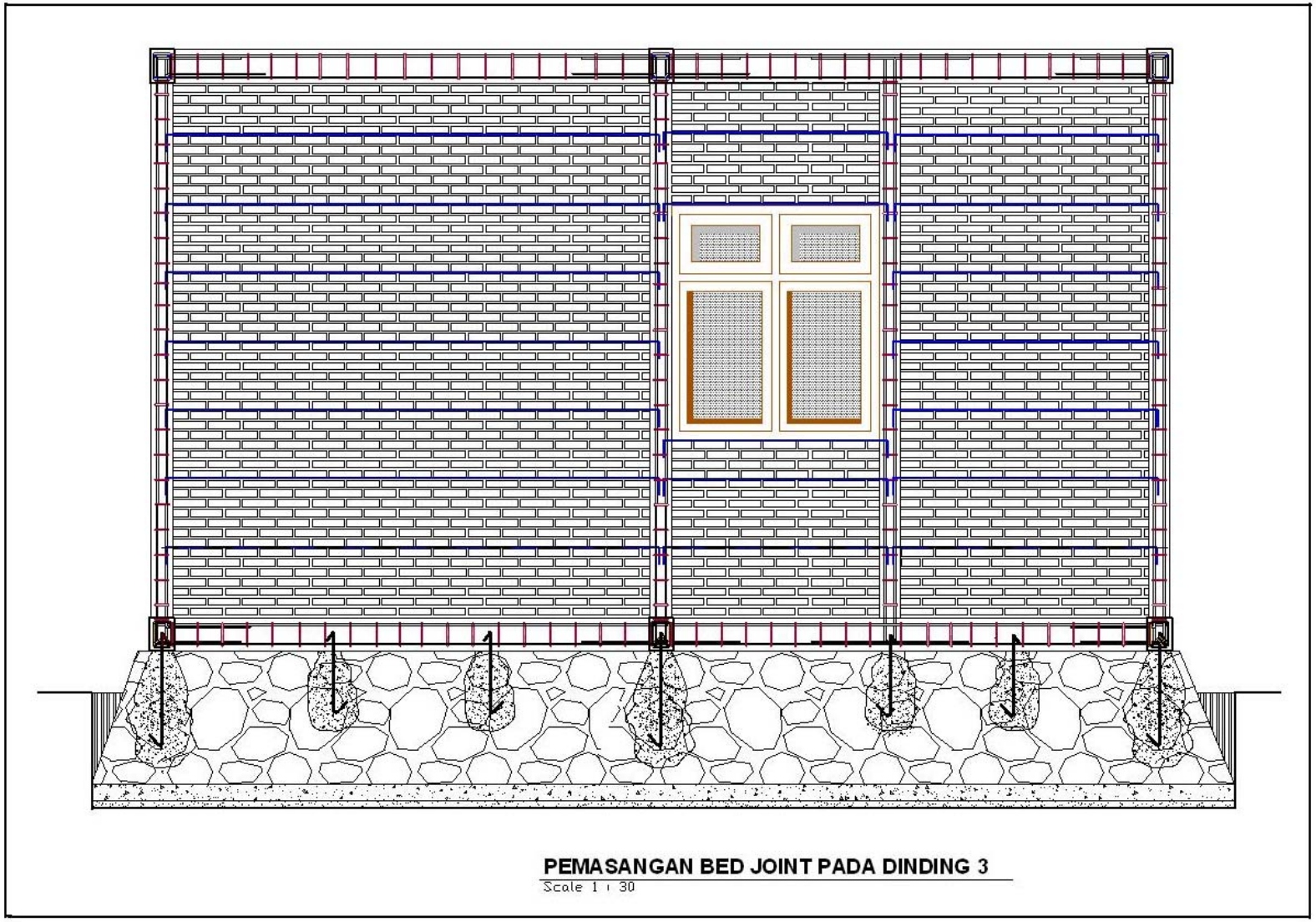
Design for Aceh: Minor Columns (Kolom Praktis)

	BRR	build change	Why We Deviate
Section	11 x 11	11 x 11	
Long bars	ϕ12mm smooth	ϕ8mm ribbed	→ Too difficult to cut and bend → Space for cover, confinement → Justified with engineering calcs
Stirrups	ϕ8mm	ϕ6mm 4cm long hook	→ Too difficult to BEND → Justified with engineering calcs
Stirrup spacing	15 cm	7.5 cm 15 cm	→ First 7 stirrups at joint → Away from joint
Cover		2.5 cm	USE BETON TAHU (concrete spacer)



Detail Column Praktis (K1)

Scale 1 : 10



Build Earthquake Resistant Houses
Change Construction Practice Permanently

build change

Newly Built Confined Masonry Buildings Generally Performed Well in the 27 May 2006 Central Java Earthquake

→ *Confined masonry house without damage or cracks, on the edge of heavy damaged Pleret*

→ *Confined masonry house with only minor (hairline) cracks, Bambang Lipuro*

POOR CONNECTIONS BETWEEN BEAMS AND COLUMNS → Major Cause of Failure of newly built houses in 27 May 2006 earthquake in Central Java

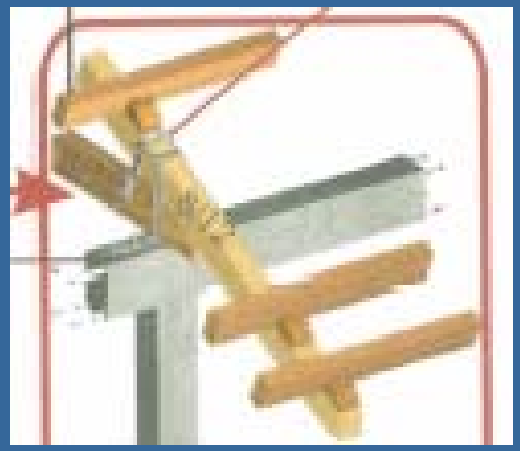
POOR CONNECTIONS BETWEEN BEAMS AND COLUMNS → Major Cause of Failure in newly built houses in 27 May 2006 earthquake in Central Java

Connection Between Ring Beam and Roof Trusses

Important for earthquakes and high winds

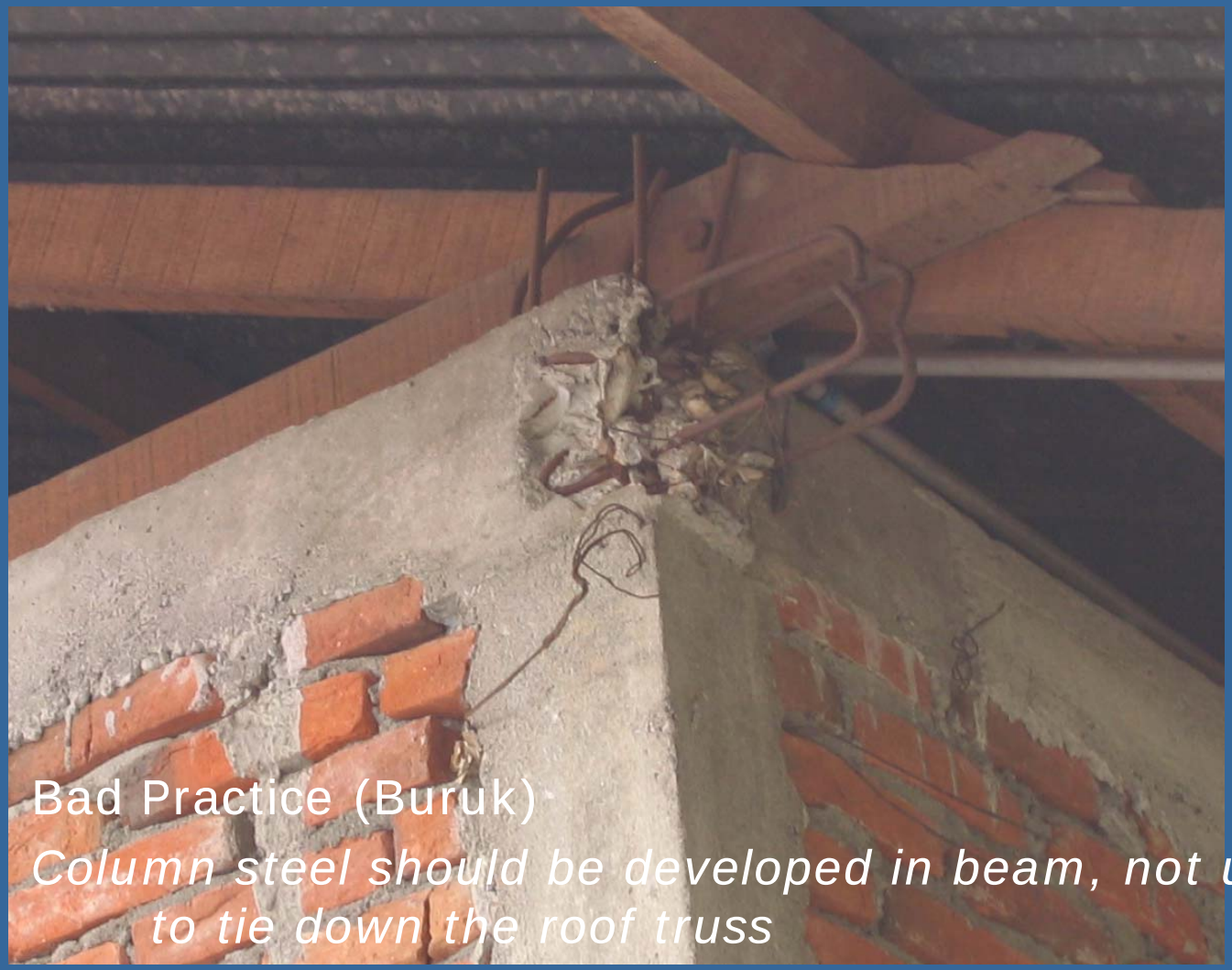
If done correctly,

- Prevents the roof from lifting off in high winds
- Provides some bracing of walls against out-of-plane failure



Teddy Boen and YIPD

Do Not Use Column Steel for Connection to Timber Truss!



Bad Practice (Buruk)

Column steel should be developed in beam, not used to tie down the roof truss

Do Not Use Column Steel for Connection to Timber Truss. WHY?

1. Tie column steel should be overlapped and connected to bond beam steel to provide good connection and confinement as discussed previously
2. Exposed steel will rust. As it rusts, it increases in volume which will cause cracks in the column and beam
3. Although not a rigid diaphragm, fixing the truss joists to the walls provides some bracing of the walls against out of plane failure
4. Simply wrapping column steel around truss members is not sufficient to resist wind loads in Aceh

CONNECTIONS

Good connections are critical for good performance of confined masonry buildings in earthquakes. Unreinforced or unconfined masonry walls fail in earthquakes. Good connections are necessary between

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- Foundation and walls
- Tie columns and walls
- Bond beam and walls
- Bond beams and tie columns
- Ring bond beam and roof