TRAINING OF TRAINERS (TOT) MANUAL FOR ENGINEERS

ON DISASTER RESILIENT CONSTRUCTION TEHNIQUES

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PREFACE

The State of Kerala was heavily impacted due the fury of nature in August 2018. Between June 1 and August 18, 2018, the State experienced the worst ever floods in its history since 1924. During this period, the state received cumulative rainfall that was 42% excess of the normal average. The heaviest spell of rain was during 1-20 August, when the state received 771mm of rain. The torrential rains triggered several landslides and forced the release of excess water from 37 dams across the state, aggravating the flood impact. Nearly 341 landslides were reported from 10 districts. Idukki, the worst hit district, was ravaged by 143 landslides. The flood left majority of people homeless due to impact to their houses severely damaging to their habitation.

Following the severe floods, a Post Disaster Needs Assessment (PDNA) was jointly undertaken by government, United Nations and other development partners to assess the damage and loss to various critical infrastructures. The assessment thus identified housing as one of the most affected sectors along with agriculture and livelihoods as most critical sectors needed priority interventions in the post flood recovery phase.

In this backdrop, UNDP and UN-HABITAT jointly with the overall guidance and leadership of the Government of Kerala initiated a project on Shelter Recovery through establishment and strengthening of Shelter Hubs in three critically affected districts of Kerala. The project aimed at building back better (BBB) through providing training to masons and engineers through a training of trainers (TOT) programme to promote disaster resilient house construction practices in various districts of the state during the recovery phase along with ensuring risk informed construction practices.

PREFACE

This training manual has been developed to provide basic understanding, concepts and overall understanding of engineers both in the private and government sectors to provide training to large number of engineers in the state through following various sections of the manual on various typologies of construction practices at each stage of shelter recovery and reconstruction process along with promoting flood and landslide resistant housing in the state.

This manual will provide the much-needed tools, technologies and construction practices by adopting disaster resilient features to enable the houses to absorb future shocks.

UN-HABITAT is thankful to the Government of Kerala, UNDP and other partners involved in this process of development of the manual. It is expected that this manual would act as a guidance note for the engineers not only to undertake future training programmes but also spread the message of safer and disaster proofing houses in the state.

This manual has been developed through wider consultations, referring to various existing manuals in similar disaster situations and taking into consideration various house construction practices in the state. A consultant was hired to develop this manual through undertaking a training needs assessment (TNA) reviewing the damage and losses due to the floods and landslides in the state an considering the existing house construction practices in the state.

It is expected that this manual will of much help to various practitioners, engineers both in the government and private sectors for sustainable reduction of disaster risks in the state of Kerala.

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Table of Contents

Annexure

Day 1

Time	Activity
09:00 am to 10:00 am	Registration and Introduction
10:00 am to 11:00 am	Elementary Presentation on various disasters and discussion on their experience during floods
11:00 am to 11:15 am	Tea
11:15 am to 12:00 am	Brick masonry construction techniques •Types of foundation •Types of beam construction •Types of column construction •Details of structural components
12:00 pm to 01:00 pm	Landslide resistant construction techniques •Retaining walls •Excavation methods
01:00 pm to 02:00 pm	Lunch
02:00 pm to 03:00 pm	Bamboo construction techniques •Bamboo preservation techniques •Bamboo foundation •Bamboo flooring •Bamboo walls •Bamboo roofing
3:00 pm to 3:45 pm	Disabled friendly construction techniques •Walkways and paths •Guiding and warning floor •Levels and groove •Approach to plinth level and ramp

	•Corridor •Entrance/Exit door
03:45 pm to 04:00 pm	Tea

Day 2

Time	**Activity**
10:00 am to 1:00 pm	Flood and landslide retrofitting techniques •Common failures in a building during disaster •Retrofitting of failures in masonry buildings •Failure of soft-stories in RCC structures •Structural crack repair techniques
01:00 pm to 02:00 pm	Lunch
02:00 pm to 03:45 pm	Session on lesson learnt
03:30 pm to 04:00 pm	Tea

Session Objectives:

- To provide an understanding of various disasters; affecting the state and impact of the floods in 2018;
- Extent of damages to housing sector in Kerala during flood;
- Effect of flood on various parts of building;
- Provide basic orientation on ensuring disaster resilient house construction considering the typologies of houses in practice in the state;
- To facilitate discussion and identifying the relevance, efficiency, effectiveness of disaster resilient construction practices in the state;

Expected Outcome

Provide a better understanding on various disasters and vulnerabilities. Causes for building damages and parts of building that are more prone to damage during a disaster.

Mode of conducting training

- Presentation
- Group Discussions and identifying the gaps and challenges and potential opportunities
- Q & A's

Materials Required

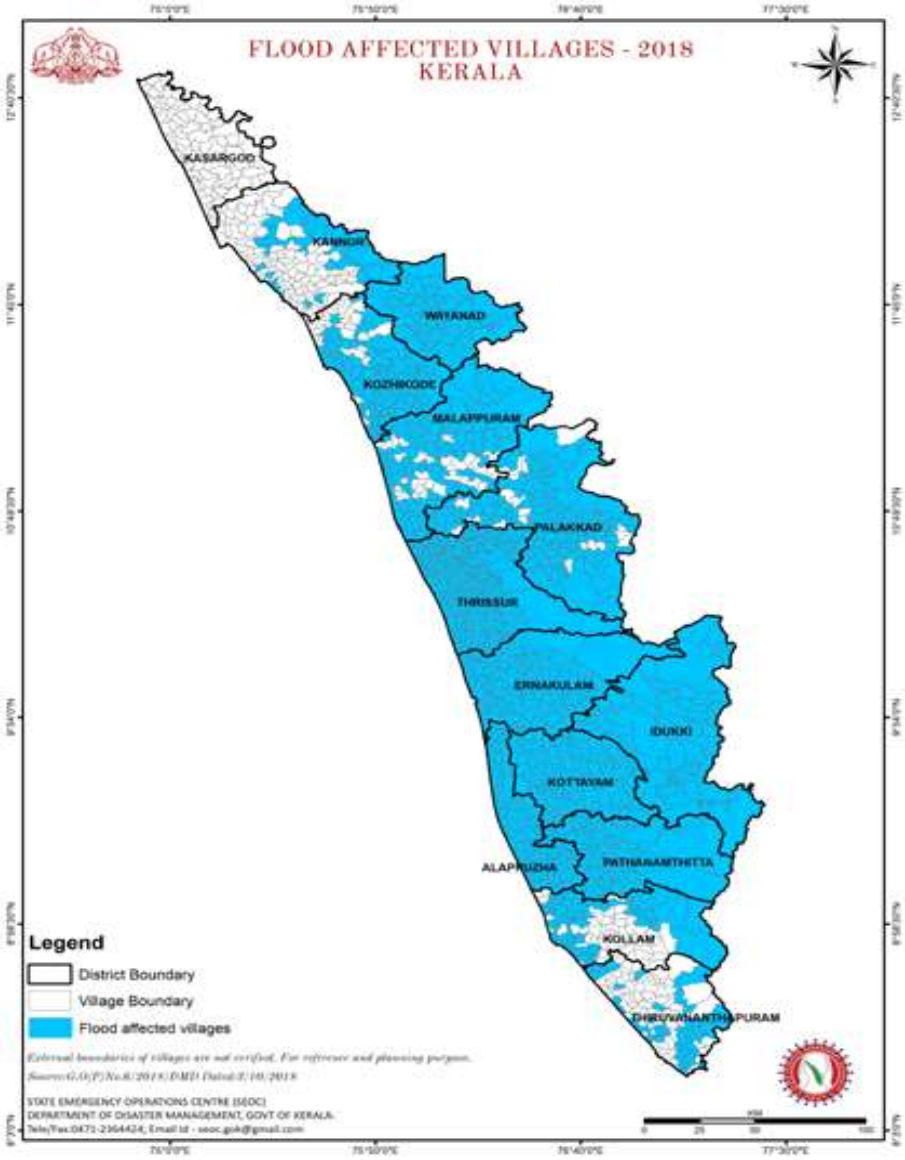
- Laptop
- Projector
- Flip Chart

1.1 Damage to housing sector in Kerala during floods

The main reasons for housing collapses in Kerala were: (i) high current of the floodwater; (ii) the inundation of the buildings for several days, causing differential settlement of the foundations; (iii) flash floods, especially where the buildings were too close to rivers and canals; and (iv) landslides.

Reasons for building failure

- Low plinth height (less than 600 mm) in flood-prone areas.
- Construction of foundation on soft soil leading to differential settlement.
- Failure of walls due to lack of bands and consequential failure of roods due to inundation.
- Due to poor construction and missing features mentioned in National Building Code.


FLOOD AFFECTED VILLAGES - 2018
KERALA
KASARGOD
KANNUR
WAYANAD
KOZHIKODE
MALAPPURAM
PALAKKAD
THRISSUR
ERNAKULAM
IDUKKI
KOTTAYAM
ALAPPUZHA
PATHANAMTHITTA
KOLLAM
THIRUVANANTHAPURAM
Legend
District Boundary
Village Boundary
Flood affected villages
External boundaries of villages are not verified. For reference and planning purpose.
STATE EMERGENCY OPERATIONS CENTRE (SEOC)
DEPARTMENT OF DISASTER MANAGEMENT, GOVT OF KERALA.

1.2. Effect of flood on various parts of buildings

Foundation

Foundations in case of pucca and semi-pucca houses are relatively durable, but in high-intensity flood, shallow foundations can become unstable due to scouring of soil-cover. Prolonged duration flood can lead to foundation settlement, thereby causing cracks and failures in different parts of the building. Houses with bamboo and sometimes timber posts embedded directly into the earthen plinth (found in tribal villages of Kerala) are extremely vulnerable and get damaged even in a low-intensity flood, thus requiring frequent maintenance.

Wall

Brick walls are relatively durable but can experience staining, peeling of plaster and weakening of mortar joints at lower ends if immersed in a flood of high depth and duration. Cracks may develop if settlement of foundation occurs. In the case of bamboo walls, during flood of high depth and moderate duration, the damage begins at the lower part of walls and hence weakening the walls and eventually resulting in complete damage.

Roof

RCC roof can withstand impact of heavy rainfall and wind, but can get weakened and may even collapse if foundation settles or walls are damaged. CI sheets can lead to corrosion in contact with water and vulnerable to secondary hazard of heavy rainfall accompanying flood. Particularly vulnerable to strong wind – can crumple and get blown off, especially if connections to frame are inadequate.

Session Objective

The session on brick masonry construction techniques focuses on various construction techniques that needs to be followed for the construction of disaster resilient buildings. Session covers all parts of the building from foundation to roof.

Expected Outcome

Equip engineers with a better understanding on various disasters and vulnerabilities. Causes for building damages and parts of building that are more prone to damage during a disaster.

Mode of conducting training

- Presentation
- Q & A's

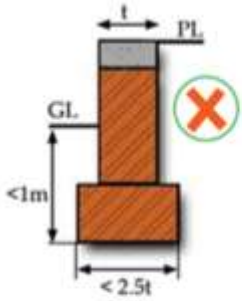
Materials Required

- Laptop
- Projector

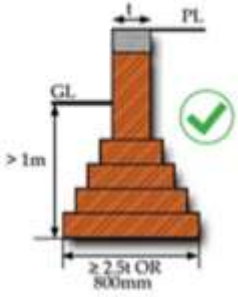
This chapter covers disaster resilient construction techniques for brick masonry buildings. The common materials used for construction in Kerala are burnt bricks, cement concrete (CC) blocks and laterite (where it is available). The common materials used for roofing are RCC, Mangalore tiles and galvanised iron (GI) sheets. In many cases the buildings are constructed without considering the possible disaster risk due to various factors like cost reduction, for early completion, etc.

In this chapter methods to be adopted while constructing foundation, walls, reinforcement and other structural components are included are explained graphically with the specifications. Special focus has been given to the structural components that are require attention during building construction.

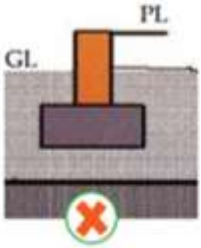
2.1 Foundation



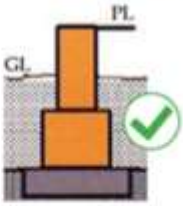
- Foundation width < 2½ times wall thickness
- Make a wall without foundation
- Use unbaked bricks in the foundation



- Foundation width > 2½ times wall thickness or 0.8m, whichever is more
- Use baked bricks and stones
- Minimum depth = 1000 mm



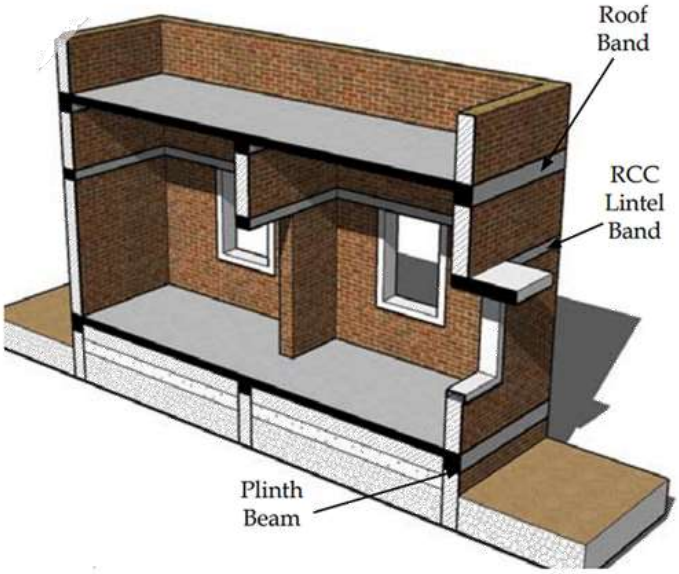
- Foundation on loose or soft soil

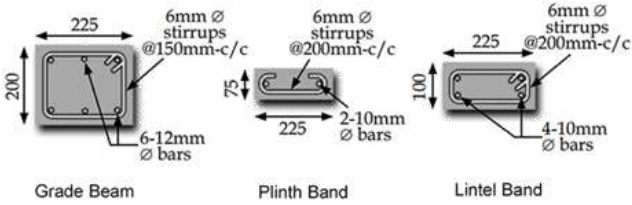


- Foundation on Hard Soil

This section shows the techniques to be adopted while construction the foundation. Common mistakes include quantity of materials used, foundation to wall thickness ratio and construction of foundation on soft soil. Solution to each of these is given above and need to be considered while constructing the foundation.

2.2 Beam

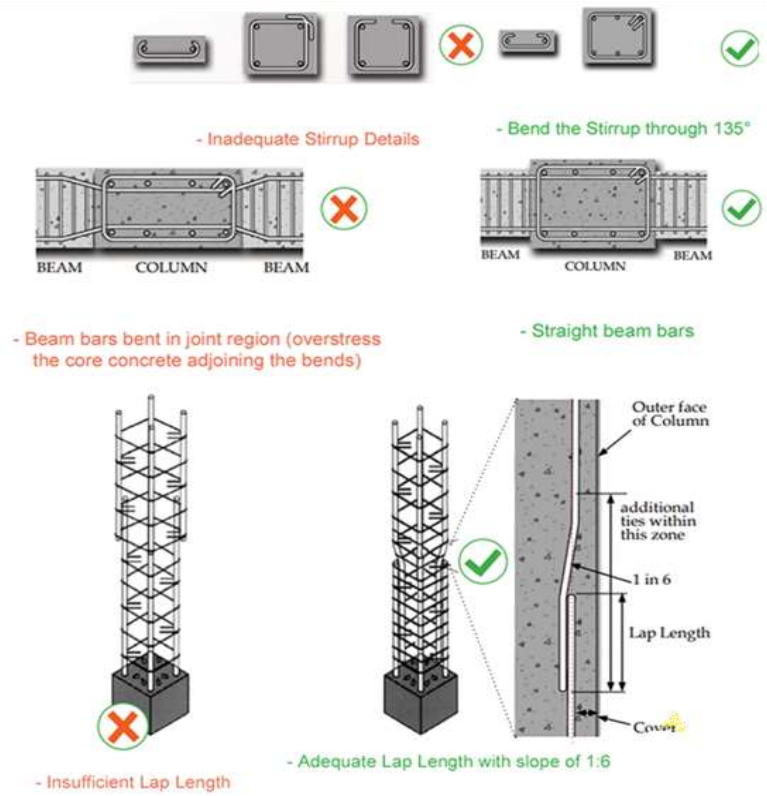




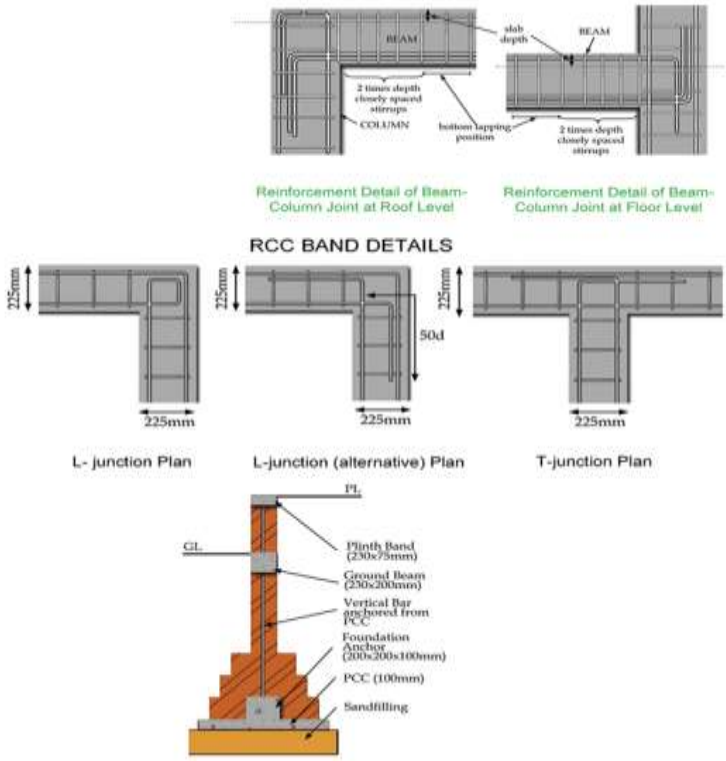
This section shows the construction of various types of beams. Beams play a major role in strength of the building and should be constructed with the above-mentioned specifications.

2.3 Column

This section shows the construction of columns. Specifications for various types of stirrups, beam-column joints and lap length of reinforcements are described.



2.4 Details of Structural Components



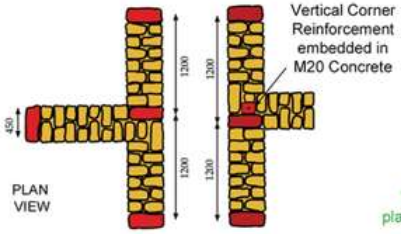
This section shows the construction of structural elements like construction of L and T-joints, and also the vertical reinforcement connecting the foundation to roof.

- Too High Walls

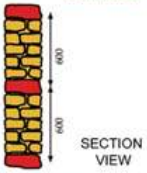
- Average wall height should be 2700 to 3000mm

- Too high walls
- Long unsupported walls

- Wall length < 8 times the thickness
- Addition of a buttress wall reduces L/H Ratio



Through stone should be placed horizontally at a minimum spacing of 1200mm center-to-center

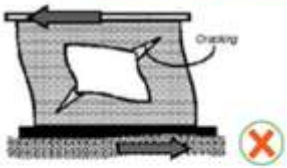


Through stone should be placed vertically at a minimum spacing of 600mm

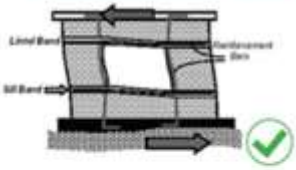
This section shows the specifications for wall height, thickness and placement of through stone.

- Openings too close to corners

- Openings well away from the corners

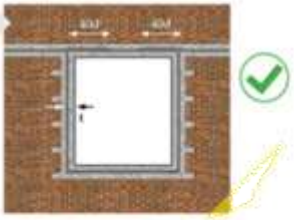


- Diagonal Cracking in building with no Corner Reinforcement



- No Cracks in Buildings with Vertical Reinforcement

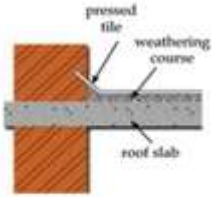
- Too many unreinforced openings (minimum distance between un-reinforced openings should be 600mm)



- Openings with Reinforced Band all around

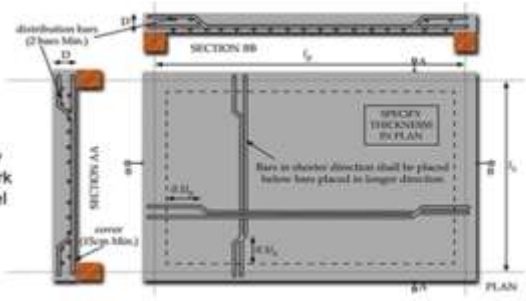
This section shows the placement of openings and placement of reinforcements around the opening to avoid cracking during a disaster.

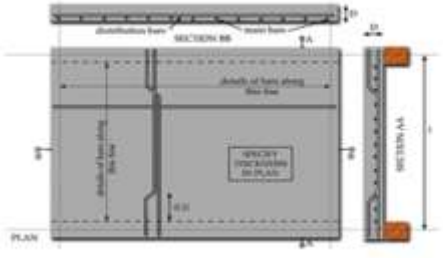
- RCC Slab at the support should be reinforced at both top and bottom



-Proper weathering course with pressed tile layer to protect RCC Slab

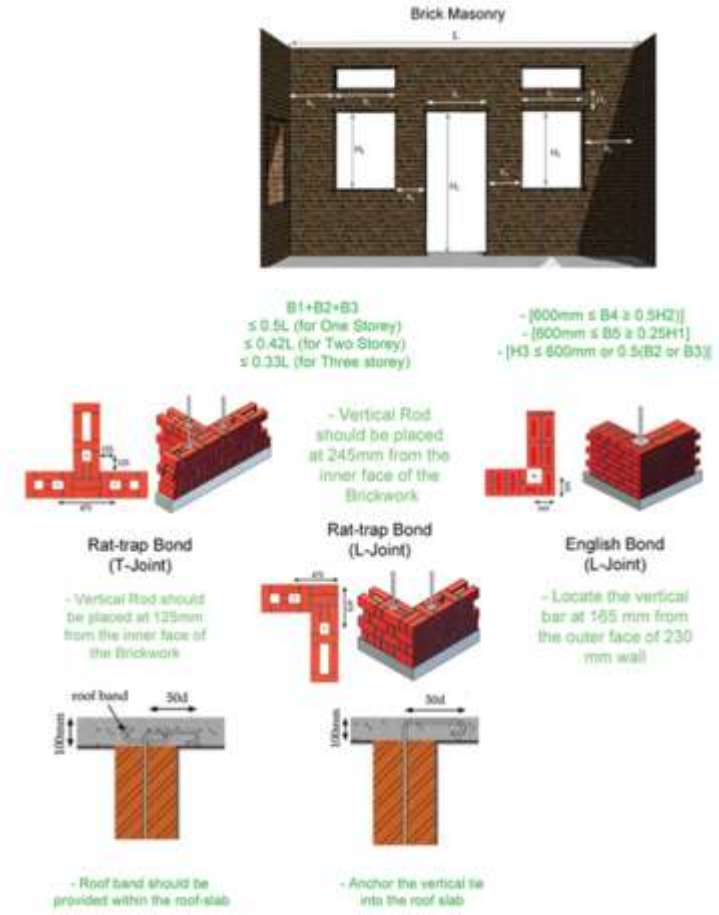
Two-way Slab simply supported on Brickwork without torsional steel





One-way Slab simply supported on Brickwork without torsional steel

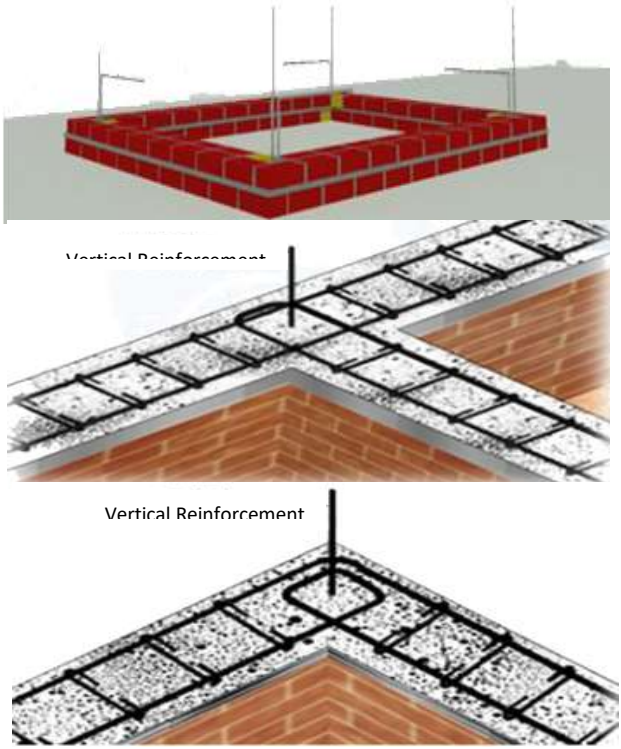
This section shows the construction of one-way and two-way slab without torsion steel along the with the placement of RCC slabs.



This section shows the specifications for vertical reinforcements and its connection with the roof band.

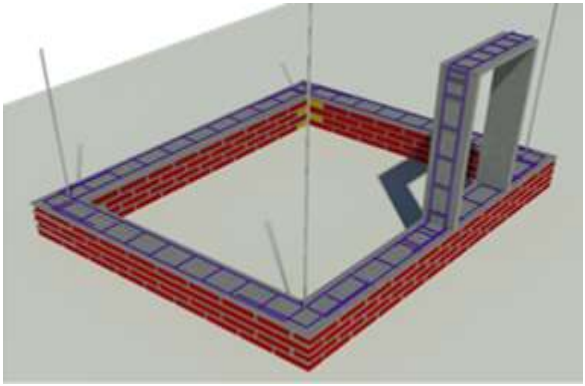
2.5 Step - wise construction of masonry buildings

Step 1

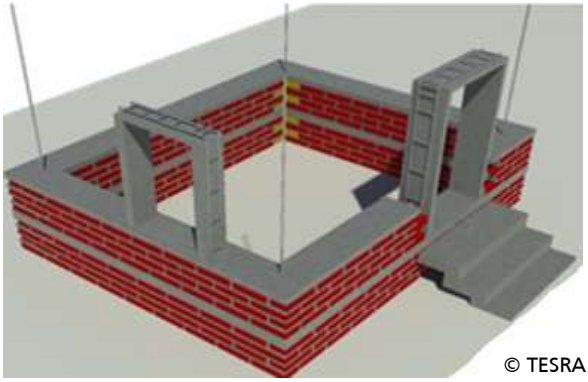


Step 1 shows the placement of reinforcement at plinth level. The vertical reinforcements should rise from the foundation. The second and third image shows the T-joint, L-joint and placement of vertical reinforcement

Step 2

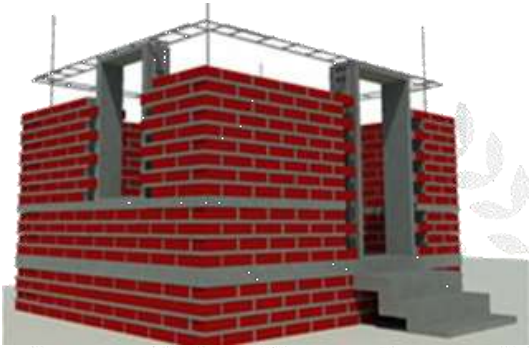


Step 3

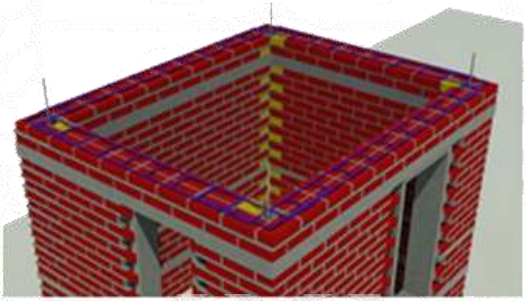


Step 2 shows the construction of plinth band and step 3 shows the construction of sill level band. Reinforcement bars should be placed along sill band (discontinuous at door openings).

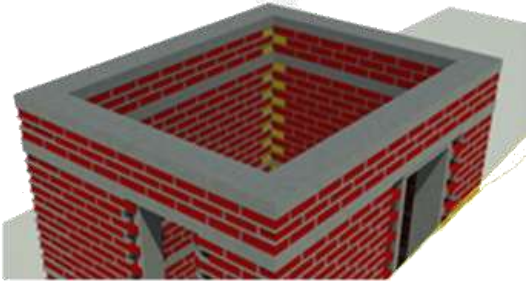
Step 4



Step 5



Step 6



Step 4 shows the construction of lintel level band. Step 5 and 6 shows the construction of roof band. It should be noted that the vertical reinforcements are connected to the roof band and roof is built over it. Flat roof is preferred to slanting roof in Kerala as it is advantageous during evacuation in case of flood.

Session Objective

- Advantage and disadvantages of bamboo structures
- Bamboo preservation techniques
- Disaster resilient construction practices using bamboo which includes foundation, flooring, walls, trusses and roof covering.

Expected Outcome

Enhance the knowledge on engineers on construction techniques using bamboo. Promote use of bamboo in their upcoming projects.

Mode of conducting training

- Presentation
- Q & A's

Materials Required

- Laptop
- Projector

Bamboo is one of the oldest and most versatile building materials with many applications in the field of construction, particularly in developing countries. It is strong and lightweight and can often be used without processing or finishing. Bamboo building are mostly found in tribal villages of Kerala. In view of its rapid growth (exceeding most fast-growing woods), a ready adaptability to most climatic and edaphic conditions and properties superior to most juvenile fast-growing wood, bamboo emerges as a very suitable alternative. There are six species of bamboo available in homesteads including reed of which Bambusa bambos is the dominant species, accounting for 96 per cent. This is followed by Bambusa vulgaris and reed, constituting 2.23 per cent and 1.38 per cent respectively.

In spite of these advantages, the use of bamboo has been largely restricted to temporary structures and lower grade buildings due to limited natural durability, difficulties in jointing, a lack of structural design data and exclusion from building codes. This section covers various construction techniques using bamboo.

3.1 Most suited species found in Kerala

	Bambusa Bamboos	Dendrocalamus Strictus
	Brighter shiny, green when fresh, yellow with age	Pale blue green when fresh dull green to yellow with age
Height	15-30m	8-16m
Diameter	Up to 150 mm	25-80 mm
Internodes	200-400 mm	300-400 mm
Thickness	Thick walled	Thick walled often solid

3.2 Preservation of bamboo

Non-chemical method of preservation

Non-chemical methods of preservation, otherwise known as traditional methods are widely used by villagers and can be undertaken without the use of any special or sophisticated plant and equipment or significant increase in costs. Typical traditional methods include:

- Smoking
- Whitewashing
- Elevated construction

Smoking method

Bamboo culms are placed above fireplaces inside the house so that the smoke and heat rise up and both dries and blackens the culms. It is possible that the process produces some toxic agents that provide a degree of protection.

Whitewashing method

Bamboo culms and bamboo mats for housing construction are often painted with slaked lime. This is carried out mainly to enhance the appearance, but there is also an expectation that the process will prolong the life of the bamboo structure by preventing moisture entering the culms. It is possible that water or moisture absorption is delayed or in some cases prevented which will provide a higher resistance to fungal attack.

Elevated construction method

The elevated construction method is designed to prevent the bamboo coming into direct contact with the ground by placing the bamboo posts on stones or preconstructedcement walls.

Chemical Treatment Method

Bamboo culms have a number of important chemical and anatomical differences from hardwoods and softwoods. These differences have a significant influence on the efficacy of treatments applied tobamboo.The following chemical treatment techniques are described below:

- Butt treatment
- Open tank method for cold soaking
- Boucherie method
- Modified Boucherie method
- Pressure treatment
- Hot and cold bath process
- Glue line treatment

Butt treatment

The butt ends of freshly cut culms, with the branches and leaves intact, are placed in a drum containing the preservative. The continued transpiration of the leaves draws the chemical solution into the vessels of theculm. The method is used for the treatment of shorter culms with a high moisture content.

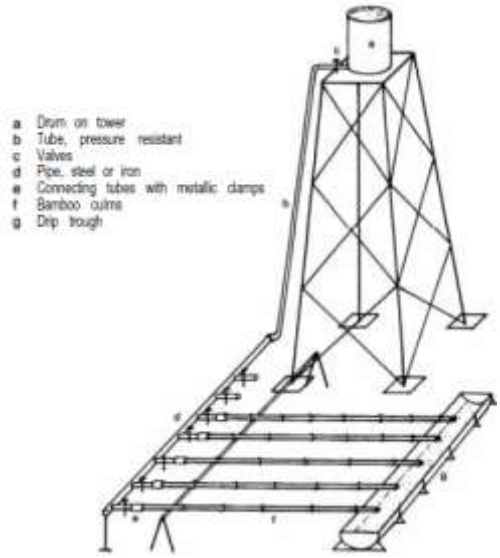
Open tank method for cold soaking

The open tank treatment method is economical, simple and provides good effective protection for bamboo. Culms, which have been prepared to size, are submerged in a solution of water-soluble preservative for a period of several days. The solution enters the culm through the ends and sides by means of diffusion.

Boucherie method

The Boucherie method requires the culms to be in agree condition. The water-transporting part of the culm can be penetrated

completely and the treatment itself is applied by an inexpensive installation. Preservative is fed by gravity from a container placed at a higher level than the culm through pipes into its base end. The culms are fastened to the tubes by rubber sheaths and clamps. The treatment is terminated when the solution at the dripping end shows a sufficiently high concentration of chemicals.



The Boucherie method

Modified Boucherie method

The basic Boucherie method has been improved by the introduction of pneumatic pressure over the preservative fluid in a reservoir, for example by using an air pump or electric pump. The preservative is forced axially through the culm by the air pressure in the reservoir. In this way the time of treatment can be reduced from several days to 3-8 hours. In other respects, the process is similar to that for the basic Boucherie method.

Pressure treatment method

Pressure treatment, using either creosote or waterborne preservatives, offers the best method of preservation for bamboo culms. The applied pressure ranges from around 0.5-l .5N/mm^2 (5-15 bar) and as such requires special plant and equipment. Accordingly, costs are high, but a service life of up to 15 years cane expected from adequately treated bamboo when used in the open and in contact with the ground.

Hot and cold bath process

When pressure treatment facilities are not available the process hot and cold bath process offers an acceptable alternative. The bamboo is submerged in a tank of preservative which is then heated, either directly over fire or indirectly by means of steel coils in the tank. The bath temperature is raised to about 90°C held at that temperature for about 30 minutes and then allowed to cool.

Glue line treatment

Glue line treatment is specific to the manufacture of bamboo mat board and involves adding preservatives to the glue during manufacture. This process is also more economical than using adhesives of a higher solid content. Additives which have been shown to provide effective preservative treatment without impairing the bond strength of the mat board include1% Chlordane or 1% sodium octaborate tetrahydratewith a 1:2 diluted PF solution containing 17% solid content.

3.3 Bamboo Foundation

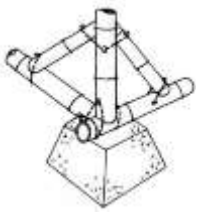
The types of bamboo foundation identified are:

- Bamboo in direct ground contact
- Bamboo on rock or preformed concrete footings
- Bamboo incorporated into concrete footings
- Composite bamboo/concrete columns
- Bamboo reinforced concrete
- Bamboo piles

Bamboo in direct ground contact

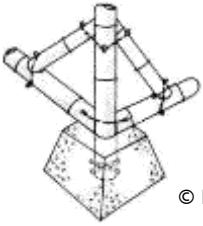
Bamboo, either on the surface or buried, can decay within six months to two years. Preservative treatment is therefore recommended together.

Bamboo on rock or performed concrete footings. Ideally, where bamboo is being used for bearings it should be placed out of ground contact on footings of either rock or preformed concrete.



Bamboo incorporated concrete footings

The third approach is to incorporate the bamboo directly into the concrete footing. This can take the form of single posts or strip footings.



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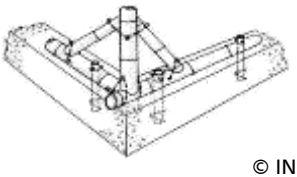

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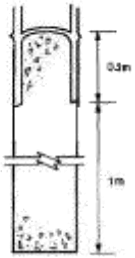
Composite bamboo/concrete columns

An innovative development involves the casting of a concrete extension to a bamboo post using a plastic tube of the same diameter. The result is a bamboo post with an integral, durable foundation.



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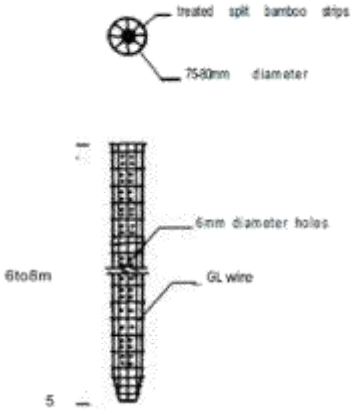
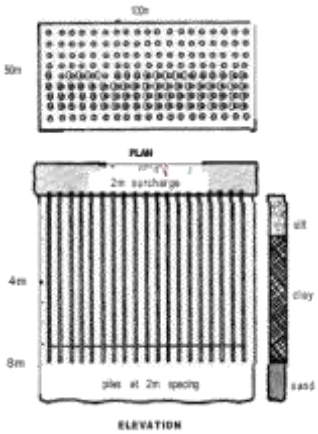
Bamboo reinforced concrete

Bamboo reinforced concrete slabs offer another solution, although this type of construction has its own specific problems.

Bamboo piles

Bamboo piles have been used successfully to stabilize soft soils and reduce building settlement. In the example cited, treated split bamboo piles 8m long and 80 to 90mm in diameter were filled with coconut coir strands wrapped with jute. The sections were then tied with wire. After installation of the piles at 2m centers by drop hammer, the area was covered with a 2.5m surcharge of sandy material.





3.4 Bamboo Floor

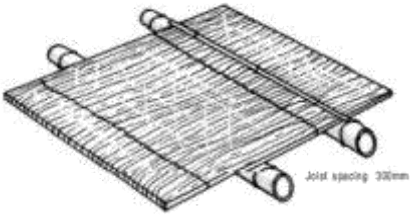
The floor of a bamboo building may be at ground level, and therefore consist only of compacted earth, with or without a covering of bamboo matting. However, the preferred solution is to raise the floor above the ground creating a stilt type of construction. This improves comfort and hygiene and can provide a covered storage area below the floor. A minimum ground to floor distance of 500mm is recommended to allow for inspection (Janssen, 1995). When the floor is elevated, it becomes an integral part of the structural framework of the building.

The floor will comprise:

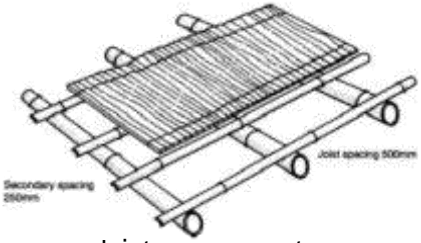
- Structural bamboo elements
- Bamboo decking

Floor structure

Floors normally consist of bamboo beams fixed to strip footings or to foundation posts. The beams therefore run around the perimeter of the building. Where the beams are fixed to posts, careful attention to jointing is required. Beams and columns are generally around 1 00mm in diameter.



Joint arrangement – Primariesonly

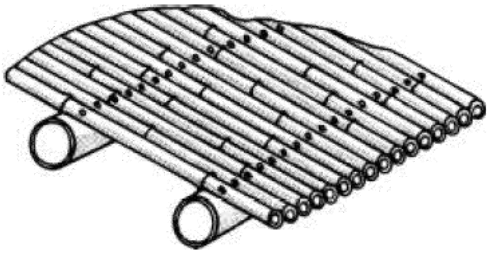


Joint arrangement – Primarise and secondarise

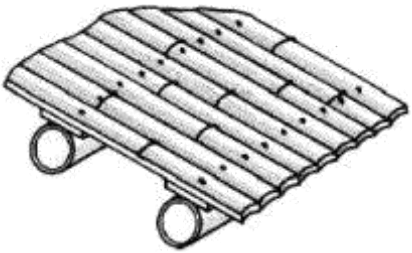
Floor decking Bamboo floor decking can take one of the following forms:

- Small bamboo culms
- Split bamboo
- Flattened bamboo (bamboo boards)
- Bamboo mats
- Bamboo panels
- Bamboo parquet's

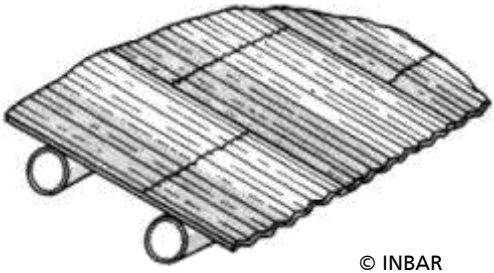
Small bamboo culms:
Small diameter culms are tied or nailed directly to the joists



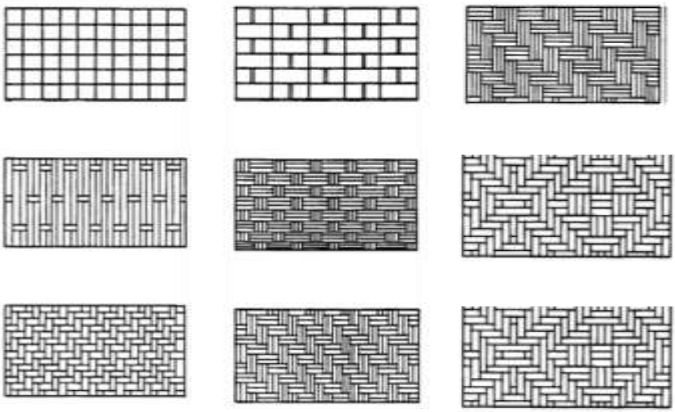
Split bamboo: bamboo culms are split along their length into strips several centimeters wide. They can be fixed directly to the joists in the case of tying or nailing, or a timber batten can be fixed to the joist beforehand to facilitate nailing.



Flattened bamboo (bamboo boards): These are formed by splitting green bamboo culms, removing the diaphragms then unrolling and flattening them. The resulting board is laid across the joists and fixed by nailing or tying. The surface finish of these three types of floor deck is, understandably, uneven and difficult to clean. They can be screeded with cement mortar for reasons of hygiene and comfort.

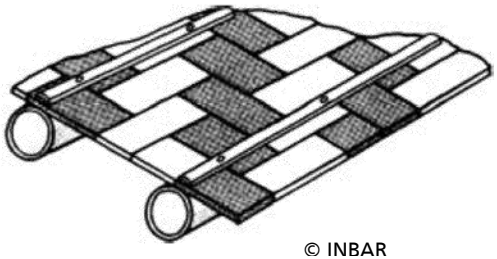


Bamboo mats: These are formed by weaving thin strips of bamboo. Strips vary in size from 20 x 2mm to 2 x 1 mm, depending on the intricacy of the pattern.



Examples of woven bamboo mats

Mats should not be fixed by direct nailing, but are held in place by bamboo strips or timber battens tied or nailed over the top. This is one of the easiest types of traditional floor to keep clean.



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Bamboo panels:

Layers of woven mats or strips, laid at right angles, are bonded together into boards, which are then nailed to the joists.

Bamboo panels:

Layers of woven mats or strips, laid at right angles, are bonded together into boards, which are then nailed to the joists.

3.5 Bamboo Wall

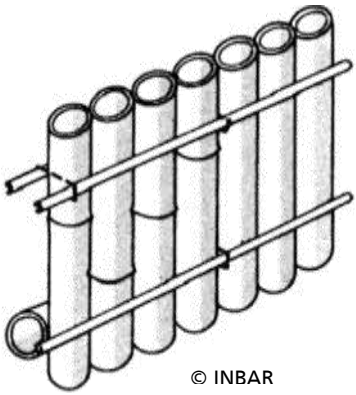
The most extensive use of bamboo in construction is for walls and partitions. The major elements of a bamboo wall (posts and beams) generally constitute part of the structural framework. As such they are required to carry the self-weight of the building and also loadings imposed by the occupants, the weather and, occasionally, earthquakes. To this end, efficient and adequate jointing is of primary importance.

Type of infill

- Whole or halved vertical or horizontal bamboo culms, with or without bamboo mats
- Split or flattened bamboo, with mats and/or plaster
- Bajareque
- Wattle (wattle and daub, lath and plaster, quincha)
- Woven bamboo, with or without plaster
- Bam boo panels

Whole or halved bamboo culms

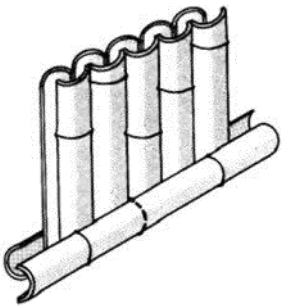
The preferred orientation is vertical as this increases the shear resistance of the wall and is also better for drying after rain. Vertical members can be driven directly into the ground or fixed back to beams by tying with or without facing battens. Halved culms can be fixed in the same way, either as a single or double ply construction, or anchored between horizontal halved culms. Woven bamboo mats can be attached to one or both faces using



© INBAR

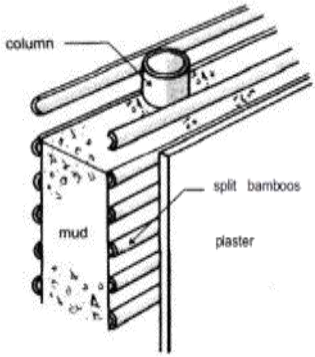
Split or flattened bamboo

Can be fixed vertically to intermediate bamboo members tied to or mortised into the posts, or fixed horizontally directly to the posts. Boards can be stretched or covered by wire mesh to provide a suitable surface for plastering. Closely woven matting can also be applied to the board surface, with or without plaster.



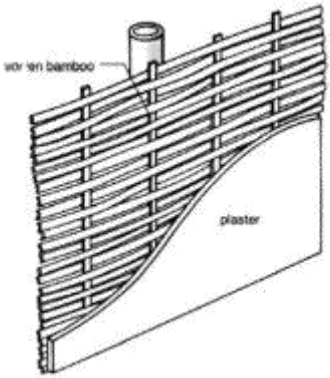
Bajareque

It consists of horizontal bamboo strips tied or nailed to both sides of the posts. The cavity is then filled with mud or mud and stones, producing a relatively massive form of construction.



Wattle

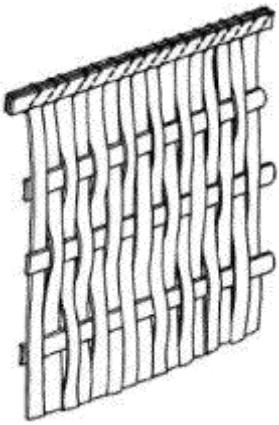
Common in parts of India, Peru and Chile, this comprises coarsely woven panels of bamboo strips (vertical weft and horizontal warp), plastered on both sides.



Woven bamboo

Coarsely woven panels similar to those for wattle but with closer wefts can be used with or without plaster. The plaster can be made from any combination of mud, clay, and sand, stabilized with lime, cow dung, cement and organic fibers. The surface can be finished

with a lime wash to give a typical stucco appearance. Preservatives may be added but due attention should be paid to health, safety and



Woven bamboo
Wall construction

Bamboo panels

Panels have been developed specifically for use in walls and partitions and have the advantage of imparting greater structural rigidity to the construction.

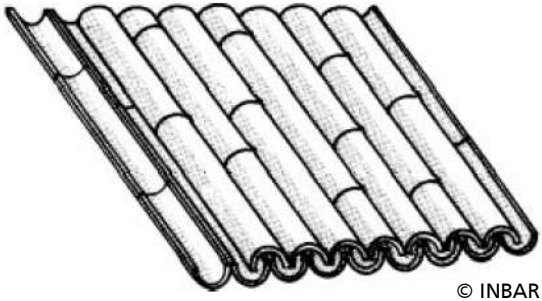
Bamboo has also been used as a reinforcement for stabilized or rammed mud walls. However, difficulties exist in achieving an adequate bond between the mud and bamboo to ensure composite

3.6 Bamboo Roof

The roof of a building is arguably its most important component - this is what defines a construction as a shelter. As such, it is required to offer protection against extremes of weather including rain, sun and wind, and to provide clear, usable space beneath its canopy. Above all, it must be strong enough to resist the considerable forces generated by wind and roof coverings. In this respect bamboo is ideal as a roofing material - it is strong, resilient and light-weight.

The bamboo structure of a roof can comprise “cut’ components - purlins, rafters and laths or battens, or triangulated (trussed) assemblies. Bamboo, in a variety of forms, is also used as a roof covering and for ceilings.

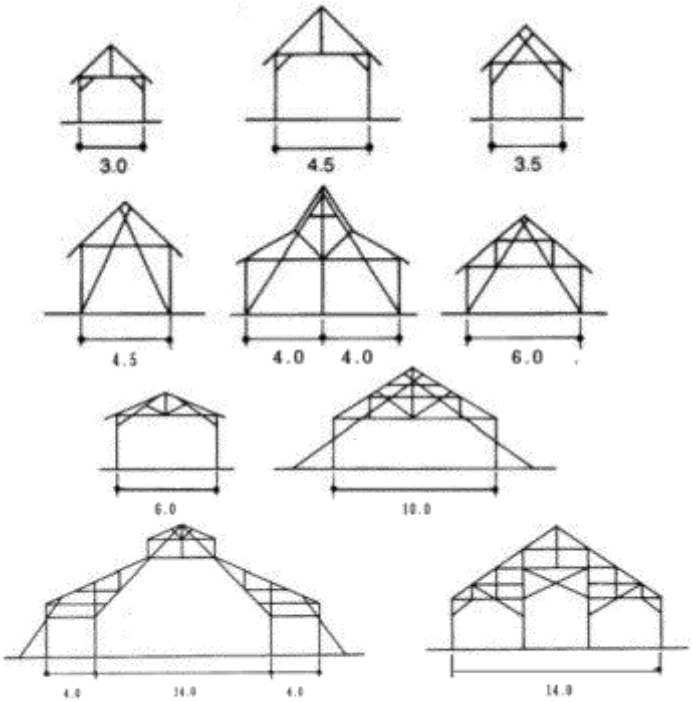
The simplest form of roof comprises a bamboo ridge purlin and eaves beams, supported on the perimeter posts. Halved culms are then laid convex side down, edge to edge, spanning from the ridge to the eaves. A second layer, convex side up, is then laid to cover the joints. The maximum overall span using this method is about 3 metres. A variation on this is the use of whole culms, suitably spaced to accept battens for tiles or thatch. To extend the span, a central post can be used.



Roof of halved bamboo culms

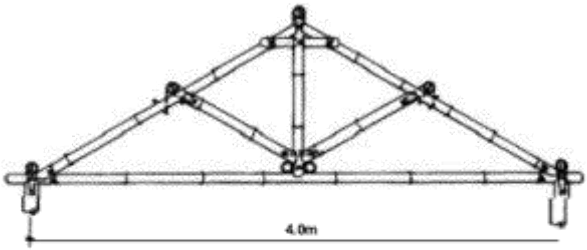
Trusses: Trusses offer a number of advantages over traditional forms of construction, including more economic and efficient use of materials, the ability to span larger distances, the use of shorter components (counteracting effects of bow, crook and taper) and the use of prefabrication.

Much research and development has been carried out in this area. This work has highlighted the relative weakness of the joints and also of the bamboo in compression perpendicular to its length. In addition, much of the deflection of a loaded truss has been found to be due to deformation at the joints.

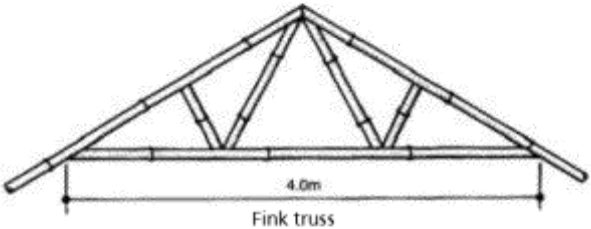


Possible roof framing configurations using traditional forms of construction - dimensions in meters

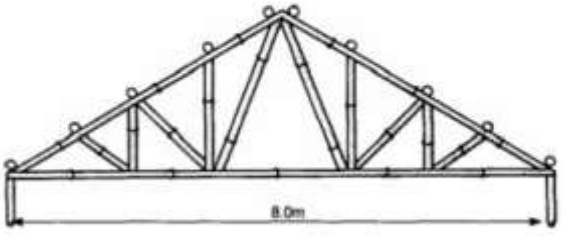
The King-post and Fink are the simplest, readily spanning 4m using traditional jointing. Culm diameters typically range from 40-100 mm. Janssen has achieved an 8m span using improved jointing



King-post truss



Fink truss

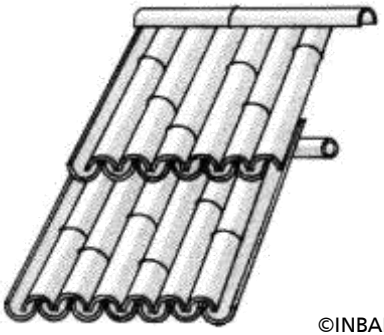


Janssen truss configuration

Roof covering: Bamboo roof coverings can form an integral part of the structure, as in the case of overlapping halved culms. More often, they are non-structural in function. Examples include:

- Bamboo tiles
- Bamboo shingles
- Bamboo mats
- Corrugated bamboo roofing sheets
- Plastered bamboo

Bamboo tiles: these can take the form of halved, intermodal culm sections, fixed to battens and overlapped in a similar manner to the full-length halved culms. Roofs covered in this manner are susceptible to leakage.

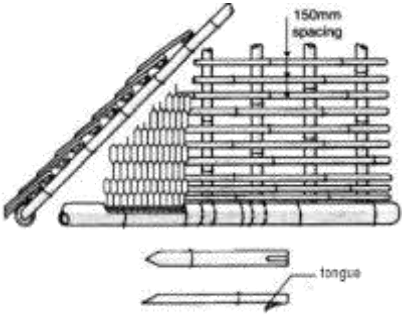


©INBAR

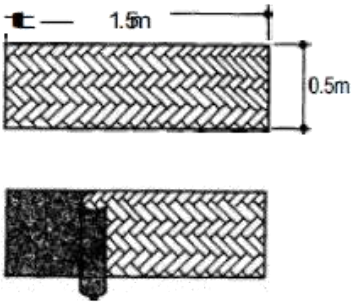
Corrugated bamboo roofing sheets: PF resin is applied to a bamboo mats to form a five-layer set which is then hot pressed between corrugated platens. UF resin bonded sheets overlaid with PF resin impregnated paper have also been produced. These products are strong and lightweight with good insulation properties.

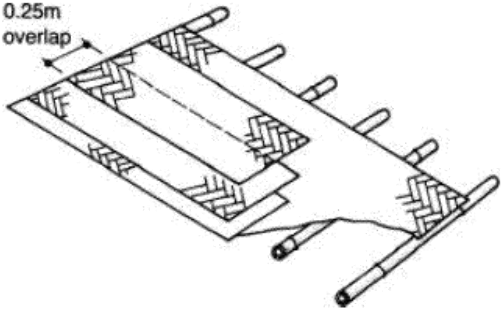
Plastered bamboo: a cement plaster, with or without the addition of organic fibers, is traditionally applied to bamboo roofs.

Bamboo shingles: shingles, measuring 30-40mm wide x intermodal length (400-600mm) are cut from green culms, 70mm or more in diameter and then air dried. The shingles are hooked onto bamboo battens by means of a tongue cut into the underside. Three laps are required to make a roof watertight, requiring some 200 shingles per square meter.



Bamboo mats: a layer of bitumen is sandwiched between two mats forming a semi-rigid panel. The mats can be fixed to rafters at 200-250mm centers. A bituminous or rubberized weatherproof coating is then applied to the finished roof.





Session Objective

Session on retrofitting techniques focuses on various failures in building during and its retrofitting techniques. Training will be provided on both residential and public buildings.

Expected Outcome

Engineers will have better understanding on repair and strengthening of building. This will be mostly applicable in case of partially damaged buildings.

Mode of conducting training

- Presentation
- Q & A's

Materials Required

- Laptop
- Projector
- White board
- Marker

4.1 Common failures in a building during disasters

During a disaster cracks are initially formed at the corners and around the opening. Severe damages of these kind can lead to the collapse of the structure.

Retrofitting technique of column

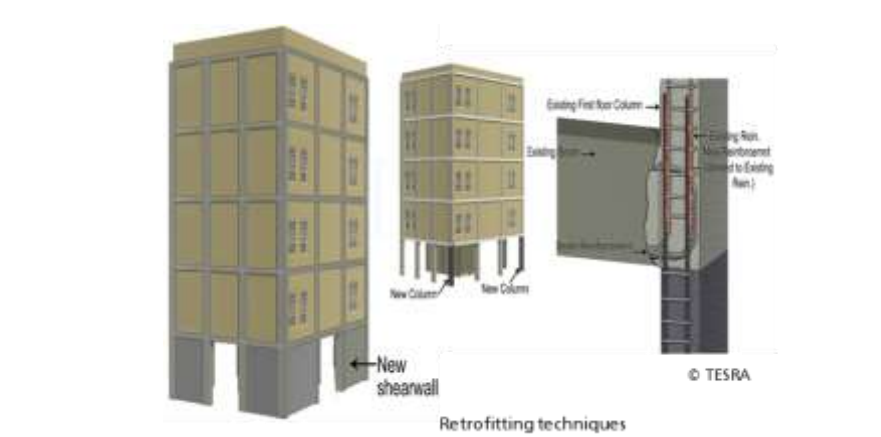
4.2 Retrofitting of failure in masonry building

In order to retrofit the cracks, we need to introduce a band around the building as shown in the above image. Band consist of 10-gauge wire mesh and 1:3 cement plaster with 30 mm thickness and it will be applied both side of the wall and wire mesh is connected through-n-through by shear keys at 300 mm c/c.

4.3 Failure of soft-stories in RCC structure and its retrofitting

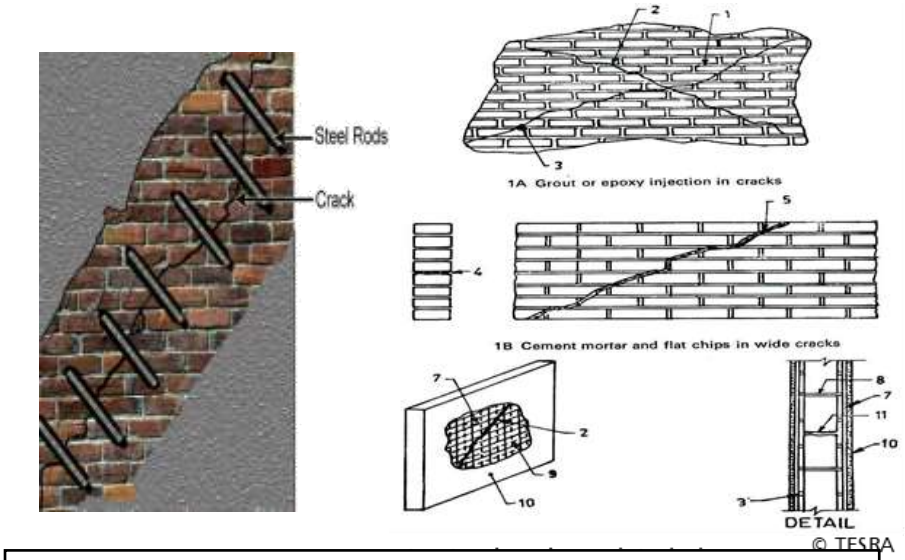
Soft-stories are most vulnerable part of the structure in multi stories most common failures is observed on soft-stories, there are several techniques of retrofitting of this type of buildings, like introduction of new column, shear wall, and bracings etc. for detail refer following images:

Failure and collapse pattern



Retrofitting techniques

4.4 Structural crack repair techniques



Steel rods are connected perpendicular to the crack and welded. Holes are not drilled simultaneously as it can cause further damage to the wall.

Session Objective

The session on landslide hazard resilience focuses on landslide hazard vulnerability in Kerala and measures to control it. Training is given on construction of various kinds of retaining walls and excavation methods to prevent landslide.

Expected Outcome

Training will equip engineers with a better understanding on various landslide resilience methods and site assessment.

Mode of conducting training

1. Presentation
2. Q & A's

Materials Required

1. Laptop
2. Projector

In Kerala, landslides commonly occur in localized areas of the Western Ghats region where the slope is steep and the soil is over saturated as a result of prolonged rainfall. These events vary from events affecting a parcel of land to those larger ones with much causality. Only the larger ones with losses of lives have been highlighted and studied in detail. The smaller events also indicate landslide potential of an area. most of the events are of debris flow type triggered by excess rainfall and are influenced by terrain factors like slope, overburden thickness, land use, relative relief, disposition of streams, landform at micro level etc.

Landslide prone area in each district				
District	Area (Km^2)	Area %	Area (Km^2)	Area %
	High		Low	
Pathanamthitta	170.28	6.41	426.25	16.04
Idukki	388.32	8.90	873.71	20.02
Wayanad	102.56	4.82	196.57	9.20

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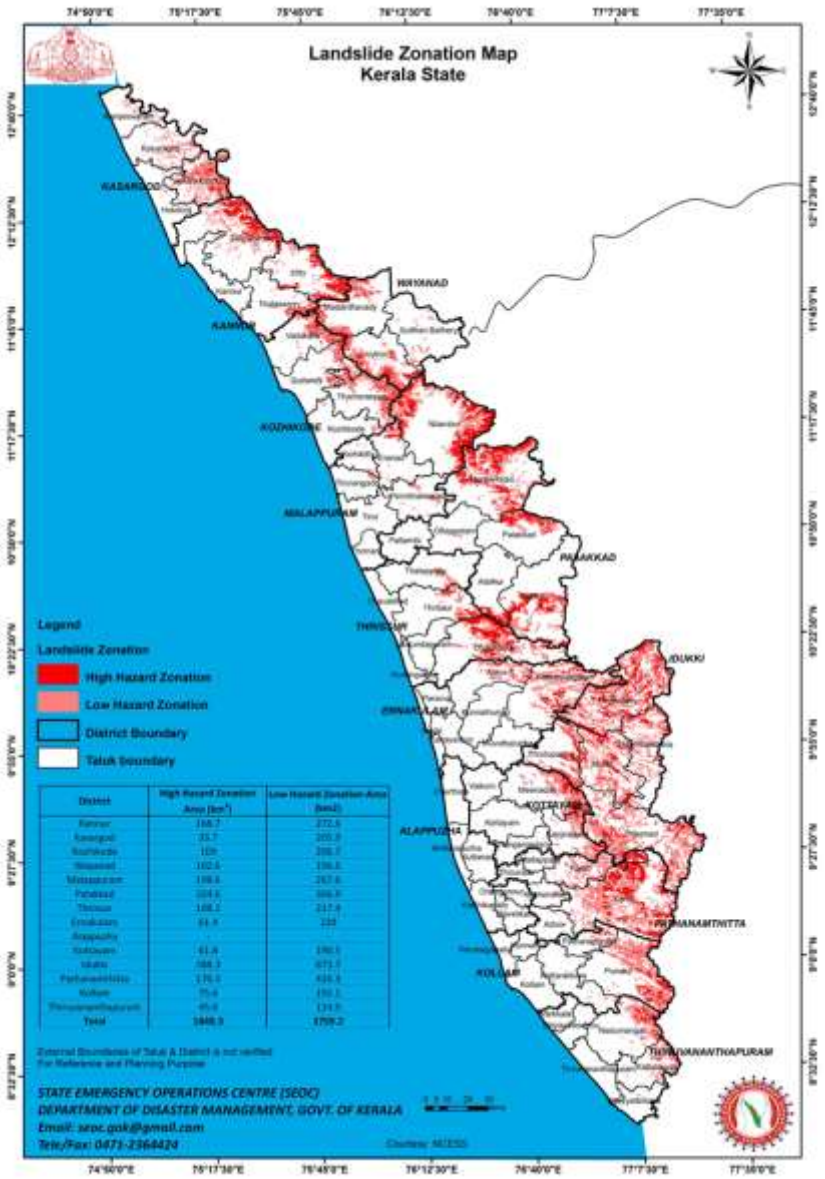
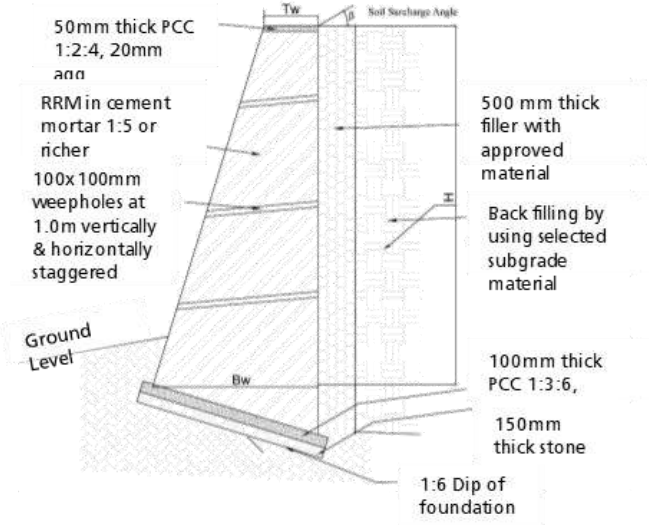
Llandslides in Kerala (2018)

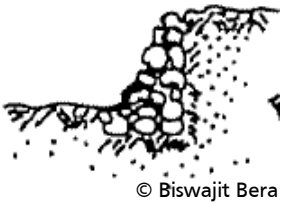

Landslide Zonation Map
Kerala State
KASARGOD
KANNUR
KOZHIKODE
MALAPPURAM
PALAKKAD
THRISSUR
IDUKKI
ERNAKULAM
ALAPPUZHA
KOLLAM
PATHANAMTHITTA
THIRUVANANTHAPURAM
Legend
Landslide Zonation
High Hazard Zonation
Low Hazard Zonation
District Boundary
Taluk Boundary
STATE EMERGENCY OPERATIONS CENTRE (SEOC)
DEPARTMENT OF DISASTER MANAGEMENT, GOVT. OF KERALA
Email: seoc.gok@gmail.com
Tele/Fax: 0471-2364424

Types of retaining walls

5.1 Masonry wall

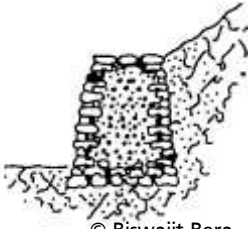
Retaining walls of up to four meters in height are constructed in random rubble-dry stone masonry. Retaining walls above four meters in height are built either in lime or cement mortar masonry or in dry stone masonry with 0.6 m wide mortar masonry bands three to found meters apart, laid both in horizontal and vertical directions.





© Biswajit Bera

Stacked Masonry



© Biswajit Bera

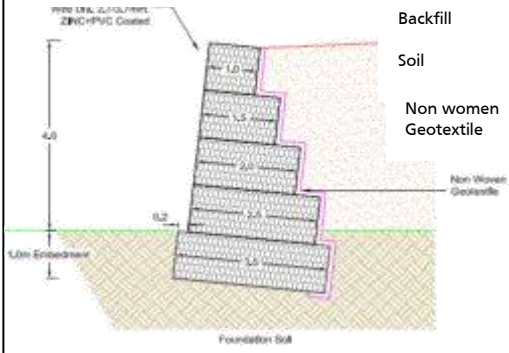
Rubble-filled Masonry

5.2. Gabion wall

Gabion Retaining walls are flexible structures which are very suitable in case of Tech 3retaining structures for protection. It is also very effective for the protection near the water body, as the porosity of boulders will dissipate the wave energy effectively. Gabions are flexible in nature and can accommodate differential settlement very well.

- Flexible structure which can accommodate differential settlement.
- Free draining structure with no pore pressure development behind wall.
- Easy in construction, as it does not require skilled laborer.
- Does not require curing time as in case of R.C.C Retaining wall.
- Eco-friendly, as the vegetation growth over it, is compatible with surrounding environment.
- Used under full or partial submergence.
- Cost incurred is very less compared to R.C.C Retaining Wall and depends only on the local availability of boulders.

Maccaferri Gabion Mesh Type 1-x12, Wire Dia. 2.7/3.7mm, Zinc + PVC coated

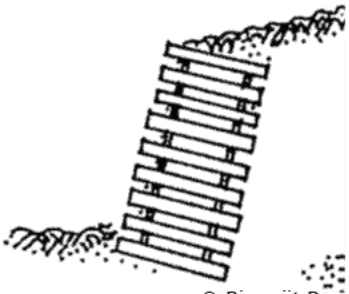


Cross-section of 4m high Gabion Retaining wall

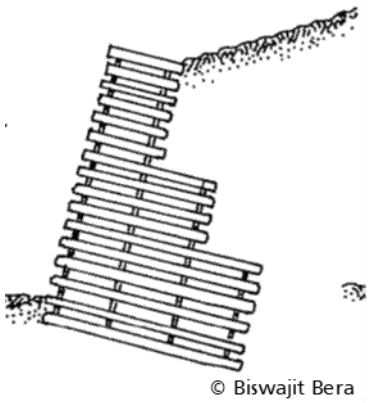
Rock Filled Gabions

5.3 Crib Wall

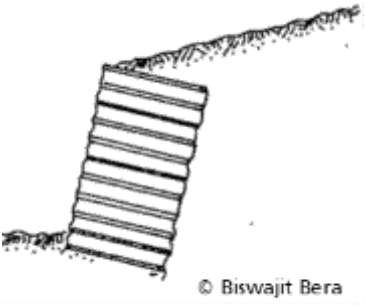
- Timber walls or concrete crib walls and sausage walls are also used as retaining structures.
- A crib wall is made in a wooden mesh in which dry stone masonry is built.
- Sausage walls are made by forming sausages of steel wire netting of eight SWG with 10 cm square or hexagonal holes. The sausages are filled with hard local boulders / stones, and the wire-net is wrapped at the top.
- This process is carried out on the site where the sausage walls are to be installed.
- It has been found that sausage walls can withstand a greater amount of deformation than stone masonry, without cracking. They also allow free passage of water.



Timber or concrete crib wall



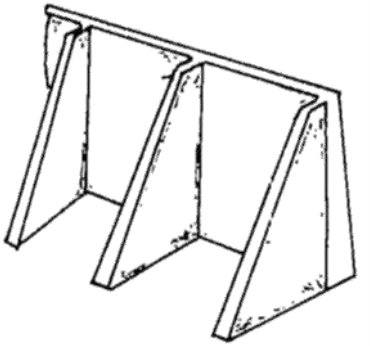
Multiple dept crib wall



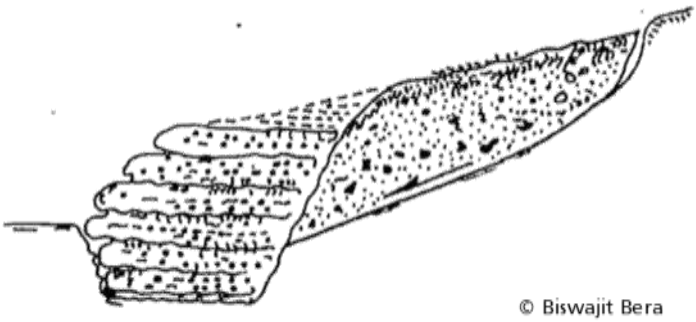
Still bin wall

5.4 Buttress Wall

Buttresses are often used as retaining devices on landslides and creep movements on hill roads. Failure of the structure can take place due to foundation failure, shear between the structure and the foundation and shear through the structure itself. Therefore, rock buttresses are constructed, preferably on solid foundations, to avoid foundation failure. The buttress is constructed with the upper face vertical and the lower face with a slope of 1.5:1.



Concrete buttress wall or braced wall

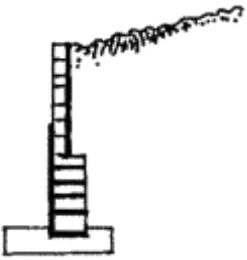


Geogrid shear key or reinforced soil embankment

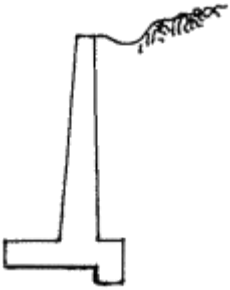
5.5 Cantilever Wall

Cantilever retaining walls are constructed of reinforced concrete. They consist of a relatively thin stem and a base slab. The base is also divided into two parts, the heel and toe. The heel is the part of the base under the backfill. The toe is the other part of the base.

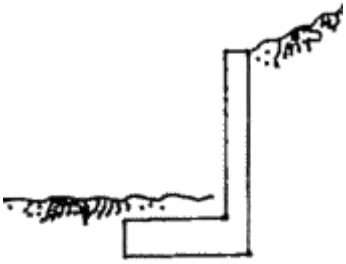
- Use much less concrete than monolithic gravity walls, but require more design and careful construction.
- Generally economical up to about 25 ft. in height.
- Can be precast in a factory or formed on site.



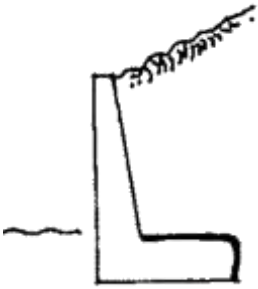
Masonry block



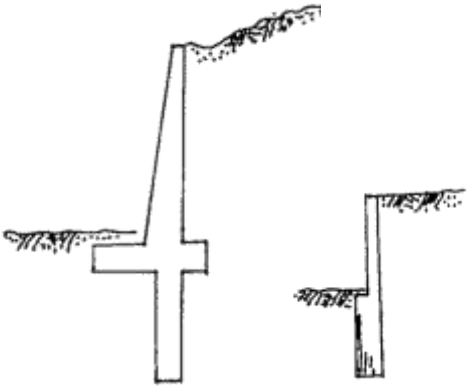
Reinforced concrete cantilever



Inside stem wall

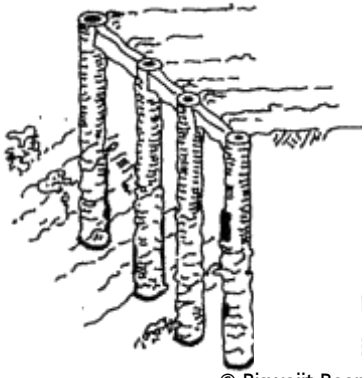


Reverse stem wall



© Biswajit Bear

Pier supported reinforced concrete walls



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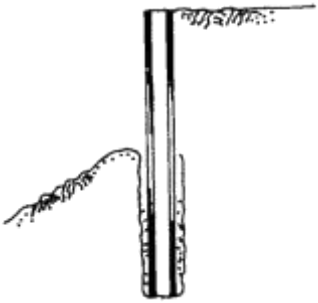
Cast-in-place reinforced concrete interconnecting grade beam



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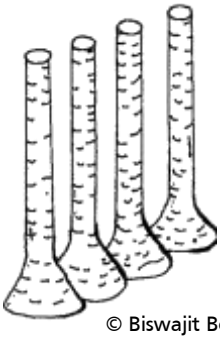
Steep H-plie wall



© Biswajit Bear

Cast-in-place caisson with interconnecting under ream cones

5.6 Excavation Methods

Excavation methods contribute to increased stability of the soil mass beneath a slope. The main methods used for landslide control are removal of unstable materials, flattening of slopes, benching of slopes, change of line or grade and alteration of slope geometry.

Removal of unstable materials

Complete or partial removal of the unstable material is considered among other alternative design methods. The removal of potentially unstable material shall vary from simple stripping of a surface layer by a few meters to depths as great as 50 m. For shallow soil profiles, consideration shall be given to a permanent solution involving the entire removal of the slide. For deep soil profiles, the removal of material at the top of the slide increase stability as it reduces the activating forces.

Flattening of slopes

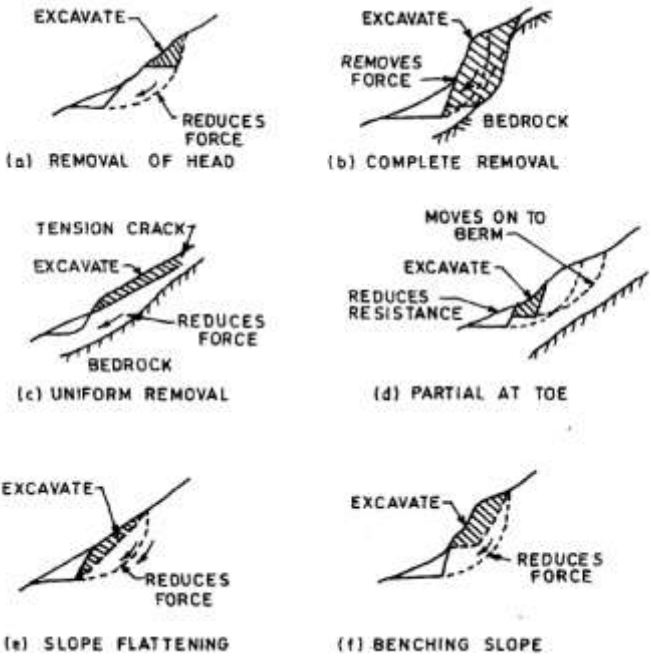
This method consists primarily of proper slope design followed by proper surface drainage measures. These are best suited to slides moving down slope towards a road and not for slides that undermine a road on its downward slope. A uniform slope is adapted from ditch line to the top of the slope.

Benching of slopes

This method involves straight slopes separated by near horizontal bench. Benching increases stability of slopes by dividing the long slope into segments or smaller slopes connected by benches, the proper width of bench shall be estimated by analysis of stability of slopes for a given soil. The width of bench shall not be less than 8 m to enable the slope segments to act independently. In this method, construction becomes easier since steeper slopes are feasible with benches.

Change of line or grade

In the early design stage, generally cut and fill slopesare evaluated for potential stability. However, adjustment to the line and grade are affected to minimize or completely eliminate the slope stability problem. Line or grade changes are generally doneto reduce the driving forces.



Excavation Techniques

Session Objective

Session on soil piping focuses on providing a brief understanding on land subsidence, tunnel formation etc and the problems cause by it.

Expected Outcome

Promote engineers to consider soil piping vulnerability during site selection.

Mode of conducting training

1. Presentation
2. 2. Q & A's

Materials Required

1. Laptop
2. Projector

The “Soil piping", also known as tunnel erosion is the subsurface erosion of soil by percolating waters to produce pipe-like conduits below ground especially in non-lithified earth materials. Soil piping or “tunnel erosion” is the formation of subsurface tunnels due to subsurface soil erosion. Piping is an insidious and enigmatic process involving the hydraulic removal of subsurface soil causing the formation of an underground passage.

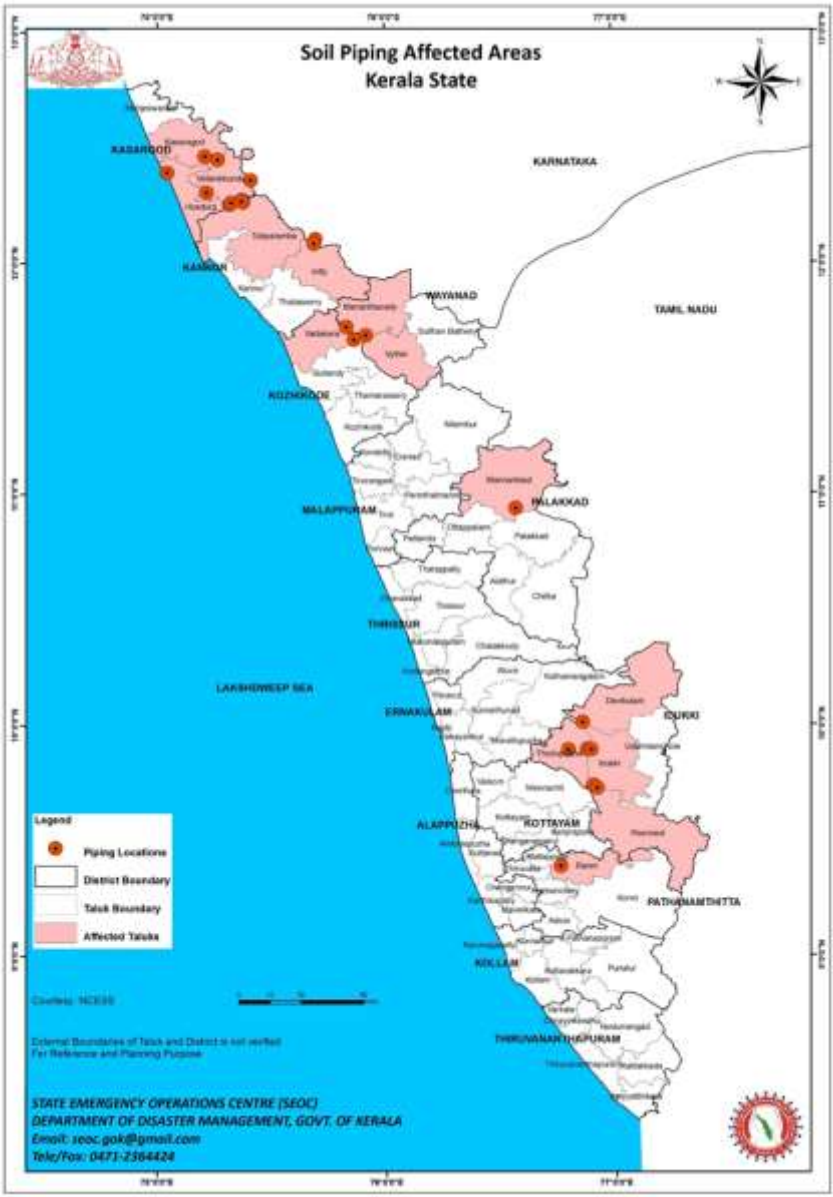
Land subsidence causes many problems including:

- Changes in elevation and slope streams, canals and drains
- Damage to bridges, roads, railroads, storm drains, sanitary sewers, canals, and levees
- Damage to private and public buildings
- Failure of well casings from forces generated by compaction of fine-grained material in aquifer systems.
- Permanent inundation of land, aggravates flooding, changes topographic gradients and ruptures the land surface.
- Reduces the capacity of aquifers to store water.

Soil piping indicates that this phenomenon occurs in many areas in the Western Ghats of the Kerala region. Many of piping are located at Idukki and Kannur, Kasaragod and then followed by Kozhikode, Palakkad, Ernakulam, Pathanamthitta, and Wayanad.

Land subsidence | Tunnel formation | Outlet of a pipe

Soil piping effects


Soil Piping Affected Areas
Kerala State
KARNATAKA
TAMIL NADU
KASARGOD
KANNUR
WAYANAD
KOZHIKODE
MALAPPURAM
PALAKKAD
THRISSUR
ERNAKULAM
IDUKKI
ALAPPUZHA
KOTTAYAM
PATHANAMTHITTA
KOLLAM
THIRUVANANTHAPURAM
LAKSHADWEEP SEA
Legend
Piping Locations
District Boundary
Taluk Boundary
Affected Taluks
STATE EMERGENCY OPERATIONS CENTRE (SEOC)
DEPARTMENT OF DISASTER MANAGEMENT, GOVT. OF KERALA
Email: seoc.gok@gmail.com
Tele/Fax: 0471-2364424

Session Objective

Disables peopled are one of the most vulnerable during a disaster. This session focuses on disabled friendly construction practices that are to be considered especially during the construction of public buildings.

Expected Outcome

Enhance the knowledge on disabled friendly construction practices and promote them to incorporate these designs in their future projects.

Mode of conducting training

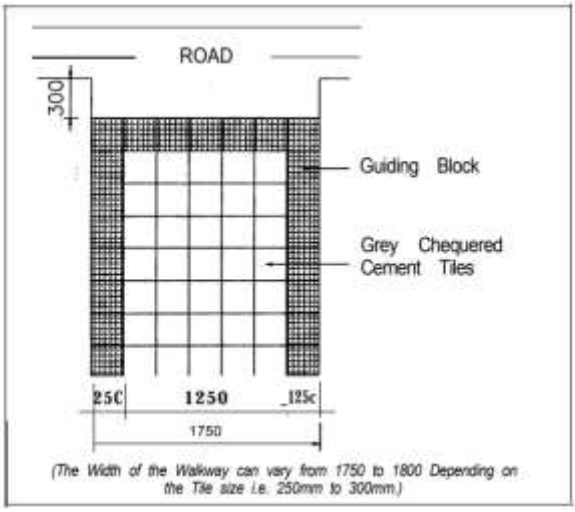
1. Presentation
2. Q & A's

Materials Required

1. Laptop
2. Projector

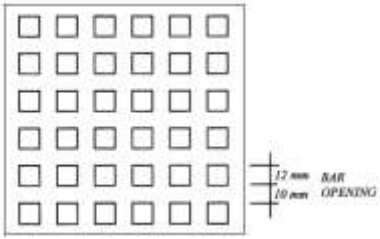
7.1 Walkways and Paths

- Walkway should be constructed with a non-slip material & different from rest of the area.
- Avoid materials that result in irregular surfaces such as cobble stones, coarsely exposed aggregate concrete, bricks etc.
- Minimum walkway width should be 1200 mm. For moderate two-way traffic, it should be between 1650 mm to 1800 mm.
- Longitudinal walk gradient should be between 3 to 5% (30 to 50 mm in 1 meter).
- Walkway should be provided with guiding blocks at the starting and finish, which should have different material and texture from rest of the area.



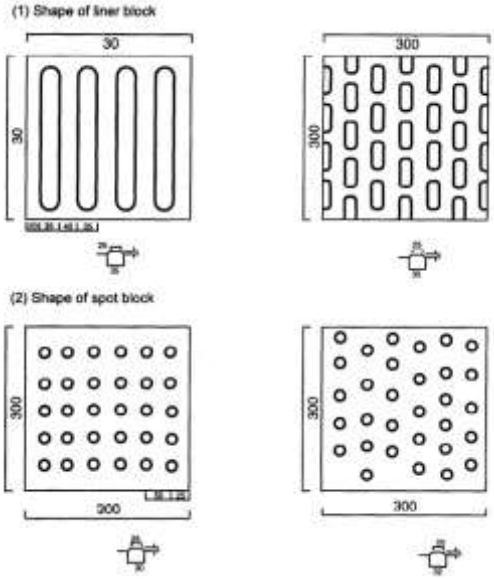
Typical Detail of a Walkway
Source: CPWD

- Grates, manholes, trees or any other obstruction should be avoided. If grates cannot be avoided then bearing bar should be perpendicular to the travel path and opening between bearing bars should not be greater than 12 mm in width.



Details of Grating
Source: CPWD

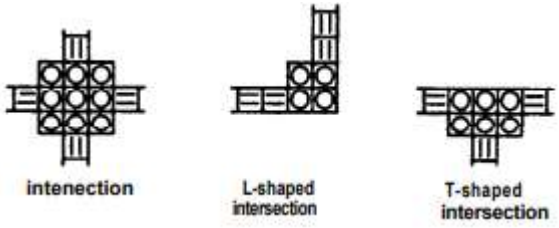
7.2 Guiding and Warning Floor



Shapes of guiding blocks for disabled person
Source: CPWD

Guiding and warning floors should be installed at following locations

- Where there is vehicular traffic.
- In front of entrance/exit to and from a staircase and multilevel crossing facility.
- At boarding areas or entrance/exit to and from public transportation terminals.
- Abrupt changes in level.
- On ramps.



Arrangement of guiding blocks
Source: CPWD

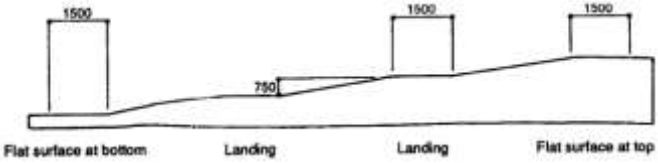
7.3 Levels and Grooves

- A wheelchair can get over only a small level difference. Therefore, the level difference should be limited to 20 mm or less.
- Edge should be rounded off or beveled.

Shape and Difference (maximum 2 cm) in Level
Source: CPWD

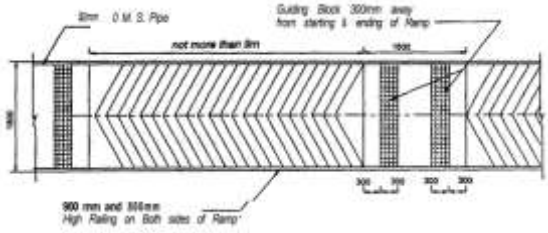
7.4 Approach to Plinth Level – Ramp Design

- Grade of a ramp should be a moderate rise of 10 mm for every 120 mm of travel.
- A flat surface 1500 mm or more in length at the top and bottom of the ramp should be provided.

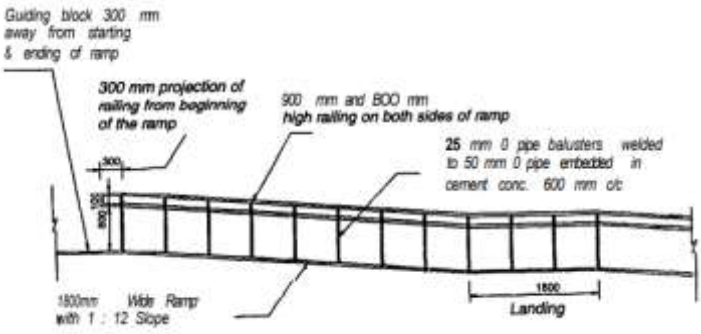


Cross-section of a Ramp
Source: CPWD

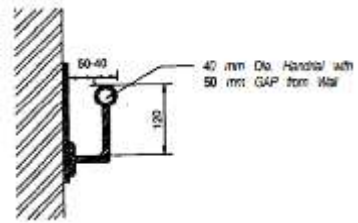
- Non-slip material should be used as a surface finish for ramps.
- Minimum width should be 1800 mm with maximum gradient 1:12.
- Maximum length of ramp should be 9 meters. Double handrails should be provided at a height of 800 mm and 900 mm on both sides.
- Minimum gap between adjacent wall and handrail should be 50 mm.



Plan of a Ramp



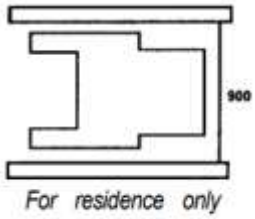
Elevation of a Ramp

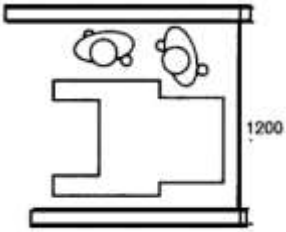


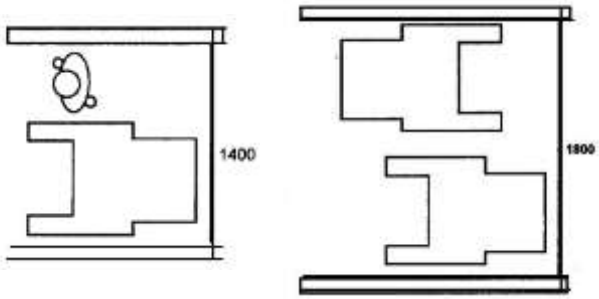
Fixing Detail of Handrail to the Wall

7.5 Corridor

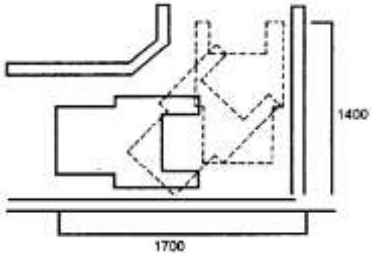
- Corridor must be at least 900 mm wide. However, width also depends on the traffic in corridors.







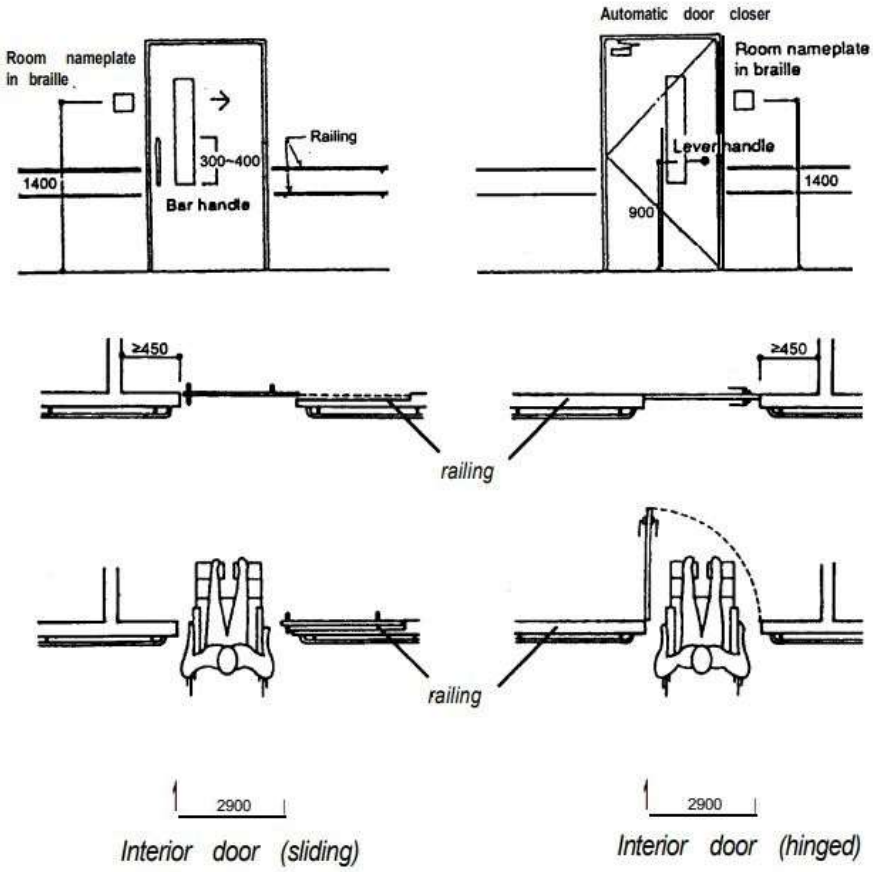
Required width for Passage of Wheelchair
Source: CPWD



Required width to turn a Wheelchair
Source: CPWD

7.6 Entrance/Exit Door

- Minimum clear opening of doors shall be 900 mm.
- Doors should not be provided with a step that obstructs passage.
- Maximum threshold height should not be more than 12 mm.


Room nameplate in braille
Railing
300~400
1400
Bar handle
Automatic door closer
Room nameplate in braille
Lever handle
1400
900
≥450
railing
≥450
railing
2900
Interior door (sliding)
2900
Interior door (hinged)

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ANNEXURE

FEEDBACK

Training on Flood Resilient Construction Techniques

1. How did you find out about the training?

2. Did you participate in a Shelter Hub Training before?

   Yes ☐ No ☐ Which one? _____

3. Did you learn something new during the training?

   Yes ☐ No ☐

4. Which elements of the training will be useful for you in your work?

5. Did you like the way of teaching?

6. Are the handouts helpful for you?

7. Was the on-site training helpful?

8. What would you like to learn more about?

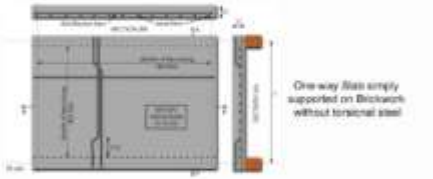
9. What was good?

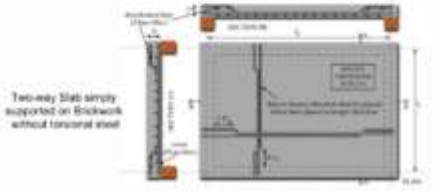
10. What can be improved?

Thank you for taking part!

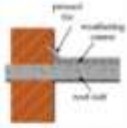
Disaster Resistant Construction Practises

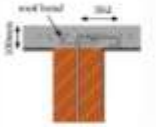
Roof / Slab





- RCC Slab at the support should be reinforced at both top and bottom





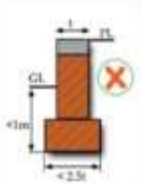
- Roof band should be provided within the roof slab

- Anchor the vertical tie into the roof slab

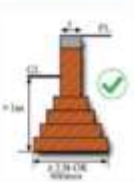
Foundation

- Straight Cut
- Sand compaction thickness = 150mm
- PCC thickness = 75mm

- Slightly Slanting cut
- Sand Compaction thickness =150mm
- PCC thickness = 75mm

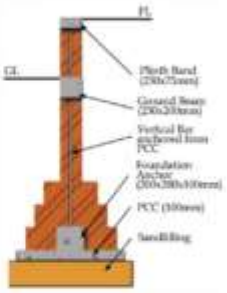


- Foundation width = 2½ times wall thickness
- Make a wall without foundation
- Use vitrified bricks in the foundation



- Foundation width = 2½ times wall thickness or 0.6m, whichever is more
- Use baked bricks and stones
- Minimum depth = 1000 mm

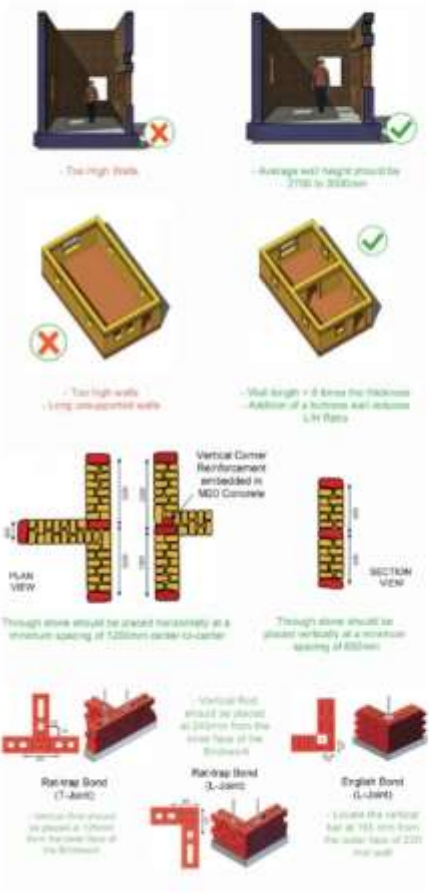
- Foundation on loose or soft soil



- Foundation on Hard Soil

Disaster Resistant Construction Practises

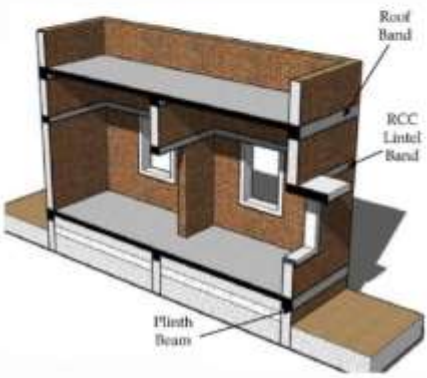
Walls



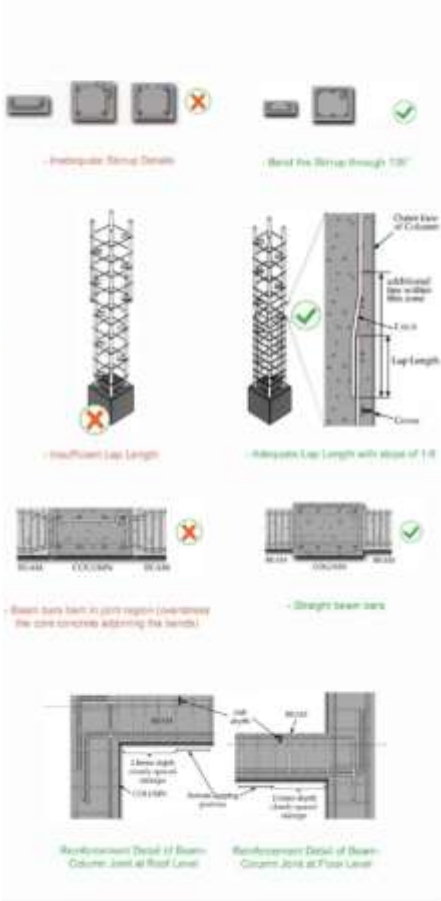
Openings

Disaster Resistant Construction Practises

Plinth / Bands



Beams / Columns



Bamboo Construction Techniques

Foundation

The types of bamboo foundation identified are:

- Bamboo in direct ground contact
- Bamboo on rock or preformed concrete footings
- Bamboo incorporated into concrete footings
- Composite bamboo/concrete columns
- Bamboo reinforced concrete
- Bamboo piles

Bamboo in direct ground contact

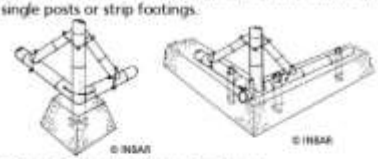
For strength and stability, large diameter thick walled sections of bamboo with closely spaced nodes should be used.

Bamboo on rock or performed concrete footings

It should be placed out of ground contact on footings of either rock or preformed concrete. Largest and stiffest sections of bamboo should be used.

Bamboo incorporated concrete footings

This approach is to incorporate the bamboo directly into the concrete footing and can take the form of single posts or strip footings.

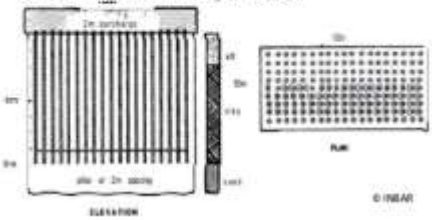


Composite bamboo/concrete columns

Involves the casting of a concrete extension to a bamboo post using a plastic tube of the same diameter. The result is a bamboo post with an integral, durable foundation.

Bamboo piles

Bamboo piles have been used successfully to stabilize soft soils and reduce building settlement.



Bamboo reinforced concrete

Bamboo reinforced concrete slabs offer another solution, although this type of construction has its own specific problems.

Floor

Floor structure

Floors normally consist of bamboo beams fixed to strip footings or to foundation posts. The beams therefore run around the perimeter of the building. Where the beams are fixed to posts, careful attention to jointing is required. Beams and columns are generally around 100mm in diameter.

Small bamboo culms:

Small diameter culms are tied or nailed directly to the joists.

Split bamboo:

Bamboo culms are split along their length into strips several centimeters wide.

Flattened bamboo (bamboo boards):

Formed by splitting green bamboo culms, removing the diaphragms then unrolling and flattening them. The resulting board is laid across the joists and fixed by nailing or tying.

Bamboo mats:

These are formed by weaving thin strips of bamboo. Strips vary in size from 20 x 2mm to 2 x 1 mm, depending on the intricacy of the pattern.

Bamboo panels:

Layers of woven mats or strips, laid at right angles, are bonded together into boards, which are then nailed to the joists.

Bamboo parquette:

thin slivers or mats of bamboo are formed into multi-layered tiles and laid on treated bamboo or wooden strips fixed to compacted earth or a concrete sub-floor.

Bamboo Construction Techniques

Walls

The most extensive use of bamboo in construction is for walls and partitions. The major elements of a bamboo wall (posts and beams) generally constitute part of the structural framework.

Whole or halved bamboo culms

The preferred orientation is vertical as this increases the shear resistance of the wall and is also better for drying after rain. Vertical members can be driven directly into the ground or fixed back to beams by tying with or without facing battens.

Split or flattened bamboo

Can be fixed vertically to intermediate bamboo members tied to or mortised into the posts, or fixed horizontally directly to the posts. Boards can be stretched or covered by wire mesh to provide a suitable surface for plastering.

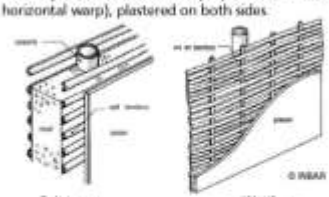
Split Bamboo

Bajaroque

It consists of horizontal bamboo strips tied or nailed to both sides of the posts. The cavity is then filled with mud or mud and stones, producing a relatively massive form of construction.

Wattle

Common in parts of India, this comprises coarsely woven panels of bamboo strips (vertical weft and horizontal warp), plastered on both sides.



Bajaroque

Wattle

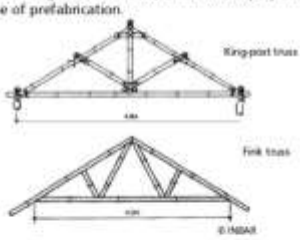
Bamboo panels

Panels have been developed specifically for use in walls and partitions and have the advantage of imparting greater structural rigidity to the construction.

Roof

The simplest form of roof comprises a bamboo ridge purlin and eaves beams, supported on the perimeter posts.

Trusses offer a number of advantages over traditional forms of construction, including more economic and efficient use of materials, the ability to span larger distances, the use of shorter components (counteracting effects of bow, crook and taper) and the use of prefabrication.

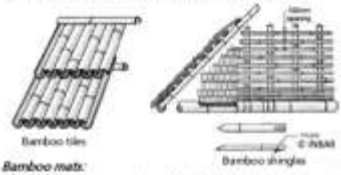


Bamboo tiles:

These can take the form of halved, internodal culm sections, fixed to battens and overlapped in a similar manner to the full length halved culms.

Bamboo shingles:

Shingles, measuring 30-40mm wide x internodal length (400-600mm) are cut from green culms, 70mm or more in diameter and then air dried.

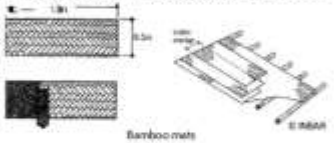


Bamboo tiles

Bamboo shingles

Bamboo mats:

A layer of bitumen is sandwiched between two mats forming a semi-rigid panel. The mats can be fixed to rafters at 200-250mm centres. A bituminous or rubberized weatherproof coating is then applied to the finished roof.



Bamboo mats

Corrugated bamboo roofing sheets:

PF resin is applied to a bamboo mats to form a five layer set which is then hot pressed between corrugated platens. Of resin bonded sheets overlaid with PF resin impregnated paper have also been produced.

Retrofitting Techniques for built-structures

Some common failures in Buildings during disaster

© IIT Roorkee

Retrofitting of Failure in Masonry Building

At the time of flood, in masonry buildings there are some common area which are most vulnerable for the damage. In above shown images cracks are developed at corners of the building and around the opening of the building. To retrofit it we need to introduce a band around the building as shown in the image. Band consist of 10 gauge wire mesh and 1:3 cement plaster with 30 mm thickness and it will be applied both side of the wall and wire mesh is connected through-n-through by shear keys at 300 mm c/c.

Failure between Beam-column joint

© TESRA

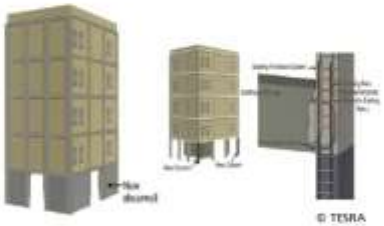
Retrofitting technique of column

Failure of soft-stories in RCC structure and its retrofitting

Soft-stories are most vulnerable part of the structure in multi stories most common failures is observed on soft-stories, there are several techniques of retrofitting of this type of buildings, like introduction of new column, shear wall, bracings etc. for detail refer following images:

Failure and collapse pattern

© TESRA



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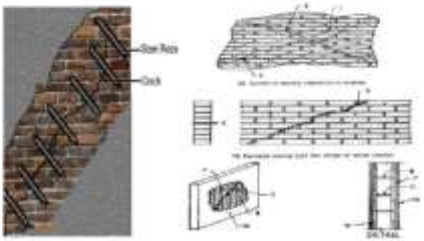
Retrofitting techniques



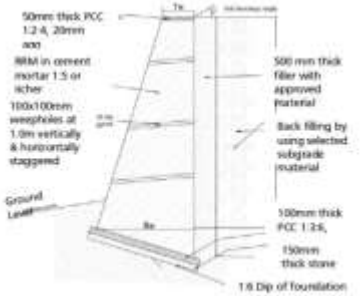
© TESRA

Image showing structural crack repair techniques

Landslide Resistant Construction Techniques

Landslide Hazard - Kerala

In Kerala, landslides commonly occur in localized areas of the Western Ghats region where the slope is steep and the soil is over saturated as a result of prolonged rainfall. These events vary from events affecting a parcel of land to those larger ones with much causality.



Typical retaining wall section © MoWHS

Standard design with soil surcharge load

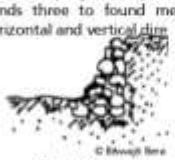
Height (m)	SBC 80		SBC 100		SBC 150	
	B.W	T.W	B.W	T.W	B.W	T.W
1	0.5	0.45	0.5	0.45	0.5	0.45
2	0.9	0.5	0.9	0.5	0.9	0.5
3	1.55	0.5	1.55	0.5	1.55	0.5
4	2.2	0.6	2.2	0.6	2.2	0.6
5	3.85	0.8	3.5	0.8	2.65	0.8
6	4.9	1	4.7	1	4.1	1

© MoWHS

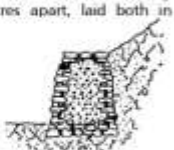
Types of Gravity Retention Structures

Masonry wall

Retaining walls of upto four metres in height are constructed in random rubble-dry stone masonry. Retaining walls above four metres in height are built either in lime or cement mortar masonry or in dry stone masonry with 0.6 m wide mortar masonry bands three to found metres apart, laid both in horizontal and vertical dire



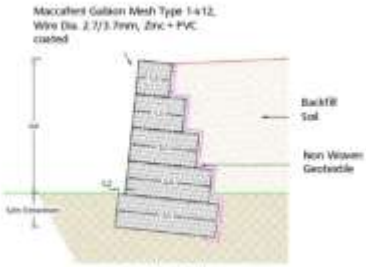
Stacked Masonry



Rubble-filled Masonry

Gabion wall

Gabion Retaining walls are flexible structures which are very suitable in case of Tech 3retaining structures for protection. It is also very effective for the protection near the water body, as the porosity of boulders will dissipate the wave energy effectively. Gabions are flexible in nature and can accommodate differential settlement very well.

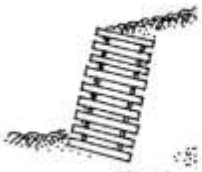


Foundation Soil

Cross-section of 4m high Gabion Retaining wall

Crib wall

A crib wall is made in a wooden mesh in which dry stone masonry is built.



Timber or concrete crib wall

Multiple dept crib wall

Buttress wall

Buttresses are often used as retaining devices on landslides and creep movements on hill roads. Failure of the structure can take place due to foundation failure, shear between the structure and the foundation and shear through the structure itself. Therefore, rock buttresses are constructed, preferably on solid foundations, to avoid foundation failure. The buttress is constructed with the upper face vertical and the lower face with a slope of 1:5:1.

Landslide Resistant Construction Techniques

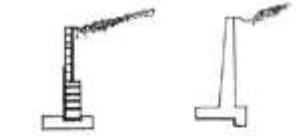
Concrete buttress wall or braced wall

Geogrid shear key or reinforced soil embankment

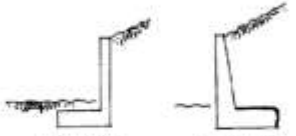
Cantilever retention structures

Cantilever retaining walls are constructed of reinforced concrete. They consist of a relatively thin stem and a base slab. The base is also divided into two parts, the heel and toe. The heel is the part of the base under the backfill. The toe is the other part of the base.

- Use much less concrete than monolithic gravity walls, but require more design and careful construction.
- Generally economical up to about 25 ft. in height.
- Can be precast in a factory or formed on site



Masonry block Reinforced concrete cantilever



Inside stem wall Reverse stem wall

Soil Piping- Kerala

The "Soil piping", also known as tunnel erosion is the subsurface erosion of soil by percolating waters to produce pipe-like conduits below ground especially in non-lithified earth materials. Soil piping or "tunnel erosion" is the formation of subsurface tunnels due to subsurface soil erosion. Piping is an insidious and enigmatic process involving the hydraulic removal of subsurface soil causing the formation of an underground passage.

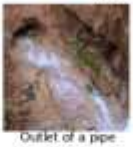
Land subsidence causes many problems including:

- Changes in elevation and slope streams, canals and drains
- Damage to bridges, roads, railroads, storm drains, sanitary sewers, canals, and levees
- Damage to private and public buildings
- Failure of well casings from forces generated by compaction of fine-grained material in aquifer systems
- Permanent inundation of land, aggravates flooding, changes topographic gradients and ruptures the land surface.
- Reduces the capacity of aquifers to store water.

Soil piping indicate that this phenomenon occurs in many areas in the Western Ghats of the Kerala region. Many of piping are located at Idukki and Kannur, Kasaragod and then followed by Kozhikode, Palakkad, Ernakulam, Pathanamthitta, and Wayanad.

Land subsidence

Tunnel formation



Outlet of a pipe

© NDMA

Intervention

The hydrological barrier technique involves construction of sand and gypsum filled trench to the depth of the foundations around the upslope area of the dwelling. The sand – gypsum mixture acts to trap the dispersed silts pugging up the developing tunnel while allowing the water to come into contact with the gypsum and rise through the sand and away from the footings.

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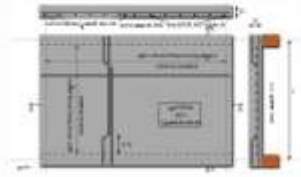

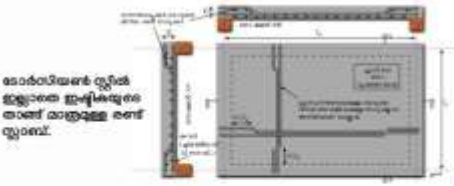

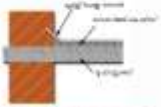

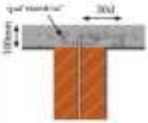

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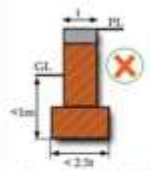

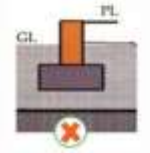

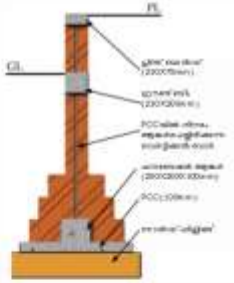

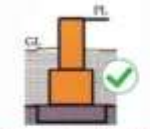

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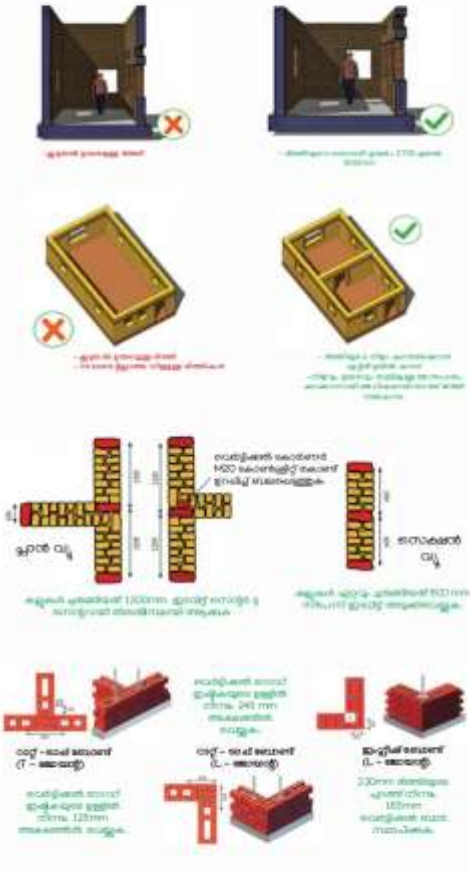
ഭിത്തി



വാതിലുകൾ

ജനൽ

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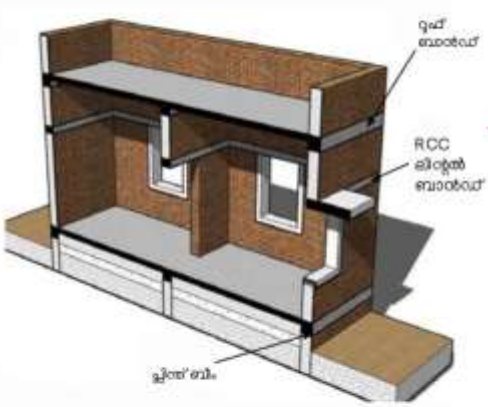
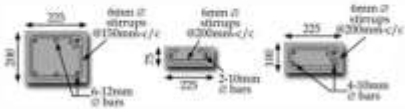
പ്ലിന്ത് / ബാൻഡുകൾ





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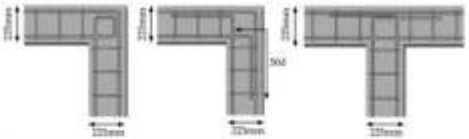

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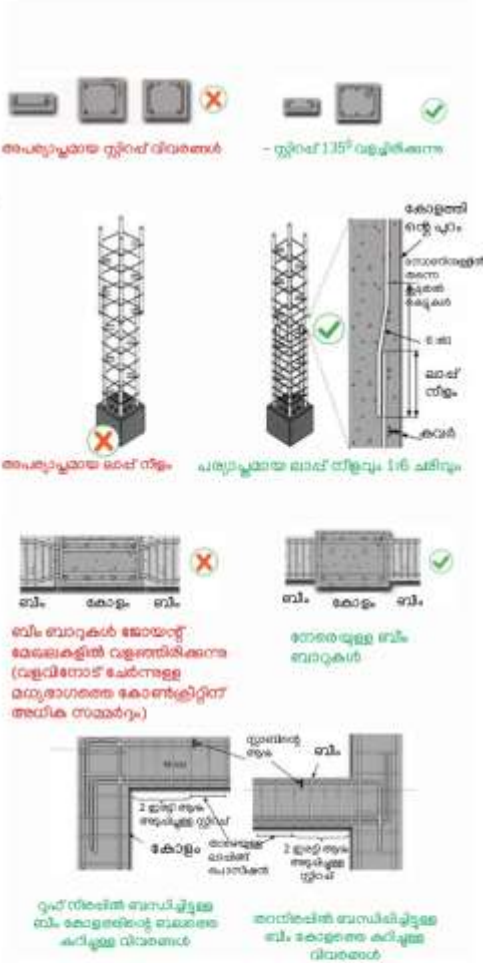


മുളകൊണ്ടുള്ള നിർമ്മാണ വിദ്യകൾ

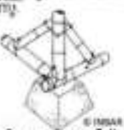
അടിസ്ഥാനം

മുളകൊണ്ടുള്ള അടിസ്ഥാനമായി തിരിച്ചറിഞ്ഞിട്ടുള്ളത്.

- മുള നേരിട്ട് തറയിൽ ഉറപ്പിച്ച് നിർത്തിയിട്ടുള്ളത്
- മുള പാറ അല്ലെങ്കിൽ കോൺക്രീറ്റിൽ ഉറപ്പിച്ചത്.
- മുള കോൺക്രീറ്റ് അടിസ്ഥാനത്തിൽ ഉൾപ്പെടുത്തിയിട്ടുള്ളത്
- കമ്പോസിറ്റ് മുള/കോൺക്രീറ്റ് കോളങ്ങൾ
- മുളകൊണ്ട് ബലപ്പെടുത്തിയ കോൺക്രീറ്റ്
- മുളകൊണ്ടുള്ള പൈൽ

മുള നേരിട്ട് തറയിൽ ഉറപ്പിച്ചിരിക്കുന്നത്
ബലത്തിനും സ്ഥിരതയ്ക്കും വേണ്ടി, വലിയ വ്യാസമുള്ള മുളകൾ അടുപ്പിച്ച് ഉപയോഗിക്കുന്നു.

മുള പാറയിൽ അല്ലെങ്കിൽ കോൺക്രീറ്റ് അടിസ്ഥാനത്തിൽ ഉറപ്പിച്ചത്
പാറ അല്ലെങ്കിൽ കോൺക്രീറ്റിന്റെ അടിസ്ഥാനത്തിനുള്ളിൽ മുള വയ്ക്കുന്നു. മുളയുടെ വലുതും കട്ടിയുള്ളതുമായ കഷ്ണങ്ങൾ ഉപയോഗിക്കുന്നു.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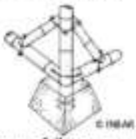
മുള ഉൾപ്പെടുത്തിയ കോൺക്രീറ്റ് അടിസ്ഥാനങ്ങൾ
കോൺക്രീറ്റ് അടിസ്ഥാനത്തിലേക്ക് മുള നേരിട്ട് ഉൾപ്പെടുത്തുന്ന സമീപനമാണ് ഇത്. ഒറ്റ പോസ്റ്റുകൾ അല്ലെങ്കിൽ മുളകിറ്റുകൾ കൊണ്ടുള്ള അടിസ്ഥാനത്തിന് ഇത് നല്ലതാണ്.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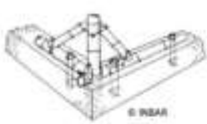
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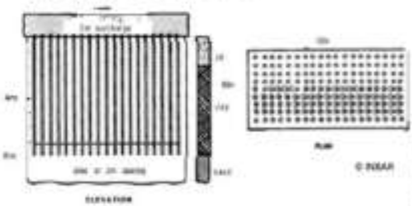
കമ്പോസിറ്റ് ബാംബൂ/ കോൺക്രീറ്റ് കോളങ്ങൾ
സമാനമായ വ്യാസമുള്ള ഒരു പ്ലാസ്റ്റിക് ട്യൂബ് ഉപയോഗിച്ച് മുള കൊണ്ടുള്ള പോസ്റ്റിലേക്ക് കോൺക്രീറ്റ് ചെയ്യുന്നു. സമ്പൂർണവും ദീർഘകാലം നിലനിൽക്കുന്നതുമായ ഒരു അടിസ്ഥാനമാണ് ഇതിന്റെ ഫലം.

മുള കൊണ്ടുള്ള തൂൺ
മുളകൊണ്ടുള്ള തൂണുകൾ ദൃഢമായ മണ്ണിനെ ഉറപ്പിക്കുന്നതിനും കെട്ടിടങ്ങളുടെ സെറ്റിൽമെന്റ് കുറയ്ക്കാനും ഉപയോഗിക്കുന്നു.

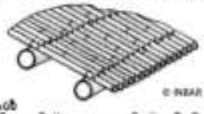


മുള കൊണ്ട് ബലപ്പെടുത്തിയ കോൺക്രീറ്റ്
മുളകൊണ്ട് ബലപ്പെടുത്തിയ കോൺക്രീറ്റ് സ്ലാബുകൾ മറ്റൊരു പരിഹാരമാണ്, മറ്റൊരുതരത്തിൽ പറഞ്ഞാൽ ഈ തരം നിർമ്മാണത്തിന് അതിന്റേതായ പ്രശ്നങ്ങളുണ്ട്.

തറ

തറയുടെ ഘടന
തറയിൽ സാധാരണയായി മുളകൊണ്ടുള്ള ബീമുകൾ മുളകിറ്റുകൾ കൊണ്ടുള്ള അടിസ്ഥാനത്തിലേക്കോ അല്ലെങ്കിൽ ഫൗണ്ടേഷൻ പോസ്റ്റിലേക്കോ ഘടിപ്പിക്കുന്നു. അതുകൊണ്ട് തന്നെ ബീമുകൾ കെട്ടിടത്തിന്റെ ചുറ്റളവിലായിരിക്കും. ബീമുകൾ എവിടെയൊക്കെ പോസ്റ്റുകളുമായി ഉറപ്പിച്ചിട്ടുണ്ടോ അവിടെയൊക്കെ ജോയിന്റുകൾ ശ്രദ്ധാപൂർവ്വം പരിചരിക്കേണ്ടതാണ്. ബീമുകളും കോളങ്ങളും പൊതുവേ 100 മില്ലിമീറ്റർ വ്യാസമുള്ളവയായിരിക്കണം.

ചെറിയ മുളന്തണ്ടുകൾ
ചെറിയ വ്യാസമുള്ള മുളന്തണ്ടുകൾ ജോയിസ്റ്റുകളിലേക്ക് നേരിട്ട് കെട്ടുകയോ ആണിയടിച്ച് ഉറപ്പിക്കുകയോ ചെയ്യുന്നു.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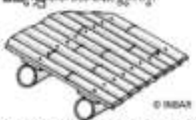
മുളകിറ്റുകൾ
മുളകൾ നീളത്തിന് അനുസരിച്ച് കീറിയെടുത്ത ശേഷം മതിയായ വലുപ്പത്തിൽ ചെയ്യുന്നു.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മുളകൾ നിരത്തിയത് (മുളകൊണ്ടുള്ള ബോർഡുകൾ)
പച്ച മുളകൾ കീറിയശേഷം അതിന്റെ ഡയഫ്രം കളഞ്ഞ് അതിന്റെ ചുരുൾ നിവർത്തിയ ശേഷം പരത്തുക. ഈ ബോർഡുകൾ നിരത്തിയിട്ട് കെട്ടിയുറപ്പിക്കുകയോ ആണിയടിച്ച് ഉറപ്പിക്കുകയോ ചെയ്യുക.

മുളകൊണ്ടുള്ള മാറ്റുകൾ:
മുളയുടെ ചെറിയ കിറുകൾ നെയ്താണ് ഇതുണ്ടാക്കുന്നത്. 20 X 2 മില്ലി മുതൽ 2X1 മില്ലിമീറ്റർ വരെ കിറുകളുടെ വലുപ്പത്തിൽ വ്യത്യാസമുണ്ടാകാം. ഇത് പാറ്റേണിന്റെ സങ്കീർണ്ണതയെ ആശ്രയിച്ചിരിക്കുന്നു.

മുളകൊണ്ടുള്ള പാനലുകൾ:
നെയ്തെടുത്ത മാറ്റുകളുടെ പാളികൾ അല്ലെങ്കിൽ കിറുകൾ ശരിയായ കോണുകളിൽ വിരിച്ചശേഷം ബോർഡുകൾ തമ്മിൽ ബന്ധിപ്പിക്കുന്നു. അതിന് ശേഷം ആണിയടിച്ച് ഉറപ്പിക്കുന്നു.

മുളകൊണ്ടുള്ള പാർക്കറ്റ്
മുളയുടെ ചെറിയ കഷ്ണങ്ങൾ അല്ലെങ്കിൽ മാറ്റുകൾ വിവിധ പാളികളുള്ള ടൈലുകളാക്കുകയും ട്രീറ്റ് ചെയ്ത മുളയിലേക്ക് അല്ലെങ്കിൽ തടികഷ്ണങ്ങളിലേക്ക് വിരിച്ചശേഷം മണ്ണൊതുക്കിയ തറ അല്ലെങ്കിൽ കോൺക്രീറ്റ് തറയിലേക്ക് ഉറപ്പിക്കുന്നു.

മുളകൊണ്ടുള്ള നിർമ്മാണ വിദ്യകൾ

ഭിത്തികൾ

നിർമ്മാണത്തിൽ മുളയുടെ ഏറ്റവും പ്രധാനപ്പെട്ട ഉപയോഗം എന്ന് പറയുന്നത് ഭിത്തി അല്ലെങ്കിൽ പാർട്ടീഷനുകൾ നിർമ്മിക്കാനാണ്. ഒരു മുള ഭിത്തിയുടെ പ്രധാനപ്പെട്ട ഘടകങ്ങളാണ് (പോസ്റ്റുകളും ബീമുകളും) പൊതുവായ ഘടനാപരമായ ചട്ടക്കൂടുകളിൽ ഉൾപ്പെടുന്നത്.

മുഴുവനെയോ പകുതിയാക്കിയതോ ആയ മുള കഷ്ണങ്ങൾ

ഉചിതമായിട്ടുള്ള ക്രമീകരണം എന്ന് പറയുന്നത് ലംബമായിട്ടുള്ളതാണ് ഇത് ഭിത്തിയുടെ പ്രതിരോധം വർദ്ധിപ്പിക്കുകയും മഴയ്ക്ക് ശേഷം വേഗത്തിൽ ഉണങ്ങാൻ സഹായിക്കുകയും ചെയ്യുന്നു.

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കീറിയ അല്ലെങ്കിൽ നിരപ്പാക്കിയ മുളകൾ

ഒന്നിടവിട്ടുള്ള മുളകളെ ലംബമായി പോസ്റ്റിലേക്ക് കെട്ടിവെയ്ക്കുകയോ ആണി ഉപയോഗിച്ച് പോസ്റ്റിലേക്ക് ബന്ധിപ്പിക്കുകയോ ചെയ്യുക അല്ലെങ്കിൽ പോസ്റ്റിലേക്ക് നേരിട്ട് തിരശ്ചീനമായി ബന്ധിപ്പിക്കുക. ഈ ബോർഡുകൾക്ക് അനുയോജ്യമായ പ്ലാസ്റ്ററിങ് ഉപരിതലം ലഭ്യമാക്കാനായി ഒരു വയർമെഷ് ഉപയോഗിച്ച് വലിച്ച് നീട്ടുകയോ മൂടുകയോ ചെയ്യും.

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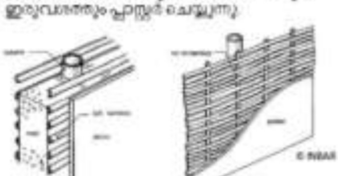
ബജാർക്യൂ

തിരശ്ചീനമായ മുളകഷ്ണങ്ങൾ തൂണുകളുടെ രണ്ട് വശങ്ങളിലും കെട്ടിവെയ്ക്കുകയോ ആണിയടിച്ച് ഉറപ്പിക്കുകയോ ചെയ്യുന്നു. ഇതിനിടയിലുള്ള സ്ഥലം ചെളികൊണ്ടോ ചെളിയും കല്ലും കൊണ്ടോ നിറച്ച് താരതമ്യേന വലിയൊരു നിർമ്മാണഘടനയുണ്ടാക്കുന്നു.

വാറ്റിൽ

ഇന്ത്യയിൽ സാധാരണമായി കണ്ടുവരുന്നു. മുളയുടെ ചീളുകൾ കട്ടിയായി നെയ്തെടുത്ത പാനലുകൾക്ക് (ലംബമായി നെയ്തതും തിരശ്ചീനമായതും) ഇരുവശത്തും പ്ലാസ്റ്റർ ചെയ്യുന്നു.



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ബജാർക്യൂ   വാറ്റിൽ

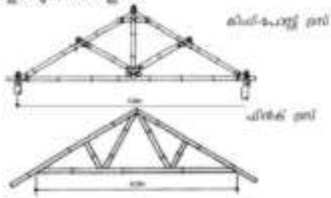
മുളകൊണ്ടുള്ള പാനലുകൾ

ഭിത്തികൾക്കും പാർട്ടീഷനുകൾക്കുമായി പ്രത്യേകമായി വികസിപ്പിച്ചെടുത്തതാണ് പാനലുകൾ. കെട്ടിടനിർമ്മാണത്തിന്റെ ഘടനയിൽ ശക്തമായ ഉറപ്പ് നൽകാൻ ഇതിന് കഴിയുമെന്ന മെച്ചമുണ്ട്.

മേൽക്കൂര

മേൽക്കൂരയുടെ ഏറ്റവും ലളിതമായ രൂപമെന്ന് പറയുന്നത്, മുളകൊണ്ടുള്ള പട്ടികയും മോന്തായത്തിന്റെ ബീമുകളും ചുറ്റളവിലുള്ള തൂണുകളാൽ താങ്ങിനിർത്തുന്നു.

വസ്തുക്കളുടെ കൂടുതൽ മാതൃകാവും ഫലപ്രദവുമായ ഉപയോഗം, കൂടുതൽ ദൂരത്തേക്ക് വലിച്ച് നീട്ടാനുള്ള കഴിവ്, ചെറിയ ഘടകങ്ങളുടെ ഉപയോഗം (വളവ്, തിരിവ്, കുറത്തത് എന്നിവയുടെ വിപരീതഫലങ്ങൾ), പ്രീഫാബ്രിക്കേഷന്റെ ഉപയോഗം എന്നിവ ഉൾപ്പടെ പരമ്പരാഗത നിർമ്മാണ രീതിയേക്കാൾ ട്രസ്സുകൾക്ക് ധാരാളം ഗുണങ്ങൾ ഉണ്ട്.



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മുളകൊണ്ടുള്ള ടൈലുകൾ

ഇന്റർനോഡൽ മുളകഷ്ണങ്ങൾ നേർ പകുതിയായി കീറിയ ശേഷം അത് പലകകഷ്ണങ്ങളിൽ ഉറപ്പിക്കുന്നു. ഇത് നേർപകുതിയായി കീറിയെടുത്ത മുഴുനീള മുളകഷ്ണത്തിലേക്ക് സമാനമായ രീതിയിൽ ഓവർലാപ്പ് ചെയ്യുന്നു.

മുളകൊണ്ടുള്ള പലകയോടുകൾ

30-400 മില്ലിമീറ്റർ വീതിയും 400-600 മില്ലിമീറ്റർ വരെ ഇന്റർനോഡൽ നീളവുമുള്ള കഷ്ണങ്ങൾ പച്ച മുളയിൽ നിന്ന് വെട്ടിയെടുത്ത ശേഷം അവയുടെ 70 മില്ലിമീറ്ററോ അതിൽ കൂടുതലോ ഉള്ള ഭാഗങ്ങൾ എടുത്ത് എയർഡ്രൈ ചെയ്യുന്നു.

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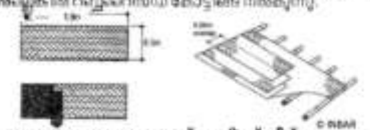
മുളകൊണ്ടുള്ള മാറ്റുകൾ

രണ്ട് മാറ്റുകൾക്കിടയ്ക്ക് ഒരു പാളി ബിറ്റുമിൻ വച്ച് ഇടത്തരം കട്ടിയുള്ള ഒരു പാനൽ ഉണ്ടാക്കുന്നു. ഈ മാറ്റുകൾ 200 -250 മില്ലിമീറ്റർ ഇടവിട്ടുള്ള റാഫ്റ്ററുകളിൽ ഉറപ്പിക്കുന്നു. പൂർത്തിയായ മേൽക്കൂരയ്ക്ക് മുകളിൽ കാലാവസ്ഥയെ പ്രതിരോധിക്കാനായി ബിറ്റുമിൻ അല്ലെങ്കിൽ റബ്ബറൈസ്ഡ് കോട്ടിങ്ങ് നൽകുന്നു.



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മുളകൊണ്ടുള്ള കോറുഗേറ്റഡ് റൂഫിങ് ഷീറ്റ്

മുളകൊണ്ടുള്ള മാറ്റുകളിലേക്ക് പിഎഫ് റെസിൻ പുരട്ടി അഞ്ച് പാളിയുള്ള ഒരു സെറ്റ് ഉണ്ടാക്കുന്നു. ശേഷം ഇത് ഹോട്ട് പ്രസ്സ് ചെയ്ത് കോറുഗേറ്റഡ് പാളിയുണ്ടാക്കുന്നു. യുഎഫ് റെസിൻബോണ്ട് ഷീറ്റുകൾക്ക് മുകളിലേക്ക് പിഎഫ് റെസിൻ ഷീറ്റ് വിരിച്ച് ഫലപ്രദമായ പേപ്പറുകൾ ഉണ്ടാക്കിയെടുക്കുന്നു.

കെട്ടിടങ്ങൾക്കുള്ള റെട്രോഫിറ്റിങ് രീതികൾ

ദുരന്ത സമയങ്ങളിൽ കെട്ടിടങ്ങളിൽ സാധാരണയായി കാണാറുള്ള തകരാറുകൾ

പ്രളയത്തിൽ കെട്ടിടങ്ങൾക്ക് കേടു സംഭവിക്കാൻ സാധ്യതയുള്ള സ്ഥലങ്ങളാണ് ചിത്രത്തിൽ കാണിച്ചിരിക്കുന്നത് (കെട്ടിടത്തിന്റെ മൂലകൾക്കും, ജനലുകൾക്കും വാതിലുകൾക്കും ചുറ്റും വിള്ളൽ വന്നിരിക്കുന്നതായി കാണാം) ഇതു റെട്രോഫിറ്റ് ചെയ്യണമെങ്കിൽ കെട്ടിടത്തിന് ചുറ്റും ചിത്രത്തിൽ കാണിച്ചിരിക്കുന്നത് പോലെ ഒരു ബാൻഡ് കൊടുക്കേണ്ടതുണ്ട്. 30 എം എം ഘനത്തിൽ 10 ഗേജ് വയർമെഷും, 1:3 സിമന്റ് പ്ലാസ്റ്റർ എന്നിവ ഉപയോഗിച്ചാണ് ബാൻഡ് ചെയ്യേണ്ടത്. ഇതു ചുമരുകളുടെ രണ്ടു വശങ്ങളിലും കൊടുക്കണം. രണ്ട് വശങ്ങളിലുമുള്ള വെയർമെഷുകൾ 300 എം എം സി/സി ഷിയർ കീ ഉപയോഗിച്ച് യോജിപ്പിച്ചിരിക്കണം.

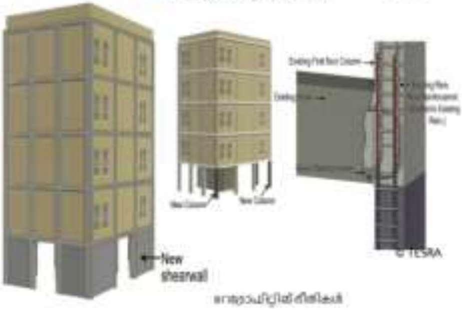
ബീംകോളം ജോയിന്റുകൾക്കുള്ള തകരാറുകൾ

കോളങ്ങളുടെ റെട്രോഫിറ്റിങ് രീതികൾ

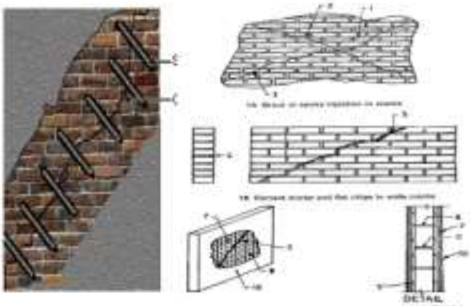
സോഫ്റ്റ് സ്ട്രക്ച്ചറുകളിൽ ഉണ്ടാകുന്ന തകരാറുകളും അതിന്റെ റെട്രോഫിറ്റിങ് രീതികളും.

കെട്ടിടത്തിന്റെ ഏറ്റവും ദുർബലമായ സ്ഥലം സോഫ്റ്റ് സ്റ്റോറീസ് ആണ്. ബഹുനില കെട്ടിടങ്ങളിൽ സാധാരണയായി സോഫ്റ്റ് സ്റ്റോറീസിലാണ് വീഴ്ച സംഭവിക്കാറുള്ളത്. ഇങ്ങനെ സംഭവിച്ച കെട്ടിടങ്ങൾ റെട്രോഫിറ്റ് ചെയ്യുന്നതിന് പലവിധത്തിലുള്ള രീതികൾ ഉണ്ട്. ഉദാഹരണമായി പുതിയ കോളങ്ങൾ, ഷിയർ മതിലുകൾ, ബ്രസിങ് മുതലായവ.

തകർച്ച സംഭവിക്കുന്ന രീതികൾ



റെട്രോഫിറ്റിങ് രീതികൾ



വിള്ളൽ നന്നാക്കുന്ന രീതികൾ

മണ്ണിടിച്ചിലിനെ പ്രതിരോധിക്കുന്ന കെട്ടിടനിർമ്മാണ രീതികൾ

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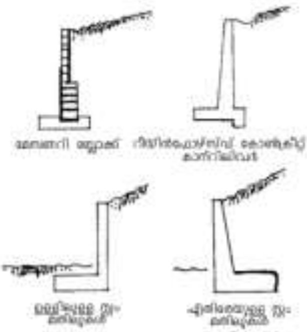
കോൺക്രീറ്റുകൊണ്ടുള്ള ബട്രസ്സ് ഭിത്തികൾ

കാന്റിലിവർ താങ്ങുഘടനകൾ
കാന്റിലിവർ താങ്ങുഭിത്തികൾ നിർമ്മിച്ചിരിക്കുന്നത് ബലപ്പെടുത്തിയ കോൺക്രീറ്റിലാണ്. താരതമ്യേന കനം കുറഞ്ഞ തണ്ടും ബേസ് സ്ലാബുമാണ് ഇതിനുള്ളത്. ബേസിനെ ഹീൽ എന്നും ടോ എന്നും രണ്ടായി തിരിച്ചിരിക്കുന്നു. ബാക്ക്ഫില്ലിന് അടിയിലുള്ള ബേസിന്റെ ഭാഗമാണ് ഹീൽ. ബേസിന്റെ മറുഭാഗമാണ് ടോ.

- മോണോലിത്തിക് ഗ്രാവിറ്റി ഭിത്തികളെക്കാൾ കുറച്ച് കോൺക്രീറ്റ് ഉപയോഗിക്കുന്നു, പക്ഷെ കൃത്യതയാർന്ന രൂപകൽപ്പനയും ശ്രദ്ധയോടുള്ള നിർമ്മാണവും ആവശ്യമാണ്.
- 25 അടിവരെ നിർമ്മിക്കുന്നത് പൊതുവേ ലാഭകരമാണ്.
- ഒരു ഫാക്ടറിയിൽ നേരത്തെ നിർമ്മിക്കുകയോ സൈറ്റിൽ തന്നെ ഉണ്ടാക്കുകയോ ചെയ്യാവുന്നതാണ്.



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സോയിൽ പൈപ്പിങ് - കേരളം

സോയിൽ പൈപ്പിങ്ങിനെ ടണൽ മണ്ണൊലിപ്പെന്നും വിളിക്കാറുണ്ട്. അതിശക്തമായ വെള്ളപ്പാച്ചിലുണ്ടാകുമ്പോൾ മേൽമണ്ണിനടിയിലെ മണ്ണൊലിച്ച് പോവുകയും പൈപ്പ് പോലുള്ള കുഴലുകൾ ഉണ്ടാവുകയും ചെയ്യുന്നു, പ്രത്യേകിച്ച് കല്ലുകളില്ലാത്ത പ്രദേശങ്ങളിൽ. സോയിൽ പൈപ്പിങ് അല്ലെങ്കിൽ ടണൽ മണ്ണൊലിപ്പ് എന്ന് പറയുന്നത് മേൽമണ്ണിനടിയിലെ മണ്ണൊലിച്ച് പോകുന്നത് മൂലം കുഴലുകൾ ഉണ്ടാകുന്നതിനെയാണ്. മണ്ണിനടിയിൽ ഒരു വഴിയുണ്ടാകാൻ കാരണമാകുന്ന വിധത്തിൽ മേൽമണ്ണിനടിയിൽ നിന്ന് മണ്ണ് വെള്ളംമൂലം ഒഴുകിപ്പോകുന്ന ഗുരുതരവും മനസ്സിലാക്കാൻ ബുദ്ധിമുട്ടുള്ളതുമായ ഒരു പ്രക്രിയയാണ് സോയിൽ പൈപ്പിങ്.

ഭൂമി താണുപോകുന്നത് പലതരത്തിലുള്ള പ്രശ്നങ്ങൾക്ക് കാരണമാകുന്നു.

- ഉയരത്തിലും അരുവികളുടേയും കനാലുകളുടേയും ഓടകളുടേയും ചരിവിലും പ്രശ്നങ്ങളുണ്ടാകുന്നു.
- പാലങ്ങൾ, റോഡുകൾ, റെയിൽ പാതകൾ, ഓടകൾ, സാനിറ്ററി അഴുക്കുചാൽ, കനാലുകൾ, ബോട്ടുകടവ് എന്നിവയെല്ലാം നാശമാകുന്നു.
- സ്വകാര്യ, പൊതുമേഖലാ കെട്ടിടങ്ങൾക്ക് നാശനഷ്ടം.
- ജലാശയ സംവിധാനത്തിലെ വസ്തുക്കളുടെ ഞെരുക്കംമൂലമുണ്ടാകുന്ന ബലത്താൽ കിണർഭിത്തി ഇടിയാൻ സാധ്യത
- ഭൂമിയിലെ സ്ഥിരമായ മലവെള്ളം, വെള്ളപ്പൊക്കത്തിന്റെ സാധ്യത കൂട്ടുകയും അത് ഭൂപ്രകൃതിയിൽ മാറ്റമുണ്ടാക്കുകയും ഭൂമി ഇടിയാൻ കാരണമാവുകയും ചെയ്യുന്നു.
- വെള്ളം സൂക്ഷിച്ച് വെയ്ക്കാനുള്ള കഴിവ് കുറയ്ക്കുന്നു.

കേരളത്തിൽ പശ്ചിമഘട്ടത്തിലെ പലഭാഗത്തും സോയിൽ പൈപ്പിങ് എന്ന പ്രതിഭാസം ഉണ്ടായിട്ടുള്ളതായി സൂചന ലഭിച്ചിട്ടുണ്ട്. ഭൂരിഭാഗം പൈപ്പിങ്ങുകളും സ്ഥിതിചെയ്യുന്നത് ഇടുക്കി, കണ്ണൂർ, കാസർകോട് എന്നീ ജില്ലകളിലാണ്. കോഴിക്കോട്, പാലക്കാട്, എറണാകുളം, പത്തനംതിട്ട, വയനാട് പ്രദേശങ്ങളിലും ഇത് കണ്ടുവരുന്നു.

© HDMA

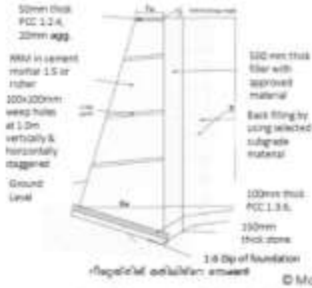
സോയിൽ പൈപ്പിങ്ങിന്റെ ചിത്രങ്ങൾ

ഇടപെടൽ
കുഴികളുടെ ചരിവില്ലാത്ത പ്രദേശങ്ങളിൽ ആഴത്തിൽ മണലും ജിപ്സവും നിറച്ച ട്രഞ്ച് നിർമ്മിച്ചുകൊണ്ടുള്ള ഹൈഡ്രോളജിക്കൽ ബാരിയർ ടെക്നിക് പരിശീലിക്കാവുന്നതാണ്. മണലും ജിപ്സവും നിറഞ്ഞ മിശ്രിതം ടണലിലെ ഏക്കൽമണ്ണിനെ തടയുകയും വെള്ളം ജിപ്സത്തിൽ തടഞ്ഞ് ഉയർന്ന് മണ്ണിന് മുകളിലേക്ക് വന്ന് ഒഴുകിപ്പോവുകയും ചെയ്യും.

മണ്ണിടിച്ചിലിനെ പ്രതിരോധിക്കുന്ന കെട്ടിടനിർമ്മാണ രീതികൾ

മണ്ണിടിച്ചിൽ ദുരന്തം - കേരളം

കേരളത്തിൽ, പശ്ചിമഘട്ടത്തിലെ കുത്തനെയുള്ള ചരിവുകളുടെയും തുടർച്ചയായ മഴ മൂലം മണ്ണ് കുതിരുന്നതിനാലും ഇവിടുത്തെ പ്രാദേശിക മേഖലകളിൽ മണ്ണിടിച്ചിൽ സർവ്വസാധാരണമാണ്. ഒരു ചെറിയ പ്രദേശത്തെ ബാധിക്കുന്നത് മുതൽ നിരവധി മരണങ്ങൾ അടക്കം വലിയ ഒരു പ്രദേശത്തെ ഒന്നാകെ ഇല്ലാതാക്കുന്നത് വരെയുള്ള വിവിധ സംഭവങ്ങൾ ഉണ്ട്.



റിട്ടെയിനിങ് മതിലിന്റെ മാതൃക © MoWHS

Standard design with soil surcharge load

Height (m)	SBC 80		SBC 100		SBC 150	
	B.W	T.W	B.W	T.W	B.W	T.W
1	0.5	0.45	0.5	0.45	0.5	0.45
2	0.9	0.5	0.9	0.5	0.9	0.5
3	1.55	0.5	1.55	0.5	1.55	0.5
4	2.2	0.6	2.2	0.6	2.2	0.6
5	3.85	0.8	3.5	0.8	2.65	0.8
6	4.9	1	4.7	1	4.1	1

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ഭൂഗുരുത്വം നിലനിർത്തുന്ന വിവിധതരം മതിലുകൾ

കല്ലുകൊണ്ടുള്ള മതിൽ

കല്ലും മണ്ണും ഉപയോഗിച്ച് നാല് മീറ്ററോളം ഉയരത്തിൽ താങ്ങുമതിൽ നിർമ്മിക്കുന്നു. നാല് മീറ്ററിൽ കൂടുതൽ ഉയരത്തിലുള്ള താങ്ങുമതിൽ ചുണ്ണാമ്പ് അല്ലെങ്കിൽ സിമന്റ് മോർട്ടാർ കല്ലുകൾ അല്ലെങ്കിൽ വലിയ കൽക്കഷ്ണങ്ങൾ ഉപയോഗിച്ച് 0.6 മീറ്റർ വീതിയിൽ മൂന്ന് മുതൽ നാല് മീറ്റർ വരെ മോർട്ടാർ കൊണ്ടുള്ള ഒരു കൽക്കെട്ട് നിർമ്മിക്കേണ്ടതാണ്. ഇത് തിരശ്ചീനവും ലംബവുമായിട്ടുള്ള ദിശകളിൽ വേണം.


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ഡ്രൈ സ്റ്റോൺ മേസണറി


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കല്ലുകൊണ്ടുള്ള മേസണറി

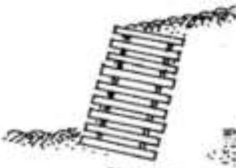
ഗാബിയോൺ ഭിത്തി

സംരക്ഷണത്തിനായുള്ള ടെക് 3 താങ്ങുഘടനകൾക്ക് ഏറ്റവും അനുയോജ്യമായിട്ടുള്ള ഫ്ളെക്സിബിൾ ഘടനകളാണ് ഗാബിയോൺ താങ്ങുഭിത്തികൾ. വലിയ കല്ലുകളിലെ സുഷിരങ്ങൾ തിരകളുടെ ഊർജ്ജത്തെ ഫലപ്രദമായി ചിതറിക്കുന്നതിനാൽ അടുത്തുള്ള ജലാശയങ്ങളുടെ സംരക്ഷണത്തിനും ഇത് വളരെ ഫലപ്രദമാണ്. ഗാബിയോൺ ഭിത്തികൾ വളരെയധികം വഴക്കമുള്ള സ്വഭാവമുള്ളവയായതിനാൽ ഏത് തരം അടിസ്ഥാന സ്ഥലത്തും ഇത് ഉപയോഗിക്കാൻ സാധിക്കും.

4 മീ. ഗാബിയൻ മതിലിന്റെ പരിച്ഛേദം

ക്രിബ് ഭിത്തികൾ

തടികൊണ്ടുള്ള ഫ്രെയിമുകളിൽ വലിയ കല്ലുകൾ കെട്ടിയാണ് ക്രിബ് ഭിത്തി ഉണ്ടാക്കുന്നത്.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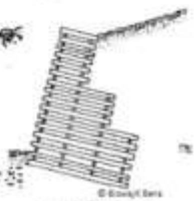
കോൺക്രീറ്റ് കൊണ്ടുള്ള ക്രിബ് മതിൽ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പല താഴ്ചയിലുള്ള ക്രിബ് മതിലുകൾ

മുട്ടുഭിത്തി

മണ്ണിടിച്ചിലിലും മലമ്പ്രദേശത്തെ റോഡുകളിൽ മണ്ണിടിഞ്ഞുവീഴുന്നതും ഒഴിവാക്കാനായുള്ള താങ്ങുപകരണങ്ങളായിട്ടാണ് മുട്ടുഭിത്തികൾ സാധാരണയായി ഉപയോഗിക്കുന്നത്. അടിസ്ഥാനങ്ങൾക്കുണ്ടാകുന്ന പരാജയമാണ് ഇത്തരം ഭിത്തികളുടെ പരാജയത്തിലേക്ക് നയിക്കുന്നത്. അടിസ്ഥാനത്തിനും ഘടനയ്ക്കും ഇടയിൽ വിള്ളൽ വീഴുകയും ഭിത്തി തന്നെ മൊത്തത്തിൽ വീഴുകയും ചെയ്യുന്നു. അതിനാൽ കല്ലുകൾ കൊണ്ടുള്ള മുട്ടുഭിത്തികൾ നിർമ്മിക്കുമ്പോൾ, അടിസ്ഥാനത്തിന്റെ പരാജയം ഒഴിവാക്കാനായി ബലവത്തായ അടിസ്ഥാനമാണ് ഉപയോഗിക്കാൻ. മുകൾഭാഗം ലംബമായിട്ടും താഴ്ഭാഗം 1.5:1 ചരിവുമിട്ടാണ് മുട്ടുഭിത്തികൾ നിർമ്മിക്കുന്നത്.