3.0 BUILDING MATERIALS

Generally, the safest materials in earthquake areas are the lightest and most flexible. The choice of building materials will depend on the following factors among others:

- Affordability
- Climatic conditions
- Resistance to certain hazards e.g. as earthquakes, hurricanes, floods, etc
- Resistance to insects & other pests
- Effect on the environment
- Cultures of a given society
- Safety considerations
- Design aspects
- Availability of necessary skill to use them
- Availability of technology to exploit or utilize the materials
- People's tastes.

3.1 Foundation Materials	Seismic Performance	Remarks
Rammed Earth Foundation	Low	The site should be well-graded & drained. Introduce concrete footing to protect from ground moisture.
Wooden Post Foundation	Low- Good	Used mostly for light weight structures; highly susceptible to attack from termites, fungus, rodents. Dry climate, drained site, plastic socks, used oil & site fumigation preserve posts.
Natural Stone Foundation	Medium to Good	Depends on the design, quality of mortar and reinforcement; use recommended ratio of 4:1:12 for cement : Lime : sand
Burnt Brick Foundation	Medium to Good	Requires good quality mortar in ratio 4:1:12 and reinforcement of masonry with wire mesh or thin steel rods.
Split Bamboo Piles	Good	Normally used in areas with high silt/clay content.
Concrete Foundation	Very Good	Requires proper ratio 1:3:4 or 1:4:7 for Cement, Sand & Gravel & curing of 3-7 days before building walls. Select the appropriate foundation type for best results.

3.2 Floor Materials	**Seismic Performance**	**Remarks**
Stabilized Earth	Low	Compacted inorganic soil stabilized surface coats of cow-dung, requires regular renewal of the finish.
Burnt Clay & Concrete Components	Good	Depends on quality of bricks/tiles, mortar and workmanship
Concrete	Very Good	Dependent on availability & affordability of cement, good quality sand to provide greater strength and durability.
Bamboo Floors	Good	Normally used in bamboo structures; they give uneven surface and requires protection against biological agents and fire.
Timber Floors	Good	Made of wooden planks nailed onto sawn timber substructure & requires protection against biological agents and fire.
3.3 Wall Materials	**Seismic Performance**	**Remarks**
Unburnt Adobe Block Walls	Low	These are bonded by mud mortar highly susceptible to moisture attack; collapse in earthquakes, as they are highly unstable.
Rammed Earth Walls	Low	Performance is dependent on quality of soil, workmanship, thickness & height of the wall. Suitable soil should contain 50-75% of fine gravel & sand, 15-30% silt, and 10-20% clay.
Stone Masonry Block Walls	Good	Cement and sand mortar to be used as a binder.
Mud and Bush poles Walls	Medium to Good	Poles and reeds provide a well inter-connected network of defense lines that ensure maximum seismic resistance provided the poles are not destroyed by insects or rot.
Compressed Stabilized Blocks	Good	These require stabilization with appropriate binders to achieve higher compressive strength. Suitable soils should be 75% - sand, 10% - clay. Reinforcement improves seismic performance.

3.3 Wall Materials (*Cont'd*)	**Seismic Performance**	**Remarks**
Bamboo Reinforced Earth Walls	Good	Due to its high tensile strength, bamboo increases seismic performance though it is susceptible to attack by biological agents, insects and moisture.
Burnt Clay Brick Walls	Good	The performance is highly dependent on quality of bricks, mortar, workmanship and design. Adding lime to ordinary Portland cement mortar achieves strength that conforms with those of bricks hence prevention of cracking.
Bamboo Walls	Very Good	Its flexibility and high tensile strength make bamboo highly earthquake resistant. In event of collapse, its low weight causes less damage to people & property, reconstruction is quick & easy.
Timber Panel walls	Very Good	There is need for seasoning of the timber and protective measures to guard against attack from insects, moisture …
Concrete Hollow Blocks	Very Good	Require less mortar, are light weight, cavities filled with reinforcement concrete to achieve seismic resistance; air spaces are thermal insulators; cavities serve as ducts for electrical & plumbing installation.
3.4 Roofing Materials	**Seismic Performance**	**Remarks**
Soil Brick Roof	Low	The roof is heavy hence inappropriate for earthquake prone areas.
Clay Tile Roofs	Low	They are loosely connected, heavy & require strong heavy structure and closely spaced battens. Normally used for sloping roofs between 20-50° in inclination of rafters.

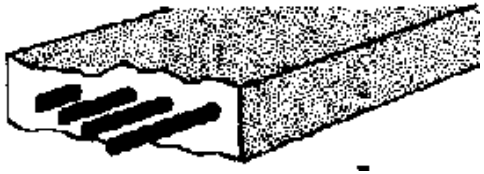
3.4 Roofing Materials *(cont'd)*	**Seismic Performance**	**Remarks**
Bamboo & Wood Shingles	Good	These are ideal and proper for earthquake resistance though of limited durability and social acceptability. Requires protective measures.
Fibre & Micro Concrete Tiles	Good	These are light and thin (6mm) in cement: sand ratio of between 1:2 and 1:3; but if not well fixed to the substructure they can easily fall off in event of an earthquake.
Ferrocement Roofs	Very Good	These are thin highly reinforced components that have high tensile strength: weight ratio. Further, strength and rigidity is achieved by curvature or folds. They also have ability to span large areas without battens.
Corrugated Metal Sheeting	Very Good	Light, cheap, span large areas without sagging. Strong gauge is recommended.
Pole Timber Roof Structure	Very Good	Poles have large tension growth stress around their perimeter and this assists in increasing the strength of the compression face of a pole in bending.
Durable Thatch with stiff Stem Grass	Very Good	The roof is light, structure is strongly interconnected although requires protective measures and regular renewal.
Bamboo Roof Structure	Very Good	Has high tensile strength, flexibility and low weight. Strong interconnectivity enables it achieve very good seismic performance.

4.0 REINFORCEMENTS

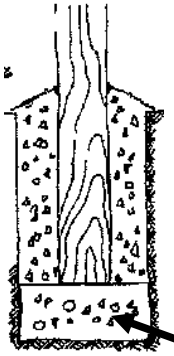
Reinforcements are intended to increase seismic performance of building components such as foundations, floors, walls, openings, and roofs and other non-structural members.

4.1 New Construction

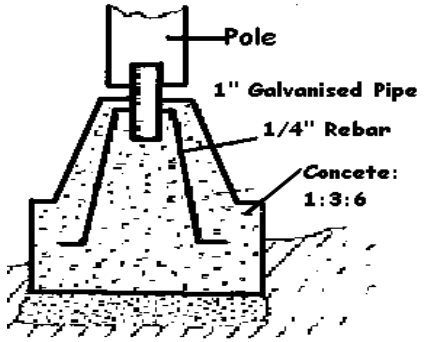
- Ensure the foundation is on a firm ground
- Use reinforcement in the foundation concrete
- Introduce vertical columns to stabilize the masonry walls
- Use ground beam
- Use wire-mesh in the floor slab
- Introduce horizontal reinforcement bars in mortar after every three courses
- Reinforce the openings with vertical steel bars
- Use reinforced window sills and lintels to strengthen the openings.
- Interconnect the ring-beam with the vertical columns
- Ensure strong connectivity of all members of the building.



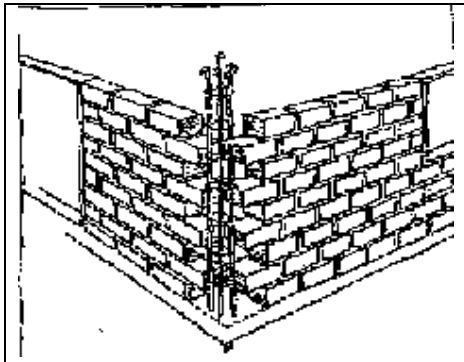
Reinforcing Foundation with steel bars



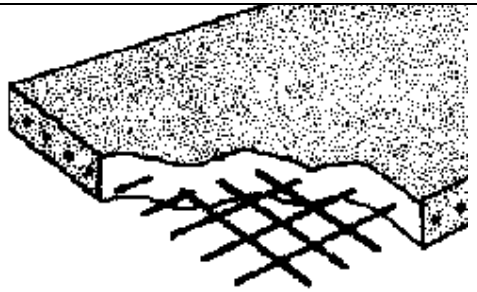
Wooden pole in Concrete to protect it against rot and termite attack. Use plastic "socks" & used oil to preserve the timber / pole.



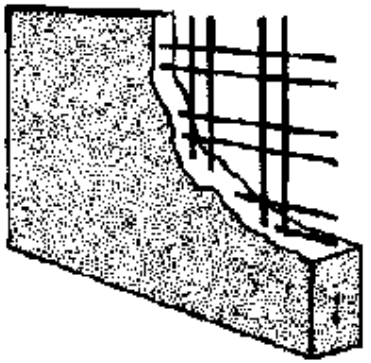
Strengthening the house built of timber poles



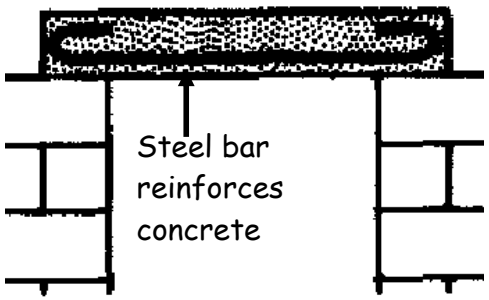
Vertical reinforcement



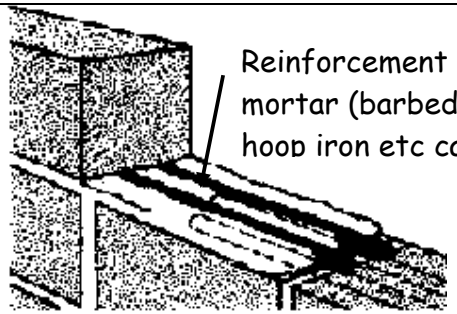
Wire-mesh in floor slab

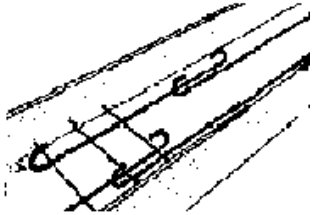


Reinforcement of walls

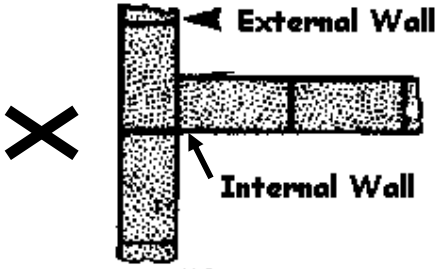


Reinforcing the lintel

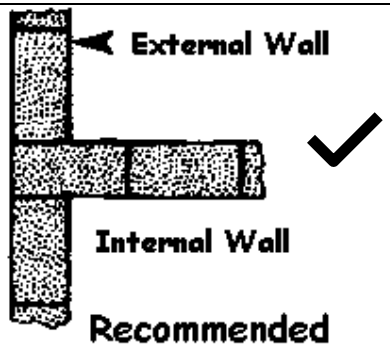




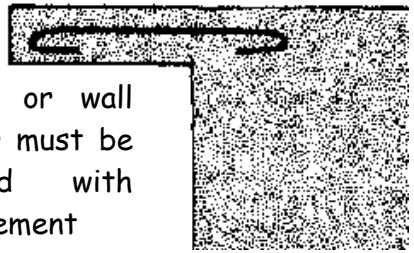
The overlap should be equal to 30 times the diameter of the bar.



Not Recommended: Weaker



Recommended



Canopies or wall overhang must be stabilized with reinforcement bars

4.2 Earthquake Upgrading

Earthquake Upgrading or retrofitting of structures is done to:

- guard against house collapse during an earthquake which could cause deaths or injuries; and
- reduce damage and economic losses.

Major damage to buildings in earthquakes is usually caused by the failure of the weakest link in the structural system. Weak links can be upgraded to match the strength of the rest of the structural system, but it is not effective to strengthen one element of a structure to a higher level without strengthening others. Retrofitting is a costly exercise as it may involve use of heavy plant to keep the structure in place during the process of upgrading.

However, since the majority of the population will continue living in existing structures that may not be seismically responsive, it is important that simple techniques are used to improve their seismic performance. This may include the following among others:

- Introduction of vertical elements such as columns and buttresses, especially in corners or where the walls meet;
- Introduction of horizontal reinforcements such as ring beam or ground beam through underpinning of the structure;
- Use of plastic mesh embedded in sand/cement mortar and applied around the wall section above the lintel or windows;
- Introduction of bracing members to reinforce wall sections;
- Simple remodeling of the existing structure to adjust on the location and size of the openings;
- Replacement of poles and tie reeds, on the mud and wattle structures, that have been destroyed by rot or termites;
- Applying anti-shatter film onto glass panes to safeguard against shattering of glass during an earthquake;

The strengthening work for major buildings should be designed and supervised by a qualified Structural Engineer. The following section provides information about checks that should be carried out to facilitate improvement of seismic performance.

4.3 Maintenance and Checks for Seismic Safety

Lack of Maintenance contributes to the damage to houses during earthquakes. Regular maintenance is therefore necessary to ensure that the building continues to be earthquake resistant. It is important that regular checks are carried out on the entire house to find out what needs repair or replacement and immediately attend to it. The most important areas for regular checks include:

• Site drainage	• Ensure that the site is properly drained to safeguard the foundation, plinth and wall
• Foundation weaknesses	• Seek advice of Structural engineer and strengthen accordingly
• Cracks in the plinth, floor slabs and masonry	• Seek advice of Structural engineer and strengthen accordingly
• DPC failure	• Systematic replacement of DPC with new DPC
• Rotting timber supports	• Ensure the site is well drained and replace the rotten supports with treated ones or even concrete.
• Termite attack on poles (traditional construction)	• Fumigate the site with appropriate chemicals. • Apply oil on the poles and dress the poles with plastic bags or covers
• Mud and wattle walls	Walls can be protected using: • Plaster of cement & sand or mud & sand • Adequately long roof overhang to stop the rain from falling onto the wall
• Weaknesses in vertical & horizontal reinforcements	• Seek Structural Engineer's advice to reinforce accordingly.
• Weaknesses with openings	• Seek advice of an Architect and improve accordingly: o if they are too many, reduce on the number, o if they have no lintels, introduce them, o if they are too wide, adjust as per recommended standards.

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- Soundness of roof structure, rafters and purlins

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- Ensure the timber structure is kept in sound state: all leakages should be sealed off, those affected by pests or insects should be replaced, weak connections should be fastened.

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- Possible damage to the roof covering and slabs

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- The roof covering should not be heavy, In case it is rusty, apply a coat of paint to protect it. In case of tiles, ensure that they are firmly tied to the battens using wires to restrain them from falling off during earthquake.

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- Check for stability of appendages such as water tanks, chimneys, canopies etc.

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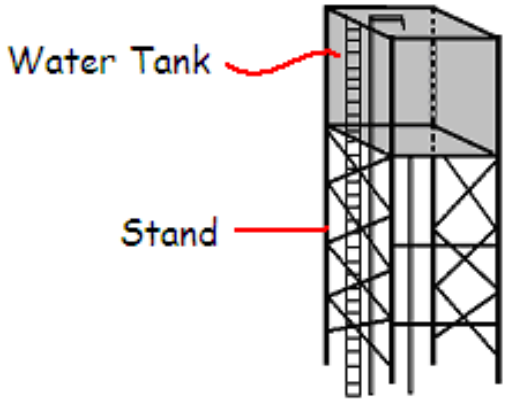

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Water tank should not be mounted in the ceiling as it introduces unnecessarily heavy load which may result into collapse of walls during the shaking and cause damage to the structure.
Water tank should be mounted on a separate stand firmly anchored or fixed to prevent it from overturning.

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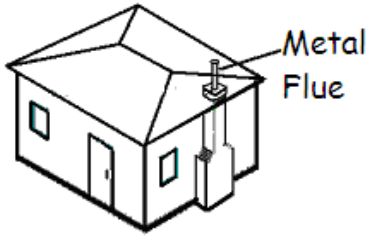
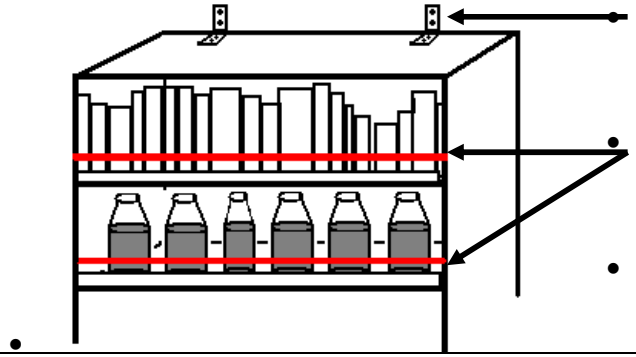
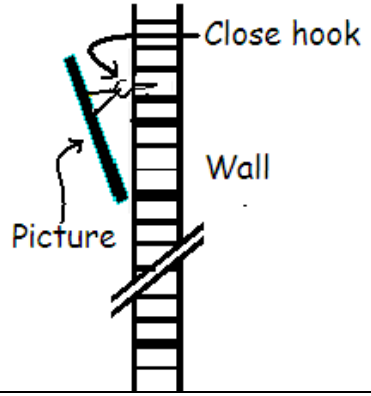
Chimneys build of masonry normally collapse during the shocks and need to be braced.	 Reducing of chimney hazards	• Remove the top of the unreinforced masonry and replace it with metal flue /pipe • Strap the chimney to the main structure to hold it firmly in place.
Tall furniture e.g. File Cabinets or Book shelves: • Secure the top of tall file cabinets or book shelves or side boards to the wall with L brackets		• Install metal "L" brackets between furniture and wall stud at top. • Install guard across shelf, or install wood trim on front of the shelf. • Place heavy objects on lower shelves.
Pictures hang on the wall		• Screw close hooks into wood members only (stud or ceiling joists). • Close hooks should be used for hanging pictures to prevent them from falling during the shaking.

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- Glass windows can shatter into dangerous small pieces during earthquakes

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- Large panes should be made of tempered or wired glass, or alternatively
- Shatter-resistant film should be applied to the glass

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- Freestanding, movable, partial-height partitions--especially if supporting bookshelves

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- Adequately brace such partitions,
- Unreinforced masonry partitions should be removed if they cannot be adequately strengthened,
- Freestanding equipment on wheels should be locked against rolling.

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Equipment on desk top or counter tops:

- Secure computers, TVs and other equipment onto the top of the desk or table or counter.

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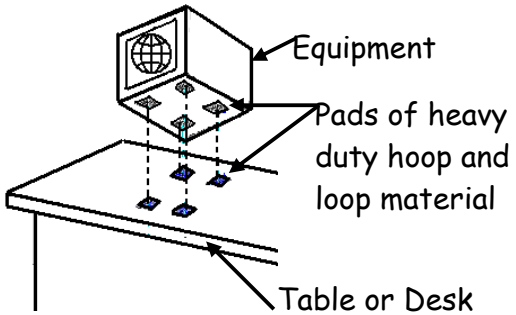

- Attach the equipment to the top of desk or table with heavy duty hoop and loop materials, or metal connectors screwed onto the desk as well as the equipment

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- Water Heaters are normally thrown off balance during the earthquake unless adequately secured

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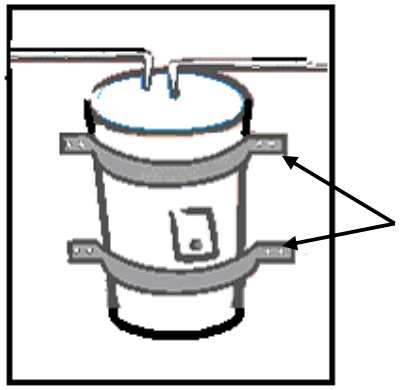

- Strap the water heater to the wall with metal straps firmly screwed into the wall to ensure stability
- Further strengthening can be achieved by anchoring the bottom of the heater to a reinforced base with bolts.

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• Electrical Appliances	• Fluorescent light bulbs, lenses, chandelier lights should be securely fastened • Generators should also be securely anchored to the floor to avoid the danger of sliding and overturning during earthquakes • Fire extinguishers should be securely mounted on the wall with necessary connectors
• Potted plants or heavy items on top of file cabinets or other high locations	• Ensure that objects placed on top of Cabinets or sideboards are securely restrained through anchoring, or strapping or attaching them with chain to keep them in place during the shaking .
• Compressed gas tanks	• Compressed gas tank legs should be anchored to a concrete footing or slab or secured top and bottom with a safety chain
• Burglar proofing of openings	• Burglar proofing of openings especially windows with fixed or sealed burglar proof should be discouraged; instead use burglar proof that is openable to facilitate exit in case of emergence. • Guard against anything that could move and block the entrance during the shaking.
Old trees near the building: • Check for root rot or for large branches that are weak	• Large trees that seem to be in poor health or leaning should be removed to avoid the danger of falling onto the structure during the earthquake.
Hanging plant especially near windows	• Hanging plants can also fall or damage nearby windows as they swing.
• Location of beds	• Move beds away from windows to avoid the risk of flying shattered glass pieces.
• Location of desks, tables	• Locate tables in such a way that they will not slide and block the exits during the shaking.
• Decorative objects	• Decorations or appendages should be adequately attached or anchored.

4.4. DECISION MAKING FOR EARTHQUAKE RESISTANT CONSTRUCTION

In order to construct earthquake resistant houses in the Rwenzori Region, it is imperative that consideration be given to the choice of materials, the mode of construction, and the building site location characteristics. The public Health Act and the Building Control Regulations will also increasingly bear upon the standard and quality of the building as the enforcement of the provisions of this law is implemented.

The Local Authorities will keep the type plans prepared and issued by the Central Government. These type plans will take into consideration the issues that impact on the performance of the building during an earthquake. The figure below illustrates the basic steps for a developer who desires to construct an earthquake resistant building.

In the decision making process, the Government and the local government down to the LC I are major stakeholders. The private sector and public institutions will use the type plans for constructing buildings.

To ensure this happens in a sustainable manner, local authorities will charge user fees at levels that are affordable to every serious developer as a means of gradually getting every one to adopt this approach in shelter construction.

The District Engineer's Department is responsible for issuing type plans. Therefore the departments will work with community based organizations, NGOs, technical training institutions in their district and the region to impart the necessary skills.

Process for Application of Type plans