



## DOMINICA HOUSING RECOVERY PROJECT:

### **ONE-DAY CONTRACTORS' WORKSHOP – *THE HRP CONTRACTOR JOURNEY***

#### RESILIENT CONSTRUCTION IN HRP

DANIEL TS CAMPBELL ME (HONS) BENG (HONS) ENV SP, PMP

WORLD BANK ENGINEERING CONSULTANT

DCAMPBELL1@WORLDBANK.ORG

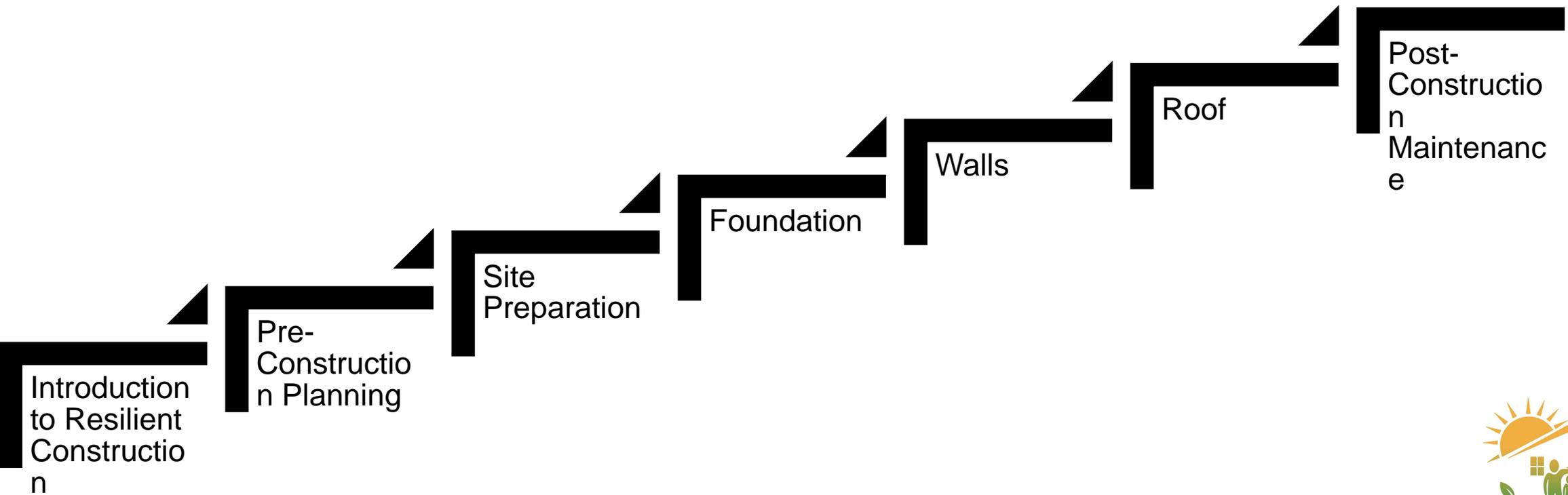
*JUNE 2021*

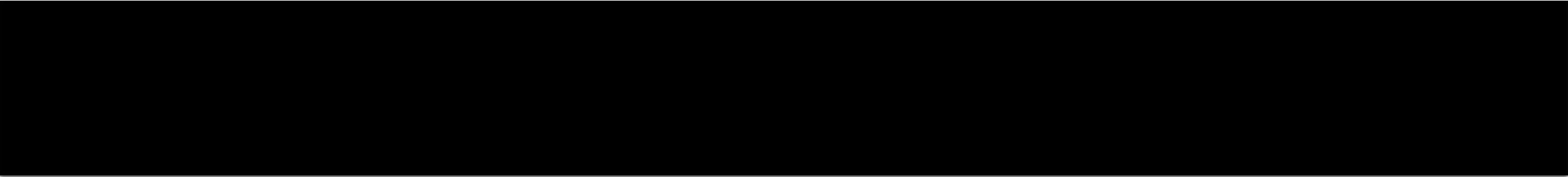
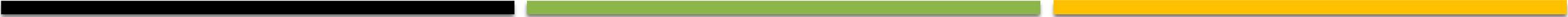
# RESILIENT CONSTRUCTION IN HRP

HOUSING AND HAZARDS – IMPROVING RESIDENTIAL CONSTRUCTION IN DOMINICA



# TOPICS





# INTRODUCTION TO RESILIENT CONSTRUCTION



# HOUSING AND IMPACTS OF HAZARDS

Hazards	Impacts	Infrastructure Implications
Sea level rise	Coastal flooding and erosion, land lost, seawater intrusion	Damage to coastal infrastructure and pollution of underground water resources
Category 4 and 5 hurricanes	Storm surge, inland flooding, wind related damage	Damage to infrastructure including electricity and water
Torrential rainfall events	Inland flooding	Damage to infrastructure including electricity and water
Prolonged drought	Limited water resources	Water supply restrictions
Increased temperatures	Heat stress Coral bleaching Increased emergence of vector borne diseases	Increased energy and water use. Coastal erosion (damage to coastal infrastructure). Vector habitats



# PRE-CONSTRUCTION PLANNING



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- It is important to understand the purpose of any resilient features that are included in the building plan.
  - The resilient construction planning process usually involves four key steps:
    1. Understand potential hazards, vulnerabilities, and impacts based on the location and type of structure.
    2. Identify opportunities to create value in terms of both mitigating hazards and creating long-term operations efficiencies.
    3. Balance first costs and long-term savings.
    4. Plan the design, materials, and building techniques accordingly.
  - On the last step, contractors can add substantial value to the discussion when we understand the technologies, materials, and techniques that are available and proven in the field.



## Pre-Construction Process

- Planning approval

Planning approval from the competent authority shall be obtained by the homeowner. The builder would need the following information which would be obtained from an approved plan:

- a) accurate and identifiable lot boundary markers;
- b) distances from the lot boundaries to the house;
- c) the provision for stormwater drainage.

- Contract with the client;

The contractor should have a written contract with the homeowner or client. The contract essentially describes the responsibilities of each party, and the rules for resolving disputes.

- The selection of quality material:

Quality materials shall be used in order to reduce the risk of extensive maintenance to the building.



## Pre-Construction Process (cont'd)

- Proper storage of construction materials:

Before construction materials become part of the permanent work, they need to be protected by being properly stored. Areas on the site therefore need to be identified for adequate storage of construction materials.

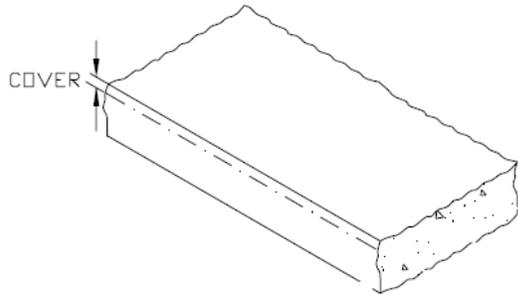
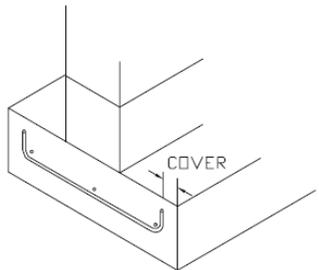
Material	Storage	Comment
Cement bags	100 mm (4") off the floor and covered with damp proof Material	To prevent the cement from getting wet thereby hard and unusable.
Sand and stone	Covered	To prevent them from being blown or washed away.
Timber	100 mm (4") off the ground and covered with damp proof material.	To reduce wet rot and deformation.
Reinforcing bars	100 (4") mm off the ground and covered with damp proof material.	To reduce corrosion.



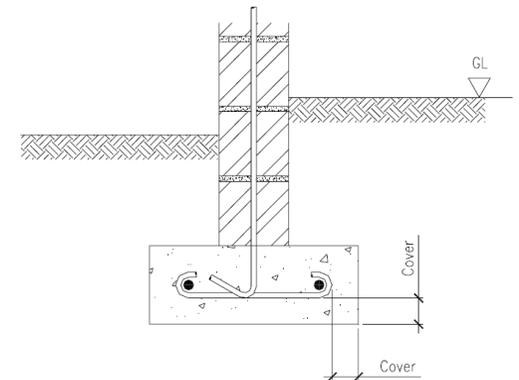
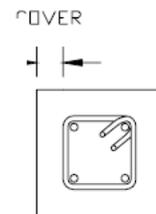
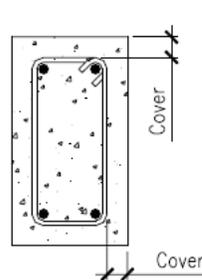
## Pre-Construction Process (cont'd)

- Ensure the protection of reinforced concrete:  
Reinforced Concrete (RC) elements shall also be protected from the natural environment and from fire. Concrete Cover (CC) is used to protect the reinforcement from corrosion and fire.

RC Structural Element	Minimum Protective CC	Fire Resistance Rating (hrs)
Foundations – surfaces in contact with earth	75 mm (3")	> 4
Slabs	25 mm (1")	1.5
Beams	40 mm (1½")	1.5
Internal Columns	30 mm (1¼")	1.5



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## Pre-Construction Process (cont'd)

- Ensure the use of good quality joints:

Good quality connections can reduce the risk of separation of the building elements during natural hazards

- Ensure the use of adequate reinforcement Lap Lengths:

Reinforcement shall have adequate lap lengths to allow the load to be transferred from one bar to the next. The lapped bars should be tied together using tying wire.

Bar Diameter (mm)	Lap Distance (mm)
6 (1/4")	300 (12")
8 (3/8")	400 (1'-4")
10 (2/5")	500 (1'-8")
12 (1/2")	600 (2'-0")
16 (3/4")	800 (2'-8")
20 (7/8")	1000 (3'-4")



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## Pre-Construction Process (cont'd)

- A basic understanding of structural stability methods:

Good quality bracing methods can keep the building stable and allow the building connections to work as they were designed to during natural hazards.

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# SITE PREPARATION



**Site Condition:** Before construction begins, ensure that the land is suitable for building e.g. it should not be unstable or prone to flooding. The house should be oriented to take advantage of the natural lighting and ventilation. Where there is doubt or uncertainty of the buildability of the land or the orientation of the house, advise the owner and consult with an engineer.

Natural hazards	Practical responses
High winds	Brace wall; Tie structural elements together; Select favourable envelope geometry; Protect the window and door openings to keep the envelope watertight.
Earthquakes	Brace wall; Tie structural elements together; The columns shall be stronger than the beams; Select favourable envelope geometry.
Flooding (wave surge, tsunami)	Brace wall; Tie structural elements together; Select favourable envelope geometry; Protect the window and door openings to keep the envelope watertight; Locate top of footings 600 mm (2') minimum below the external ground; Position the ground floor 460 mm (18") minimum above the external ground.



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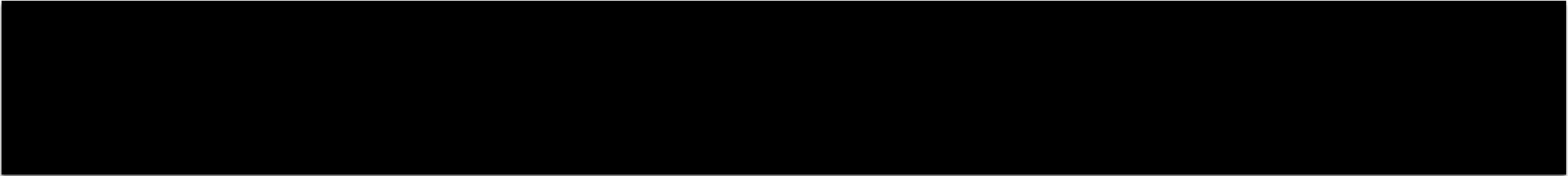
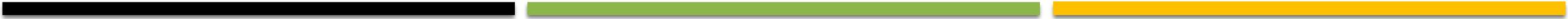
**Clearing the site:** Clear the site of overgrown bush to reduce the risk of accidents occurring.

The area where the building is to be located should be stripped of topsoil which should be stockpiled for landscaping.

**Setting out:** Once the site is cleared, the house should be set out on the land from the dimensions provided in the approved plans. The dimensions are typically from the site boundary, therefore identify the boundary markers (stakes or irons). If there is uncertainty regarding the location of the boundary markers, then request the owner to identify them, and/or provide a copy of the Land Surveyor's drawing of the property. If the wall is built on the neighbour's property, or too close to the owner's s boundary, without planning permission then the owner may be forced to demolish part of the house.

**Access to roads:** Construct a temporary access road if the site is difficult to access. If a permanent access road or driveway is required, ensure that the road is accurately set out and properly constructed.





# FOUNDATION



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Foundations are designed to support the building and to prevent it from moving during natural hazards. The methods of constructing foundations are described in this section. An experienced engineer should be consulted in determining the appropriate level for the foundation if there is uncertainty. We will explore the three likely types of footings to be used:

1. **Reinforced Concrete Pad Foundation** – Used on firm soil, for columns and poles, with beams tying the pads.
2. **Reinforced Concrete Strip Foundation** – Used for areas with varying soil types, supports walls (can be stepped to adapt to steeply sloping ground).
3. **Reinforced Concrete Slab or Raft Foundation** – Used on soft soils, spreads the weight over a wider area.



## RC Pad Foundation:

Construction methods	Comments
Excavate to good bearing layer.	To reduce settlement.
Termite treatment should be applied to the ground under the footings by a reputable company that will offer a minimum 5-year guarantee.	To protect the timber from termites.
Place 50 mm (2") thick sand layer or mass concrete blinding layer if the surface is uneven.	To provide a flat surface to accommodate the placement of reinforcement.
Erect formwork to fit the pad footing. Use braced timber with close-fitting joints.	To prevent deformation and leakage of fine aggregate, cement or water.
Place reinforcement (CARICOM yield strength 460 MPa, or equivalent) including column starter bars in the formwork and tie the bars together or place the reinforcing cage in the formwork.	For durability and structural safety and to prevent the reinforcing bars from moving out of position during the concreting.



## RC Pad Foundation (cont'd):

Construction methods	Comments
Raise the reinforcement at the correct level to maintain the concrete cover using concrete spacer blocks or plastic chairs. Concrete cover to surfaces in contact with earth should be 75 mm (3”).	To protect the reinforcing bars from corrosion.
Remove any debris from within forms. Blowing debris with compressed air or flushing with pressurized water are effective methods.	To avoid contaminating the concrete.
Apply a release agent to the formwork surface which will be in contact with concrete.	To facilitate stripping the formwork.
Pour concrete of compressive strength of 21 N/mm <sup>2</sup> (3,000 psi) at 28 days	For durability and structural safety.
Compact the concrete using a vibrator.	For strength and durability of the concrete



## RC Pad Foundation (cont'd):

Construction methods	Comments
Trowel finish.	To provide a flat bearing surface for the walls.
Cure by keeping continuously wet for at least 3 days.	To allow the concrete to achieve the design strength.
Lap column bars to starter bars and install tie-beam reinforcing bars.	To help transfer the loads.
Erect formwork to fit the columns and tie-beams.	To prevent deformation and leakage.
Pour concrete to fill the column form work, and fill half of the depth of the tie-beam form work. Compact, trowel finish, and cure the concrete.	For durability and structural safety.
Carefully strip column formwork	To reuse.



## RC Strip Foundations:

Construction methods	Comments
Excavate to good bearing layer.	To reduce settlement.
Termite treatment should be applied to the ground under the footings by a reputable company that will offer a minimum 5-year guarantee.	To protect the timber from termites.
Place 50 mm (2") thick sand or mass concrete blinding layer if the surface is uneven.	To provide a flat surface to accommodate rebar placement.
Erect formwork to fit the strip footing. Use braced timber with close-fitting joints.	To prevent deformation and leakage of fine aggregate, cement or water.
Place reinforcement (CARICOM– CARICOM –yield strength 460MPa, or equivalent) including concrete block wall starter bars in the formwork and tie the bars together or place the reinforcing cage in the formwork. Strip footing rebar laps or splices are to be 600 mm (2').	For durability and structural safety and to prevent the reinforcing bars from moving out of position during the concreting.
Excavate to good bearing layer.	To reduce settlement.

## RC Strip Foundations (cont'd):

Construction methods	Comments
Excavate to good bearing layer.	To reduce settlement.
Termite treatment should be applied to the ground under the footings by a reputable company that will offer a minimum 5-year guarantee.	To protect the timber from termites.
Place 50 mm (2") thick sand or mass concrete blinding layer if the surface is uneven.	To provide a flat surface to accommodate rebar placement.
Erect formwork to fit the strip footing. Use braced timber with close-fitting joints.	To prevent deformation and leakage of fine aggregate, cement or water.
Place reinforcement (CARICOM– CARICOM –yield strength 460MPa, or equivalent) including concrete block wall starter bars in the formwork and tie the bars together or place the reinforcing cage in the formwork. Strip footing rebar laps or splices are to be 600 mm (2').	For durability and structural safety and to prevent the reinforcing bars from moving out of position during the concreting.



## RC Strip Foundations (cont'd):

Construction methods	Comments
Raise the reinforcement at the correct level to maintain the concrete cover using concrete spacer blocks or plastic chairs. Concrete cover to surfaces in contact with earth = 75 mm (3").	To protect the reinforcing bars from corrosion.
Remove any debris from within the forms. Blowing debris with compressed air or flushing with pressurized water are effective methods.	To avoid contaminating the concrete.
Apply a release agent to the formwork surface which will be in contact with concrete.	To facilitate stripping the formwork.
Pour concrete of compressive strength of 21 N/mm <sup>2</sup> (3,000 psi) at 28 days	For durability and structural safety.
Compact the concrete using a vibrator.	For concrete strength and durability



## RC Strip Foundations (cont'd):

Construction methods	Comments
Trowel finish.	To provide a flat bearing surface for the walls.
Cure by keeping continuously wet for at least 3 days.	To allow the concrete to achieve the design strength.
Construct a 200 mm (8") thick block wall from the foundation up to 200 mm (8") below ground floor level. Use 12 mm (½") diameter rebar at 600 mm (2') centres and all cores filled solid. For concrete block walls, extend the rebars to a minimum of 600 mm (2') above the ground floor level.	To help transfer the loads.
Erect formwork to fit the 200 mm x 200 mm (8" x 8") RC ring beam.	To prevent deformation and leakage.
Install reinforcement 4 x 12 mm (½") diameter bars + 6 mm (¼") diameter links at 200 mm (8") centres.)	To tie the wall together.



## RC Strip Foundations (cont'd):

Construction methods	Comments
For timber wall, insert 12 mm (1/2") diameter anchor bolts at 800 mm (2'-8') centres.	To connect the wall to the foundation.
Pour, compact, trowel finish, and cure concrete.	For durability and structural safety.
Carefully strip formwork	To reuse



## RC Raft Foundation:

Construction methods	Comments
Excavate slab area to good bearing layer.	To reduce settlement.
Backfill and compact the slab area using well graded granular fill, in layers not exceeding 200 mm (8"). The finished level of the compacted backfill should be 150 mm (6") below the top of the slab level.	To reduce settlement.
Excavate the slab thickening foundation areas.	To support the walls.
Termite treatment should be applied to the ground under the footings by a reputable company that will offer a minimum 5-year guarantee.	To protect the timber from termites.
Place 50 mm (2") thick sand or mass concrete blinding layer if the surface is uneven.	To provide a flat surface to accommodate the placement of reinforcement.
Place damp proofing membrane (DPM).	To reduce the upward migration of moisture.



## RC Raft Foundation (cont'd):

Construction methods	Comments
<p>Erect formwork to fit the slab thickenings. Use braced timber with close fitting joints.</p>	<p>To prevent deformation and leakage of fine aggregate, cement or water.</p>
<p>Place reinforcement (CARICOM - yield strength 460 MPa, or equivalent) in the following manner: a) in block walls, place wall starter bars. For exterior wall use 12 mm (1/2") diameter at 600 mm (2') centres. For interior walls use 12 mm (1/2") diameter at 800 mm (2'-8") centres.</p> <p>b) for timber walls, install wall anchor bolts or straps. For exterior and interior walls use 12 mm (1/2") diameter at 800 mm (2'-8") centres.</p>	<p>For durability and to prevent the reinforcing bars from moving out of position during the concreting.</p>



## RC Raft Foundation (cont'd):

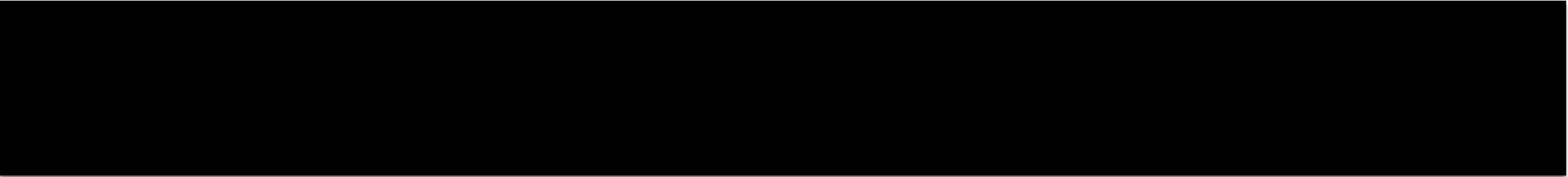
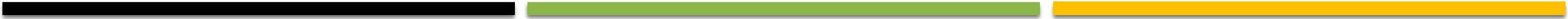
Construction methods	Comments
Raise the steel reinforcement to the correct level to maintain the concrete cover using concrete spacer blocks or plastic chairs. Concrete cover to surfaces in contact with earth is 75 mm (3”).	To protect the reinforcing bars from corrosion.
Remove any debris from within forms. Blowing debris with compressed air or flushing with pressurized water are effective methods.	To avoid contaminating the concrete.
Apply a release agent to the formwork surface to be in contact with concrete.	To facilitate stripping the formwork.
Pour concrete of compressive strength of 21 N/mm <sup>2</sup> (3,000 psi) at 28 days	For durability and structural safety.
Compact the concrete using a vibrator.	For strength and durability



## RC Raft Foundation (cont'd):

<b>Construction methods</b>	<b>Comments</b>
Screed and float finish.	To provide a flat bearing surface for the walls and floor covering.
Cure by keeping continuously wet for at least 3 days.	To allow the concrete to achieve the design strength.
Carefully strip formwork.	To reuse.





# FLOORS



**The floor** is used to support the floor loads and to transmit them to the foundations. Three types are described below:

- a) Raft foundation with integral ground floor slab supported on fill
  - Reinforced concrete ground floors may be used to support both concrete block and timber walls. Construction method already described in raft foundation construction methods.
- b) Reinforced Concrete (RC) ground floor slab supported on strip footings.
  - The area enclosed by the strip footings and walls may be filled with well graded granular fill compacted in layers not exceeding 200 mm (8"). This fill may support a ground floor.
- c) Suspended RC floor slab supported on pad footings.
  - A reinforced concrete floor may be suspended and supported by beams and columns



**Reinforced Concrete (RC) ground floor slab supported on strip footings:**

<b>Construction methods</b>	<b>Comments</b>
Excavate footing and slab area to good bearing layer. Construct RC strip footing and block wall.	To reduce settlement.
Backfill and compact the slab area using well graded granular fill, in layers not exceeding 200 mm (8"). The finished level of the compacted backfill should be 150 mm (6") below the top of the slab level.	To reduce settlement.
Excavate the slab thickening foundation areas.	To support the walls.
Termite treatment should be applied to the ground under the footings by a reputable company that will offer a minimum 5-year guarantee.	To protect the timber from termites.



## Reinforced Concrete (RC) ground floor slab supported on strip footings (cont'd)

Construction methods	Comments
Place 50 mm (2") thick sand or mass concrete blinding layer if the surface is uneven.	To provide a flat surface to accommodate the placement of reinforcement.
Place damp proofing membrane (DPM).	To reduce the upward migration of moisture.
Erect formwork on the external side of the 200 mm x 200 mm (8"x8") ring beam. Use braced timber with close fitting joints.	To prevent deformation and leakage of fine aggregate, cement or water.



## Reinforced Concrete (RC) ground floor slab supported on strip footings (cont'd)

Construction methods	Comments
<p>Place beam and slab reinforcement (CARICOM - yield strength 460 MPa, or equivalent) in the following manner:</p> <p>a) in block walls, place wall starter bars. For exterior wall use 12 mm (1/2") diameter at 600 mm (2') centres. For interior walls use 12 mm (1/2") diameter at 800 mm (2'-8") centres.</p> <p>b) for timber walls, install wall anchor bolts or straps. For exterior and interior walls use 12 mm (1/2") diameter at 800 mm (2'-8") centres.</p>	<p>For durability and to prevent the reinforcing bars from moving out of position during the concreting.</p>
<p>Raise the steel reinforcement to the correct level to maintain the concrete cover using concrete spacer blocks or plastic chairs. Concrete cover to surfaces in contact with earth is 75 mm (3").</p>	<p>To protect the reinforcing bars from corrosion and fire.</p>



## Reinforced Concrete (RC) ground floor slab supported on strip footings (cont'd)

Construction methods	Comments
Remove any debris from within forms. Blowing debris with compressed air or flushing with pressurized water are effective methods.	To avoid contaminating the concrete.
Apply a release agent to the formwork surface to be in contact with concrete.	To facilitate stripping the formwork.
Pour concrete of compressive strength of 21 N/mm <sup>2</sup> (3,000 psi) at 28 days	For durability and structural safety.
Compact the concrete using a vibrator.	For strength and durability of the concrete
Screed and float finish.	To provide a flat bearing surface for the walls and floor covering.



## Reinforced Concrete (RC) ground floor slab supported on strip footings (cont'd)

Construction methods	Comments
Cure by keeping continuously wet for at least 3 days.	To allow the concrete to achieve the design strength.
Carefully strip formwork.	To reuse.



## Suspended reinforced concrete floor slab on pad footings:

Construction methods	Comments
Construct RC Pad footings	To reduce settlement.
Erect formwork for suspended beams and slab. The formwork is to remain in place for at least 14 days.	To support the beam and slab.
Place beam and slab reinforcement (CARICOM - yield strength 460MPa, or equivalent)	For durability and structural safety.
a) in block walls, place wall starter bars. For exterior wall use 12 mm (1/2") diameter at 600 mm (2') centres. For interior walls use 12 mm (1/2") diameter at 800 mm (2'-8") centres. b) for timber walls, install wall anchor bolts or straps. For exterior and interior walls use either 12 mm (1/2") diameter bolts or 3 mm (1/8") thick x 25 mm (1") wide galvanised straps at 800 mm (2'-8") centres.	To connect the wall to the foundation.



## Suspended reinforced concrete floor slab on pad footings:

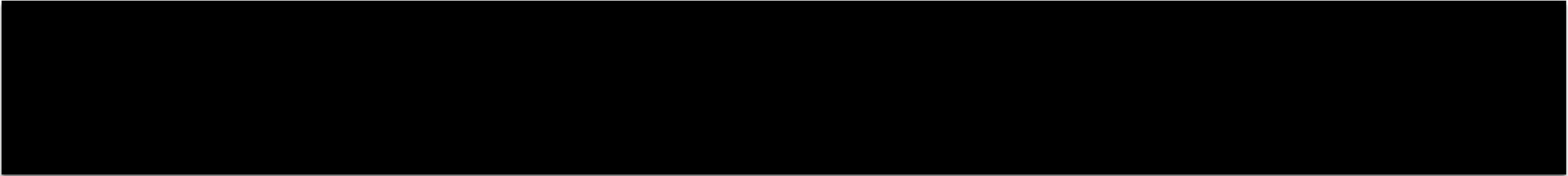
<b>Construction methods</b>	<b>Comments</b>
Raise the steel reinforcement to the correct level to maintain the concrete cover using concrete	To protect the reinforcing bars from corrosion and fire.
Remove any debris from within forms. Blowing debris with compressed air or flushing with pressurised water are effective methods.	To avoid contaminating the concrete.
Apply a release agent to the formwork surface to be in contact with concrete.	To facilitate stripping the formwork.
Pour concrete of compressive strength of 21 N/mm <sup>2</sup> (3,000 psi) at 28 days, in beam and slab formwork	For durability and structural safety.



## Suspended reinforced concrete floor slab on pad footings:

Construction methods	Comments
Compact the concrete using a vibrator.	For strength and durability of the concrete.
Screed and float finish.	To provide a flat bearing surface for the walls and floor covering.
Cure by keeping continuously wet for at least 3 days.	To allow the concrete to achieve the design strength.
Carefully strip formwork	To reuse.





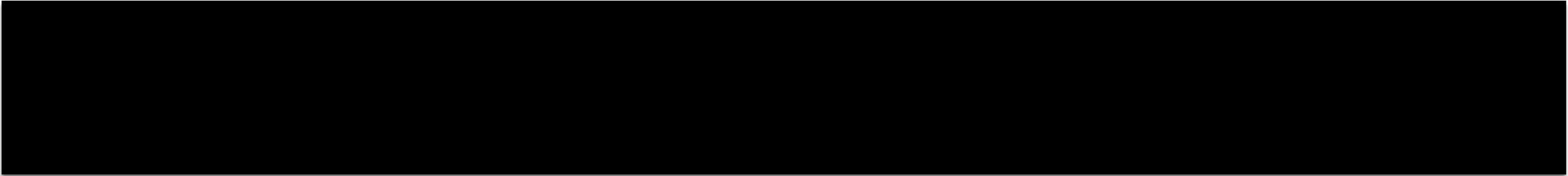
# WALLS



## Concrete block walls

Construction methods	Comments
After the reinforced concrete floor slab has been constructed, the wall started bars shall be exposed in the wall locations at least 600 mm above the slab level.	To connect the wall to the floor.
Construct 200 mm (8") thick block wall to perimeter beam. Use 12 mm (1/2") diameter rebar at 600 mm (2') centres and fill only those cores containing rebars with concrete. Internal walls shall be reinforced with 12 mm (1/2") diameter bars at 800 mm (2'-8") centres.	To strengthen the walls.
Erect formwork to fit the 200 mm x 300 mm (8"x12") ring beam.	To prevent deformation and leakage.
Install reinforcement (4x12 mm (1/2") diameter bars and 6 mm (1/4") diameter links at 200 mm (8") centres.)	To tie the wall together.





# ROOF



## Reinforced Concrete Roofs

- **Advantages**

- It can Withstand Harsh Weather Conditions
- Tried and Tested Durability
- Hassle-Free Maintenance

- **Disadvantages**

- Leakage Problems
- Plant Growth
- Construction Process





**THE END**

THANK YOU FOR PARTICIPATING

