Guiding Principles for Design and Construction of

Flood, Cyclone and Storm Surge Resilient House

A CDMP Approach

for Cyclone and Flood prone rural areas.

Ministry of Food and Disaster Management
Comprehensive Disaster Management Programme

September, 2009

European Union

DFID Department for International Development

CDMP Comprehensive Disaster Management Programme

UNDP Bangladesh

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A CDMP APPROACH

A comprehensive compilation of different agency's housing experience and expert consultation.

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Dedication:

.... all the public and private institutions, organizations, and groups willing to support new housing projects, post disaster reconstruction and rehabilitation projects or projects on housing strengthening/retrofitting

Acknowledgement

In bringing this guiding-book into light, we express our sincere gratitude to Disaster Response Facilities (DRF), UNDP, Bangladesh Disaster Preparedness Centre (BDPC), CARE-Bangladesh, Bangladesh Red Crescent Society and Department of Architecture - BRAC university for providing organizational contribution in terms of Invaluable Experience and operational Learning . Their safe shelter practicing experience, made our life of producing this book a lot more easier.

Another important contribution, we must acknowledge for receiving at different workshops, learning brought by Sub Implementing Agengies - our esteemed partners. Their field level experience helped expediting the draft finalization: Without their help, this out-put would have been much delayed. Their assistance saved us from a lot of trial & error type frustrating findings. We are grateful to our partners that are Area Development Organization (ADO); Sushilan ; Bangladesh Center for Advanced Studies (BCAS); Jesh Foundation and Uttarayan Jana-kallayan Mohila Songstha (UJMS).

After conceptualizing the document, Craftsmanship expertise from Mr. Munjur Elahi, Project Engineer, ADO; Mr. Partho Sharkar, Upazilla Engineer, Shushilan and Mr. Fazlul Haques, Project Engineer, (BCAS) helped sketching CDMP's theoretical stand/ realizable dreams on to the papers for easier communication and functional understanding.

Experts' Certification and suggestion can add significant value to any intervention. We humbly acknowledge the valuable guidance that made our structure stronger and aided to achieve another organization mandate: Cost-effectiveness. On this note, we humbly acknowledge the contribution we received from two DFiD shelter Experts Mr. Peter Beresford, Structural Solutions Management Ltd. and Bill Flinn, Architech, Shelter Specialist.

Table of Contents

SECTION – 01: INTRODUCTION

1.1 Background

With a vision of the Government of Bangladesh to reduce the risk of people, especially the poor and the disadvantaged from the effects of natural, environmental and human induced hazards to a manageable and acceptable humanitarian level and to have in place an efficient emergency response system, the Comprehensive Disaster Management Programme (CDMP), implemented by the Ministry of Food and Disaster Management (MoFDM) and funded by UNDP, DFID-B and EC was conceptualized and being implemented.

Under the European Commission's funded component 3d i.e. "Support for livelihood Security- Hazard Awareness", CDMP has already tried different models at field with notions of demonstration and field-testing. Following the process, CDMP has finalized the design of a house with extra structural protection to minimize Cyclone and Flood threats to an acceptable extent.

1.2 Programme Scopes

As part of ensuring community awareness and preparedness through different awareness raising activities and supportive accessories to vulnerable households, CDMP is assisting the most vulnerable communities with construction of cyclone and flood resilient houses for reducing disaster vulnerabilities. The elementary notion of this development assistance is to create a demonstration/motivational effect among numerous households built around rather than meeting only the primary requirements of a particular household/individual.

As an integral part of component activities, these cyclone and flood resilient houses will be constructed ensuring such a safety standard that neighboring inhabitants of other vulnerable houses can also use these houses as a 'community shelter point (small scale)' while disaster strikes.

1.3 Programme Rationale

- The coastal belt of Bangladesh has got affected severely by cyclones like, Sidr-2007, Aila-2009 and consequently lost many of her human and other resources. The large number of people living in and around of our coastal opening, a cyclone resilient house is of basic necessity that can ensure

security, safety along with household sustainability. Similarly flood prone areas also got affected by devastating flood like flood 2004 and 2007.

- All the recent cyclones and floods called up a huge economic loss that includes destroying development grants distributed with an objective of helping the representatives living at 'the bottom of the pyramid'. To a large extent the patterns and causes of destruction seems to be resulted from economic constraint and access to appropriate know-how of building a safer house ensuring optimum cost-effectiveness. With the learning from this guideline, builders and development practitioners can ensure minimum safety standard required.

- In usual cases, cost is significantly prohibitive in terms of ensuring cyclone and flood safety and security. So, with this guideline, the need for developing housing which is appropriate for cyclone and flood affected areas can be addressed more effectively, in a 'cost effective' manner – that is rationalization of economy without compromising the quality.

1.4 Who will use this document?

Comprehensive Disaster Management Prgoramme (CDMP) with the funding from European Commission (EC) is implementing this programme at the field through the facilitation extended by partner NGOs, formally called as Sub-implementing Agencies (SIA).

Apart from CDMP and its partners, other institutions, organizations, and groups willing to support new housing projects, post disaster reconstruction and rehabilitation projects or projects on housing strengthening/retrofitting can use this guideline as a reference point while implementing their programmes.

1.5 Target Groups

Wide cross-section of rural people that includes marginal occupational groups e.g. fisherman, day laborer etc. female headed households, elderly people along with ethnic minorities (*adivashi)* living in the predominantly cyclone and flood prone areas of Bangladesh.

To be regarded as a valid choice, prospective beneficiary has to ensure 'land security' in terms of decision making (owning/ legal document ensuring his/her right to the land also suffice) so that the existence of the structure will not get threatened.

1.6 Damages resulted from Cyclones and Floods

The impact of cyclone to housing is due to several reasons: a) wind speed and direction b) cyclone duration and c) Storm surge. Alike the impact of floods to housing is due to several other reasons: a) Flood Height b) Flood Duration, c) Uplift due to soil saturation and d) Horizontal force created by flood waves or currents.

Direct cyclone and flood hazards are associated with other types of secondary hazards such as lightening, ground settlement, slope instability, structural collapse and others.

Storm Surge and Flood can submerge buildings and cause various degrees of damage from staining of walls to structural collapse depending on flood/storm surge and type of Plinth built.

More specifically, the risks associated to housing frequently caused by cyclones and flood are like:

- Uprooting of Tree/s causing collapse or damage of roof and walls.
- Over turning of walls and boundary
- Failure of roofing materials at the gable ends due to high negative wind pressure
- Failure of door/ window frames and shutters
- Failure of plinth by high tide and flood water flow.

SECTION – 02: TECHNICAL DETAILS

2.1 Structural Design of Recommended Housing

Cost-Effective Solution Semi-Pucca House (half building)

- **Foundation:** Brick Plinth; Brick perimeter wall with earth (compact Soil)infill;
- **Floor:** one layer brick flat soiling and 1.5" cement concrete
- **Walls:** 5 Inch Brick wall.
- **Roof:** CI sheet with timber framing.

2.2 Risks, Mitigation measures and CDMP Suggested Construction Techniques

2.2.1 Foundation

In building semi-pucca houses, this type of foundation is relatively durable. But in high intensity wind accompanied by storm surge, shallow foundation can become unstable due to scouring of soil-cover. Prolonged duration of flood water can lead to foundation settlement, thereby causing cracks and failures in different parts of the building.

2.2.2 Plinth, Floor & Veranda perimeter wall

2.2.2.1 Construction aspects

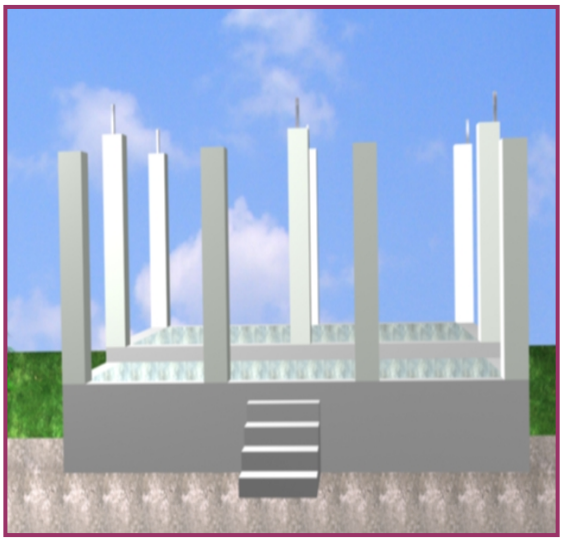
- For, Plinth a 10 inch brick perimeter wall of height of 3 feet will be constructed. Outer wall of the plinth will be of 0.5 inch plastered outer wall with neat cement finishing. Room Plinth size= 16feet x 9 feet and Veranda size = 16 feet x 6 feet.
- For Veranda, a 5 inch brick perimeter wall, with four 10"x10" brick pillar will be constructed. 0.5 inch plastered outer wall with neat cement finishing will be built.
- 2.5 feet Compact Soil both for plinth and veranda. Caution: after putting every 6 inch, the soil has to be compacted properly. While compacting, adequate watering has to be ensured for expected result.

2.2.2.2 Construction Method

- For Brick wall construction and plastering, cement – sand proportion should be 1:4.
- For floor casting, cement-sand-'khoa' (gravel sized) proportional mix should be 1:2:4
- Soil should be crushed to be added in dry state.
- For further compaction, a simple hand hammer or wooden battens can be used.
- For Floor, at least 3 weeks curing by water should be done. Floor can be covered by jute sacks to keep moist and water poured at regular intervals to avoid drying. For brick wall, a one week curing will suffice.

2.2.2.3. Construction Rationale

- Brick wall and cement plaster with neat cement finishing can resist wave strength: even if submerged for prolonged time (in extreme case, water logging), damage can be avoided.
- Though comparatively a bit costlier, this type of foundation can ensure a strong base that will help the house to stand for a significantly longer time.
- The structure going to be built on this plinth and will have a strong base to stand up on consecutively will lengthen the life of the structure.



- Concrete floor with neat finishing will ensure a more hygienic living style for the dwellers. Besides, it will also help the belongings not to get moistened. Apart from aesthetic achievement, House hold neatness and cleanliness can also be maintained more easily.
- This floor can stand even after getting sub-merged for a longer period thus help the dwellers to get back to their safer house even after a devastating prolonged flood.
- A brick perimeter wall around the typical earthen plinth resists erosion from the sides.

2.2.3. 10"x10" Brick Pillar

2.2.3.1 Construction aspects

- Brick pillar used for main room : height – 7 Feet (7feet x 10" x 10"): 6 pcs
- Brick Pillar used for veranda: Height – 6.5 Feet (6.5 feet x 10" x 10"): 4 pcs
- Pillars have to be plastered neatly.
- At the pillar center, a MS rod of 3/8 dia will be used.

2.2.3.2 Construction method

- Relatively inexpensive option, but resistant to deterioration by water and provide extra strength against wind power.
- Better to produce on site to avoid handling and transport costs.
- Should use one mild steel 3/8 inch diameter re-bars,
- Better to have a small spread footing for stability and to avoid leaning over during flood.
- For attaching to roof structure, a 1.5"x1.5"x1/8" angel box embedded 15 inch inside the pillar. The MS rod coming out of the pillar has to be hooked with the angel box.
- At least 1 weeks curing by water is necessary.

2.2.3.3 Construction rationale

- Through Replacing RCC column with this brick pillar, embedded with a MS Rod in the center will help to reduce cost manifold without hampering the structural strength significantly.
- Brick pillar is more effective in providing strength to super-structure of 5 inch brick wall than regular RCC column.
- Hook bond (attached to the angel box) on the top of the pillar will provide extra strength to the roof structure against wind pressure during cyclone or storm.

2.2.4 Walls (Brick)

Brick walls are relatively durable, but can experience staining, peeling of plaster and weakening of mortar joints at lower ends if immersed in flood of high depth and duration. Cracks may develop if settlement of foundation occurs.

2.2.4.1 Wall & wall opening: Brick Wall

- Wall takes the lateral pressure and its weakest points are the door and window opening areas
- Brick walls inside the room (4 walls), and Brick wall with the door (out side) have to be plastered. The other 3 outside walls should be kept Flash Pointing.

Fig: Back View (wall)

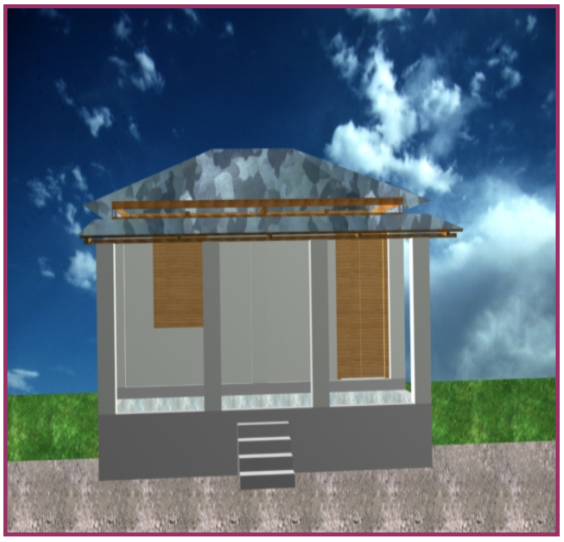


Fig: Front View (wall)

- Door and window if on masonry wall should not be with in h/6 distance to maintain the strength. h: height of the wall up to eve level.
- Opening just below roof level should be avoided but perforations are needed without shutters incase water reaches above human level.
- All openings should have strong closing : hinges and locks so they do not collapse

2.2.4.2 Doors and windows

Effects of storm and water on door and windows vary according to the type of material. Most durable are Mild Steel (MS) frame and shutters, although they may experience corrosion if not adequately painted with corrosion-resistant paint – but this will increase the building cost manifold. Hence, considering the cost and local availability, project recommends using timber frame (Seasoned Rain Tree is preferred) with Iron grill for ensuring theft-safety. But, the timber used has to be of good quality and properly seasoned and treated (if available, seasoned Rain Tree wood)

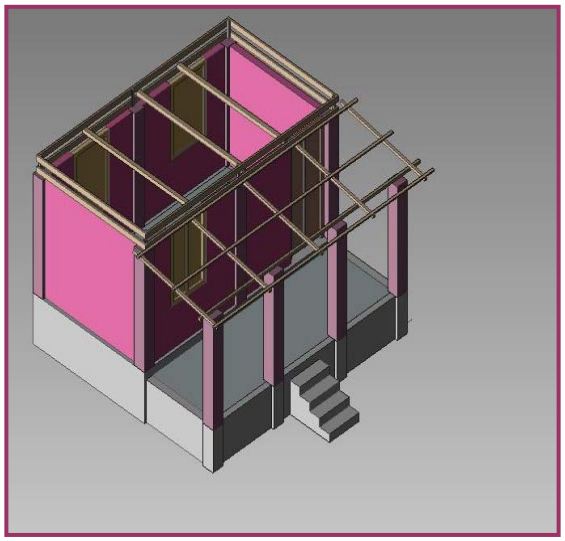
Construction Guidelines (Figure Reference Page: 23):

- For Door (single shutter- sized 6.5'x3.5') would thickness would be 1.5". Door has to have 2 wooden "Z" crosses inside.

- For Door Frame of 7' feet height, wood dimension would be 3"x3".
- For windows (double shutter, each shutter with single "Z" cross) wood thickness would be 1". (Window frame would be 3'5'x3')

2.2.5 Roofing

2.2.5.1 Roof (CI Sheet with timber framing)



CI sheet with timber framing can address the wind-force if built with adequate planning. It can lead to corrosion in contact with water and can be flown away if strong cyclones hit. It is mention worthy that this type of roof is particularly vulnerable to strong wind – can crumple and get blown off, especially if connections to frame are inadequate.

It's of high importance that the roof is strong and well-built, in addition to durability, water-resistant materials and wind resistant design. In the following please find the roof construction guidelines explicitly: (Figure Reference: Page 23)

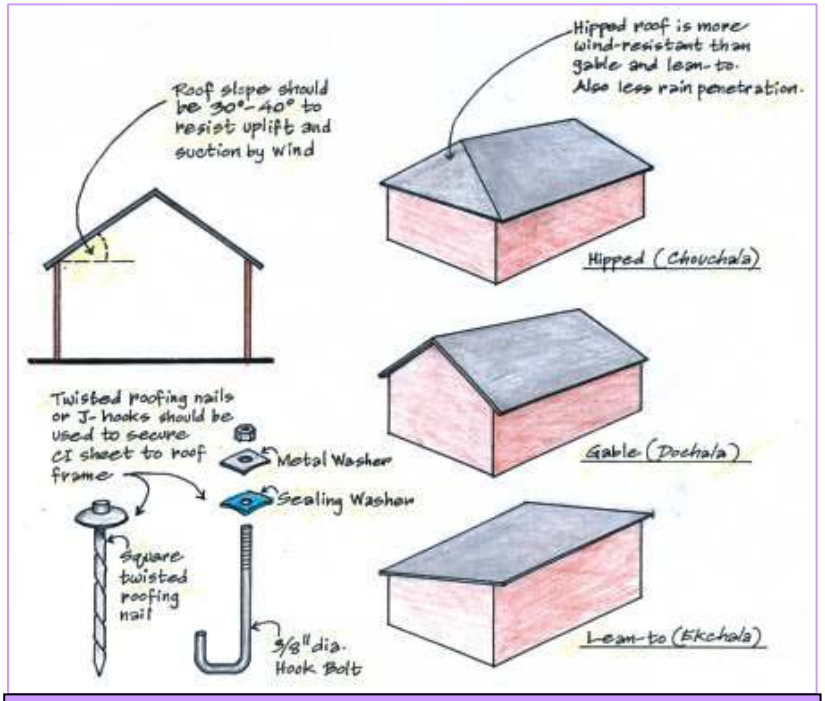
- For Straight Rafter each 12 feet long: wood dimension would be 2"x2".
- For Corner (Diagonal) Rafter each 8.5 feet long: wood dimension would be 2.5"x2.5".
- Surrounding Lintel in 4 sides on Brick Wall will be of 60 feet (15x4) long of which wood dimension would be 4"x1.5"
- For the Purlines, wood dimension has to be 2"x1".

2.2.5.2. Wind resistant roofing

- Protection against wind-hazard contributes to the overall improvement of housing in cyclone-prone regions.
- Four basic principles should be followed:

- **Aerodynamic roof form**
  - ✓ Roof pitch 30º- 40° to reduce effects of suction and uplift.

- ✓ Hipped instead of gable roof. If gable, then ends tied down firmly to rest of structure. Lean-to should be avoided.
- ✓ Overhang <2´- 6´´, vents in roof and masonry parapet.
- ✓ RCC roof provides superior protection, but heavy in earthquake. Need for adequately braced vertical structure.
- ✓



Courtesy: ADPC Handbook

- **Roof connected to structure**
  - ✓ Rafters at recommended spacing.
  - ✓ Cross-bracing in plane of roof and ceiling, and also for openings, if any. Openings restricted in size.
  - ✓ Strong connections between roof and vertical structure. Metal straps, bolts with washers on both ends instead of simple nails.
- **Well-fixed roof covering**
  - ✓ CI sheet screwed at every corrugation. Tiles fastened individually.
  - ✓ Use of J-hook bolts and threaded/ twisted roofing nails.
- **Regular maintenance**
  - ✓ Should make regular checks, especially around ridge and corners.
  - ✓ Should replace weakened members, repair loose members.
  - ✓ CI sheet should be tied strongly to structural frame to resist uplift by strong wind. To further increase wind-resistance, number of purlins should be increased near eaves, ridge and corners.

- Every sheet fixed to purlins with hook bolts or twisted nails at each corrugation. More frequent fixings at edges to prevent uplift.
- Adequate connections should be made with GI wire or other good quality of galvanized wires (instead of jute/nylon rope).
- Roofing elements should be connected properly: purlin to rafter, rafter to wall plate, wall plate to posts.
- Even though more expensive than lean-to (akchala) and gable (dochala) roofing, hipped roofing (chouchala) is more resistant to wind and protects gable end walls from exposure to rain and water penetration.
- Considering the wind direction pattern and expected resistance need to up-hold, in Intervened areas, CDMP recommends Hipped roofing (chouchala).

SECTION – 03: PLANNING GUIDELINE

3.1 Planning Aspect: Site Selection

- Cyclone approaches from the direction of Sea toward the Coast. Building' elongated side should not face Sea.

3.2 Planning Aspect: Building Features

- Use of Bracing: Since Cyclonic wind may come from any direction Both Axis of Building should be designed to take wind pressure. In Rural Setting using diagonal bracings is more successful than other methods.
- Plinth Height: Cyclone generates storm tide and cyclonic inundation. So high ground should be used for building. Plinth height should be raised in accordance with historical data.
- In case where high ground is unavailable STILT should be used to raise the building
- Roof pitch should be less than 30 degree in gable/pitch roof
- Heaped or Pyramidal roof is better than Gable roof in high cyclonic areas.
- Buildings usually have shallow foundation for sandy soil and deep foundation for clay soil. Foundation is important for the affect of surge and wind pressure.

SECTION – 04: CONCLUSION

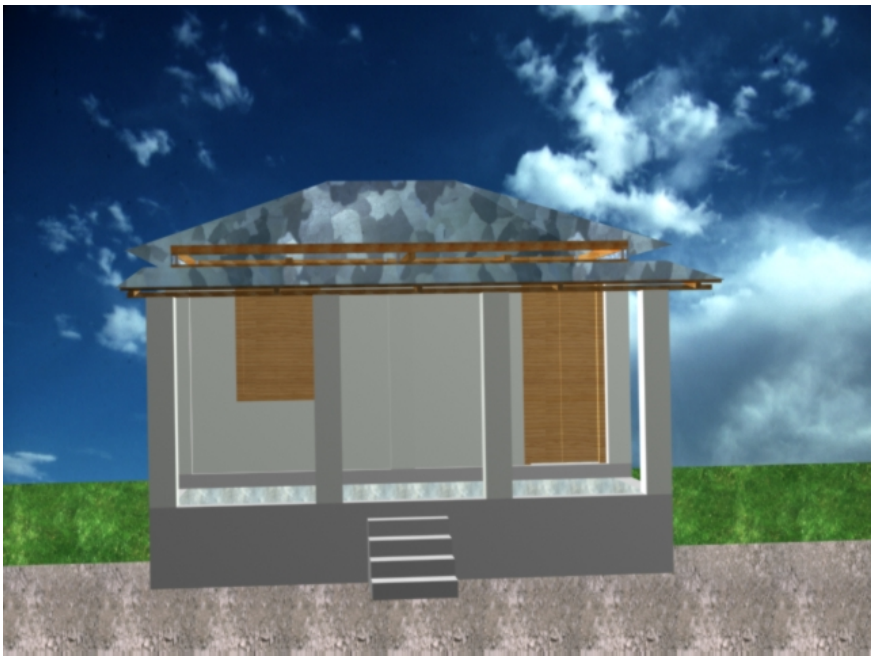
4.1 Conclusion

The most frequent hazard in the disaster prone south-Asian region (with special emphasis on Bangladesh) is that of cyclone/tornados. This brings not only high winds, but the possibility of flooding, storm surge and cause secondary effects such as landslides due to the loosening of the soil.

There are other hazards that may affect the houses of this region such as earthquakes or saline water intrusion. Earthquakes can also cause Tsunamis (tidal waves), as well as landslides and liquefaction of unstable ground.

But the most important consideration is, none of the above mentioned hazards are necessarily a disaster, if the houses are strong, built on a good foundation, and sited out of the danger area (wind directions, flood leveling etc.). This document is a CDMP output that is expected to provide these 'minimum safety guidelines' in house construction as development assistance.

SECTION – 05: DESIGN AND LAYOUTS



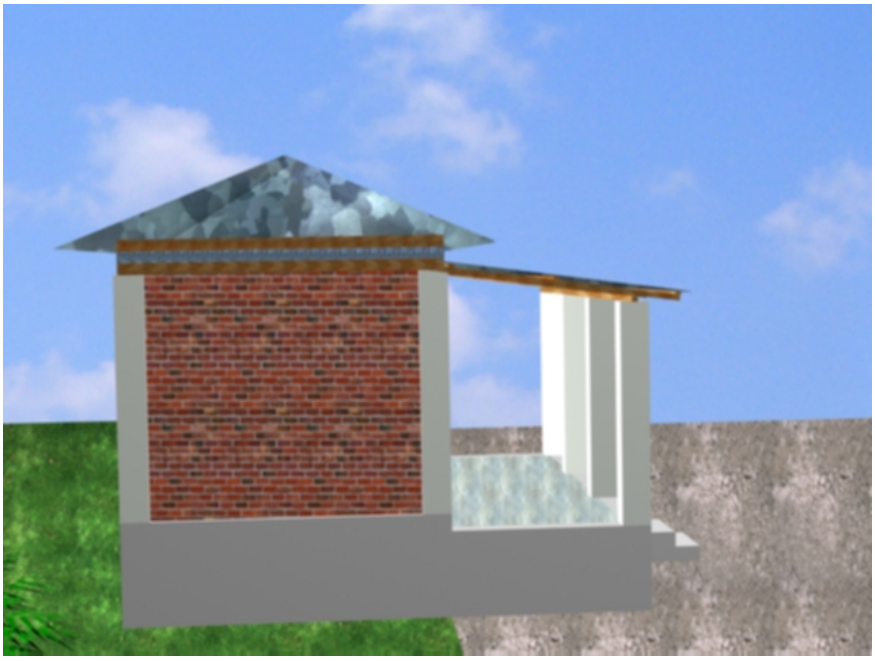
Front Elevation (CDMP House)

Side Elevation (CDMP House)

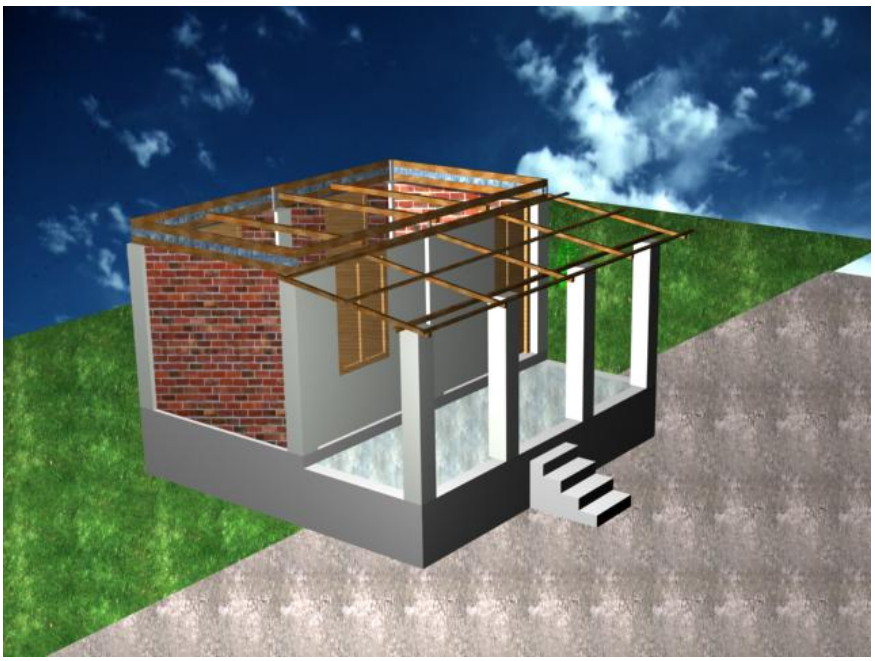
Back Elevation (CDMP House)

CDMP House – 3D view

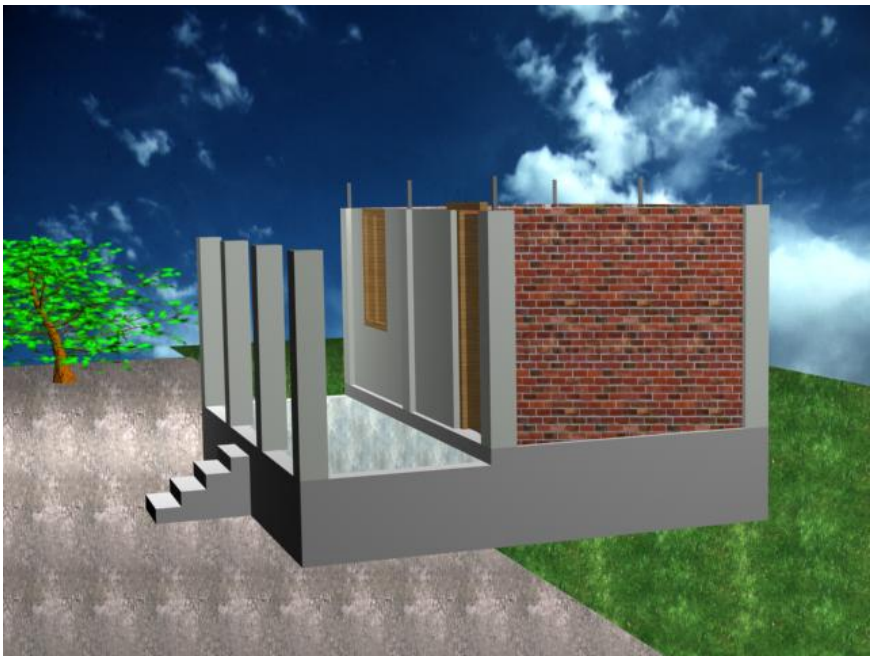
CDMP House – Distant View



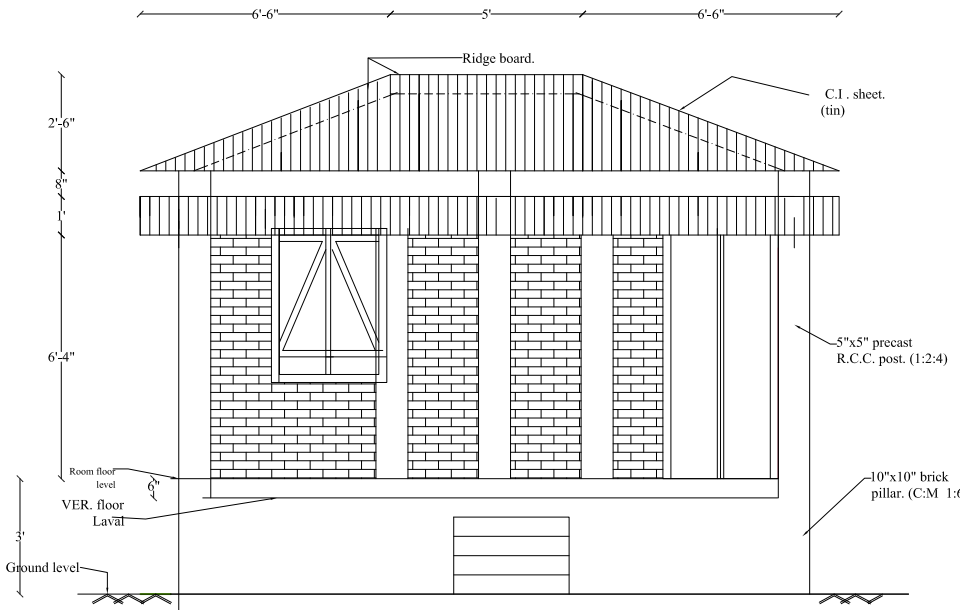
CDMP House – Side Elevation



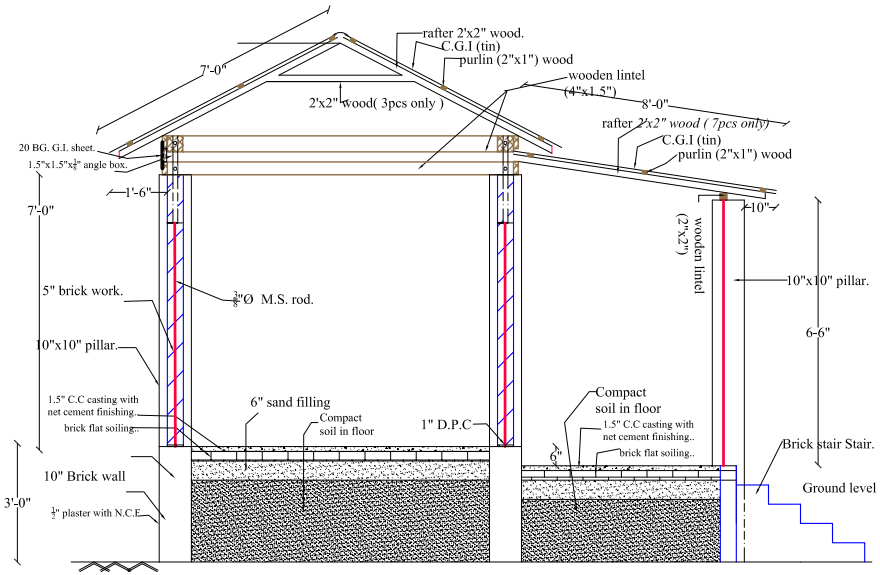
CDMP House – Roof Structure

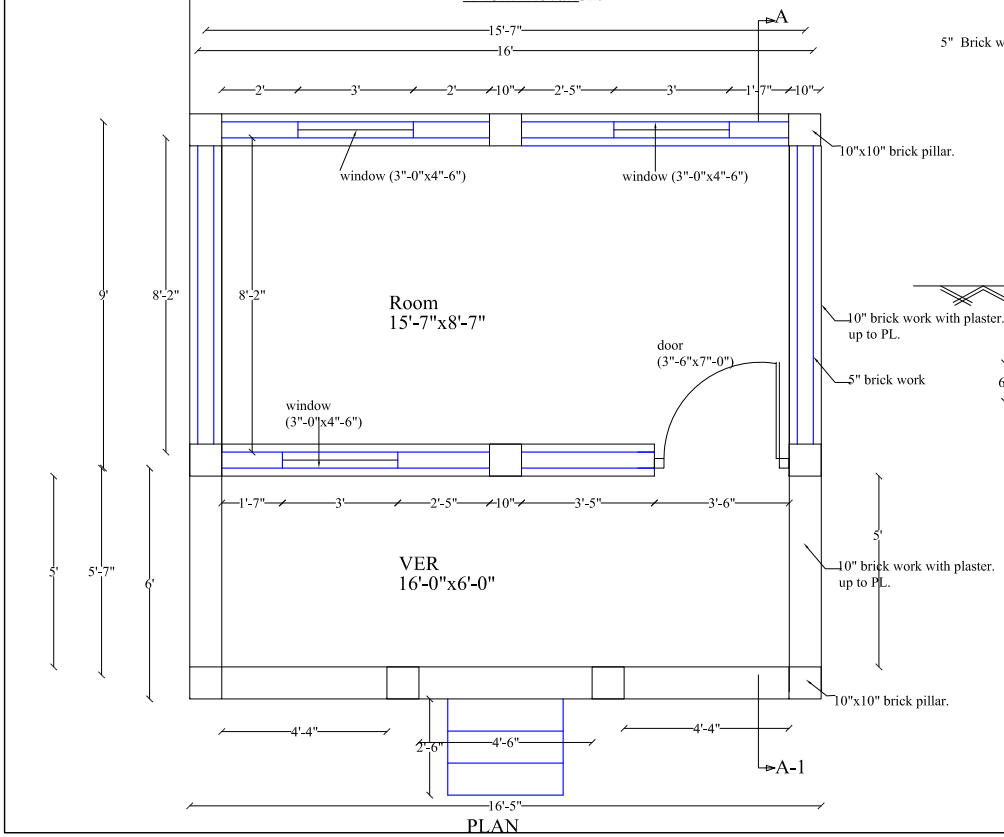


CDMP House – Pillar Structure

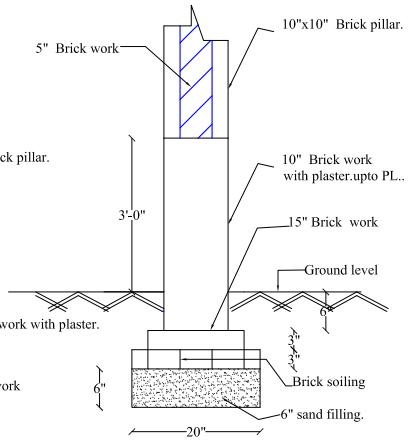


Front Elevation.



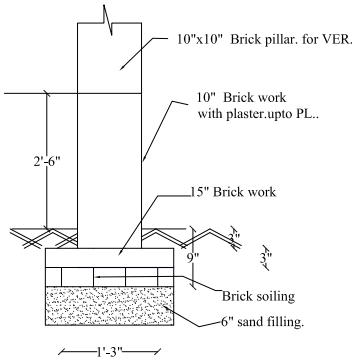


PLAN

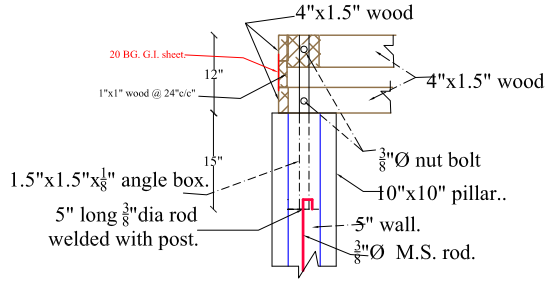


Foudation of room wall
(Cement : M -1:4)

SEC. --A, A-1



Foudation of
10" Brick wall for VER with pillar.
(Cement : M- 1:4)



Details of M.S angle post in wall.

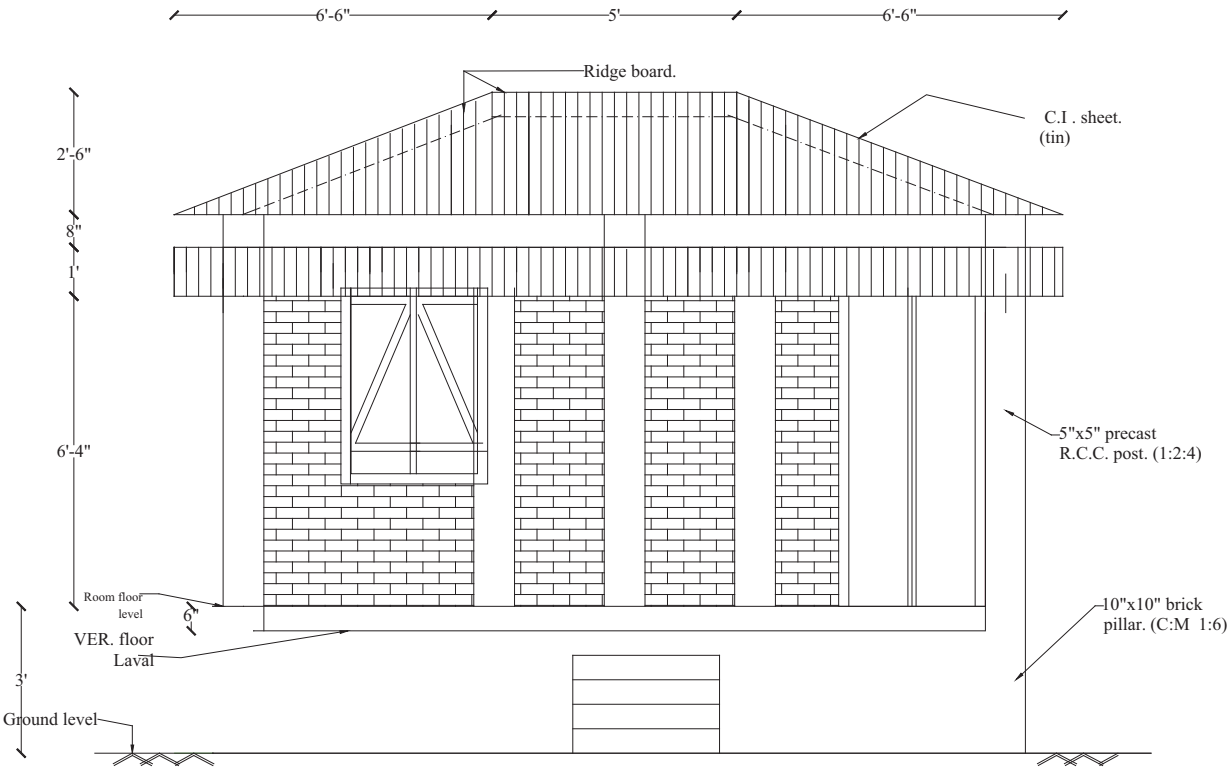
Drawn & Designe by.
Comprehensive Disaster Management Programme (CDMP)
United Nations Development Programme (UNDP).

Scale as shown

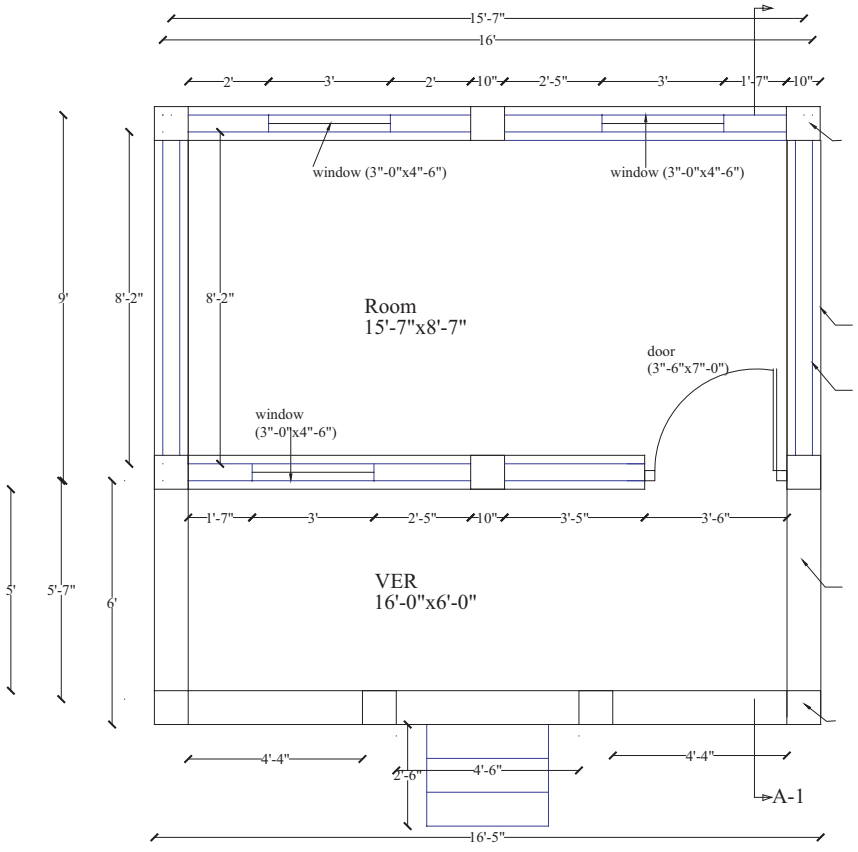
Dated 09-09-09

Title:
Plan, Front Elevation , Section & Foundation Details.

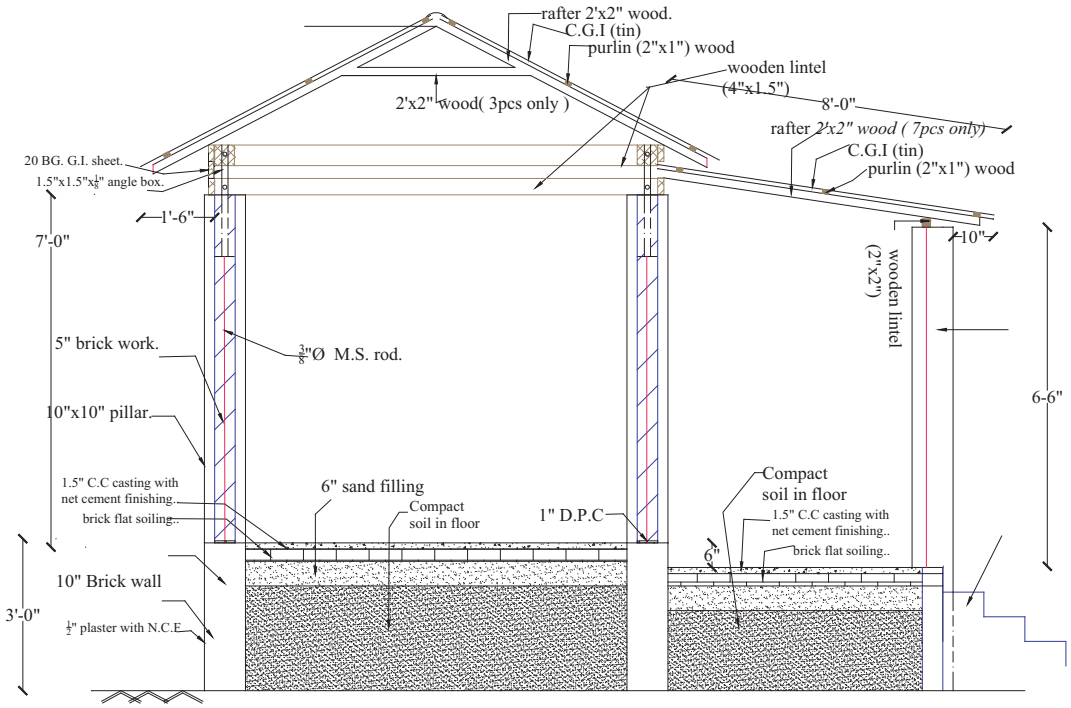
Project:
Flood/cyclone and storm surge Resilience. House : A CDMP Approach



Front Elevation.



PLAN



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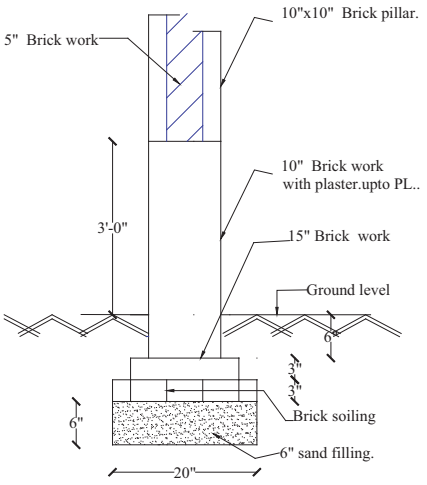
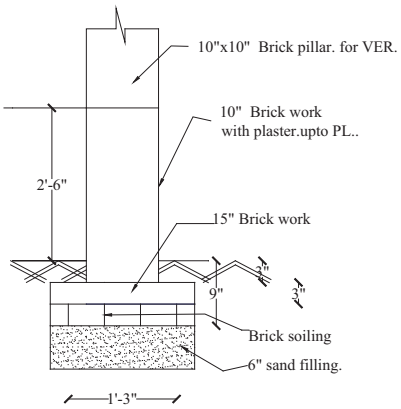
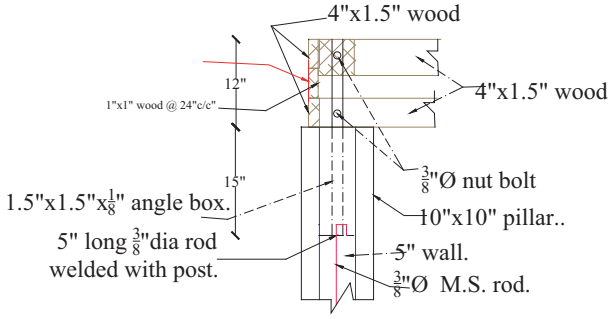


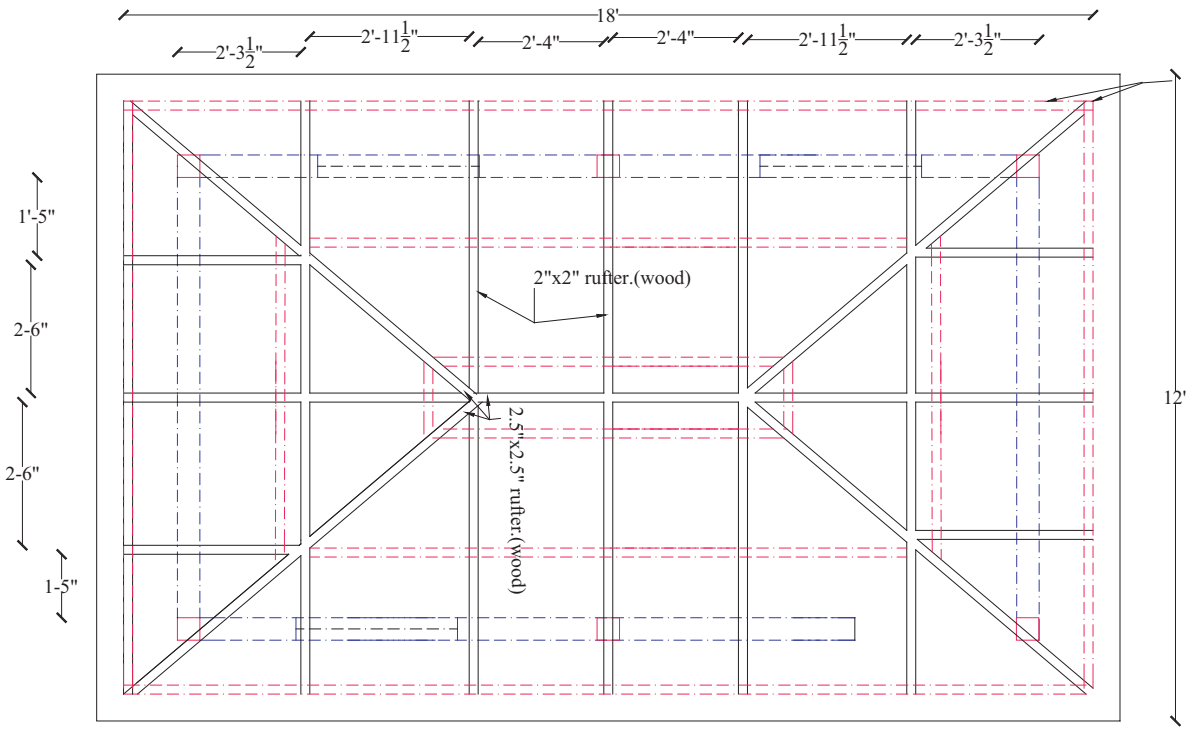
Foudation of room wall
(Cement : M -1:4)



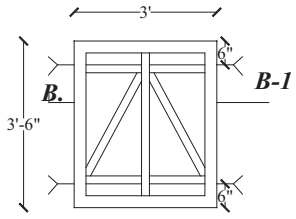
Foudation of
10" Brick wall for VER with pillar.
(Cement : M- 1:4)



Details of M.S angle post in wall.



plan of rufter (main room.)



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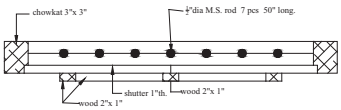
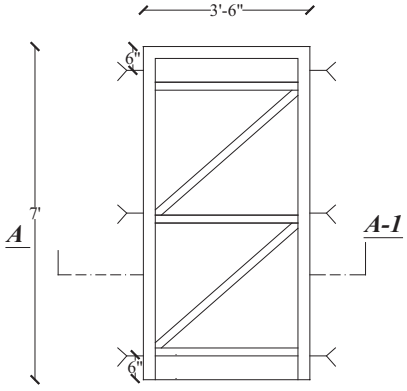
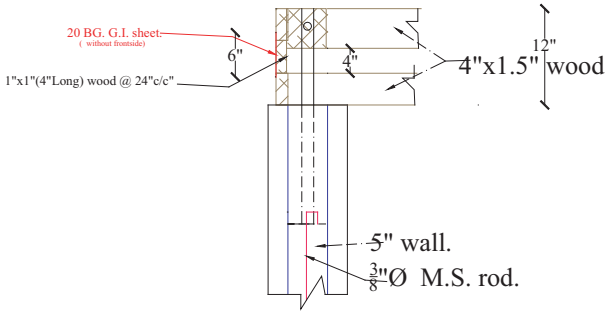


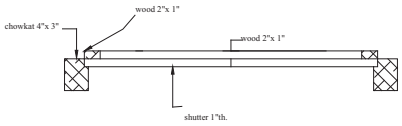
SEC. of .window B.B-1



Door



Details of G.I sheet fixing.



SEC. of Door (A, A-1)

SECTION – 06: COST ESTIMATION

Household Risk Reduction Action Plan (HRRAP)

Elementary Information on "Flood, Cyclone and Strom Surge Resilient House"

COST ESTIMATION FOR HOUSE

Sl No	Name of Item	Quantity	Unit	Total Quantity	Rate Per Unit(BDT)	Total Amount(BDT)
1	**20" Brick work for foundation**					
1.1	At main room	20.83	cft	32.5		
1.2	At Veranda	11.67	cft		127.58	4,146
2	**15' Brick work for foundation**					
2.1	At main room	15.63	cft	24.38		
2.2	At Veranda	8.75	cft		127.58	3,110
3	**10" Brick work Up to plinth level**					
3.1	At main room	131.25	cft	187.75		
3.2	At Veranda	56.5	cft			
3.3	At stair		cft		127.58	23,953
4	**10"x10" Brick column**					
4.1	At main room	43.75	cft	69.45		
4.2	At Veranda	25.7	cft		127.58	8,860
5	**5" Brick work**					
5.1	For main room	350	sft	415		
5.2	Deduction	65	sft		55.01	22,829
6	**Brick Flat solling work**					
6.1	At main room Floor	144	sft			
6.2	At veranda Floor	96	sft	240	20	4,800
7	**1/2" Plaster work**					
7.1	Up to Plinth level of main room	102	sft			
7.2	Up to Plinth level of veranda	70	sft			
7.3	Inner walls of main room	350	sft	634	16	10,144
7.4	Front wall of main room	112	sft			
7.5	For stair		sft			
8	**1.5" C.C. Casting**					
8.1	At main room Floor	18	cft	30		
8.2	At Veranda Floor	12	cft		120	3,600
9	**Net Cement Finishing work**					
9.1	At main room Floor	144	sft			
9.2	At Veranda Floor	96	sft			
9.3	Up to Plinth level of main room	102	sft	438	20	8,760
9.4	Up to Plinth level of veranda	96	sft			
	Sub Total					**90,203**
	Deduction for VAT ,IT & Contactor's Profit(18.5%)					**-16,674**
	Sub Total (a)					**73,529**
10	**M.S. Angle (1.5"x 1.5" x 3/8")**	22	kg	22	110.5	2,431
11	**3/8" dia M.S. rod**					
11.1	For Brick Column	19	kg	41.75		
11.2	For window	22.75	kg		45	1,879
12	**S/F 0.36 mm C.I. Sheet**					
12.1	8'-0" Long =19 nos	1.85	ban			
12.2	8'-0" Long=8	0.89	ban	2.74	6300	17,262
13	**Ridge Board**	10	nos	10	400	4,000
14	**Wood work**					
14.1	Wood for roofing (tie beam,rafter & purline)	15.5	cft	15.5	959	14,865
14.2	Wooden door chowkat with shutter all works	1	nos	1	3240	3,240
14.3	Wooden window chowkat with shutter all works	3	nos	3	2434	7,302
15	**Shutter wood & bamboo for brick work**					500
16	**10 mm dia nut bolt, nail, G.I. wire.Tin screw & cap washer, rubber washer etc.**					2,000
17	**Synthetic Enamel Paint (2 coats Burger)**	0.5	gallon	0.5	800	400
18	**White wash**					1,000
19	**G.I. Sheet**	12.75	sft	12.75	60	765
20	**Signboard (Lump Sum)**					500
	Sub Total(B)					**56,143**
	Total(A+B)=					**129,673**
	Contngency & Unforsin Item (L.S)					**328**
	Grand Total=					**130,001**
	In Word: Taka One Lac Thirty Thousand and One only.					
	N.B: :Earth Cutting & Filling will be done by the Beneficiary.					

REQUIREMENT OF MATERIALS

SI No	Name of Item	Unit	Quantity
1	Brick 1st class	nos	6389
2	Cement	bag	38
3	Sand	cft	193
4	Sylhet Sand	cft	9
5	Brick Chips	cft	28
6	Wood for Roof (Seasoned Rain Tree)	cft	15.5
7	C.I. Sheet (0.36 MM to 0.40 MM)	ban	2.74
8	Wooden Door (3.22 cft)	nos	1
9	Wooden Window (8.25 cft)	nos	3
10	Ridge Board	nos	10
11	M.S rod 3/8" dia	kg	19
12	M.S rod 1/2" mm dia	kg	22.75
13	M.S. Angle 1.5"x1.5"x1/8"	kg	22
14	Synthetic Enamel Paint (2 coats Burger)	Lit	0.5
15	G.I. Sheet	sft	12.75
16	10 mm dia nut bolt, nail, G.I. wire.Tin screw & cap washer, rubber washer etc.		As required
17	Scaffolding wood & bamboo for brick work (*"bash'er Macha")*		As required
18	White wash		As required