INFRASTRUCTURE
THE GOOD & THE BAD
INFRASTRUCTURE
THE GOOD & THE BAD
HOUSE CONSTRUCTION
SETTING OUT - FOUNDATION - CONCRETE WORKS - WALLS - ROOF - FLOOR - SERVICES
INTRODUCTION

Housing Construction

Indonesia has experienced a number of natural disasters in the recent past that have damaged or destroyed large numbers of residential housing. Major reconstruction efforts by local, national and international agencies were initiated, and because of many homeless families, speedy completion was an important factor.

The need for speed can sometimes lead to low quality workmanship. However, it has been shown that poor construction techniques waste materials, time and efforts; they may make the house uncomfortable, and at the worst, may cause the structure to be unsafe. Costly repairs and early replacement are serious consequences of poor construction practice.

On the other hand, good quality housing makes for happy occupants, and has important economic benefits in terms of a longer lifespan and savings in materials and construction costs. If a house is well built, the owners are also much more likely to make further investments in expanding and improving their basic core houses.

A lot has been learned in the many recent reconstruction projects, in terms of both, good and bad examples of house construction. While the bad examples are obvious and speak for themselves, the good examples show how much can be achieved by making serious efforts, using good experience, common sense and some technical training.

Considering the above mentioned, this book is made to complete the existing standard manual for housing that have been published by the government or other institution. The book presented is simple and easy to understand because each picture are complimented by simple explanation.

It is also hoped that the book will be used not only for disaster reconstruction programs but that housing construction in general will benefit from the good and bad practice examples that are being presented. The book is intended not only for builders, contractors and their technical staff, but should also be perused by bureaucrats, managers, staff of multilateral and bilateral assistance agencies, international and Indonesian NGOs active in the housing and community sectors, and lastly but not least, the beneficiaries themselves.

Hence, the book should be distributed widely and should be made available to all who ask for a copy; it could also be adapted for training in house construction.
AKNOWLEDGEMENTS

Scott Guggenheim who had the original idea and arranged the funding, Ekart Hartmann (with help from Heinz Unger) who prepared the technical pages, Octaviera Herawati who managed the efforts (including coordination of inputs, management of production until publication, and also the translation into Bahasa Indonesia), the many technical staff who provided reviews and suggestions, such as Saleh Siregar, Purnomo Sutantyo, Eka Hasfi Adha, Festina Lavida. Special thanks to Victor Bottini and Sentot Satria who keep supporting this book. Also the layout artist and printing company, and anybody else, including admin and support staff who may have done a lot of work ……..
## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>i</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>ii</td>
</tr>
<tr>
<td><strong>SETTING OUT</strong></td>
<td></td>
</tr>
<tr>
<td>Setting out</td>
<td>1</td>
</tr>
<tr>
<td><strong>FOUNDATION</strong></td>
<td></td>
</tr>
<tr>
<td>Excavation</td>
<td>7</td>
</tr>
<tr>
<td>Rock</td>
<td>10</td>
</tr>
<tr>
<td>Concrete</td>
<td>19</td>
</tr>
<tr>
<td><strong>CONCRETE WORKS</strong></td>
<td></td>
</tr>
<tr>
<td>Concrete Production</td>
<td>21</td>
</tr>
<tr>
<td>Formwork</td>
<td>23</td>
</tr>
<tr>
<td>Reinforcement</td>
<td>41</td>
</tr>
<tr>
<td>Beams, Columns</td>
<td>66</td>
</tr>
<tr>
<td>Slab</td>
<td>82</td>
</tr>
<tr>
<td><strong>WALLS</strong></td>
<td></td>
</tr>
<tr>
<td>Materials</td>
<td>83</td>
</tr>
<tr>
<td>Construction</td>
<td>85</td>
</tr>
<tr>
<td>Windows &amp; Doors</td>
<td>97</td>
</tr>
<tr>
<td>Plaster</td>
<td>105</td>
</tr>
<tr>
<td><strong>ROOF</strong></td>
<td></td>
</tr>
<tr>
<td>Roofing materials</td>
<td>107</td>
</tr>
<tr>
<td>Aluminium</td>
<td>112</td>
</tr>
<tr>
<td>Wood</td>
<td>116</td>
</tr>
<tr>
<td><strong>FLOOR</strong></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>131</td>
</tr>
<tr>
<td><strong>SERVICES</strong></td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>135</td>
</tr>
<tr>
<td>Water &amp; Sanitation</td>
<td>139</td>
</tr>
</tbody>
</table>

12 Important Rules

THE GOOD & THE BAD INFRASTRUCTURE
12 Important Rules

THE GOOD & THE BAD INFRASTRUCTURE
Setting out

Clean up site before setting out

How can I do it better?

• It is easier to fix the floor level with straight-edged boards
• Before starting the excavation the site should be cleaned up
• Organic material will rot and make a bad foundation

Why?

• Organic material will rot and the ground will settle
• Waste might be contaminated
Setting out

Dispose of plants and waste first

Rotten plants and waste are not a good base for floor construction

How can I do it better?

• The site should be cleaned up before starting the excavation

Why?

• Organic material will rot, and the ground will settle
• Waste might be contaminated
Chapter 01     Setting Out

**Clear ground of all plants and rubbish**

**Mark out the boundaries of the construction area**

**Why is it better?**

- Plants and other organic material will rot and cause the ground to settle
- Set up boards around the building outline and leave a working space of at least 1m

**Alternative:**

- There is no alternative to setting out properly
Setting out

**Why is it better?**

- Taut strings form a straight line from which all measurements can be made
- Set the top of the boards level with the finished floor
- Straight-edged boards help to define the floor level - use a spirit level

**Alternative:**

- Instead of strings, the lines can be made of chalk, but they would get easily covered up if earth or concrete is dumped on them
- There is no alternative to setting out the structure properly
Strings can mark the width of the foundation…

…but strings can also mark centerlines of foundations

Intersecting strings show the center of columns

The above examples show the importance of strings in marking all important points and lines of the structure
Chapter 02
Foundation
Excavation

How can I do it better?

- Start with it - Setting out the trench alignment and trench bottom and top with boards on each side of the site – start with it
- Before starting the excavation the site should be free from all organic material and waste
- For a good foundation a minimum 70cm deep trench is required

Why?

- Organic material will rot and cause the ground to settle
- A deep trench foundation makes a solid base for the house
Excavation

Trenches that have been excavated for foundations

- No boards for strings
- Trench is too shallow
- Roots of plants not disposed of

Why is it better?

- Trench is straight and has slightly sloped walls
- Trench is deep enough for the subsoil at the site – a minimum of 70cm

Alternative:

- There is never an alternative to good and clean excavation
Excavation

Why is it better?

- Trench is straight with slightly sloped trench walls
- Trench is deep enough for the subsoil at the site— a minimum of 70 cm

Alternative:

- There is never an alternative to a good excavation of the foundations
Rock

Rock layer of foundation is not embedded in concrete

**How can I do it better?**

- Deepen the trench to get a better, more solid base for the foundation
- The rocks have to be embedded in concrete
- For a good foundation a minimum of 70cm deep trench is required

**Why?**

- A deep foundation trench makes a solid base for a house
How can I do it better?

- Rocks are set too much in a straight line – they should be placed randomly

Why?

- There is never an alternative to solid foundation material
Rock

How can I do it better?

- Deepen the trench to get a solid base for the foundation
- The rocks have to be well-embedded in concrete
- For a solid foundation a minimum of 70cm deep trench is required

Why?

- A deep foundation trench makes a solid base
A crack is the consequence of poorly compacted subsoil or a poor foundation generally

**How can I do it better?**

- The excavation of the trench bottom for the foundation and the construction of the foundation itself have to be carried out with great care.
- Rocks in the foundation have to be well-embedded in concrete

**Why?**

- A deep foundation trench makes a solid base and reduces the chance of ground settlements.
Rock

Rocks for foundation

Why is it better?

- Rocks have to interlock each other
- Rocks of different size fill the remaining spaces between big rocks
- Rocks carry the load of the house

Alternative:

- There’s never an alternative to solid foundation material
WHY IS IT BETTER?

- Sand or lean concrete stabilize the rocks on the trench bottom
- Rocks are well-embedded in concrete
- Top layer levels the foundation top
- Roughen the surface of the top layer for better bond with the concrete of the foundation beam

ALTERNATIVE:

- There’s never an alternative to a solid foundation
Rock

Why is it better?

- Rebars of the column have to set be out before laying the rock foundation
- There must be enough space for L-shaped bottom end of rebar

Alternative:

- There's never an alternative to solid foundation material
Space left in foundation for columns

**Why is it better?**

- Rebars of the column have to be set out before laying the rocks of the foundation
- There must be enough space for L-shaped bottom end of rebar
- The higher the foundation the lower the risk of water damage

**Alternative:**

- There’s never an alternative to solid foundation material
**Rock**

A well-built strip foundation

**Why is it better?**

- Concrete with water-resistant cement avoids moisture in the wall
- A well-made foundation is the best base for a building
- Rough surface of top layer enables better bond to beams

**Alternative:**

- There's never an alternative to solid foundation material
Single foundations instead of stripfoundation

Why is it better?

- Single foundation for columns are a solid base for elevated floor slabs

Alternative:

- Strip foundation is an alternative
- There’s never an alternative to solid foundation material
Concrete

Rebars have to be supported

Filled up with stone masonry

Height acc. to requirements

Individual foundations

Individual foundations for elevated floor slab

Why is it better?

- Individual foundations for columns are a solid base for them
- The stone masonry supports foundation beams
- Neat appearance of the masonry work

Alternative:

- Strip foundation is no alternative for elevated floor slabs
- There’s never an alternative to solid foundation
Chapter 03
Concrete Works
Concrete Production

Why is it better?

- The quality of concrete depends on the correct proportions of all ingredients, i.e. cement, sand, aggregates and water.
- Not enough cement in the mix makes weak, low strength concrete
- Too much water also makes poor quality concrete
- It is important to measure and add gravel and sand separately for making dense concrete of good quality

Alternative:

- There is never an alternative to good quality workmanship.
Concrete Production

Why is it better?

- Good preparation is essential for good concrete
- Do not drop the concrete into the formwork from any height, but let it slip
- Maximum drop of concrete is 5m, otherwise the aggregates get separated
- Avoid cold joints during pouring - do one section in one lift

Alternative:

- There is never an alternative to good quality workmanship
Watch that concrete “cover” is the same over entire length

**How can I do it better?**

- Keep the distance between rebars and formwork constant (minimal cover 2 cm)
- Use continuous formwork
- Fix the bottom edge of formwork board to keep it straight

**Why?**

- The strength of reinforced concrete depends on the proper installation of rebars and formwork
Formwork

Spacer (blocks) under rebars keep the right distance to the formwork

How can I do it better?

• Use spacer (such as a cement block) to keep “cover” distance between rebars and formwork constant (2 cm)
• Support beam formwork every 50 cm

Why?

• Spacers are essential for ensuring the correct and constant concrete cover
• The strength of reinforced concrete depends on the proper installation of rebars and formwork
How can I do it better?

- Use spacer blocks to keep distance between rebars and formwork constant from 2 cm

Why?

- There will be no concrete cover, i.e. the steel bars will be exposed, when the rebars touch the formwork
- Spacers are essential to ensure correct and constant concrete cover
- The strength of reinforced concrete depends on the proper installation of rebars and formwork
Formwork

The two concrete beams must be continuous, including the rebars

How can I do it better?

• Cut open the formwork between the two beams so that they are cast as one connected structure

Why?

• Joints are always a weak spot in the concrete
• Beams up to a length of 5 m can be cast in one pour
Support roof ridge and formwork for beam first, then start concreting

Formwork

Beam support every 50cm

Beam supports are essential before concreting the adjacent section

**How can I do it better?**

- Support formwork of concrete beams every 50cm until concrete reaches its full strength
- Support reinforcement before pouring the adjacent section

**Why?**

- During pouring the rebars must not moved nor vibrated
Formwork

Avoid concreting in short sections

How can I do it better?

- Solidly built formwork is the basis for strong concrete structures
- Support formwork of beams at 50cm intervals until concrete reaches its full strength
- When casting beams (or columns) place concrete in one lift

Why?

- Avoid “cold” concrete joints as much as possible
- Joints are always weak points of any concrete structure
- Beams up to a length of 5m can be cast in one pour
Formwork

Avoid pouring concrete in short sections

How can I do it better?

- Solidly built formwork is the basis of good concrete structures
- Place concrete for all beam (and columns) in one pour (lift)

Why?

- Avoid “cold” concrete joints as much as possible
- Joints are always weak points in any concrete structure
- Beams up to a length of 5m can be cast in one pour
Formwork

Formwork for columns should be built like this

Why is it better?

- Brackets tie the plywood sheets (or boards) of the formwork together
- The spacing between brackets should be between 50 cm and 80 cm
- Formwork should be at least 2 cm thick
- Well-built strong formwork keeps its shape when filled with wet concrete

Alternative:

- Plywood is good. It is has a smooth surface, but it is not thick enough.
- Plywood must be supported by timbers to strengthen the formwork
- There are no alternatives to well-built formwork
- The more time you spend on building the formwork, the better the concrete will be
Formwork

A column formwork set up on site

Why is it better?

- Brackets tie the plywood sheets (or boards) of the formwork together
- The distance between brackets should be between 50 cm and 80 cm, closer together near the bottom.
- Sheets of formwork are thick enough
- Strong formwork will keep its shape when filled with wet concrete

Alternative:

- There are no alternatives to well-built formwork
- The more time you spend on building the formwork, the better the concrete will be
Formwork

Formwork for the columns

Braces hold up formwork

Braces hold up formwork for columns

Why is it better?

- Strong formwork will keep its shape when filled with wet concrete
- Brackets tie the sheets (or boards) of the formwork together
- Formwork boards are thick enough
- Formwork for columns is braced from two sides to keep it straight

Alternative:

- There are no alternatives to well-built formwork
- The more time spent on building formwork, the better the concrete will be
Formwork

Bracing from two directions is essential for formwork for columns

**Why is it better?**

- Well-braced formwork will not shift or tilt during pouring
- Formwork for columns shall not exceed 5m in height because concrete should not be dropped from a great height
- Height between horizontal beams shall not exceed 3m in order to maintain safety during earthquakes
- There are holes and wall anchors installed through the formwork
- The tie brackets can be of different shape but they should tie the boards of the formwork together

**Alternative:**

- Wet concrete shall not be dropped more than 5m, otherwise the aggregates will separate
- There is no alternative to good workmanship
Formwork

Horizontal bracing provides more stability to the column formwork

**Why is it better?**

- Bracing provides more stability to the formwork, so it cannot shift or tilt when the wet concrete is placed
- Leave holes in the formwork for the wall anchors

**Alternative:**

- Concrete shall not be dropped more than 5m, otherwise the aggregates will separate
- There is no alternative to good workmanship
Formwork from two sides is essential for vertical columns

**Why is it better?**

- The formwork cannot move during concrete placement
- The formwork for columns shall not exceed 5m in height
- Height between horizontal beams shall not exceed 3m to make sure the structure is earthquake-proof

**Alternative:**

- Wet concrete shall not be dropped more than 5m, otherwise the aggregates will separate
- There is no alternative to good workmanship
Formwork

2 direction braces for columns

Brackets

Wooden forms

Well-built and strong formwork for concrete beams and columns

Why is it better?

- Strong, well-built formwork is essential for good quality concrete structures
- The thickness of the sheets of formwork is adequate – at least 2 cm thick

Alternative:

- There is no alternative to strong formwork
Formwork

Solid support for formwork

Why is it better?

- Well-built formwork is essential for good quality concrete structures
- Elevated slabs or beams must be supported at 50cm spacing to avoid sagging
- Do NOT remove the bottom formwork and supports for 28 days, so that the concrete will reach its design strength

Alternative:

- There is no alternative to strong formwork
Formwork

Formwork for roof beams must be well supported

Why is it better?

- Support forms for beams at 50cm spacing until concrete reaches its strength

Alternative:

- There is no alternative for strong supports for formwork
Formwork for beams must be well supported

**Why is it better?**

- Support formwork for beams at 50 cm spacing until concrete reaches its strength
- Use wooden tie brackets instead of wire

**Alternative:**

- There is no alternative for good support
Formwork

Formwork for concrete rafters must be supported

Why is it better?

- Support formworks for beams at 50cm spacing until concrete reaches its full design strength

Alternative:

- There is no alternative for good supports
Reinforcement

These rebars should overlap 50cm

50cm overlap

Top layer – red
Bottom layer - green

Top Layer Ø12 mm 12mm
Tie Ø 8mm
Bottom Layer Ø 12mm

There must be a connection between both the rebars of the bottom and the top layer of reinforcement

How can I do it better?

• Bend the rebars as shown and fix them together with wire
• Length of overlap must be 40 times the diameter, or a minimum of 50cm

Why?

• Overlap is essential to extend the strength of the rebars throughout the structure
• Well-tied and connected rebars are a basic element of reinforced concrete structures
• Fixing the reinforcement should be done with great care
Reinforcement

There must be a connection between both these rebars (bottom and top layers)

How can I do it better?

- Bend the rebars as shown in drawing
- Fixing the reinforcement must be done with great care

Why?

- Well-tied and connected rebars are a basic element of reinforced concrete structures
Reinforcement

There must be NO “dead” end of rebars – they must be connected to the adjacent rebars in the same plane

**How can I do it better?**

- Use longer pieces of rebars
- Rebar must never end without a “U” hook
- Bend the rebars as shown in the picture (and drawings)
- Fixing the reinforcement must be done with great care

**Why?**

- Well-tied and connected rebars are a basic element of reinforced concrete structures
Reinforcement

Rebars must be connected, i.e. tied and overlapped, to each other

**How can I do it better?**

- Tie rebars together with thin, flexible wire
- Each rebar must be tied or connected to the adjacent rebars

**Why?**

- Only well-tied rebars will ensure the strength of the concrete
- Connecting the rebars must be done with great care
- Well-tied and connected rebars are a basic element of reinforced concrete structures
Reinforcement

There shall be NO space between rebars

How can I do it better?

• Bend the rebars in accordance with what’s shown on the drawings
• Rebars have to overlap by a minimum of 50 cm
• Fixing the rebars must be done with great care

Why?

• Well-tied and connected rebars are a basic element of reinforced concrete structures
Reinforcement

Rebars must be tied to each other

Design dimension of column

Rebars must be centered in concrete structure

How can I do it better?

- The concrete cover of rebars must be at least 1-2 cm
- Each rebar has to be connected to the adjacent one(s)
- Fixing the rebars must be done with great care

Why?

- Adequate concrete cover enables the concrete to reach its design strength
Reinforcement

The cross section of the column **MUST NOT** be less than the design

Bricks are **NOT** formwork

Rebars must be straight and vertical

Rebars must be fixed in a straight vertical line from bottom to top

**How can I do it better?**

- Rebars for columns must be in a vertical straight line from the foundation up to the roof beam
- The dimensions of the cross section of any column or beam must not be reduced
- The dimensions of a column shall not be less than 15x15 cm
- Bricks are **NOT** formwork

**Why?**

- The column is a key element of the house structure
- Columns carry the load of the entire roof
- A reduced cross section increases the risk of collapse during an earthquake
- Columns must be built with great care
- The stability and structural integrity of the columns are potentially affected by earthquakes
Reinforcement

Rebars of columns must be STRAIGHT, not bent

How can I do it better?

- Rebars for columns must be fixed to be vertical and straight from the foundation up to the roof beam
- Never reduce the dimensions of the cross section of any column or beam
- For columns, vertical rebar must be a minimum diameter of 12 mm, and horizontal rebar a minimum diameter of 8 mm

Why?

- The column is a key element of the house structure
- Columns carry the load of the entire roof
- Reduced cross sections increase the risk of collapse during an earthquake
- Columns must be built with great care
- The stability and structural integrity of the columns are potentially affected by earthquakes
Reinforcement

Bent rebars weaken the stability of the structure
Column rebars must be straight and vertical
Foundation beam
Rebars are not covered in concrete

Rebars of columns must be STRAIGHT, not bent

How can I do it better?

- Rebars for columns must be vertical and straight from the foundation up to the roof beam
- The size of the cross section of any column or beam must not be reduced
- The dimensions of a column shall not be less than 15x15 cm
- For columns, vertical rebars must be a minimum diameter of 12mm, and horizontal rebars a minimum diameter of 8mm
- Concrete cover over rebars must be 2 cm

Why?

- The column is a key element of the house structure
- Columns carry the load of the entire roof
- Reduced cross sections increase the risk of collapse during earthquakes
- Columns must be built with great care
- The stability and structural integrity of the columns are potentially affected by earthquakes
Reinforcement

The distance between the rebar ties should be constant

How can I do it better?

- Fix rebar ties exactly 15 cm spacing from each other
- Fixing the reinforcement must be done with great care

Why?

- Rebars are essential for attaining the full strength of a reinforced concrete structure
Reinforcement

Rebars must be fixed straight in the formwork

**How can I do it better?**

- Rebars must be placed in a straight line
- Use spacers (blocks) under rebars to get the right cover over the steel rebars
- Fixing the reinforcement must be done with great care

**Why?**

- Twisted rebars cannot develop the full strength of the reinforced concrete structure
- Rebars are a key element of a reinforced concrete structure
Reinforcement

No spacers / blocks are used to hold the rebars in the right position

How can I do it better?

• Rebars must be set on spacers / blocks to get the right concrete cover

Why?

• There are no alternatives to properly fixed reinforcement
• The more time you spend on fixing the rebars and formwork, the better the concrete will be
Reinforcement

Assembly and storage of rebars and cages

Why is it better?

- Properly sorted and stacked rebars ease the assembly of rebar cages as well as the progress of house construction
- Supports under the materials keep rebars and cages off the ground and clean

Alternative:

- There is never an alternative to well-organized clean storage
Reinforcement

8 and 12 mm diameter steel bars are the main elements used for reinforcement.

**Why is it better?**

- Check the diameter of rebars to make sure they are the correct size.
- The length of bends at each end of the 8 mm diam. Ties shall be 5 cm, for the 12 mm diam rebars the length of the bends shall be 8 cm.
- Properly fixed and tied rebars of the right diameter are important for reaching the design strength of the reinforced concrete elements.
- All rebars must be tied to each other at points where they cross.

**Alternative:**

- There are no alternatives to correctly sized and fixed reinforcement.
- The more time spent on reinforcement, the better the concrete will be.
**Reinforcement**

Column rebars - grey

Foundation rebars – green and blue

All blue ties are at the same spacing of 15cm on centers

Overlap 50cm

Hook 8cm

Hook 5cm

Example of a beam & column rebars (Colours for illustration only)

Why is it better?

- Correctly sized and fixed rebars are important to reaching the design strength of reinforced concrete structures
- All rebars must be clean, free of rust and tied to each other

Alternative:

- There are no alternatives to properly fixed reinforcement
- The more time spent on reinforcement, the better the concrete will be
Reinforcement

All ties are at equal spacing

No spacer blocks are used - yet

Rebars are fixed properly

Why is it better?

• Correctly sized and fixed rebars are important for reaching the strength of reinforced concrete structures
• All rebars must be tied to each other
• Ties locations are varied
• Use spacer blocks below rebars to ensure correct concrete cover

Alternative:

• There are no alternatives to correctly sized and fixed reinforcement
• The more time spent on reinforcement, the better the concrete will be
Reinforcement

Rebars are neatly assembled but spacer blocks are not used - yet

Why is it better?

- The length of overlap shall not be less than 50 cm
- Correctly sized and fixed rebars are important for reaching the design strength of reinforced concrete structures
- All rebars must be tied to each other

Alternative:

- There are no alternatives to properly fixed reinforcement
- The more time spent on reinforcement, the better the concrete will be
Reinforcement

Correctly and neatly installed rebars

Why is it better?

- Correctly fixed rebars are important for reaching the strength of reinforced concrete structures
- All rebars must be tied to each other

Alternative:

- There are no alternatives to correctly sized and fixed reinforcement
- The more time spent on reinforcement, the better the concrete will be
**Reinforcement**

Column rebar well centered on beams

Equal spacing between ties

Adequate concrete cover

Note the concrete cover

**Why is it better?**

- Concrete cover must be at least 2 cm to make sure steel rebars are not exposed
- All rebars must be tied to each other

**Alternative:**

- There are no alternatives to adequate concrete cover over reinforcement
- The more time spent on reinforcement, the better the concrete will be
Reinforcement

Fixing the vertical column rebars in the foundation trench

**Why is it better?**

- A large footing provides a good base for the column reinforcement
- Bend the column rebars at an 90° angle into the footing
- Rebars are clean and not rusty

**Alternative:**

- There are no alternatives to correctly and neatly fixed reinforcement
- The more time spent on reinforcement, the better the concrete will be
Rebar cage for a footing pad for an elevated floor

Why is it better?

- Rebars are correctly and neatly fixed in place
- Rebars are bent at an exact 90° angle

Alternative:

- There are no alternatives to correctly and neatly fixed reinforcement
- The more time spent on reinforcement, the better the concrete will be
Reinforcement

Supports form two sides to keep the rebars vertical

Why is it better?

- The rebars must not move during concreting
- Rebars must be truly vertical so that the column will be perfectly straight

Alternative:

- There are no alternatives to correctly and neatly fixed reinforcement
- The more time spent on reinforcement, the better the concrete will be
Reinforcement

Why is it better?

- The rebars must not move during concreting
- Rebars must be truly vertical so that the column will be perfectly straight

Alternative:

- There are no alternatives to good reinforcement
- The more time spent on reinforcement, the better the concrete will be
Reinforcement

Steel anchors are necessary to tie the brick wall to the concrete columns

Why is it better?

- Anchors tie the brick wall to the concrete columns
- Columns and walls are both elements of the structural system and are essential for the strength and stability of the house

Alternative:

- There are no alternatives to correctly fixed reinforcement
- The more time spent on reinforcement, the better the concrete will be
Reinforcement

Why is it better?

- All static elements have to be connected to the static system of the building
- All rebars have to be connected to each other

Alternative:

- There are no alternatives to correctly and neatly fixed reinforcement
- The more time spent on reinforcement, the better the concrete will be
Beams & Columns

Lintels missing

Columns were cast in 3 sections

Bricks used as formwork

Solid framework is essential

How can I do it better?

• First pour the concrete columns up to the roof beam (before building the walls)
• Check steel reinforcement
• Use continuous formwork for the entire column
• Build the brick walls after formwork has been removed

Why?

• The strength of a concrete column increases with the size of its cross section.
• A column that is too long relative to its cross section can buckle under heavy loads.
Columns must have the design cross section along their entire length

**How can I do it better?**

- Use plywood formwork instead of using the bricks as formwork
- The dimensions of any column shall not be less than 15x15cm
- Brickwork is NOT formwork!

**WHY?**

- The column is the key bearing element of the house structure
- Columns help hold up the walls and carry the load of the entire roof
- Columns must be built with great care
- The stability and structural integrity of columns are easily affected by earthquakes
Beams & Columns

Columns must have the design cross section

**How can I do it better?**

- The dimensions of a concrete column shall not be less than 15x15cm
- Use plywood formwork instead of using the bricks as formwork
- Brickwork is NOT formwork!
- Rebars must be fixed in a vertical position

**WHY?**

- The column is the key bearing element of the structure of a house
- Columns help hold up the walls and carry the entire load of the roof
- Columns must be built with great care
- The stability and structural integrity of the columns are likely affected by earthquakes
Beams & Columns

The full design cross section of a column is essential for the strength and stability of the entire structure.

How can I do it better?

• The dimensions of a column shall not be less than 15x15cm
• Use continuous formwork for the entire column
• Use plywood formwork instead of using the bricks as formwork
• Brickwork is NOT formwork!

WHY?

• The column is the key bearing element of the structure of a house
• Columns help hold up the walls and carry the entire load of the roof
• Columns must be built with great care
• The stability and structural integrity of the columns are likely affected by earthquakes
Beams & Columns

Concrete is not well compacted and the columns are completely out of shape – the actual cross section cannot carry any loads

How can I do it better?

- Rebars must be embedded in well-compacted concrete
- Cover over reinforcement must be a minimum of 2cm

Why?

- Every beam or column is a load-bearing element in the system of a house and has to be carried out very carefully
- Concrete will never reach full strength when it is not well compacted
- Reinforcement and the concrete around it constitute the strength of the beam / column
Beams & Columns

These columns can never carry any loads!

**How can I do it better?**

- Make sure that the concrete is well-compacted
- Use solid formwork only – bricks are not formwork
- Watch out that the reinforcement has a minimum cover of 2cm

**WHY?**

- Only the joint action of reinforcement and concrete will make strong columns and beams to get a rigid and stable load-bearing system.
- Earthquake-proof system needs a rigid framework
Beams & Columns

Honeycombs showing less compaction during pouring

How can I do it better?

- Compact the concrete well during the entire pouring

WHY?

- Only well-compacted concrete has structural strength
- The concrete frame is potentially affected by earthquakes, therefore full attention has to be given to the concrete works
Beams & Columns

Honeycombs weaken the strength of concrete

How can I do it better?

- Compact concrete often and with care during pouring
- Make sure that concrete aggregates do not get separated

WHY?

- Only well-compacted concrete achieves the necessary strength
- The concrete frame of columns and beams is potentially affected by earthquakes, therefore concrete works must be done with great care
Beams & Columns

King post should be placed straight on top of the column

**How can I do it better?**

- Move the king post to the top of the column

**WHY?**

- The vertical load on the king post should be transferred directly to the columns and foundation
- The concrete frame is potentially affected by earthquakes therefore the concrete works must be done with great care
A solid stone foundation

Foundation beams are well-built

This well-shaped foundation grid is a solid base for the house structure

Why is it better?

- A solid foundation is the best base for a house
- Build a strong grid of foundation beams to get a strong structure

Alternative:

- There is no alternative for a good foundation
Beams & Columns

**Fill must be compacted**

**Foundation beams**

**Brickwork foundation**

**Foundation beams were cast with good formwork**

**Stone foundation**

Why is it better?

- Strong formwork helps to achieve the full strength of the concrete so that the structure can resist earthquakes

Alternative:

- There is no alternative if full concrete strength should be attained
The house structure must be built on a solid foundation grid

Why is it better?

- A solid foundation is the base of a strong house structure
- A solid grid of foundation beams will make a strong structure

Alternative:

- There is no alternative for a good foundation
Beams & Columns

A good connection between roof ring beams and column is important.

Columns are well built.

Roof ring beam

Lintel beam

The skeleton (framework) of the structure should look like this.

Why is it better?

- A solid skeleton (framework) is essential for an earthquake-proof building

Alternative:

- There is no alternative for building a solid structure
**Beams & Columns**

Column built with formwork

**Why is it better?**

- A skeleton (framework) is essential for an earthquake-proof building

**Alternative:**

- There is no alternative for building good quality structure
Beams & Columns

Foundation beams and columns with wall anchors built using good formwork

Why is it better?

• Good formwork is essential for an earthquake-proof building
• After removal of the formwork, the bricklaying can start

Alternative:

• There is no alternative for getting good quality concrete
Beams & Columns

A lintel beam must be used when the distance between bottom of the roof beam and top frame of any windows or doors is more than 50cm

Why is it better?

- The area inside any frame of columns and beams shall not exceed 12 square meters
- Solid formwork is essential for attaining the good quality concrete that is needed for earthquake-proof buildings

Alternative:

- There is no alternative for building a good quality concrete structure
Slab

The elevated slab is supported by a concrete post (or pile) foundation

**Why is it better ?**

- In areas where flooding is possible, it is recommended to build the houses on an elevated slab
- The concrete post (pile) foundation must be built with great care, because the piles carry the entire load of the house

**Alternative:**

- There is no alternative to doing good quality concrete work
Chapter 04
Walls
**Materials**

**Untidy storage of bricks**

**How can I do it better?**

- Stack bricks neatly – there is less chance of breakage

**WHY?**

- Broken bricks make weaker brick walls
Materials

Left: Well stacked clay bricks of standard dimensions, i.e. 20x10x5cm

**Why is it better?**

- Well-stored bricks will not get broken and bricklaying will be easier

**Alternative:**

- Walls made of hollow concrete blocks
Defective, broken and poor quality bricks weaken the wall

**How can I do it better?**

- Bricks of good quality make for stronger walls
- Handle bricks with care and stack them in tidy piles on the storage area

**WHY?**

- Bricks are made of fired clay and break easily
- Bricks get their strength when laid in cement mortar in masonry walls
Construction

The joints are too large

**How can I do it better?**

- Make vertical & horizontal joints only 1.0 to 1.5cm wide
- The bricks must be laid perfectly level

**WHY?**

- Wide joints are not good for the stability of the wall
Bricks not laid level, i.e. not in a horizontal line

**How can I do it better?**

- The joints must be between 1.0 and 1.5 cm maximum
- The bricks have to be laid level, i.e. in a horizontal line

**WHY?**

- Uneven joints and brickwork not laid level may affect the stability of the wall
Construction

This wall shows many defects

How can I do it better?

- This wall may not withstand an earthquake
- Follow the suggestions in this book for building brick walls
- First cast the concrete columns and then start with the bricklaying
- Bricks must be laid level and plumb, and the joints must be offset by half a brick length in each layer
- The steel anchors from the columns must be embedded in the brick wall

WHY?

- Using GOOD construction practice as shown in this book will result in good quality house
Bricks must be laid exactly level

**How can I do it better?**

- Set bricks exactly level, i.e. in a horizontal line
- The joints must be the same width, i.e. 1.0 to 1.5 cm maximum

**WHY?**

- A well built, solid wall contributes to the stability of the house
- It is easier to put plaster on a smooth brick wall
Bricks must be laid exactly aligned (on top of each other) to get a smooth wall surface

**How can I do it better?**

- Lay bricks with a plumb line to get a perfectly vertical line

**WHY?**

- A well built brick wall contributes to the stability of the house
- It is much easier to put plaster on a smooth wall surface
Wall should be built after columns have been built

**How can I do it better?**

- Build the beam first (with good supports), then build the columns, and last the brick wall

**WHY?**

- Building in the right sequence is important for a good quality house
Construction

How can I do it better?

- Lay the bricks for the lintel as shown on the picture above

WHY?

- A lintel must carry and distribute the load of the wall above the opening to the adjacent walls and columns (which carry the load to the footings)
Clay brick wall

**Why is it better?**

- The joints must not exceed the dimensions shown
- The bricks of the next layer up are laid centered on the joint of the lower layer
- The joint to the column is executed neatly

**Alternative:**

- Wall made of hollow concrete blocks
Construction

Max. height between beams 3m

The indicated area is to 12 m² max.

Area between columns and beams shall not exceed 12 m²

Why is it better?

• Areas larger than 12 m² will not resist even moderate earthquakes
• For stability reasons it is very important that the anchors from the columns are embedded in the brickwork

Alternative:

• There is no alternative for building stable walls
Construction

Bricklaying takes place after building the columns

Why is it better?

- After removal of the formwork (for beams & columns) bricklaying can start
- For reasons of stability it is important that the anchors are embedded in the brickwork
- Up to 60cm above foundation beam the joints of the brickwork have to be done with water resistant mortar (1.5 units of cement instead of 1 unit)

Alternative:

- There is no alternative to good construction practice
Construction

Connection of column to brickwall

Why is it better?

- The connection must be done with care
- To make the connection effective, it is important that the steel anchors are embedded in the brickwork

Alternative:

- There is no alternative to good wall anchors
Doors & Windows

Door & window frames must not be installed before the concrete work has been finished.

How can I do it better?

• Build columns and beams before starting brickwork

WHY?

• It is preferable to finish all concrete works first and then start with wall construction and then do the door and window installation.
Doors & Windows

Window frame must be installed before building the wall

How can I do it better?

- Install the window and door frames together with building the wall
- Bricks for lintel should be set in two directions (similar to an arch)
- Keep a small space between wall and frames and fill it with masonry

WHY?

- A good design minimizes problems on site
Doors & Windows

Frames ready for installation

Why is it better?

• Frames are stacked for storage (they should be on supports)

Alternative:

• Good preparation and organization eases the progress of work
Doors & Windows

Window frames ready for installation

**Why is it better?**

- Temporary supports hold and fix the frames in an upright position during construction

**Alternative:**

- Good preparation eases the progress of work
Spacers below the frame hold it in a level position

**Why is it better?**

- Temporary supports keep the frames in a vertical position during construction work
- Spacer (blocks) hold the frame in a level position during the construction of the wall

**Alternative:**

- There is no alternative to good quality workmanship
Doors & Windows

Supports can also be installed outside the structure

**Why is it better?**

- Supports hold the frames in a vertical position during the construction of the walls
- Spacers keep the frame in a level position during wall erection

**Alternative:**

- There are none – good temporary supports are essential
The rigid triangles formed with the supports keep the frames in a fixed position.

Why is it better?

- Temporary supports and frames form a rigid triangle
- Supports keep the frames in a vertical position during construction work

Alternative:

- Good work preparation ease the work at all
Doors & Windows

Lintel

A lintel has to carry the load of the wall above

Why is it better?

- Bricks in lintel are inclined in both directions
- Roof beam is extended down to top edge of window frame

Alternative:

- Lintels can be built of bricks or of concrete
- Use concrete lintel beam when vertical distance to roof beam exceeds 50cm
The Good & The Bad Infrastructure

**Plaster**

Plaster makes a smooth wall surface

**Why is it better?**

- To prevent moisture from penetrating the walls the lower 60cm of walls should be plastered with a water-resistant plaster (1.5 units instead of 1.0 unit)

**Alternative:**

- Tar paper or plastic sheets can be laid on top of foundation beam to prevent moisture from penetrating the bricks
Plaster

A lintel has to carry the load of the wall above

Why is it better?

- To prevent moisture from penetrating the walls the lower 60cm of walls should be plastered with a water-resistant plaster
- The final appearance of the house can be somewhat shaped with plaster to give it an individual look
- Before painting the plaster have to be dried out

Alternative:

- The alternative is to leave the exterior finish up to the owner
Chapter 05
Roof
Roofing Materials

Sheets have to be fixed really well

How can I do it better?

- Only properly installed and sealed roofing materials guarantee a leak-proof roof
- Improperly fastened or loose roofing materials pose a serious risk during storms

WHY?

- There is no alternative to good workmanship
Roofing Materials

Rubber seal is needed for a leak-proof roof
Note the large head of the roofing nail

How can I do it better?

• Use rubber seals around the roofing nails or screws
• Put nails on the top of ridges

WHY?

• There is no alternative of good workmanship


Roofing Materials

Corrugated steel sheets to get fixed on purlins

Why is it better?

- Start at the bottom end to mount the sheets
- A sufficient overlap ensures no water leaks into the house

Alternative:

- Other design of corrugated roof sheets
- Fibre cement sheets – may be colourful
- Roof tiles, but much more expensive
Roofing Materials

Example of fibre cement roofing sheets

Why is it better?

- Overlap is essential for all types of roofing sheets
- All nails or screws must be of stainless steel/galvanized and have rubber seals
- All nails or screws should be covered with a plastic cap

Alternative:

- Roof tiles, but they are much heavier and more expensive
- Galvanized steel sheets are currently the cheapest roofing material
Roofing Materials

Use nails with a plastic cap

Why is it better?

- There must be a rubber seal between roofing sheet and roofing nails (or screws)
- Galvanized or stainless steel materials should be used because they do not rust

Alternative:

- Roofing tiles, but they are much heavier and more expensive
- Fibre cement sheets
- Galvanized steel sheets are currently the cheapest roofing material
Aluminum Construction

Why is it better?

• Rigid and strong connections are essential for a stable roof frame

Alternative:

• The traditionally used material is still wood and it is a good alternative Aluminum Construction

Truss must be fixed to roof ring beam
Aluminum Construction

Why is it better?

- Roof truss frames of aluminum are lightweight and do not rust
- Aluminum needs no painting
- This metal is strong, but also expensive

Alternative:

- The traditional material is still wood, but it must be painted regularly.
Aluminum Construction

Why is it better?

- All roof trusses must be tied to the roof ring beam

Alternative:

- Wood is still a good alternative
Aluminum Construction

Why is it better?

- It is easier to fix the front board to the wooden rafter extensions

Alternative:

- Wooden roof trusses are still a good alternative.
Wood Construction

The rafter must be supported on entire length of the wall

This wire is not enough to fix the rafter to the wall

Well supported rafters improve the stability of the roof

**How can I do it better?**

- Build the wall all the way up to the rafter, so the support is over its entire length
- Use flat steel (plates) and bolts to fix the rafter to the wall

**WHY?**

- The better the rafters are supported, the stronger the roof construction will be
- Rafters need to be supported when they are not tied together by the tie beam
Wood Construction

The entire roof truss must be fixed to the roof ring beam

How can I do it better?

- Use flat steel (plates) and bolts to tie the truss to the roof ring beam

WHY?

- The better the connection of the truss to the wall, the stronger the roof construction will be.
Wood Construction

Make sure that the roof truss is properly connected

**How can I do it better?**

- Bolts are better than just nails for all truss connections
- Use flat steel (plates) and bolts to tie the truss to the roof ring beam

**WHY?**

- The better the connections of the truss to the wall, the stronger the roof construction will be.
Wood Construction

A roof truss will reach its full strength when all members are tied together

**How can I do it better?**

- Use proper angle struts instead of unapproved connections to the wall

**WHY?**

- A roof truss is a structural system and can only function as such when all members are tied together
- The better the connections of the truss, the stronger the roof construction will be.
**Wood Construction**

Connect the extension **ON TOP** of the rafter

**How can I do it better ?**

- The extension must be mounted **on top** of the rafter and must be connected with at least 2 bolts through both members

**WHY ?**

- Both members must function like one structure to carry the load of the roof
- The better the connections of the truss, the stronger the roof construction will be.
Wood Construction

Why is it better?

- Timber sorted and stacked by size ease the production of roof trusses as well as the progress of house construction.

Alternative:

- There is never an alternative for a good organisation on a construction site.
Wood Construction

The main parts of a roof truss frame

Why is it better?

- Well-built roof trusses will resist windstorms and earthquakes

Alternative:

- There is no alternative for good workmanship
Wood Construction

Connection of king post and tie beam with bolts only

Connect rafter sections with bolts only

How connections of wooden truss members should be made

Why is it better?

- The connections of the wooden truss members make it a rigid frame
- Bolts connections are much better and stronger than nails
- Bolts are screwed through both wooden sections and tie them together

Alternative:

- None
Wood Construction

Cross beams fixed to the kings posts make the structure stable

Why is it better?

- The trusses must be tied together with two cross beams to connect the trusses to each other
- The cross beams stabilize the trusses vertically
- Bolted connections are better than nails

Alternative:

- None
The picture shows where the trusses have to be connected

**Why is it better?**

- Tight connections are important to make the trusses strong

**Alternative:**

- There is no alternative to good workmanship
Wood Construction

The truss must be mounted on, and fixed to, the roof ring beam

Why is it better?

- Tight connections between truss and concrete roof ring beam are essential for a strong construction
- Bolts fasten the flat steel plate tightly to the beam

Alternative:

- Bent rebars of the column can also be used to tie the trusses to roof beam, but they must be fixed to the truss
Wood Construction

Different types of truss anchors

Why is it better?

- Tight connections between truss and concrete roof ring beam are essential for a rigid truss frame
- Bolts fix the flat steel tight to the truss

Alternative:

- There is no alternative to strong connections between the truss and the roof ring beam
Wood Construction

Why is it better?

- Tight connections are important to keep the purlins in place for the roofing
- Spacing of purlins depends on roofing materials

Alternative:

- There is no alternative to good workmanship
Wood Construction

Good examples of roof truss frame construction

Why is it better?

- Tight connections are important to hold the purlins in place for the roofing
- The connection of rafter extensions must be done with care – at least 2 bolts must be used through both wooden sections

Alternative:

- There is no alternative to good workmanship
Chapter 06
Floor
Why is it better?

- This floor does not draw in moisture
- Water can seep away into the ground and does not affect the building or its foundations

Alternative:

- The more time spent on placing the different layer, the better the quality of the house will be.
Construction

Compacted backfill is the base for the floor construction

Why is it better?

- Although compaction has not been done in this layer, but well-compacted backfill prevents later settling of the concrete floor slab

Alternative:

- The more time spent on placing the different floor layer, the better gets the quality of the house will be
Backfill is the base for the floor construction and must be well compacted.

**Why is it better?**

- Compaction to be done for each layer of backfill
- Layers of backfill shall not exceed 20 cm in depth
- When the backfill is well compacted the concrete floor slab cannot settle or crack

**Alternative:**

- The more time spent on compacting, the smaller the risks of floor settlements or cracking
Construction

Floor slab is the base of the finished floor

Why is it better?

• The surface is smooth and well levelled
• This is good base for floor tiles, linoleum or just painting the surface

Alternative:

• There is no alternative to good workmanship
Chapter 07 Services
How can I do it better?

- For increased safety, electrical wires should be installed in PVC ducts
- Install the ducts in a straight line under the plaster – it makes it easier to find them later on
- Preferably, electrical wires should be installed out of reach, i.e. higher than 2,5m
- In masonry walls, the ducts should be installed in the wall or at least in the plaster, in wooden structures the ducts are installed on the surface

WHY?

- A safe electrical installation should prevent system failures and also be no threat to human health and safety
Electricity

Wire ducts have to be fixed to the wall

How can I do it better?

- Minimize penetrating beams with ducts to avoid weakening of the beam
- Electrical wires and ducts should be out of human reach, higher than 2.5m

WHY?

- A safe electrical installation prevents system failures and should meet human health and safety requirements
How can I do it better?

- Electrical cables shall not rub at the edge of the suspended ceiling
- Install wires in a PVC duct that extends below the suspending ceiling

WHY?

- A faulty electrical installation could cause damage to the house
- A poor installation is also a risk to human health and safety
Electricity

Why is it better?

- The wires are installed in a duct and laid in the plaster
- The safety risk is reduced to a minimum

Alternative:

- There’s never an alternative to a safe electrical installation
Water & Sanitation

Never penetrate a beam with a larger pipe

How can I do it better?

- Never penetrate beams with any larger pipe to avoid weakening the beam
- Set water and sanitation pipes below natural ground level
- Cross foundation about 60cm below ground level

WHY?

- Do NOT weaken the strength of a concrete beam – it is an important element of the earthquake-proof structure
- Pipes laid below ground are better protected against damage or destruction
Sanitation

**Why is it better?**

- The two chambers partially treat (clean) the waste water
- Chamber with settled sludge must be pumped out regularly (when full)
- Access manhole is essential for inspection and pumping out
- Vent pipe is needed
- Remove formwork of tank cover

**Alternative:**

- Direct connection to a sewer system – if available