SHA Construction Course, March 16 - 20, 2009 in Walkringen

Retrofitting: some basics

Tom Schacher

Retrofitting

Vulnerability assessment

- Assess the structural concept and execution using the general rules for earthquake resistant construction.

Decide on possible interventions

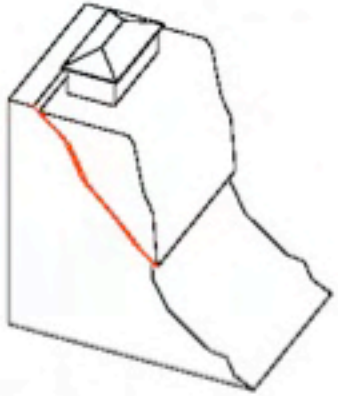
- Technical possibilities (know-how, materials)
- Cost/effectivness ratio (is it worth retrofitting?)

Vulnerability analysis

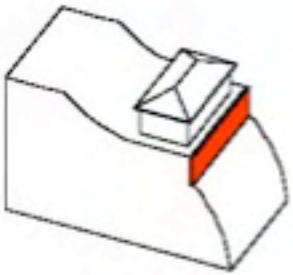
1. Site aspects
2. Geometrical aspects
3. Structural aspects
4. Construction aspects

1. Site aspects: Safe site

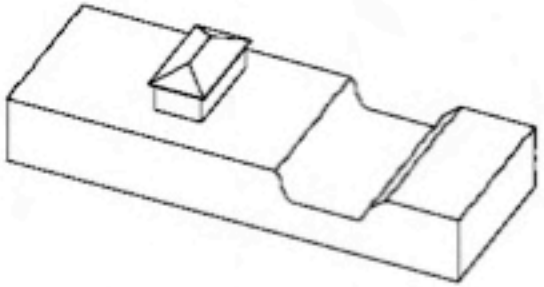
Away from steep slopes



Away from steep slopes



Away from retaining walls



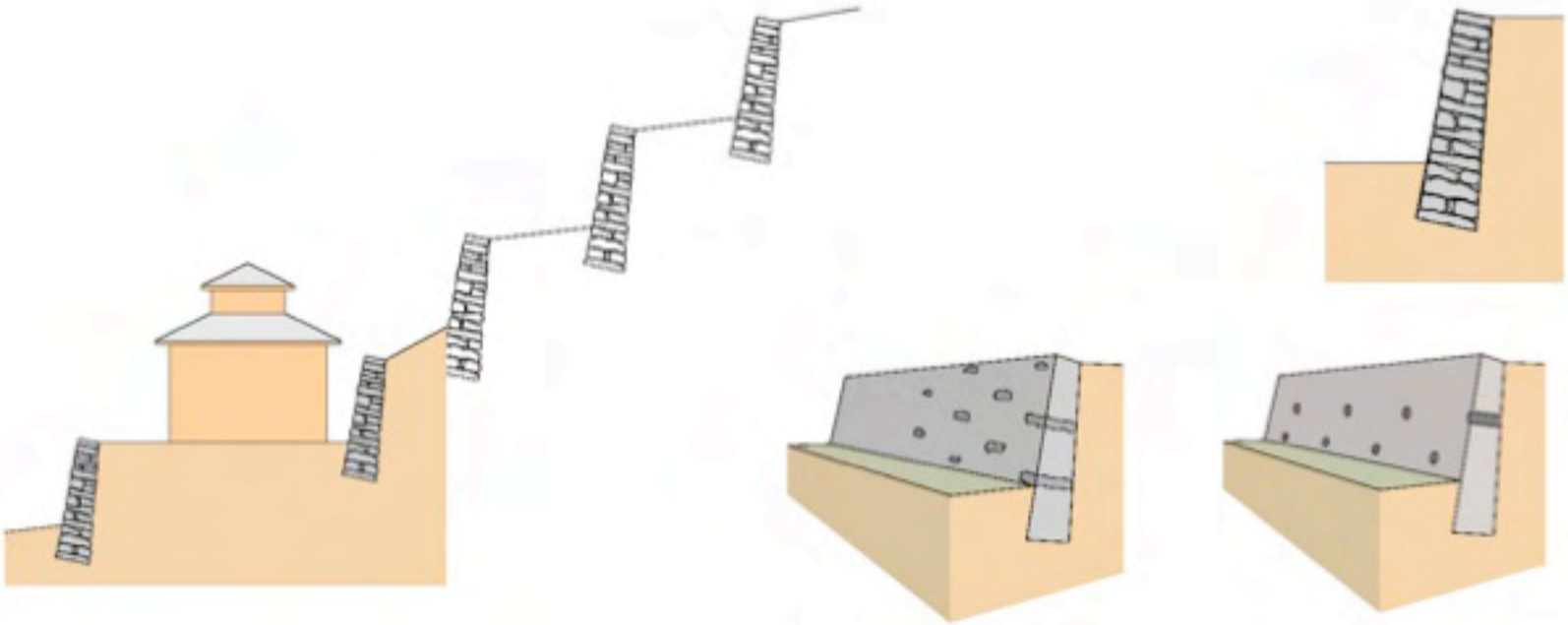
Away from flood prone areas

1. Site aspects: Soil quality

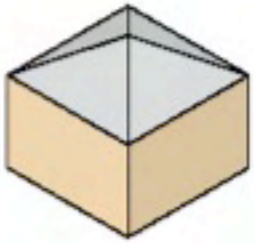
Si nuestro suelo no es grava o roca
¿Cómo podemos reconocer de qué tipo es?

Puedes hacer este ensayo simple.

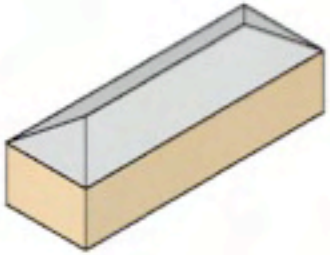
1. Site aspects: Retaining walls



2. Geometrical aspects: Simple form



Excellent



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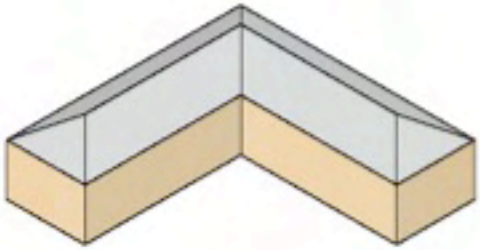

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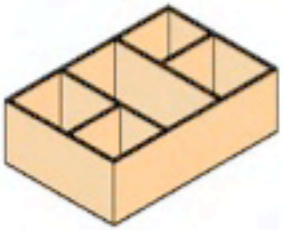
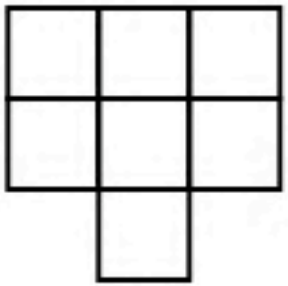
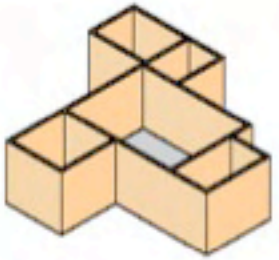




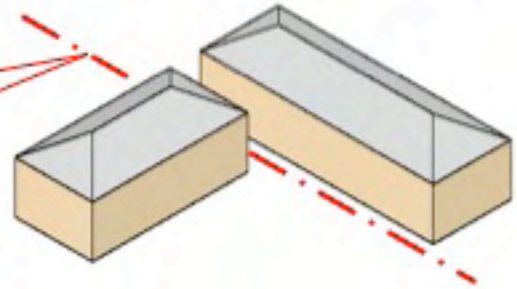


2. Geometrical aspects: Simple form

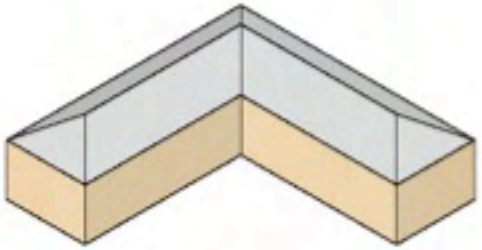
Separate the buildings to achieve simple shapes:

Theoretically 1/100th of height,

Practically much more (30cm?) to make sure that the joint is clean.



Good



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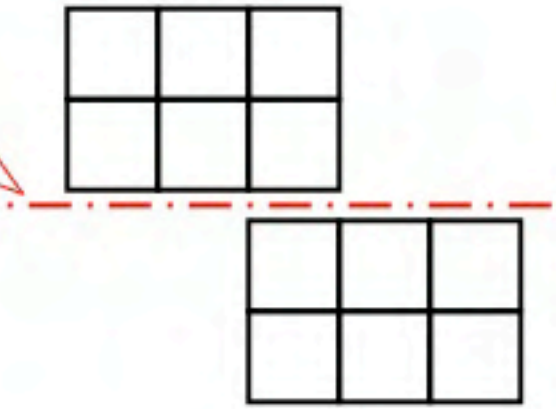
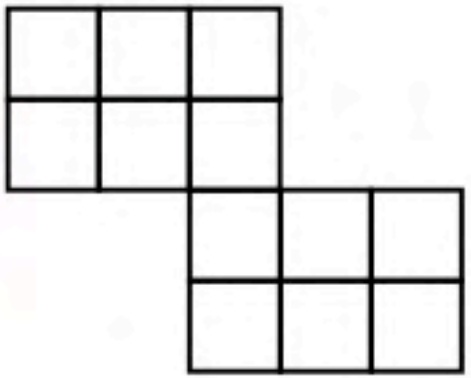
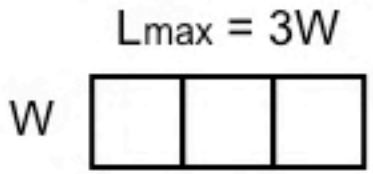
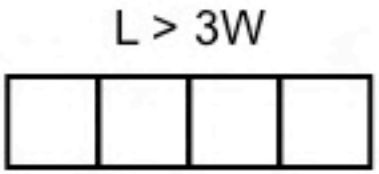
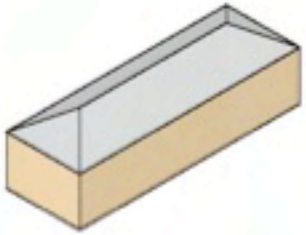


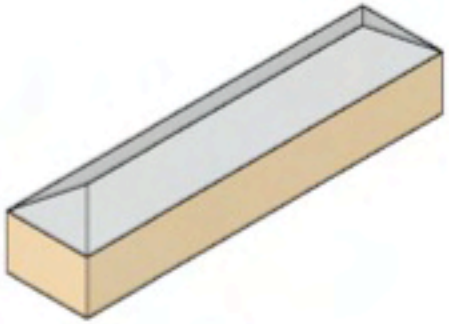


2. Geometrical aspects: Correct proportion









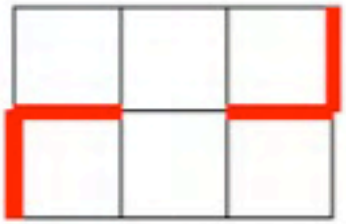
Good

Bad

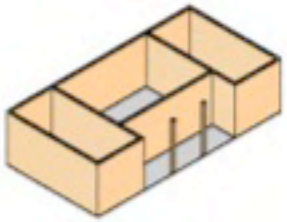
3. Structural aspects: Horizontal distribution of lateral-load resisting elements

Best

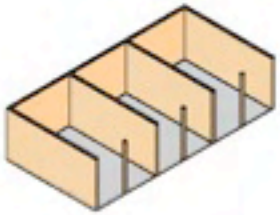
Good



Sufficient

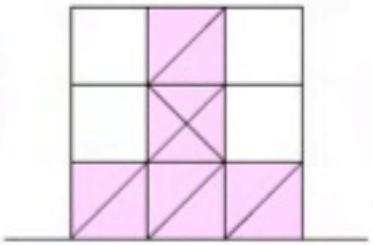


Good

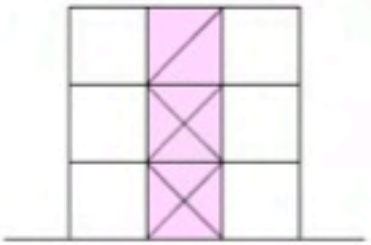


Bad

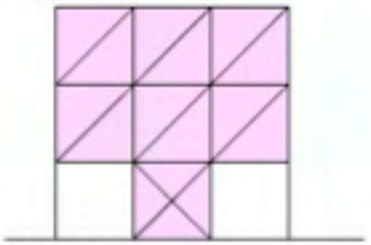
3. Structural aspects: Vertical distribution of lateral-load resisting elements



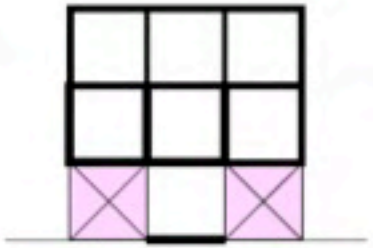
Best



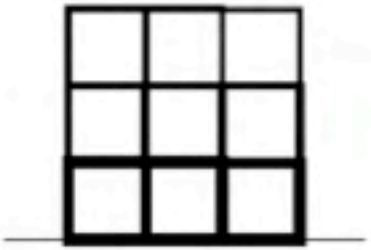
Acceptable



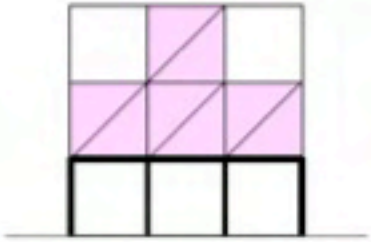
Bad



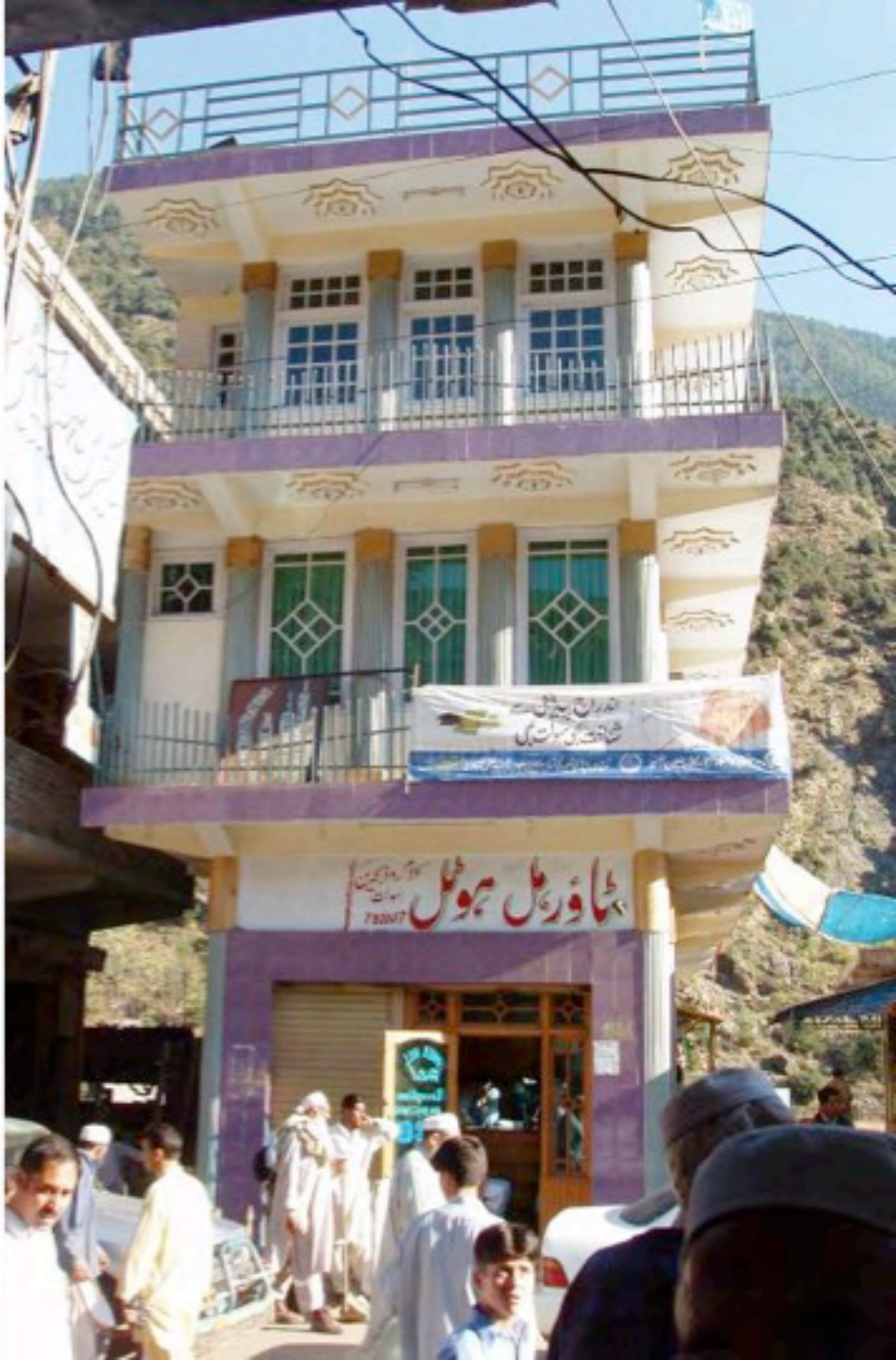
Good



Good



Very bad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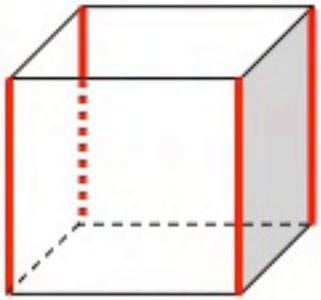
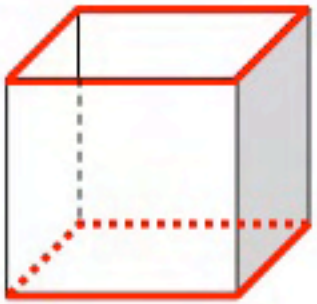
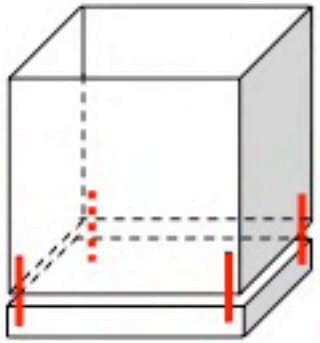
3. Structural aspects: Hold elements together



Vertical
(ties)

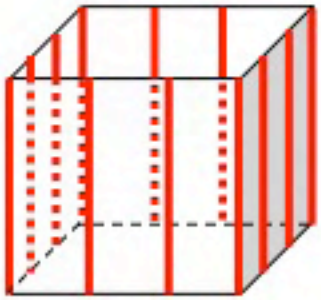


Horizontal
(ring beams)



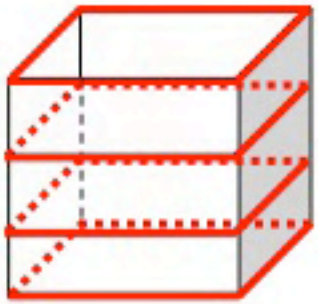
To foundations

3. Structural aspects: Hold elements together

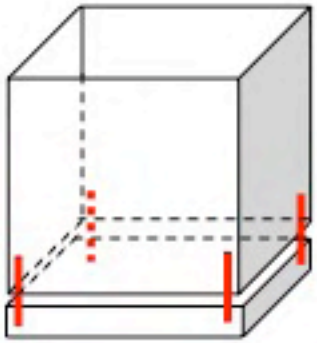


Vertical
(ties)

e.g.
Reinforced masonry
Confined masonry



Horizontal
(ring beams)



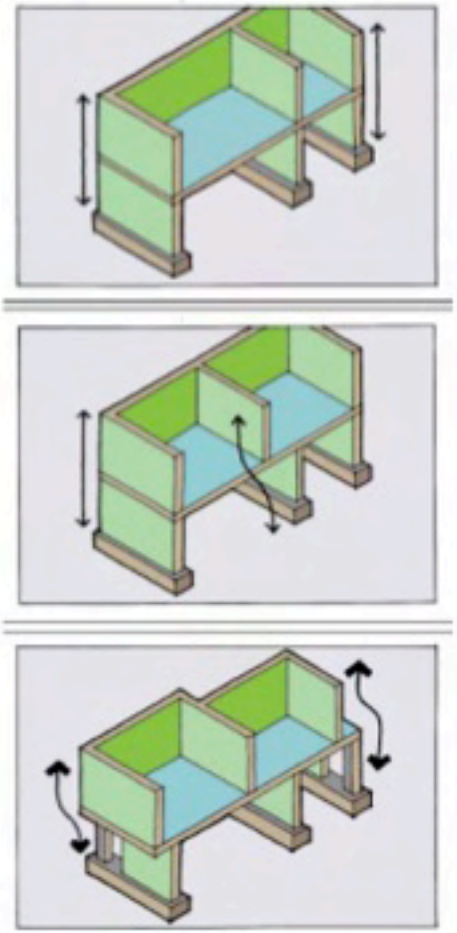
To foundations

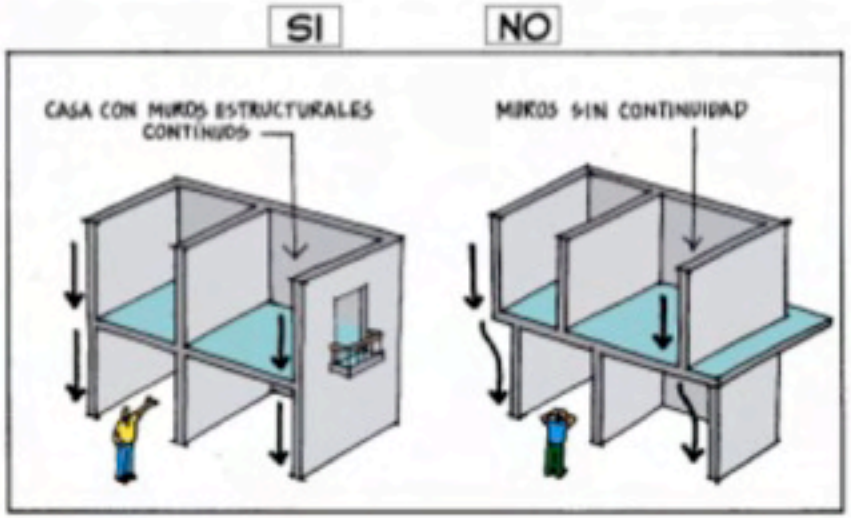
(Perhaps not?)

3. Structural aspects: Vertical continuity

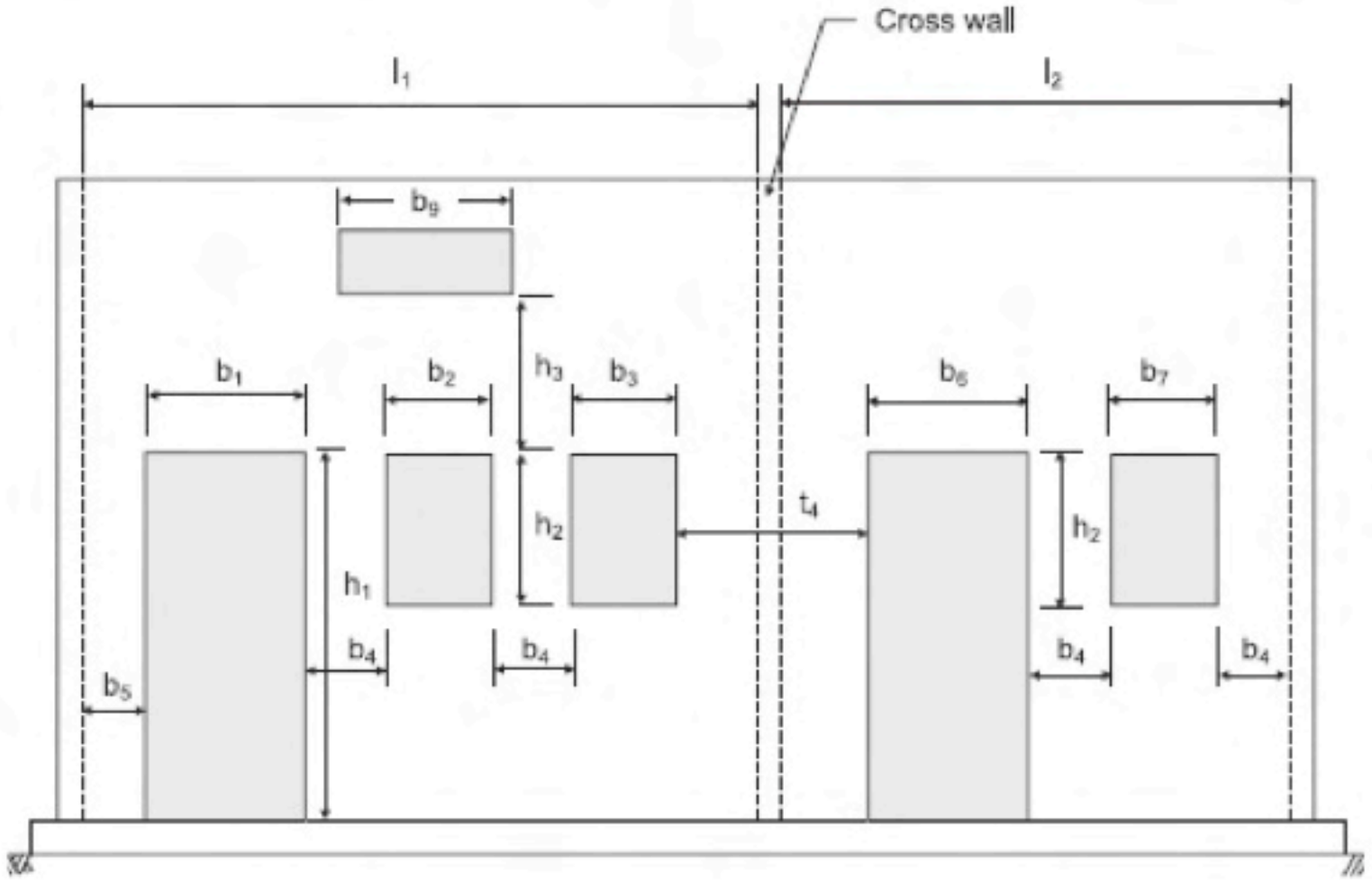
Good

Bad





3. Structural aspects: Openings



Notes : $b_1+b_2+b_3 < 0.5l_1$ for one storey, $0.42l_1$ for two storey, $0.33l_1$ for three storey,

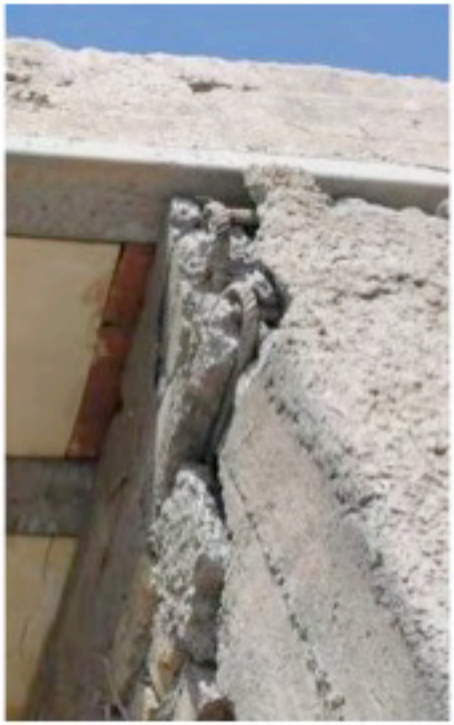
$b_6+b_7 \leq 0.5l_2$ for one storey, $0.42\ l_2$ for two storey, $0.33l_2$ for three storey,

$b_4 \geq 0.5\ h_2$ but not less than 60cm

$b_5 \geq 0.25h_1$ but not less than 60 cm

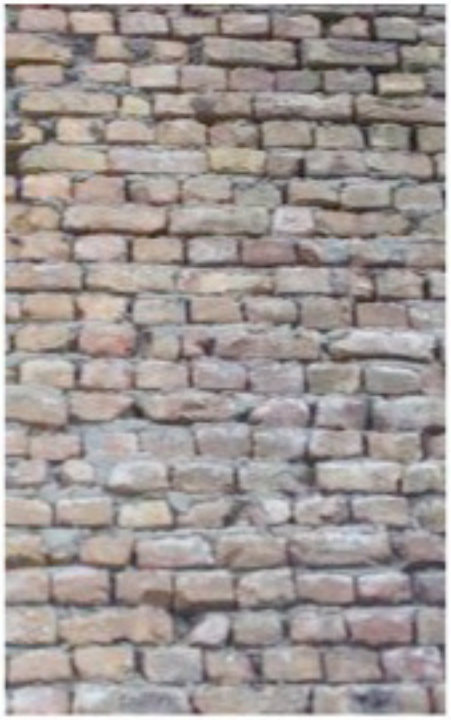
$h_3 \geq 60$cm or $0.51b_2$ or b_9 whichever is more

4. Construction aspects: Quality




4. Construction aspects: Quality



Possible interventions

1. Reinforcing walls
2. Adding cross walls
3. Reduce openings
4. Add reinforcements around openings
5. Connect with foundation
6. Lintel and roof bands

Most of the following pictures are from the

Compliance Catalogue

Guidelines for the Construction of Compliant Rural Houses

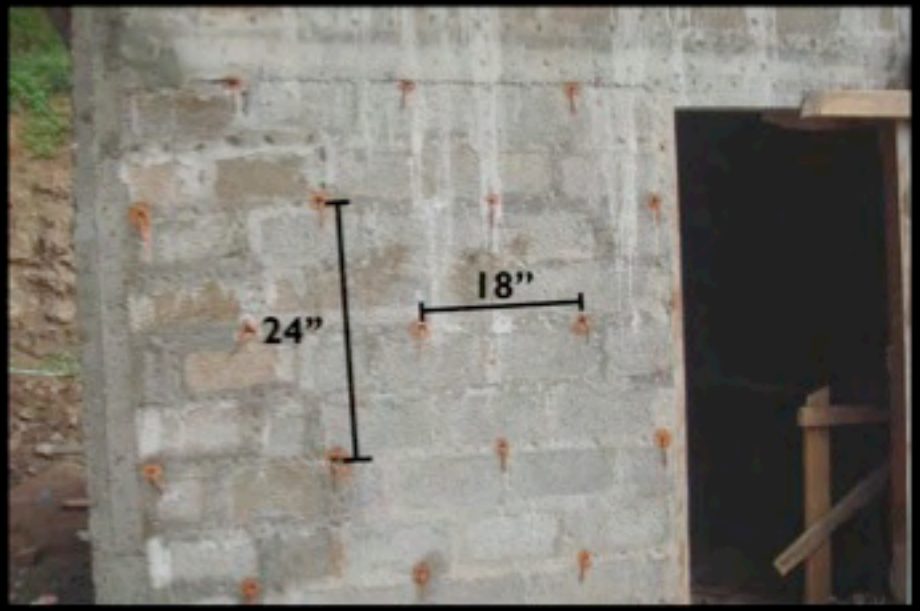
ERRA

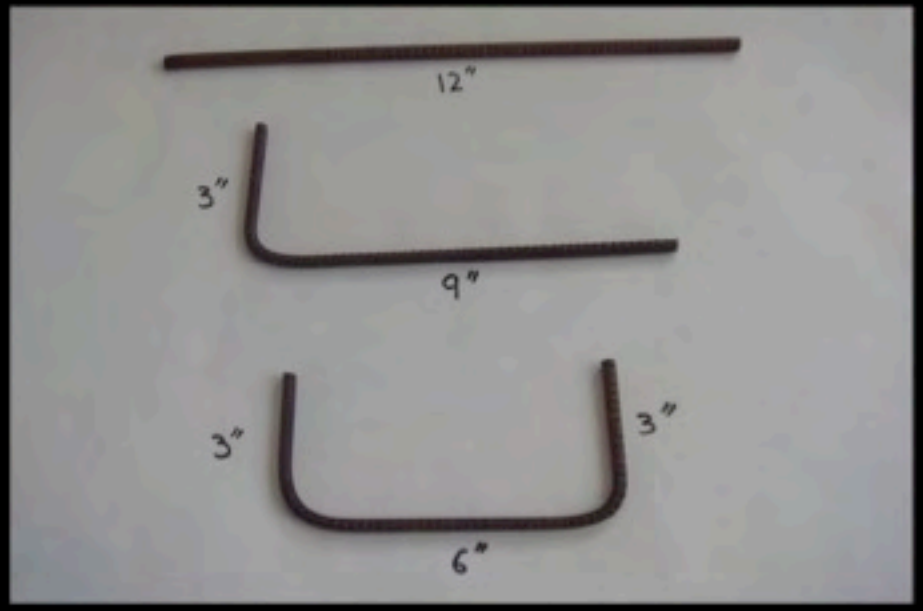
ERRA Build Back Better for a safer future

Version: September 18, 2007

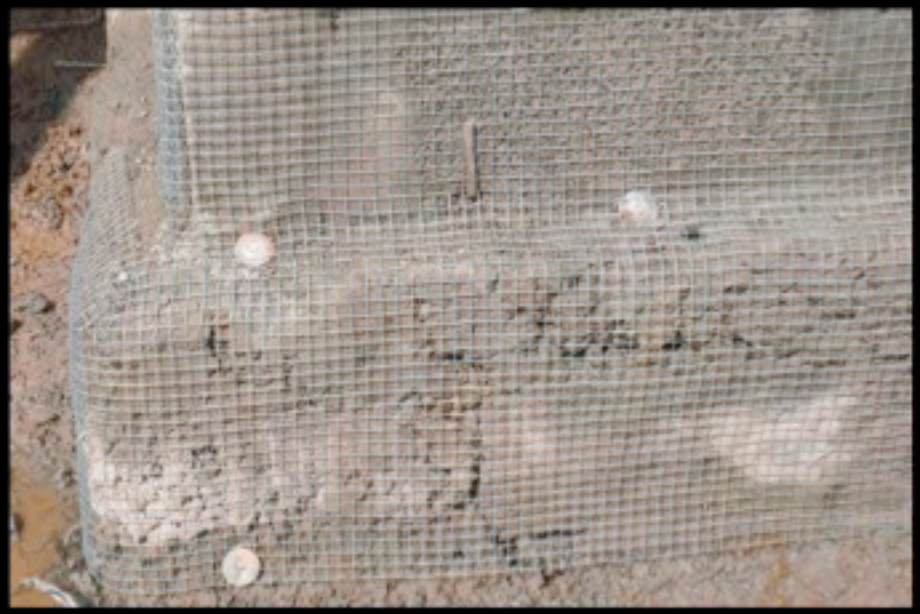
http://www.erra.gov.pk/Reports/Rural%20Housing/Compliance%20Catalogue%20-%20Eng-%2018-Sep-07.pdf

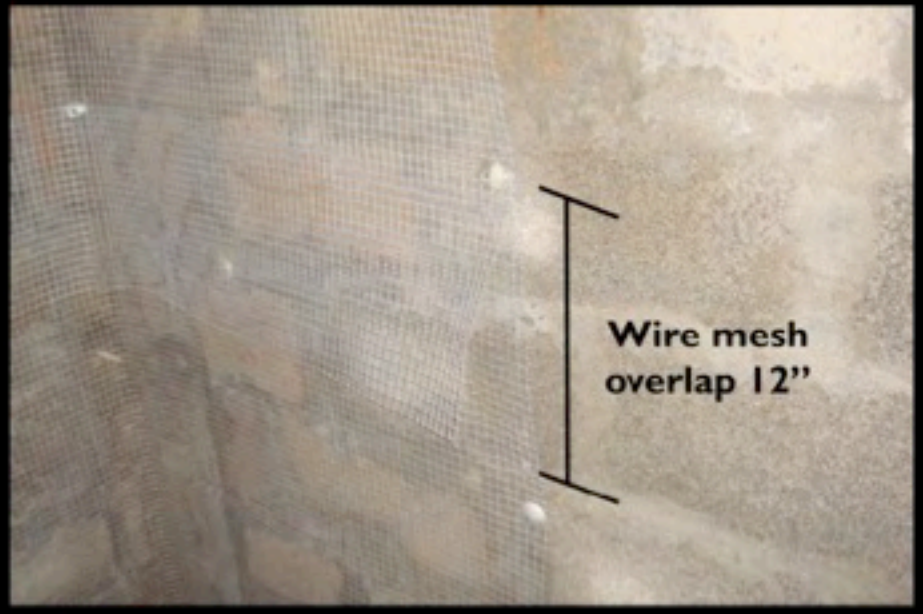
1. Reinforcing walls: Strengthen weak masonry





Con't: Reinforcing walls: Strengthen weak masonry





Con't: Reinforcing walls: Strengthen weak masonry

Wire mesh holds the wall together (jacketting)

2. Excessive wall lengths: Adding cross walls

Cont'd: Excessive wall lengths: Add cross walls

3. Reduce opening size

4. Strengthen openings: Adding reinforcement

5. Improve anchorage: Connect to foundations

Cont'd: Improve anchorage: Connect to foundations

6. Horizontal reinforcement: Adding lintel band

Cont'd: Horizontal reinforcement: Adding lintel band

Cont'd: Horizontal reinforcement: adding a roof band

Reinforcing buildings

7. Adding bandages
8. Adding confining elements
9. Connecting walls
10. Connecting walls of different materials
11. Strengthening foundations
12. Strengthen retaining walls

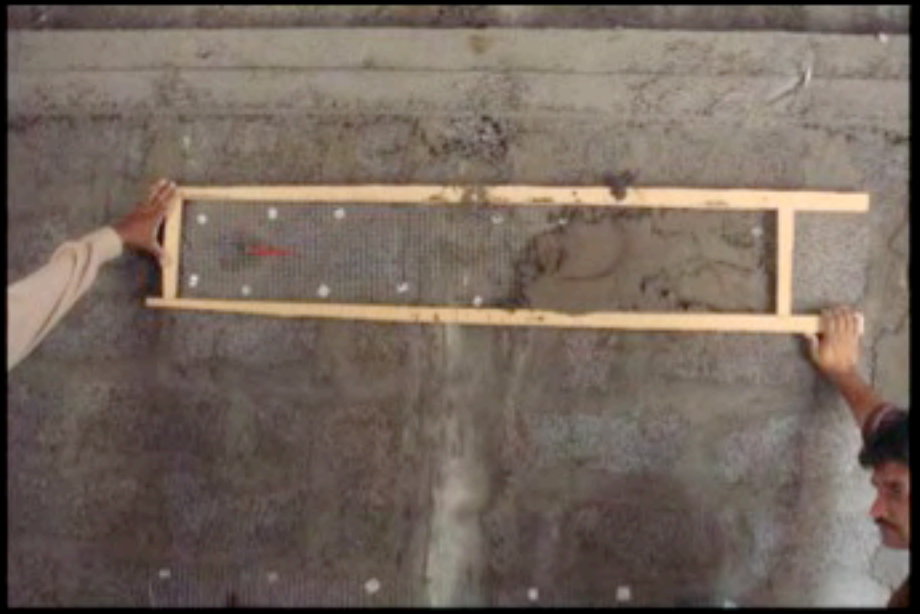
7. Horizontal reinforcement: adding bandages

Cont'd: Horizontal reinforcement: adding bandages

8. Adding vertical reinforcement: confining masonry

Cont'd: Adding vertical reinforcement: confining masonry

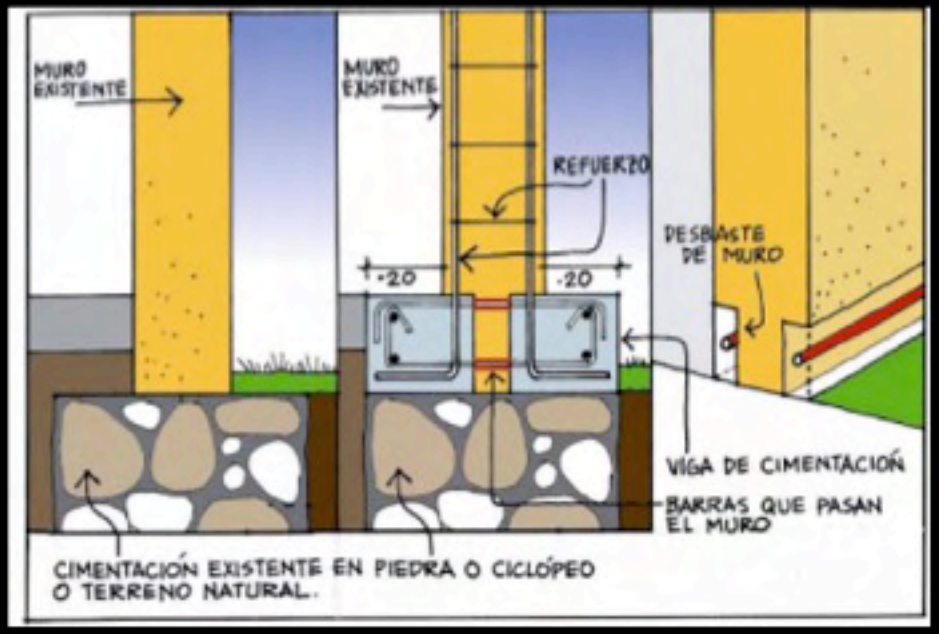
9. Connecting walls: External mesh

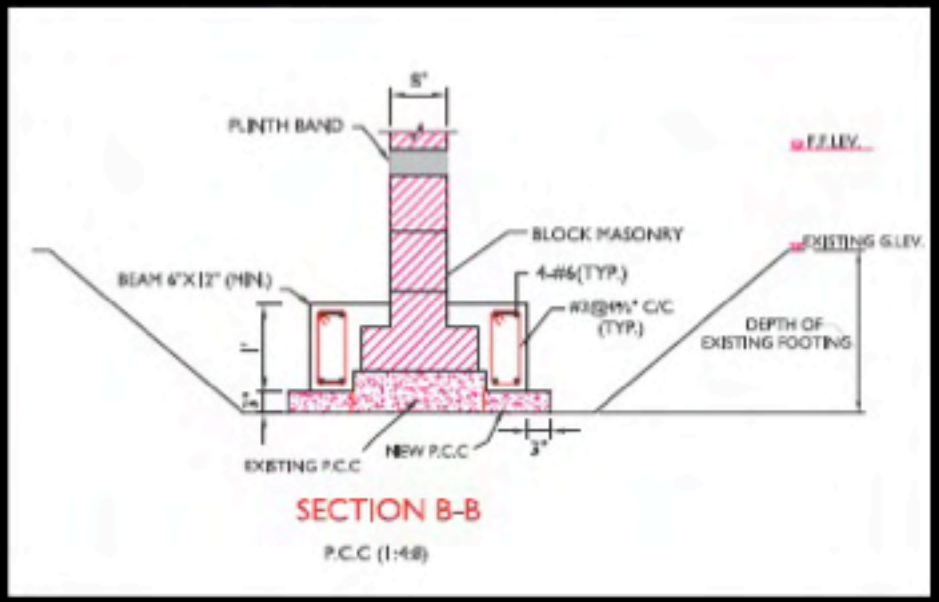


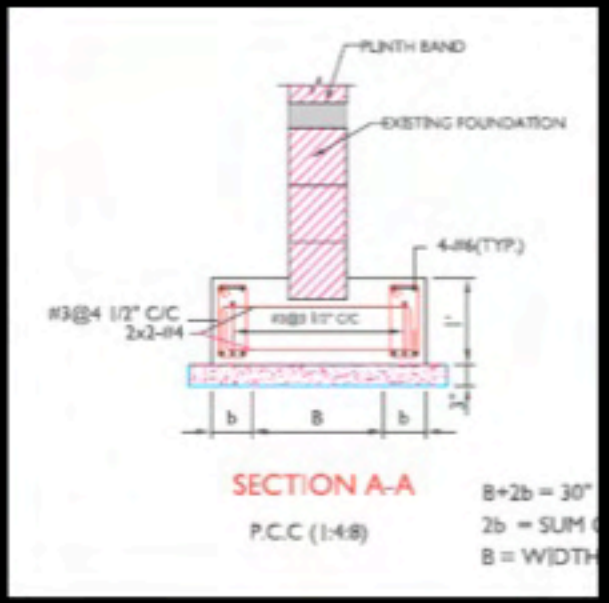
10. Connecting walls of different materials

Cont'd: Connecting walls of different materials

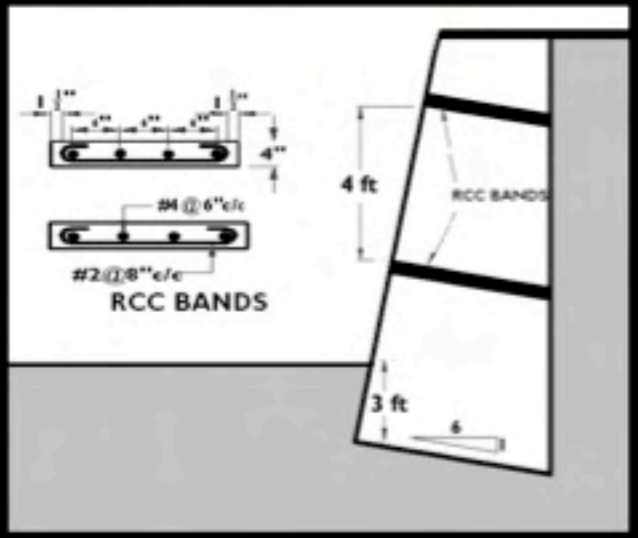
11. Strengthening foundations

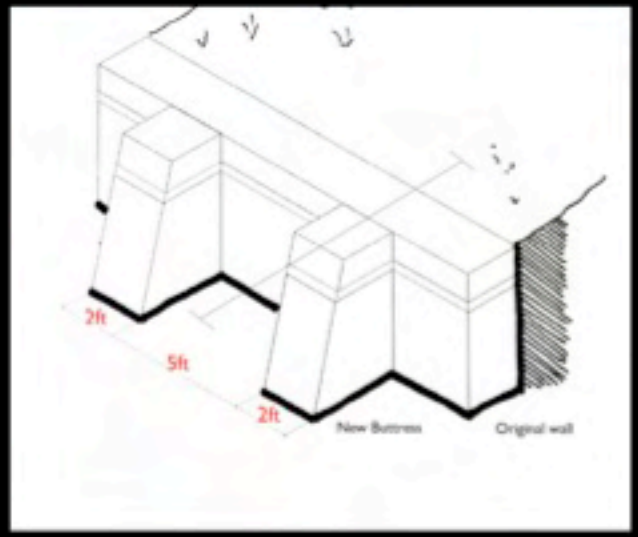


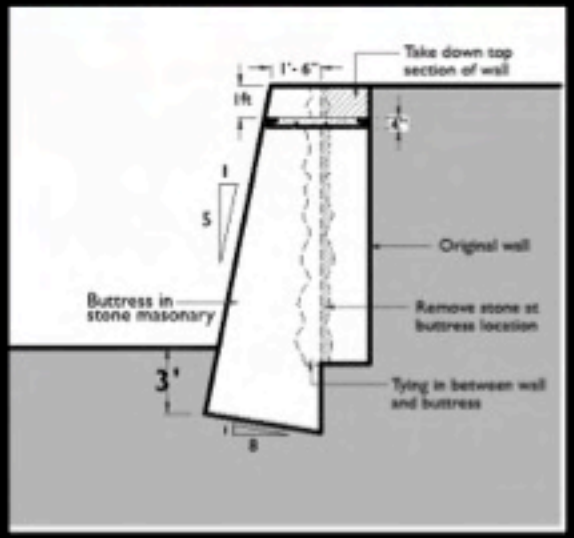




12. Verify and strengthen retaining walls







Conclusion

Retrofitting is difficult and potentially dangerous.

One has to

- Make a mental structural model of the building, taking into account the existing structure.
- Use existing features and strengthen them if necessary.
- Add new elements where requested.
- Verify if the operation is worth the money.

Last but not least: the Guillod Principle

Earthquake Resistance is achieved through:

Proper planning:

- Right concepts — 40% of resistance
- Right details — 40%
- Perfect dimensioning — 20%

Proper execution:

- Good workmanship
- Tight control
- Good explanations to the workers (that's my point)

Suggested Reading

Compliance Catalogue: Guidelines for the Constructuion of Compliant Rural Houses, Earthquake Rehabilitation and Reconstruction Authority ERRA, 2008, Islamabad, Pakistan, http://www.erra.gov.pk/Reports/Rural%20Housing/Compliance%20Catalogue%20-%20Eng-%2018-Sep-07.pdf

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