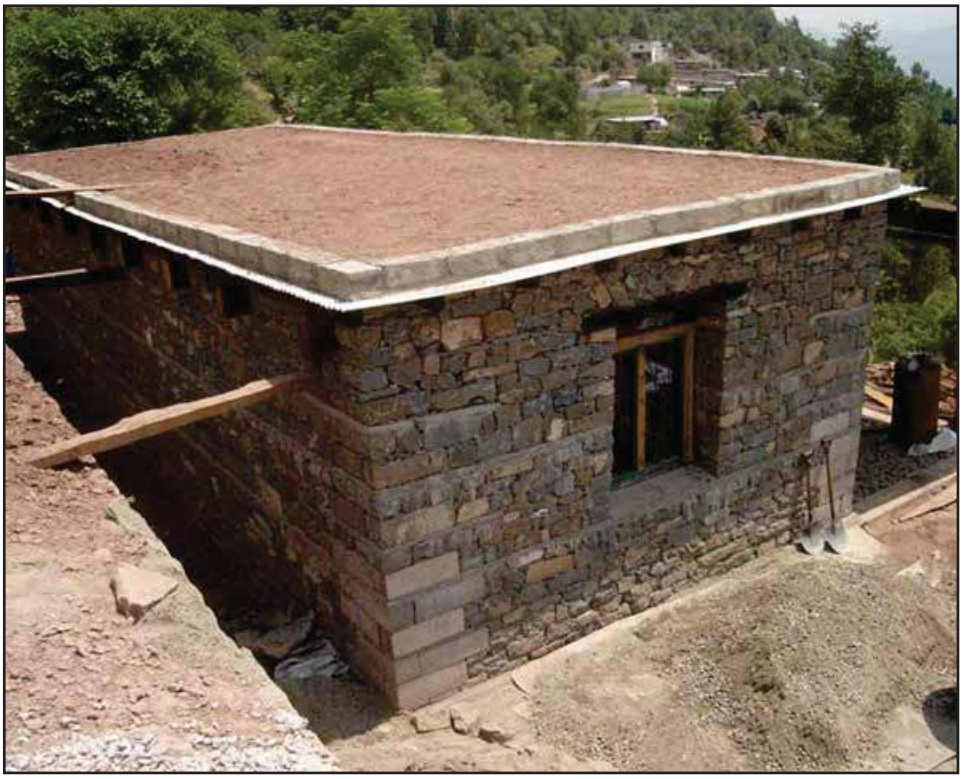
Technical guide for master trainers: Earthquake resistant buildings using local materials in Kafal Ghar (Kashmir, Pakistan)



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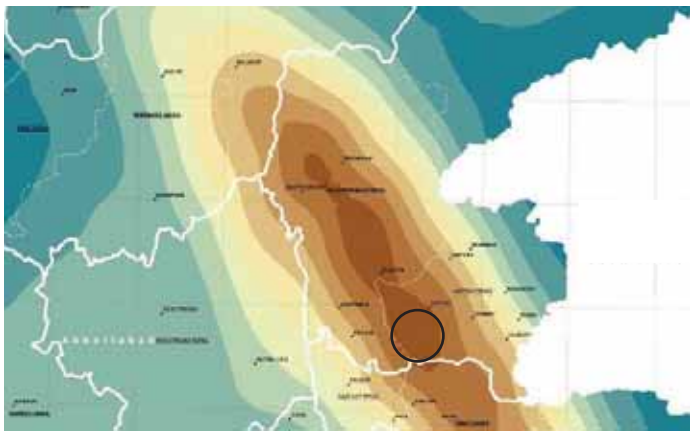
www.inkscape.org
www.blender3d.org
www.gimp.org

SUMMARY



This guide is primarily aimed to be used for the projects of reconstruction of the village of Kafal Ghar, in the Bagh district , Kashmir, Pakistan.

The reader should know that:

The general methodological approach of this guide can be adapted to other regions.

Some of the technical proposal are specifically fitted to the cultural, economical and social context of Kafal Ghar and may not be usable directly in other regions.

LESSON PLAN

Origin of earthquakes

0-2

Session duration: 1 hour

Objectives:
Make participant conscious that earthquake are recurrent and intensity may vary
Help Trainees to develop an earthquake prone area behaviour (identify indicator, plan of rescue, etc.) and conscientize them about the necessity to advocate for the development of such behaviour.

Method:
Help trainees to understand the tectonics plate movements. Trainees will share their knowledge about earthquake, the trainers will synthetise and complete after trainees restitutions. He will illustrate the plate movement and their consequences.
Ask trainees to talk about their previous experience when they faced the earthquake, and to develop a security plan based on the lessons learnt.

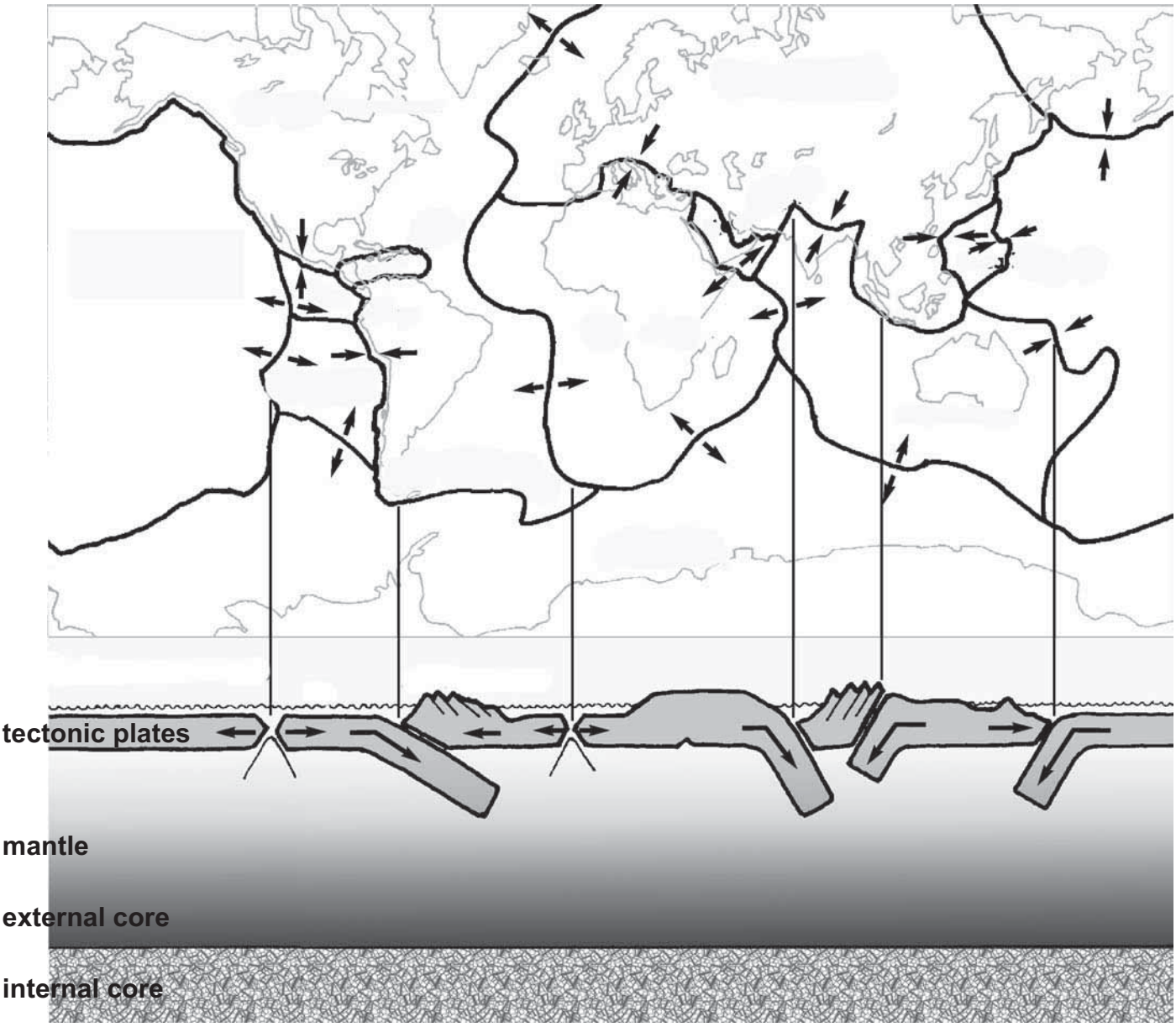
Trainer team	**Session**	**Pedagogical support** :	**Tools :**
Lecture One trainer for 20 participant	Preparatory work : Organise a board where can be fixed the pedagogical material (plasticized paper) Organise the room or open site in order to help trainees to have free access to all the documentation fixed on the boards Organise chairs, booknote and pen for participant Translate necessary material in local language. Lecture: Introduction about the topic of the session The trainer will explain the necessity to understand a phenomenon before to try to develop adequate answer to face its potential effect. Trainees will be required to organise themselves in group of 4 to 6 persons in order to answer the following questions (the trainers may add other questions, adapt or complete these questions, this in order to its own sensibility). 20 mn will be given to the trainees to answer the questions. Then they will be required to restitute their discussion to the others. What do the trainees know about earthquake? *(objective: to help trainees to share their knowledge and discuss this issue)* Do they know how it happens? *(objective: to help trainees to understand the recurance of such events)* Do they remember precedent earthquake; does their ancestor was use to talk about earthquake? *(objectives: To help to know about the periodicity of earthquake in the particular region. For the trainer, it may help to understand if there is chance or not for a surviving local sismic culture).* Does this earthquake can be considered as a big one or a normal one in the region? *(objectives: This question aim to give back confidence to the trainees in order to think on reconstruction. Even if there is no certitude, they may realise that the present earthquake was particulary big and that there is some chance for it to not happen again similarly in the next decades).* Describe what were the different step of the earthquake? *(sound, ground movement, animal behaviour; let the trainees relate the different things they notice)*. During the restitution, the trainer will help various trainees to interact on the subject and develop a common perception of the phenomenom. Then, he will synthesise and if necessary complete the information given by the trainees. It is recommended to use the trainees arguments or expalnation to develop this synthesis. Then, He will ask the trainees to develop a emergency policy related to their own families, or village. The trainer should be mind open and note interesting comments given by the trainees as it can give relevant information about the seismic activity in the area and about people perception of this phenomenon.	Demonstration: Possibility to use two stone to represent the tectonic plate. Illustrate the various interaction between the plate. Explain reason of earthquake intensity.	Two flat stone.

Planning

Before the session: Identify site for the session, taking care of potential risk related to weather conditions
Take into account the method of working into group while selecting the site (need for group to isolate themselves during group work)
Be sure of language to be used during the training.

Lecture Take care to help all trainees to participate in the discussion. Leaders, or trainees who attented other related training may take the lead for all the group and reduce the interest of the participatory approach.

After lecture Adjust the lecture plan as well as the pedagogical support if necessary.


tectonic plates
mantle
external core
internal core

LESSON PLAN

Earthquake's effects on buildings

0-4

Session duration: 10mn

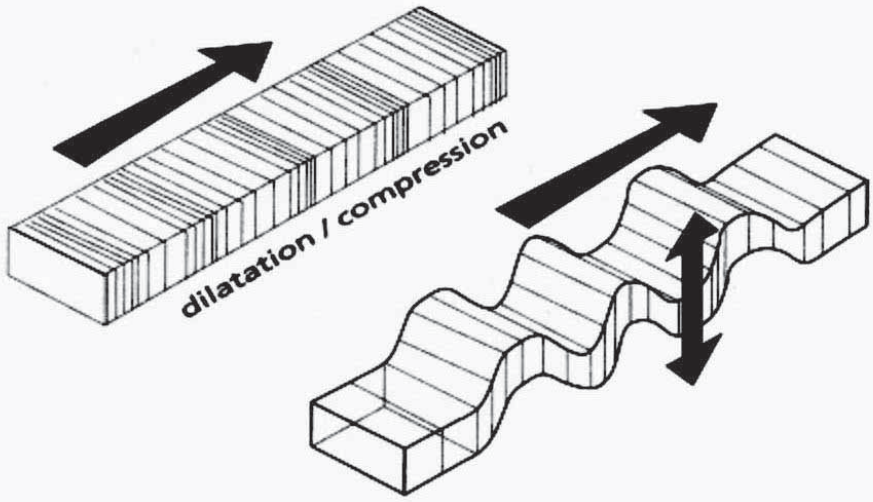
Objectives :
Help trainees to understand how a construction behaves when facing an earthquake.

Aim:
Help trainees to take into account the seismic effect when they will design and construct a building.

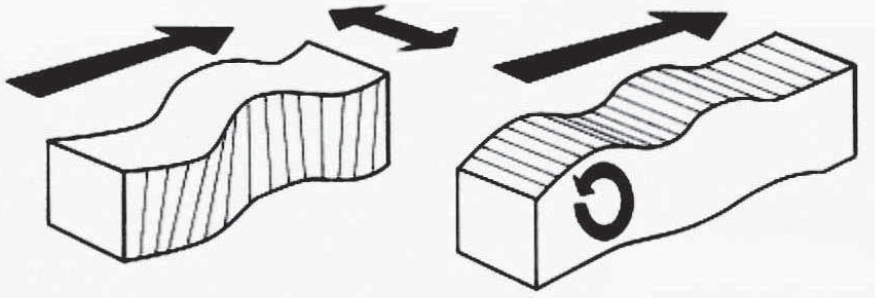
Method : Interaction with the trainees
- Help trainees to understand the various constraints given to a building by a seism
- Help trainees to understand the movement generated.
- Help trainees to understand possible effect on the building and its surrounding

Trainer team	**Session**	**Pedagogical support** :	**Tools :**
Lecture One trainer for 20 trainees.	Lecture: After a short recap on the Earthquake actions ask the trainees on how the soil may react to this phenomenon (what could be the different movement created). ❋ Illustrate the different waves and explain them shortly ○ Compression ○ Vertical movement ○ Horizontal movement ○ Elliptic movement ❋ Dynamic effect ○ Acceleration ○ Speed ○ Displacement ○ Frequency and intensity related to nature of the soil Then, ask the trainees on how these different phenomenons interact with the building. ❋ Main action on the building ○ Vertical ⊙ Loose of mass ○ Horizontal ○ Torsion Then, ask the trainees on what could be the consequence of these actions to the building and its surrounding. ❋ Main effect on buildings and its surrounding ○ Effect on the site (landslides, rolling rocks, etc) ○ Ground distortion ○ Separation of element ○ Shearing of the element	Demonstration: One flexible wooden or plastic stick.  Trainees guide: Copy of the flyers	

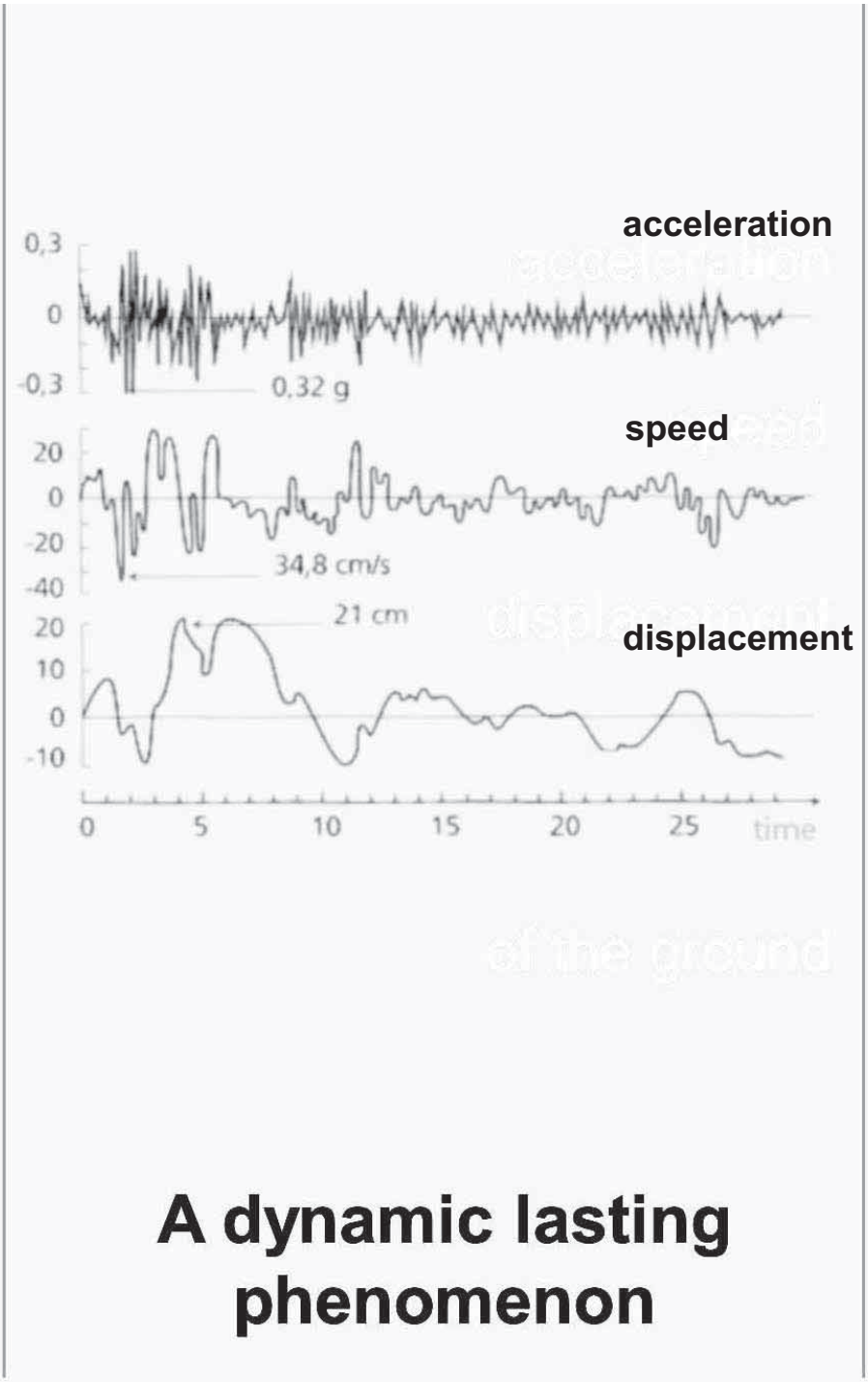
Planning	
J- 5 weeks	Identify in the area existing example of the issue the trainers want to demonstrate. A compilation of picture may be addeb to the existing files containt into this trainer guide.
Lecture	Note all remarks and inputs from the trainees.
After lecture	Improve on the lecture contain, add relevant material according to trainees response to the one presented.

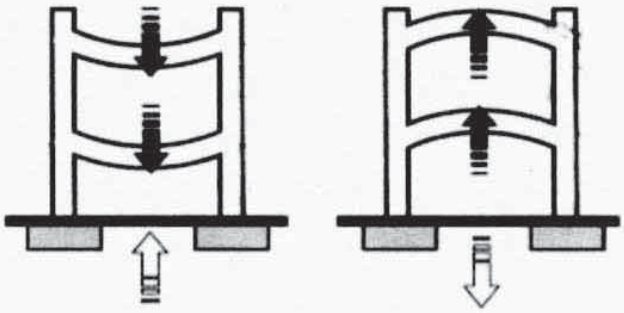


VOLUME WAVES

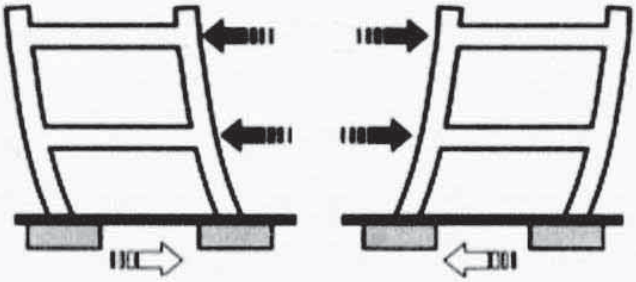


SURFACE WAVES

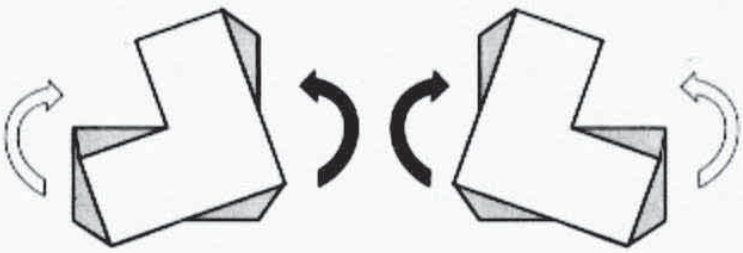

acceleration
0,3
0
-0,3
0,32 g
speed
20
0
-20
-40
34,8 cm/s
displacement
21 cm
20
10
0
-10
0
5
10
15
20
25
time
A dynamic lasting phenomenon



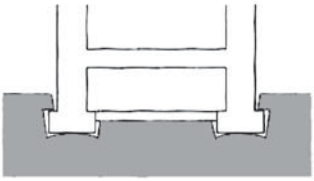
vertical oscillations



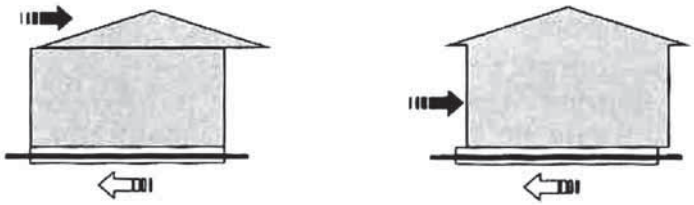
horizontal oscillations



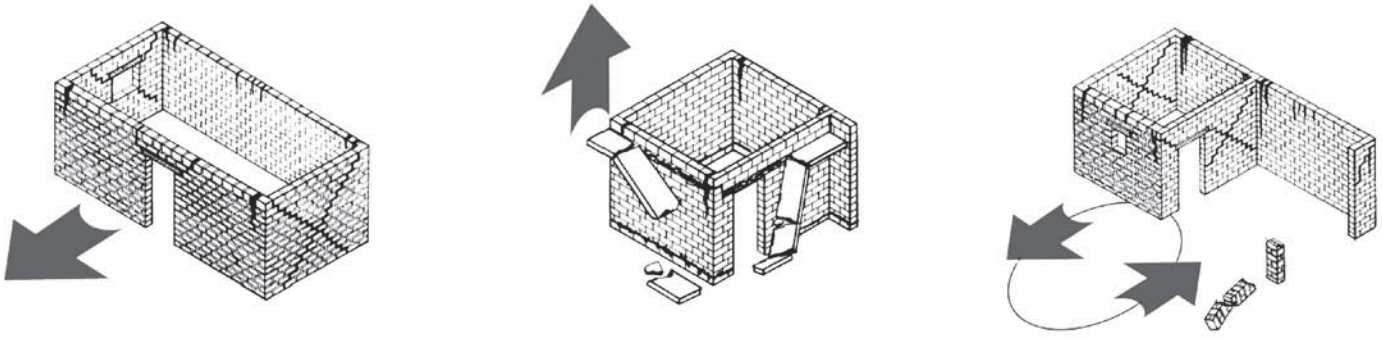
torsion oscillations



ground distorsion



separation of the elements



shearing of the elements

LESSON PLAN

Approach on earthquake resistant buildings

0-9

Session duration: 10mn

Objectives: Understand the different factors that are interfering in the seismic resistance of a building.

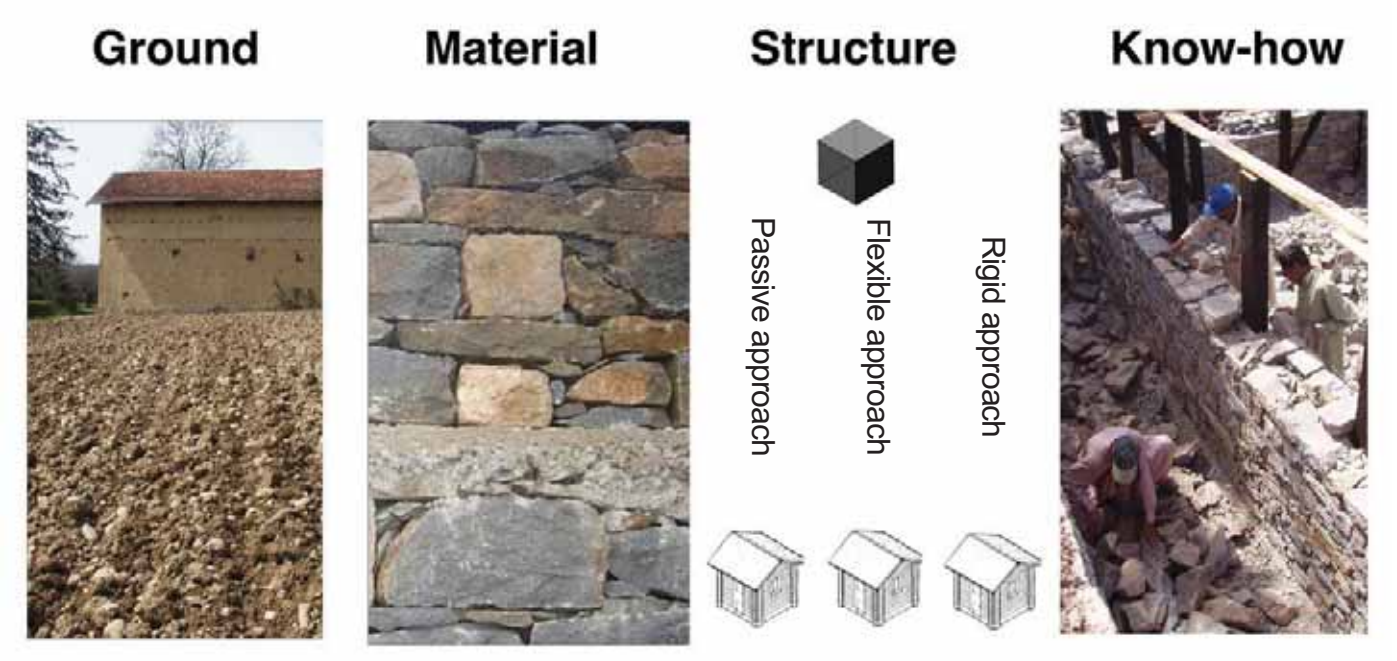
Aim:
Sensitize trainees to the fact that there are numerous factors to take into account to achieve seismic resistant building. There is not a unique solution.

Method : participatory discussions

Trainer team	**Preparatory work :**	**Pedagogical support :**	**Tools :**
Lecture: One trainer for 20 trainees.	Lecture: To understand ground effect and interactions with the building; The resonance factors ❋ Demonstration with the wire and mass on the plank. ❋ Analysis by the trainees (open discussion) ❋ Conclusion; importance of the design and the structural choice in relation with the type of ground where the building will be implemented ❋ Ask trainees to relate the topic to some existing and real case (high mountain versus valley) Nature of material and their specific quality and weaknesses. ❋ Compression ❋ Traction ❋ Ductility ❋ Mode of rupture Various structure ❋ Passive ❋ The choice of absorption ❋ The choice of resistance Quality of workmanship. ❋ Quality / Skills / Training ❋ Quality control ❋ Capacity or not of technical choice to accept poor workmanship.	Demonstration: Model to illustrate the movement of a building according to its frequency (wire loaded on a plank) Trainer guide:	

Planning
J- 5 weeks
Lecture
After lecture

Earthquake resistance depends directly on the four following factors:



The aim of building design in earthquake prone areas is to save human life.

We can see 3 main different approaches about earthquake resistant design in history:

the rigidity approach: building ever more rigid structures capable of withstanding horizontal and torsional forces,

the flexibility approach, protecting a building against the effects of earthquakes by allowing its structure to deform, and dissipate energy

the passive approach, leaving the building collapse, but with minimum problems for the inhabitants, and making the buildings as easy and fast to rebuild as possible.

This guide is providing design and building technics aiming to obtain buildings that will preserve as many lives as possible, leaving maximum time for the people living in to come out before an eventual collapse.

LESSON PLAN

The local seismic cultures (LSC)

0-11

Session duration: 20mn

Objectives: Enlighten the capacities of local engineering to develop adequate answer to their own needs. Help people to believe on their potential; to be proud of their own culture. Make people open to understand the existing and learn from it.

Method: Help people to rediscover their own local seismic culture

Trainer team	**Session**	**Pedagogical support :**	**Tools** :
Lecture One trainer for 20 trainees.	Preparatory work : ❋ Identified the existing LSC in the area ❋ Document it ❋ Find similar example existing in other part of the world Lecture: ❋ Definition ❋ Conditions required for their development ❋ Ask the trainees to identified the LSC they know; how do they learn from it. ❋ Synthesis of the existing LSC ○ Principle of LSC in Bagh area. ❋ Potential interest in the reconstruction programme ○ Existing local culture ○ Existing knowledge ○ Existing material ❋ Risk and limitation ○ Availability of material (sustainability) ○ Acceptability by the inhabitant ○ People expectation Note: At the end of this lecture, it is very scarce to have a lot of identified LSC. But this lecture open people mind and feed back from the trainees come latter during the following sessions.	Demonstration: Trainer guide:	

Planning
J- 5 weeks
Lecture
After lecture

"Before the modern movement toward systematization started, the only way in which a local community could protect itself from natural disasters was to draw on its experience and, in particular, to build upon previous failures. Ineffectual techniques were abandoned, while those which proved to be effective were handed down from generation to generation and were further improved following each earthquake.

No wonder, therefore, that in earthquake prone regions all over the world (and only there) the techniques adopted to build monuments were extremely sophisticated and provided effective protection against horizontal stress.

No wonder, also, that the rules governing anti-seismic building in earthquake regions everywhere are fairly similar despite the use of different materials and different local techniques.

No wonder, lastly, that these areas, especially poorer ones, continue to employ techniques used in villages nearly 4,500 years ago.

Ancient buildings have been able to withstand earthquakes thanks to specific anti-seismic techniques used to construct them. A rich body of literature even provides evidence that traditional anti-seismic techniques dating back thousands of years (Shiping Hu, 1991; Touliatos, 1992) have survived to this day with few changes and have generated widespread standard practices and mechanical models clearly recognizable today (Giuffrè, 1993). There is enough evidence to conclude that real ***Local Seismic Cultures*** *are firmly established in earthquake regions with technical, cultural as well as social and economic implications making them extremely current."*

Ferruccio Ferrigni in *ANCIENT BUILDINGS AND EARTHQUAKES Reducing the vulnerability of historical built-up environment by recovering the Local Seismic Culture: principles, methods, potentialities , 2005 - Edipuglia , p.298 and 299*

The modernist approach has always had the tendency to make us believe that the human being can free himself of his natural environment and the formal education system has often blindly promoted foreign models in a very detrimental way to the local ones. It has also extracted from communities their best individuals, those who would probably have been the ones who could have invented new solutions, adapted to the new situation. In these conditions, traditional models have often been depreciated and the know-how attached to it partly lost. New initiatives, even if ingenious, remain often poorly adapted, from the social, technical, cultural or environmental points of view. This evolution is peculiarly clear when looking at the evolution of human settlements and architectural models.

This project is an initiative to respond to these problems. The hypothesis is that traditional architecture can be a basis on which one can develop a new local architecture that addresses contemporary expectations and needs of the population but also better respects the realities of the environment and therefore contributes to the establishment of a sustainable development process".

The project implementation methodology has benefited from CRATerre experience over 25 years of existence.
The proposed iterative method is based on the successive implementation of the four following activities.

- Study and analyze of the building sector and its environment
- Design of relevant action and strategies to be implemented
- Implementation of activities
- Evaluation and analyze of results obtained to be able to design following activities
- Etc.

This cycle is repeated as often as it is necessary to allow a permanent improvement of technical proposal given to beneficiaries as well as to permit projects partners to build their own competencies progressively up to handle all projects activities on their own.

We could call this approach the elastic domain approach

In this approach, the way to ensure the resistance of the building is to increase the resistance of the elements. The structure is designed to resist and stay in its elastic domain.

The energy is stocked and given back during the oscillations. The only way for it to dissipate energy is through internal damping of the structural elements, and eventually through breakage of elements which could lead to destruction of the building.

One of the important points in this type of design is the necessary homogen rigidity of the structure. This point is generally assessed through maximum rigidity of every element and of every link between the different elements.

This is the most common “engineered” way of designing buildings. One of its advantages is that the behavior of building materials in the elastic domain is easily predictable and models are accurate. It is therefore suitable for calculation, codes and regulations.

On the other hands, the know-how and materials necessary to reach the quality necessary to ensure the seismic resistance are of high standards and may not be available in every context.

In this approach, the main source of protection is the dissipation of energy mainly through post-elastic or plastic response of structural elements.

The “modern engineering” way of doing this is by using damping apparatus (through plastic deformation or friction), breakable fuses or designing structure with high degree of hyperstatism with plastic nodes.

The vernacular way that we can find in many seismic cultures around the world is not so different in theory, but using mainly:

-**the friction between elements.** For example friction between wooden structure and stone masonry, between the parts of the wooden structure.

-**the post-elastic behavior of masonry structure.** For example fissuring and breakage of elements and friction at the interfaces between broken parts or between stones in dry masonry. The 12 years research program of the Getty Institute shows the importance of this phenomenon for earthquake resistance of adobe walls.

In this approach it is therefore important to keep the ability of the structure to deform, but ensuring their stability even after breakage or deformation of elements.

This type of phenomenon is very difficult to model and predict, as every structure has a different behavior. It is therefore difficult to use as standard. But the observation shows a lot of local seismic culture using this type of structure with good results.

The reader could learn more about this in:

Getty seismic adobe project, report of third year activities. Shaking table tests of large scale adobe structures */ W.S. Ginell, E.L. Tolles, P. Gavrilovic, L. Krestevska, V. Sendova, L. Taskov / Los Angeles: GCI, 2001*

Local seismic cultures and earthquake vulnerability reduction in traditional masonry buildings */ Proceedings of the 12th intensive course of the European university centre for cultural heritage, Ravello, Italy, December 11-17 2002*

WHAT YOU WILL FIND IN THIS GUIDE

Technical solutions that can be applied in the geographical, social, economic context of the village of Kafal Ghar in the Bagh district. They can be applied to the following materials: stone and wood




WHAT YOU WILL NOT FIND IN THIS GUIDE

Solutions that can be applied to any context and/or any constructive system.

LESSON PLAN

Effects on site

1-17

Session duration: 20mn

Objectives: To help the trainees to take into account the risk linked to the site

Method: Observation, Historical background.

Trainer team	**Preparatory work :**	**Pedagogical support :**	**Tools** :
Lecture One trainer for 20 trainees.	Identify evidence of site effect in the concerned area. If not, develop a database including picture of the various site effect described durring the lecture. Print these picture in A4 format. Expose the picture in the classroom as the trainees could have free access to these picture. Lecture: Ask the trainees to describe potential effect of an earthquake on the site stability. Complete with exhaustive list of potential effects Indicator of historical ground movement Indicator of recent movement Indicator of potential future movement Synthezise the information given by trainees. If possible organise a site visit or a case study to help the trainees to acquire physical experience of identification of potential risk.	Demonstration: Use picture of in situ situation Trainer guide:	

Planning
J- 5 weeks
Lecture
After lecture

Proper selection of the building site before construction is of major importance.

General considerations

The land should be preferably high and slightly sloppy in order to avoid the risks of stagnant water and the over-flow of the rain waters.

Made-up-grounds, water lodged areas are unsuitable for buildings. Greater care must be taken when dealing with such ground or soils.

Avoid constructing on a land with too many trees, where roots could affect the construction. It is advised not to construct within 15 feet away from a tree.

Seismic considerations

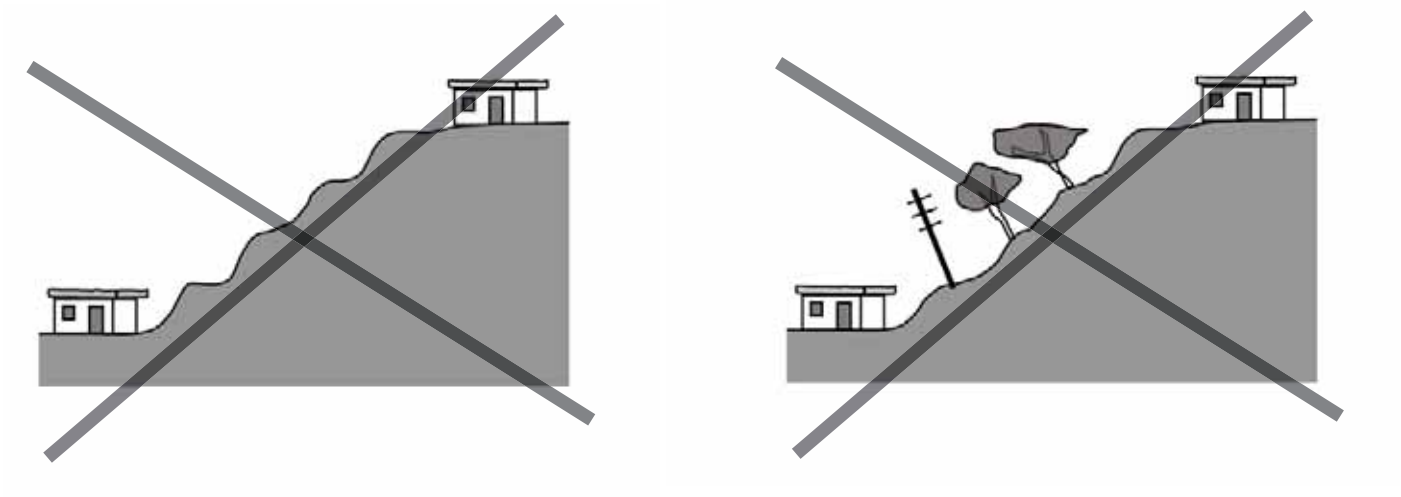
The land should not present signs of landslides possibilities, particularly for terrace building sites. Avoid the following lands:

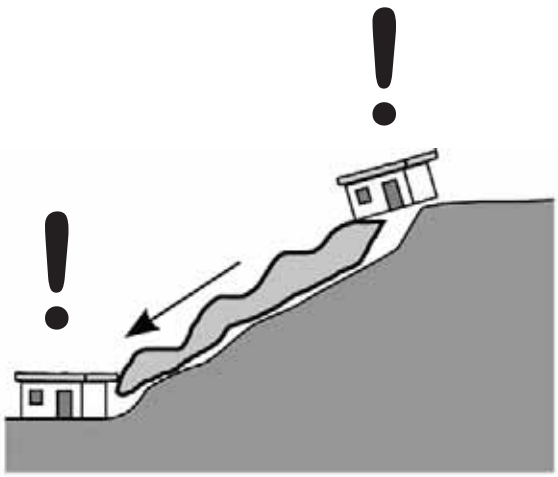
-under or on top of cliff presenting cracks,

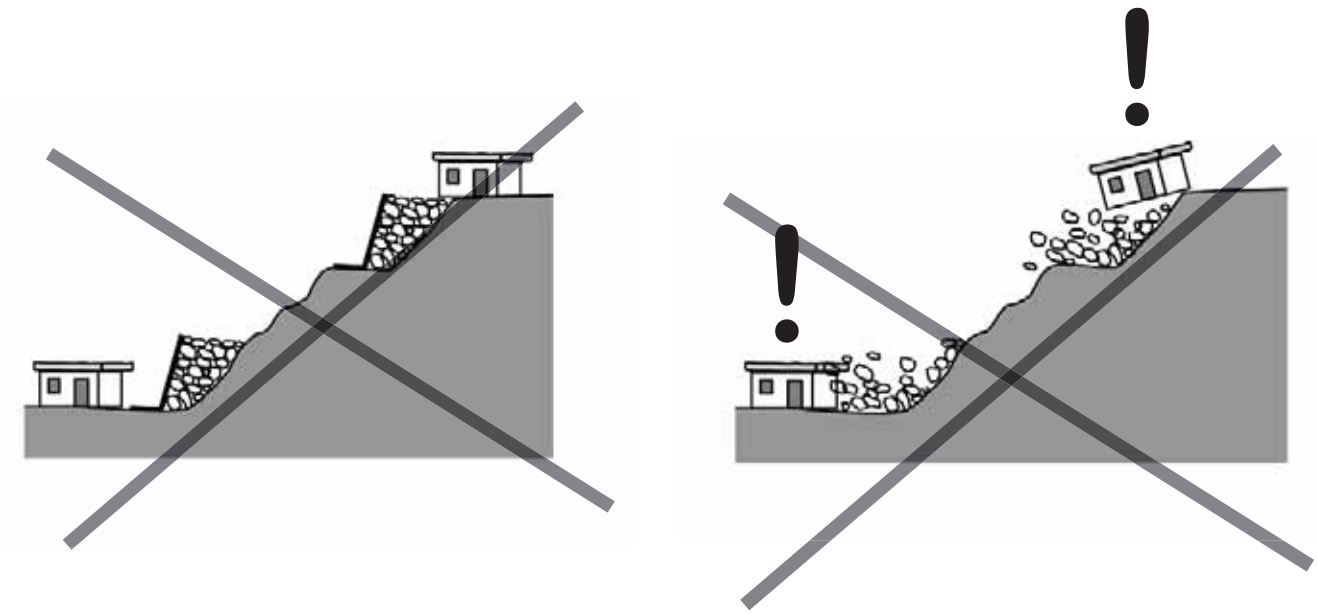
-close to retaining walls , and/or have suffered from the last earthquake,

-on slopes with old landslides, that can be revealed by the wave form of the soil,

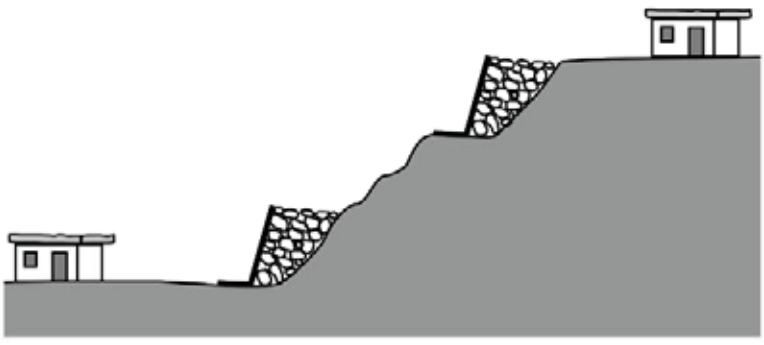
-on lands near trees or electric poles that are inclined.







GOOD LOCATION:



LESSON PLAN

BUILDING DESIGN

Structure and shapes

1-21

Participatory approach : time, 30 mn

Objectives: Understand how to reduce the strees in a building by adopting relevant shape and structure..

Method: Help trainees to indentify where the buildings will be the more affected in case of earthquake

Trainers	**Session**	**Pedagogical support :**	**Tools** :
One trainer for 7 trainees	To help the trainees to develop their own knowledge on how to reduce the risk of damage on the building by choseen adequate shape and design Part 1 ❋ Showing some example of design to the trainees, ask them which part of the building will be the most affected. ❋ Make the synthesis Part 2 ❋ Ask the trainees to compare differents quality, shape and design of walls or building and to give their impression on the best adapted to resist earthquake ❋ Make the synthesis Part 3 ❋ Relate the previous assessment to the local building culture Part 4 ❋ Synthesis of good practice	Trainer guide-line	

Planning
J- 5 weeks
Lecture
After lecture

Earthquake resistant forms

The form of the building is the first point to take care of in an earthquake resistant design. The form of the building has a strong influence on its response to the oscillations, particularly on the torsion importance.

The best form is a square plan, but we can give the following advises:

The building should be symmetrical in both direction to prevent torsion phenomenon.

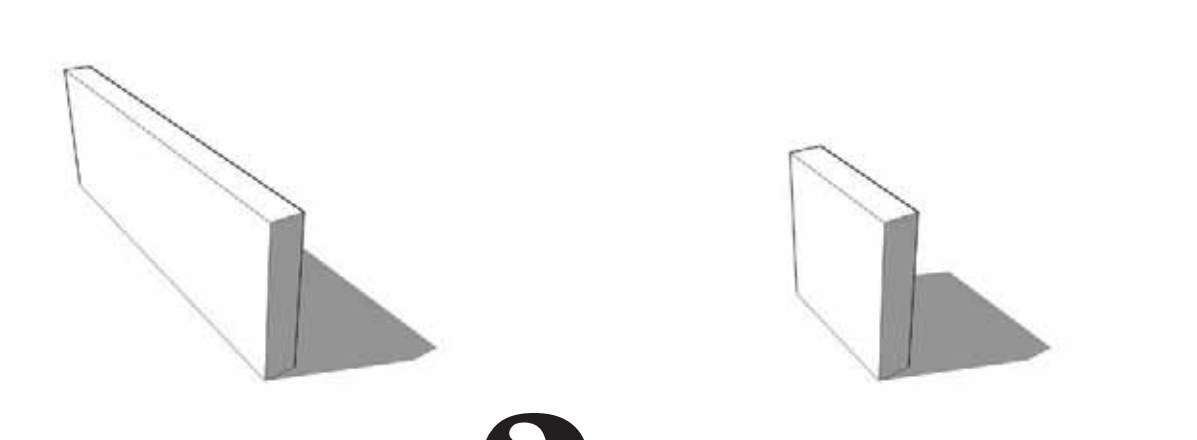
The ratio between length and width should be less than 3 to limit the torsion.

Inner angles should be avoided as they are the place of stress concentration. Therefore, difference of height in one building must be avoided.

If the upper points cannot be followed or if complicated forms are requested, the building should be divided in symmetrical separated parts.

Remark:
In case of a building designed with independant autostable elements, those rules may not be compulsary but still improve the general resistance of the building

Which of the following walls will be the most affected by an earthquake ?



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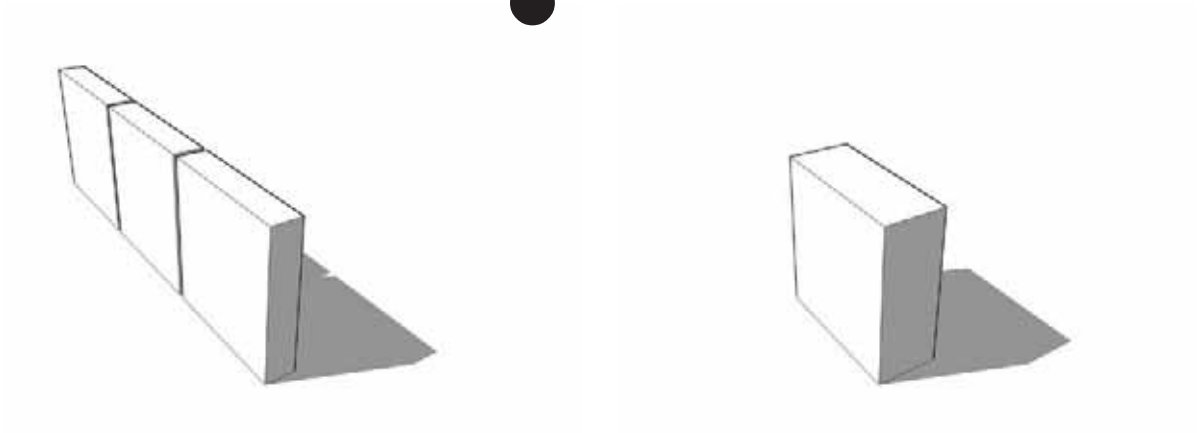

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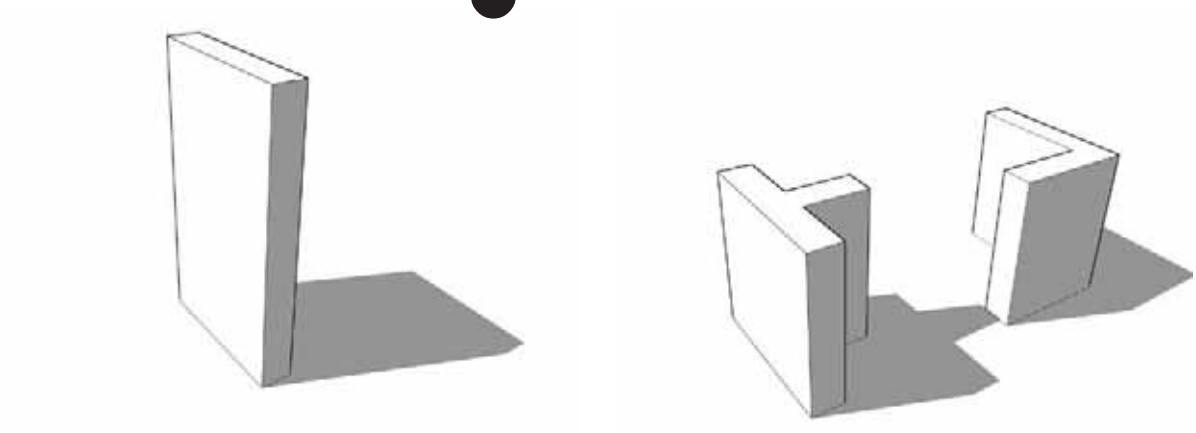

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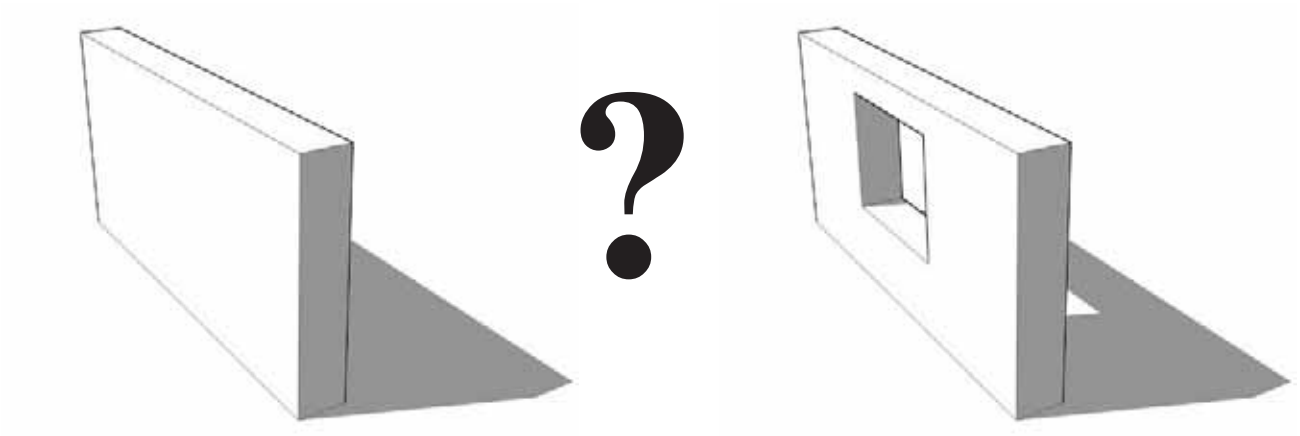
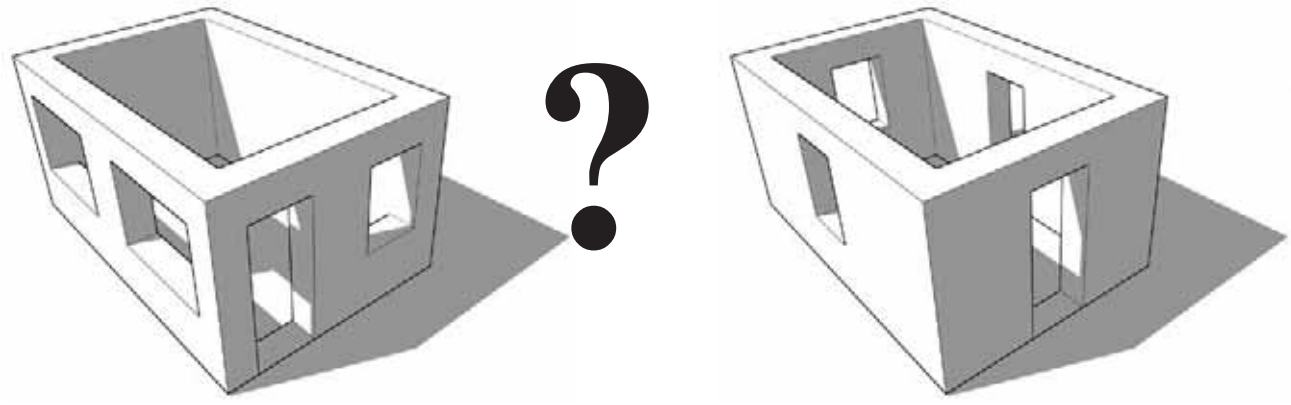
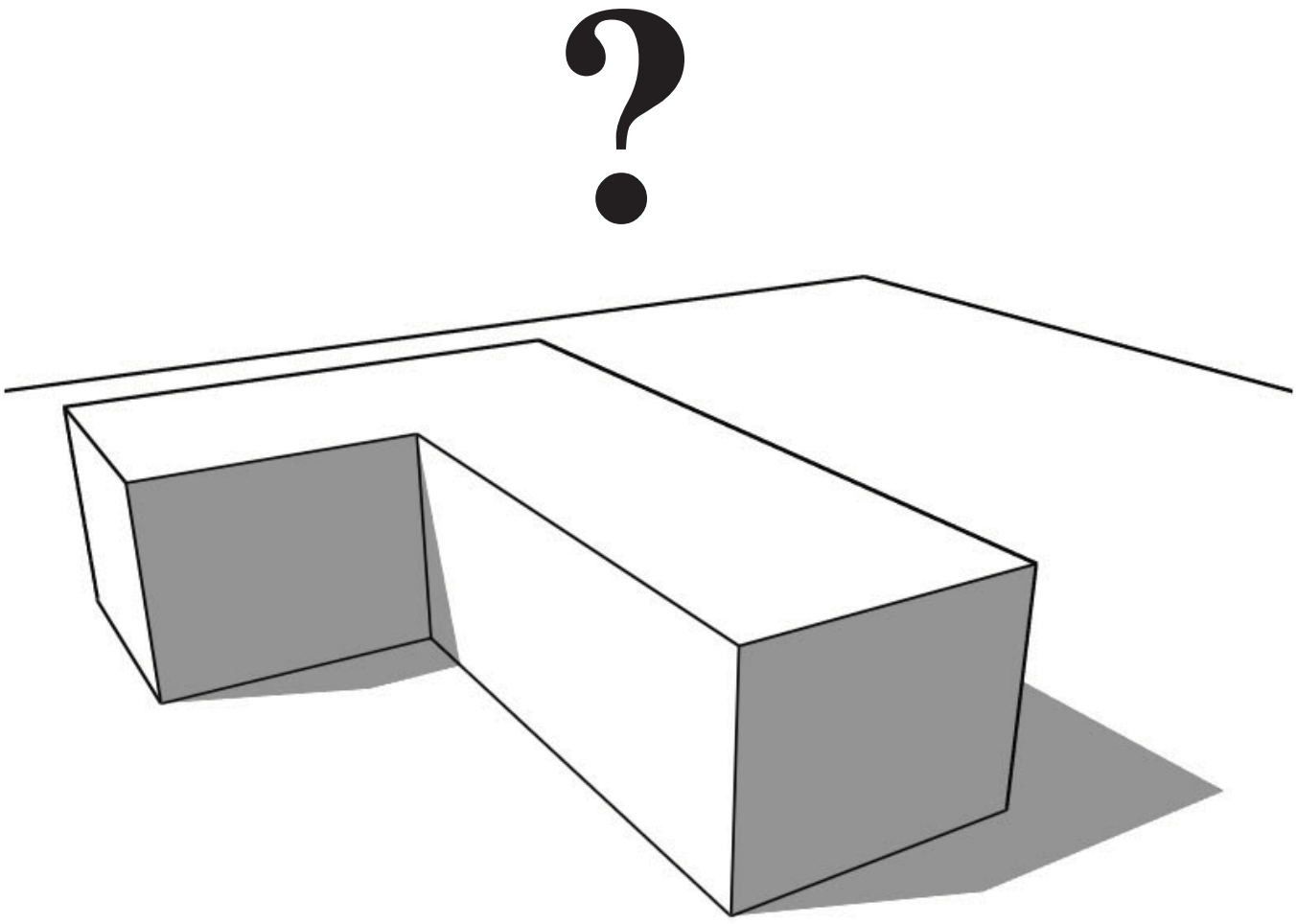
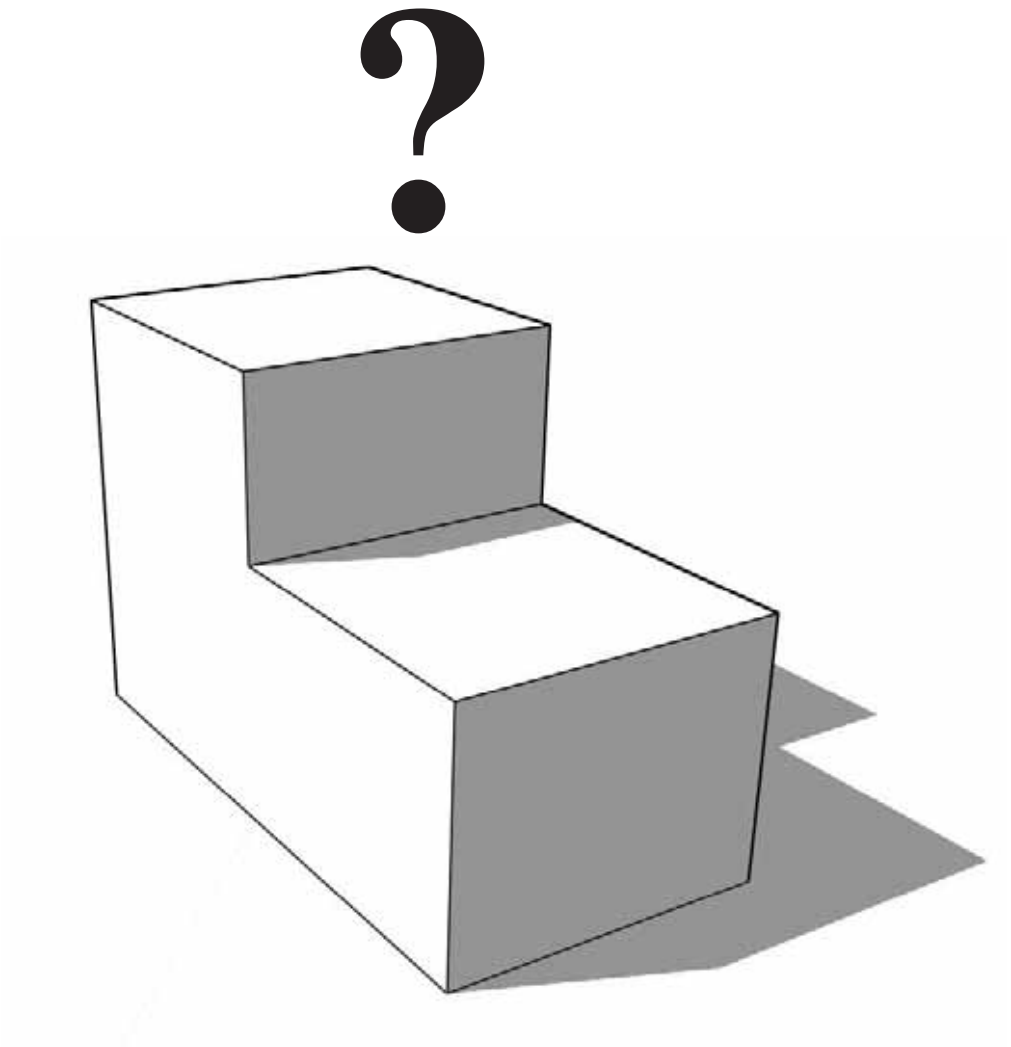




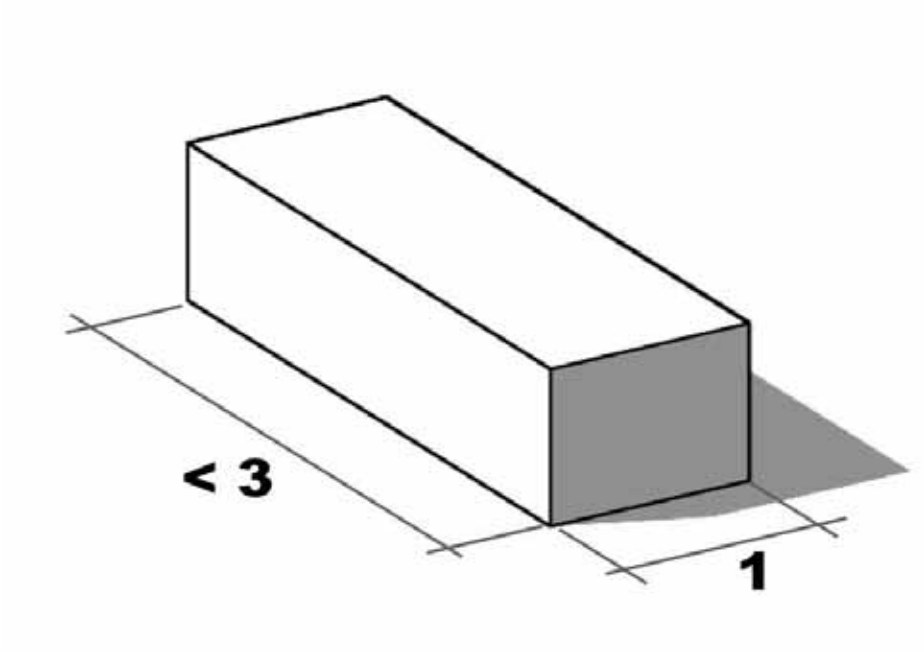
Which part of the building will be the most affected by an earthquake ?

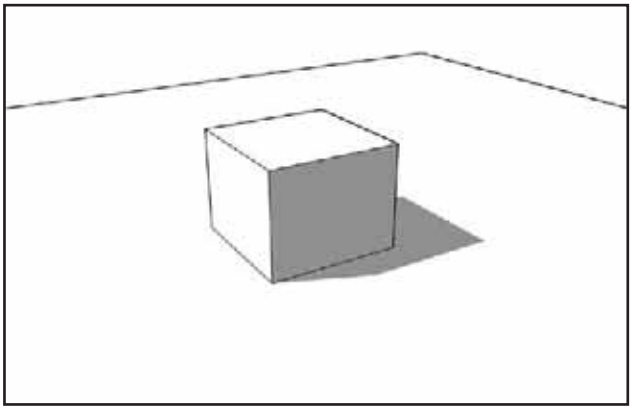


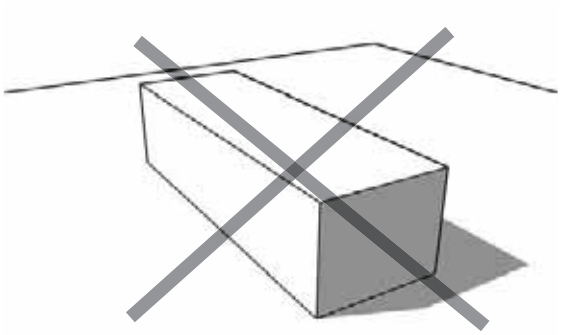
Which part of the building will be the most affected by an earthquake ?

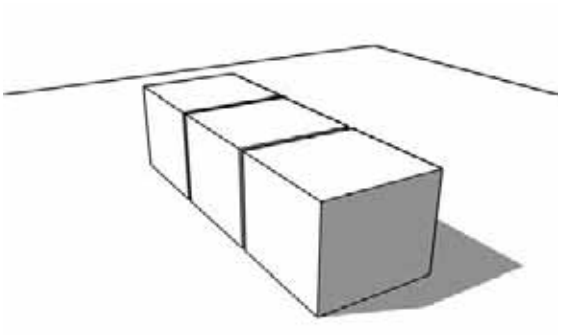


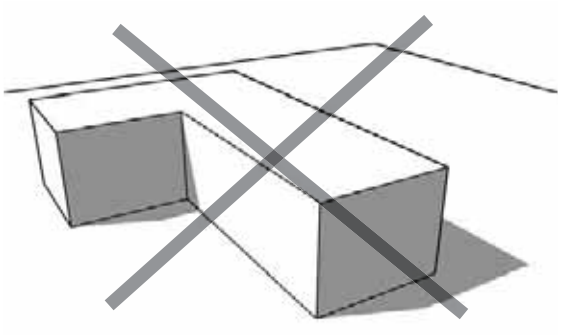
The ratio between length and width of the building should be less than 3

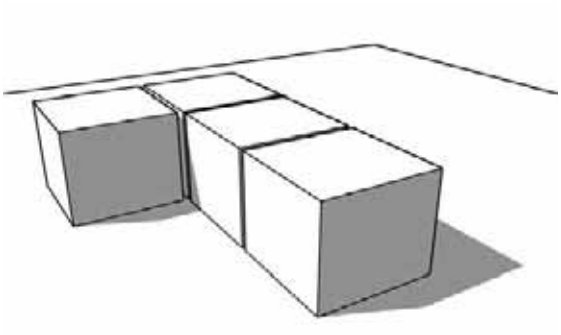


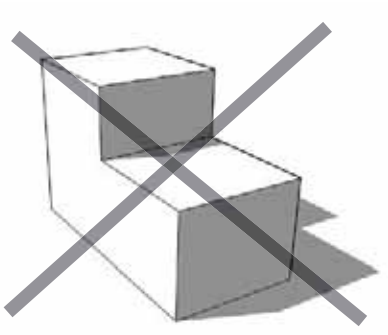


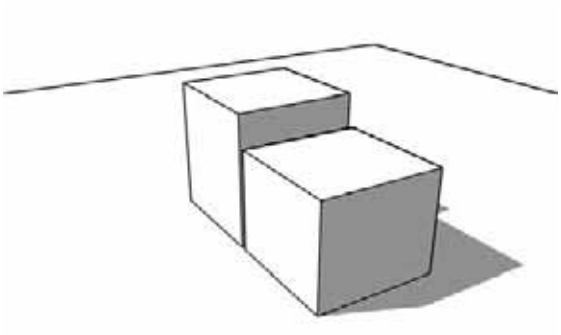










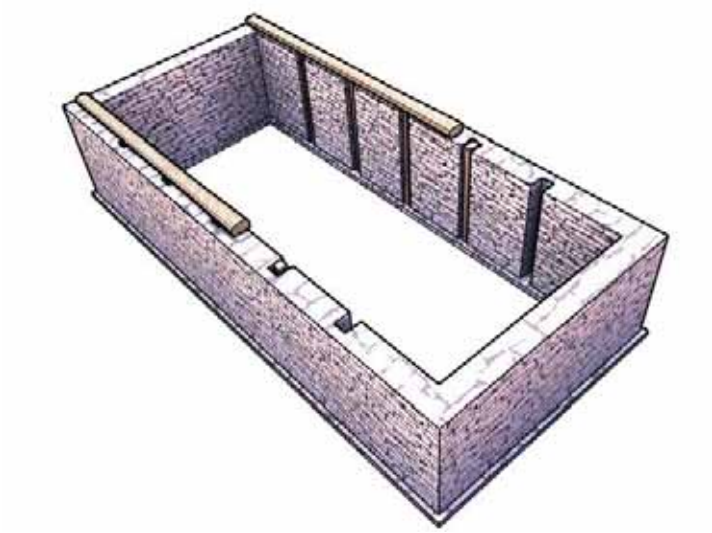


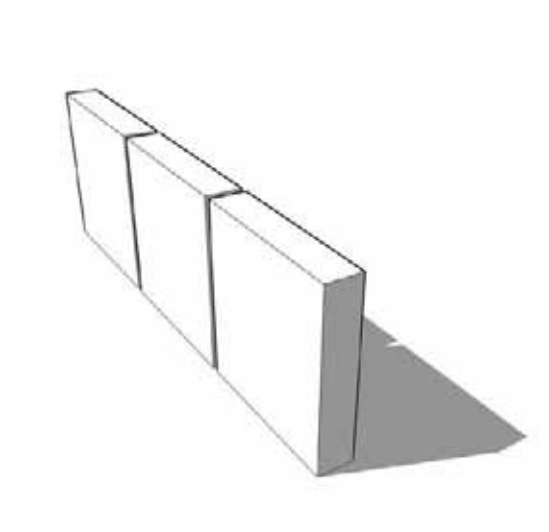
The traditionnal buildings in Kafal Ghar have good shape and forms regarding to earthquake resistance:

Their walls have limited height and length.

They are divided into smaller parts by the wooden posts.

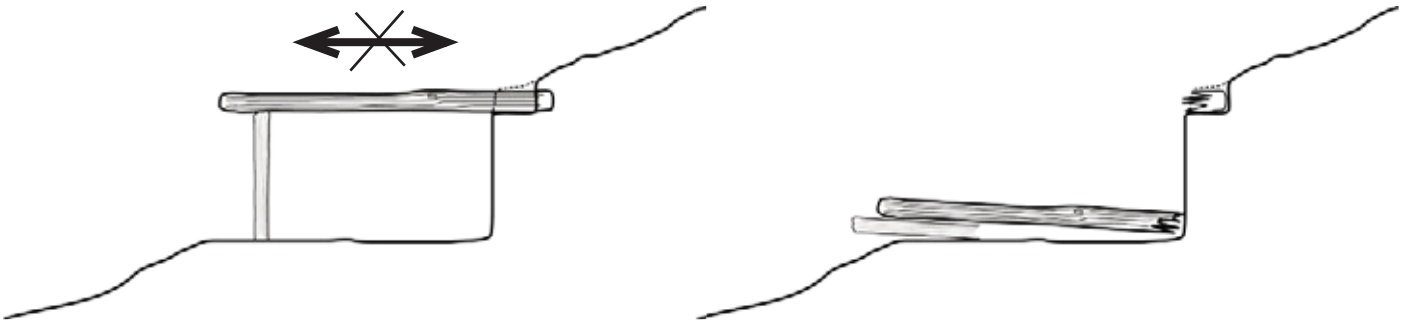
The general form is symmetrical.



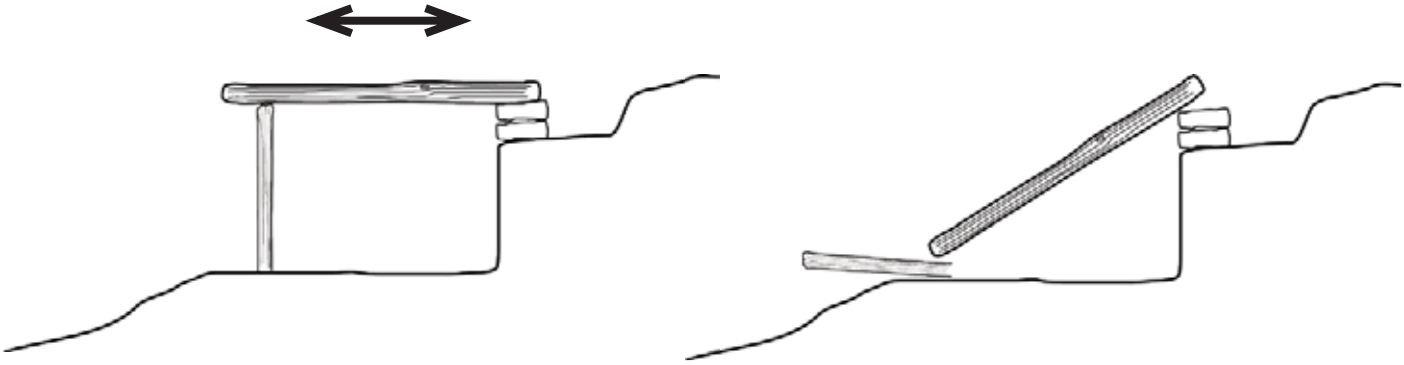


A common practice is to set the building right on the mountain, which is in fact the back wall of the house. This can be a good practice but must be done with care:

If the wood is fixed inside the mountain wall, it can rot because of the moisture, it prevents the sliding of the roof, and in case of excessive load, it can break .



It is recommended to put the beams on stones to prevent the moisture to affect it, allow sliding and therefore dissipation of energy, and in case of excessive load, the fall of the beam leaves safety space.



LESSON PLAN

THE BUILDING MATERIALS

1-31

Session duration: 15 mn

Objectives:
Help trainees to make the best use of the material recovered from the damaged buildings.

Method:
Analyse the characteristics of existing available material and discuss the best way to secure them and to use them back for reconstruction.

Trainer team	**Session**	**Pedagogical support** :	**Tools :**
Lecture One trainer for 20 partici-pant	Preparatory work : Organise a board where can be fixed the pedagogical material (plasticized paper) Organise the room or open site in order to help trainees to have free access to all the documentation fixed on the boards Organise chairs, booknote and pen for participant Translate necessary material in local language. Lecture: Introduction about the topic of the session. With the trainees, identified available local material that could be use for recon-struction purpose. List their characteristics and accordingly, the way to optimise their use for recon-struction (potential use, sizing, sharing out etc.). Give recommendation on storage and then selection of recyclabe material. Give recommendation on how to take care of “modern material “ that may be newly used in high quantities in the reconstruction process.	Trainer guideline	

Planning

Before the session:

Lecture

After lecture

In a building, the different elements are submitted to different kind of stresses, and have to fulfill different kind of functions. The different materials that can be used for a building are more or less fitted to answer correctly to each kind of stress and function.
In this guide will be presented only the materials locally available in the village of Kafal Ghar in the Bagh District, at a reasonable cost, and the way they are used to be transformed and combined to build homes. Some other technics exist with those materials, but as they are not part of the local culture, their use is much more difficult and may result in a lot of problems, technically or culturally.

The stone

It has a very good behaviour under compressive stress. It is difficult to produce but widely available. It is very heavy and therefore difficult to carry on long distances.
It is best used for walls and sometime for paving.
Elements of stone masonry have a high compressive strength and a very low tensile strength.

The wood

It has a very good strength both under traction and flexion. Its strength/weight ratio is very good. It is easy to work with. Its use must be well planified has its availabality may be reduced in case of intensive use. It is very sensitive to water and moisture problems, therefore its use near the ground must be done with great care.
It is best used for lintels, roofing and openings.

The earth

It is not used in this region to build walls themself. It has a good compressive strength and a very low tensile strength. It is available in small quantities and easy to use. It needs a lot of water to be used, and water can be scarce in some parts of the year. It is sensitive to water and therefore should be used with care. Its water resistance and strength can be improved in some extent by mixing it with additives, like pine straw or bitumen.
It is best used for plaster on walls and roof, and for mortar in some cases.

Re-use of remaining stones of destroyed buildings

The stones from destroyed buildings must be cleaned or at least brushed so that they don't present any trace of plaster or mortar. They must not present cracks.

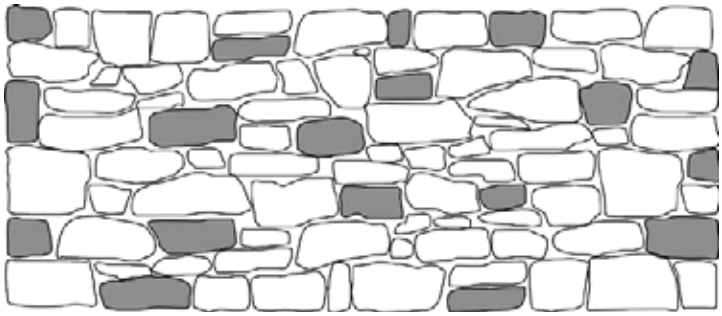
How to organize the storage of stones

The stones to be used in masonry work must be organized on the building site by size and form, as their use will change in function of their sizes and forms, and by height to be able to have regular layers of masonry.

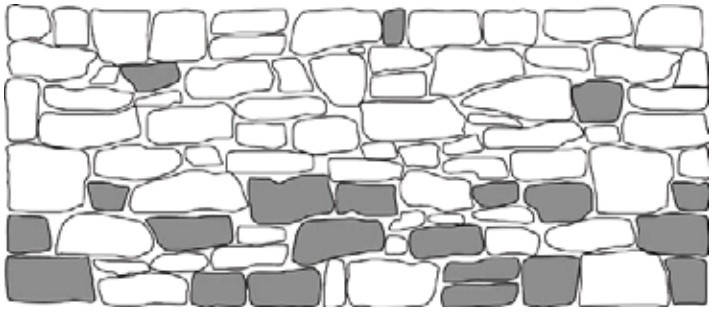
The largest and most regular stones will be used for foundations and the base of the wall, as they will support more weight, and to prevent lifting too heavy stones. They will be used for the corners too, as it is a weak point of the building.

Long and thin stones will be used as through stones or bond.

It is important to know at the beginning of the work the availability of the different types of stones in order to have the best distribution of the stones on the whole building.



Good distribution of the through stones in the wall.



Bad distribution of the stones in the wall: all the through stones have been used at the beginning, resulting in a weak top of the wall

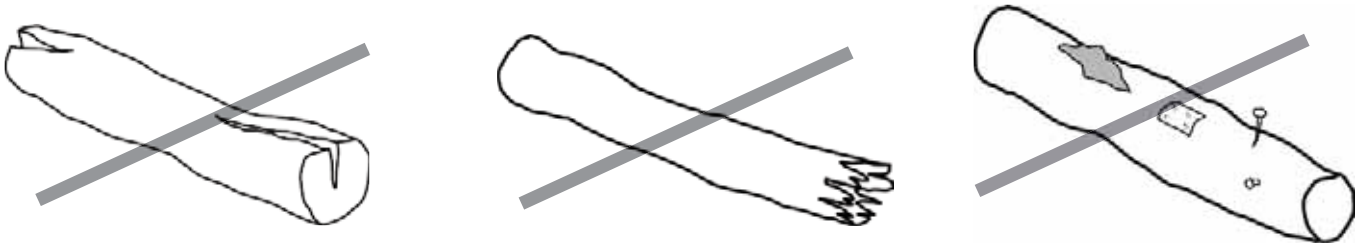
The different pieces of wood

A wood trunk can be divided with a band-saw into more convenient pieces of wood. The center part of the trunk is the best one and should be use for pieces that need a higher resistance, like beams, while the outer part should be used for planks.

It is better to take older (and therefore bigger) trees and cut it into smaller beams than to use young trees with small diameter. If possible, let the wood dry before cutting it.

Use of recycled wood

Wood from destroyed buildings can be re-used but with great care. The pieces should not be rotten nor present cracks.
If old wooden parts are to be cut with the band-saw, all the dust, mud and nails should be removed from it to preserve blade sharpness.

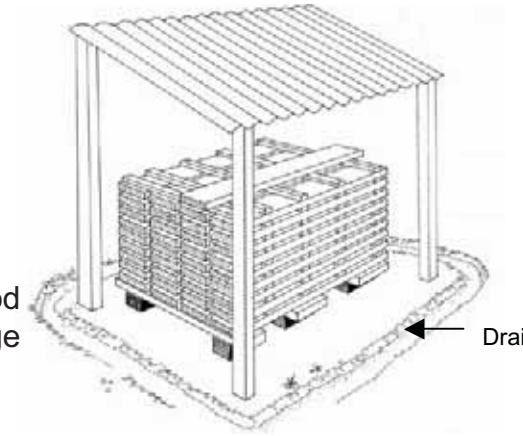


Availability of wood

The available quantity of wood is definite. The deforestation can be a serious problem not only for the building sector. The use of wood should be rationalized to prevent the waste. The cut of trees should be planned to prevent shortage of this resource.

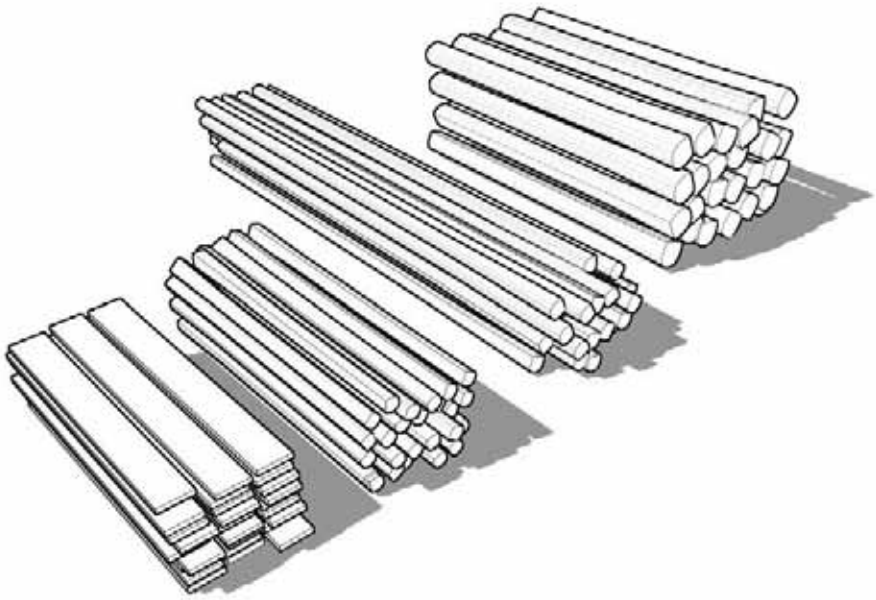
Stocking of the wood

Wood should never be stocked right on the ground, to prevent it to rot.
It should be stacked on stones in a ventilated space protected from the rain.
The different pieces should be vertically separated by small wood pieces to improve the drying.



It is important to know the availability of the different pieces of wood at the beginning of the building process to plan the use of it.

It is therefore recommended to organize the storage of the wood parts according to their sizes and shapes.



It has been observed on site that a high level of skill and know-how is spread about earth use as a plaster and for roofing.

We can notice the differentiation between different technics and practice for the plasters:

-outside plaster,
-inside plaster
-finishing plaster

A study of the local practises will allow a better understanding of the possible uses of the local earths. Those study will be necessary on several points of view, technical, economical, social and cultural.

Once the information collected and analyzed it will be possible to study proposals for improvements based on the local practices.

We can notice among others practices the use of pine straw to reinforce the plasters.

During the urgency reconstruction process, some temporary shelters have been built.

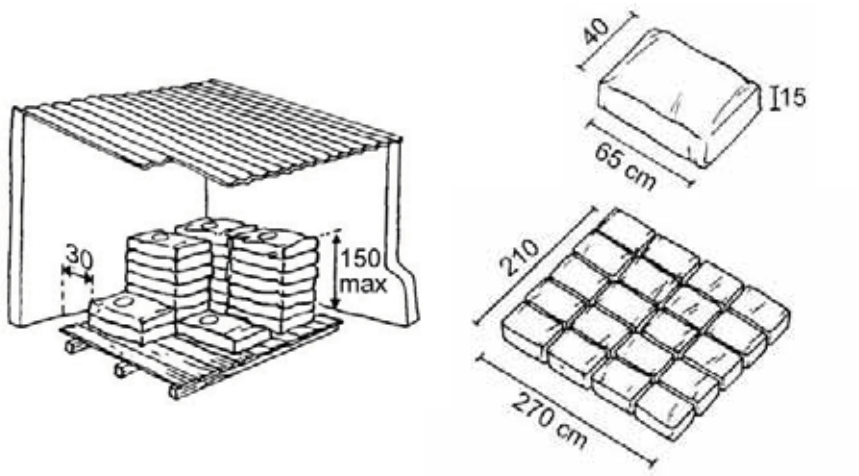
This urgency reconstruction brought a large quantity of material, that should not be neglected for reconstructing the houses. Among them we have:

-galvanized metal sheets
-corrugated iron
-wood in small sections
-plastic sheets

The metal sheets and corrugated iron, in spite of their stainless quality, should be stored away from moisture to allow the longest time of conservation.

Cement and lime

Cement and lime may be available. Both of them can be used to improve the resistance of the earth plasters and mortar to water and their compressive strength. They can be used for example to make floor slabs.



- **CEMENT :**

The bags are kept in a locked place. They are insulated from floor and at a distance from walls to protect them from moisture.

Shake the bags every 3 weeks. Especially during rainy season.

Bitumen

Bitumen is used in Kafal Ghar region to improve the quality of the earth floor slabs.
A study of the local practices will allow a better understanding of the possible uses of the bitumen for improvement of earth plasters, particularly their waterproofing efficiency.

LESSON PLAN

LOCAL SEISMIC CULTURE
General description

1-39

Session duration: 20mn

Objectives: Assess the existing identified LSC.

Method: Analyse the local LSC in relation with the knowledge acquired by trainees during the previous lecture.

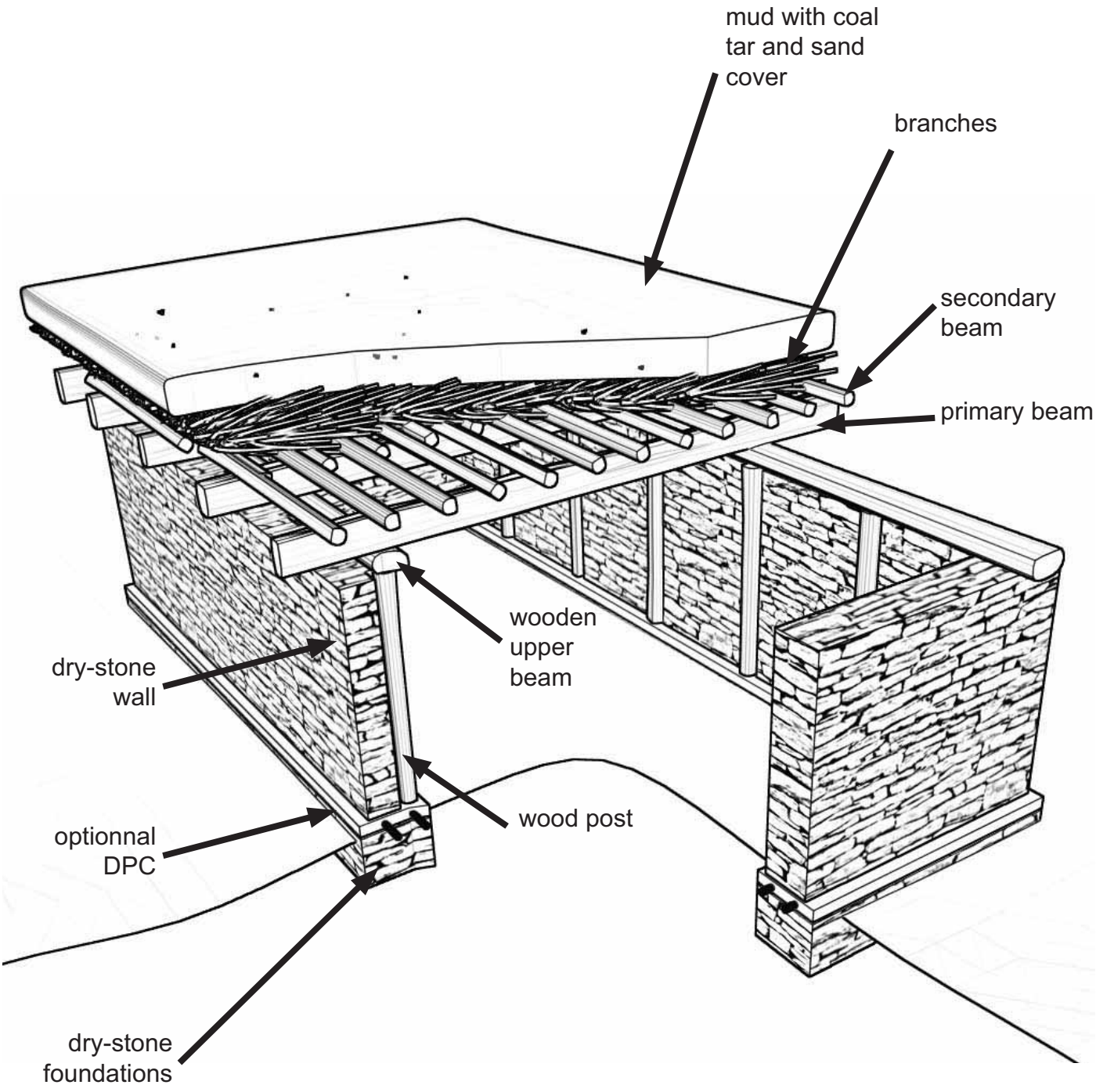
Trainer team	**Session**	**Pedagogical support :**	**Tools** :
Lecture One trainer for 20 trainees.	Preparatory work : ❋ Identified the existing LSC in the area ❋ Document it ❋ Find similar example existing in other part of the world Lecture: ❋ Describe the general structure of vernicular architecture (stone, wood structure, flat roof). ❋ Give back to the trainees the basics principle of the sismic culture developed locally.	Demonstration: Trainer guide:	

Planning

J- 5 weeks

Lecture

After lecture


mud with coal tar and sand cover
branches
secondary beam
primary beam
wooden upper beam
dry-stone wall
wood post
optionnal DPC
dry-stone foundations

Some of the houses in Kafal Ghar resisted the earthquake. Here are the features we find in all of them that ensured their resistance:

Small and regular shapes:

The houses are symmetrical.
The wall height is less than 2.5m.
The openings are small and not close to the corners.

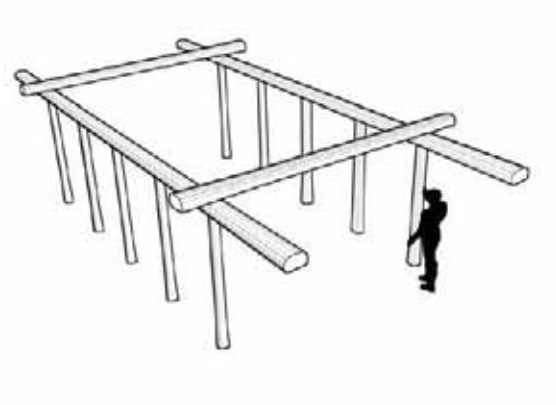
Good quality dry stone masonry:

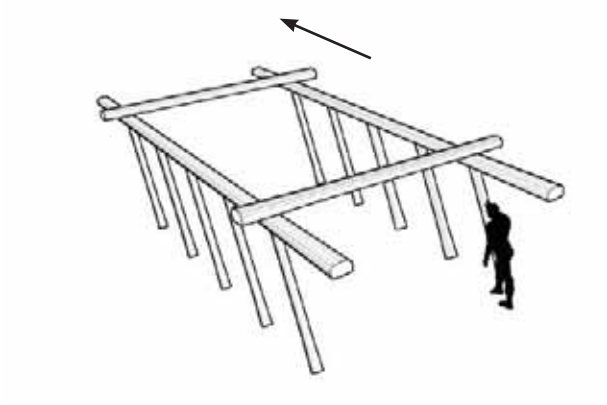
The skill in dry stone masonry is high, ensuring a good resistance of the walls.

Wooden posts that support the roof:

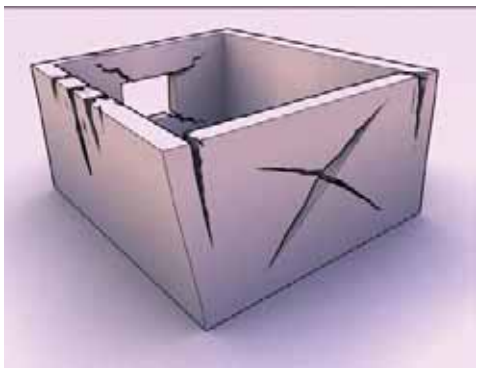
The wooden posts are included in the masonry. They are supporting beams on which the roof is resting.

The wooden structure alone has some weakness against seismic loads because it is not braced. Therefore, it can not stand lateral load which occurs during earthquakes.

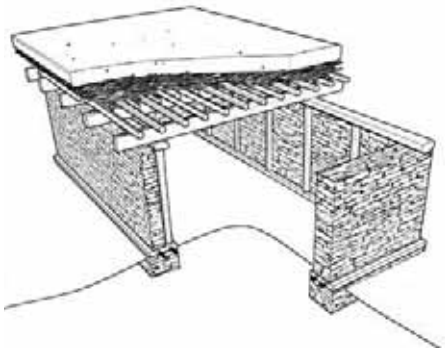




The dry stone wall alone has some weakness against seismic loads because of its lack of tensile strength and because the lack of confinement may allow some stones to fall apart which can dramatically reduce the wall stability.



In the local seismic culture the stone wall is confined by the wooden structure and the wooden structure is braced by the stone walls.
The two structures complete themselves to reach better earthquake resistance.
The wall is divided by the wooden posts so that the fall of one part of the wall doesn't affect the rest of the wall.



LESSON PLAN

FOUNDATIONS

2-43

Session duration: 60 mn theorie; 1 day practice

Objectives: Understand role, behaviour in static conditions and in dynamic condition (case of earthquake) this in order to help trainees to make conscious decisions when they will be on the job.

Method: Assess the trainees understanding in the related subject
Debate on information collected

Practice in the field (on the real building or on demonstration sample)

Trainer team	**Preparatory work :**	**Pedagogical support :**	**Tools :**
One trainer for 7 trainees on theorie One trainer for three group of 7 trainees on practice	❋ Identify construction opportunity or site for sample demonstration ❋ Clear the site and make preliminary work if necessary. ❋ Supply necessary material and tools for on site training. Size to be related to the number of trainees **Session**: Part 1; normal conditions ❋ Ask trainees to describe the role of the foundation in the common situation ❋ Ask the trainees to list the different quality the foundation itself and the material used to do it should have ❋ Make the synthesis ○ Transfer the load from the structure to the good soil ⊙ In contact with the good soil (stable and with enough compressive strengh) ⊙ Compression resistance ⊙ Good practice in masonry ⊙ Stability ○ Water resistant Part 2; Behaviour in seismic conditions ❋ How the ground movement are transferred to the top structure. ❋ Rigidity approach: consequence on the superstructure ❋ Flexibility approach: ○ How to reduce the energy transferred from the soil to the super-structure. ○ How to secure the stability of the foundation component or to prevent foundation partial collapse to affect the entire superstructure Part 3; step by step of the good practice of dry stone massonry Part 4; Practice on site	Demonstration: Trainees guide:	Massonry tools

Planning
J- 5 weeks
Lecture
After lecture

Definition
The foundation is the part of a construction below the ground level.

Function generals
The foundations permit equal distribution of the weight of walls and roof into the ground. They should be strong, resistant to compression, and should ensure total wall stability. Foundations should limit the moisture and capillarity problems.
To achieve this function, they should be constructed on hard and good soil and designed in order to make the material used for building them, resistant and durable, this regarding particularly the risk of water and moisture penetration in these materials.

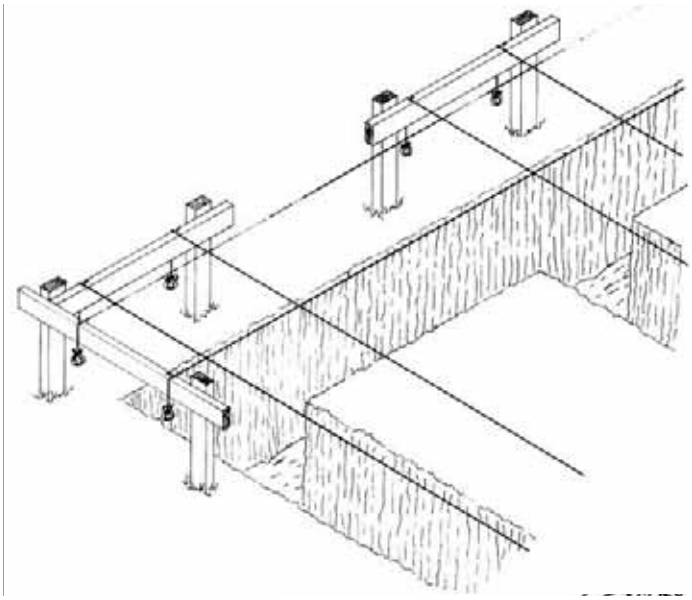
Seismic behavior
The foundation quality is particularly important in earthquake prone areas, as the foundation is the link between the ground and the structure. During an earthquake, the foundation transmit to the structure not only vertical load but horizontal load too.

In the flexibility approach, the foundations are able to deform like the rest of the structure. It can absorb some energy by friction. The flexibility should prevent the differential displacement to reach the whole structure, like in the picture below from Turquy.

IN A FLEXIBLE APPROACH, A BREAKAGE OF THE FOUNDATIONS DOESN'T MEAN A FAILURE OF THE BUILDING.

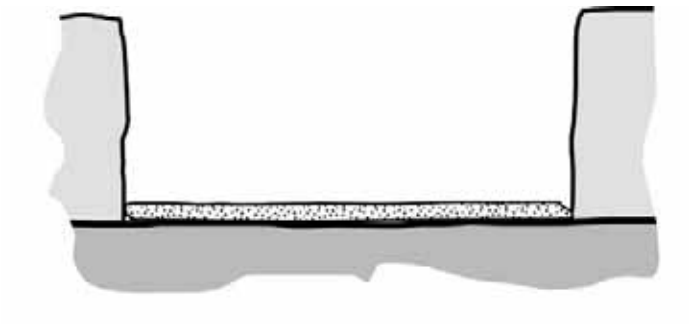
Function:
The trench is necessary to reach the firm stone soil. It serves as a form work to cast the foundation.

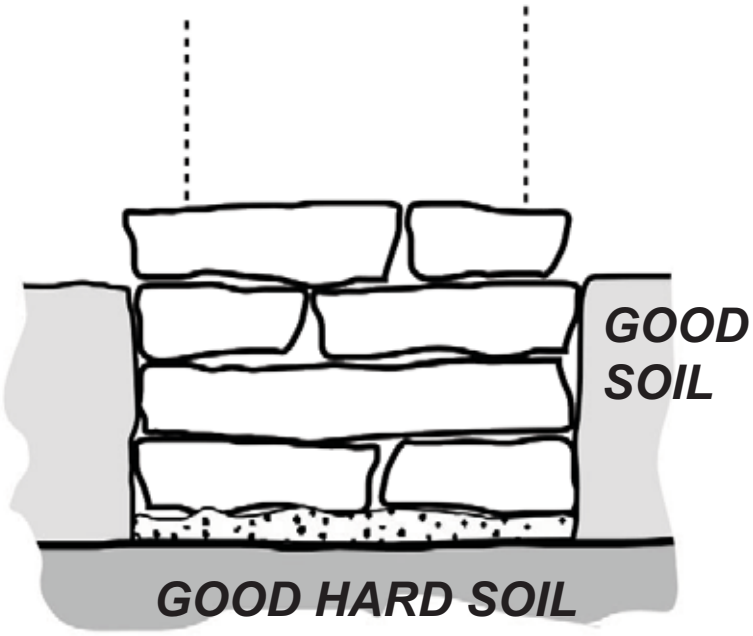
It is essential to dig the trench neatly, following the alignment with the line.
In case there is no need to dig to reach the stone, the place for the foundation must be very clean.



Function:
The sand layer allows the foundations stones to rest firmly on the hard ground and to distribute uniformly the load.

The thickness of the sand layer must be between 2” and 4”.





Apply stones in horizontal layers and ensure level of each layer by checking the distance from the line.

Use the best stones, the biggest, flattest and most regular in height possible. Use the most through stones possible. The best would be one over four in each layer, but one must do his best with the material he can find.

Bring the foundation at least 4” above ground level
The foundation should be at least 2” larger on each side than the wall.

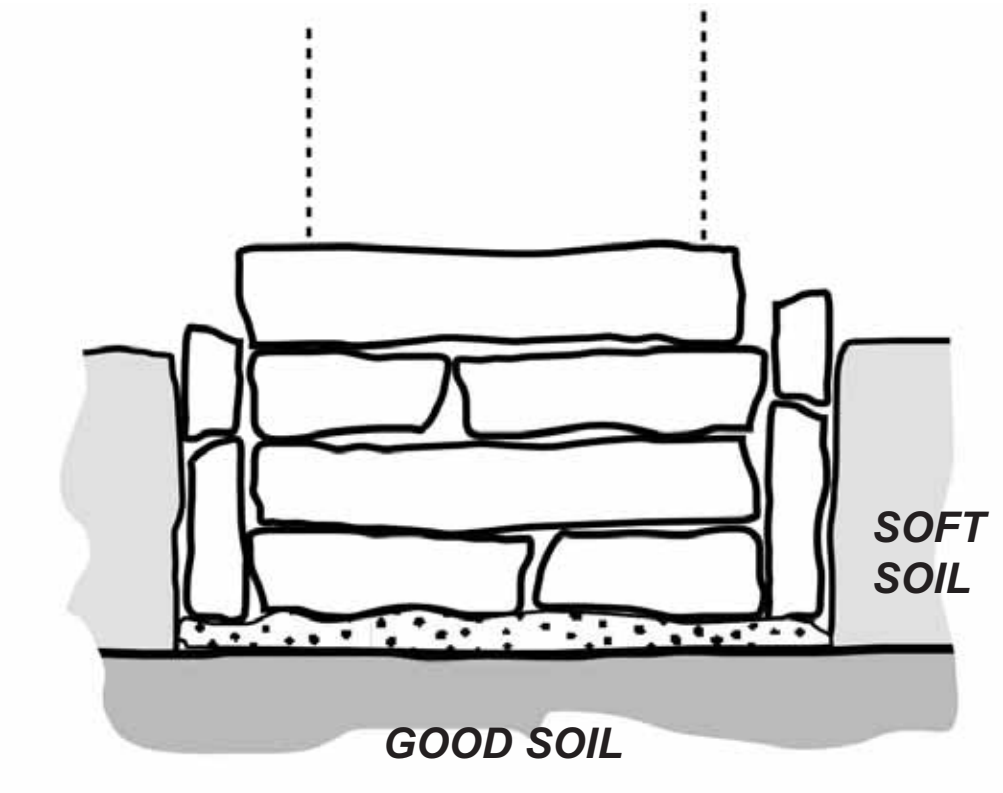
Stability:	**Friction:**	**Maintenance:**
The foundation ensure the stability of the wall by distributing the load evenly on the firm ground.	The dry stone foundation allow some dissipation of energy through friction.	The foundation larger than the wall allow an easier maintenance of the plasters.

To help stone in the fondation to be properly confined within the trench, some flat stone can be used to face the vertival side of the trench.

Stability: The foundation ensure the stability of the wall by distributing the load evenly on the firm ground. The vertical stones ensure the foundations stones to remain in place and not penetrate in the ground	**Friction:** The dry stone foundation allow some dissipation of energy through friction. The surface of the vertical stones allow additive friction.	**Maintenance:** The foundation larger than the wall allow an easier maintenance of the plasters.

A particular care will be taken concerning the interface between the foundations and the wall. A partial breakage or collapse of the foundation should not make the wall collapse.

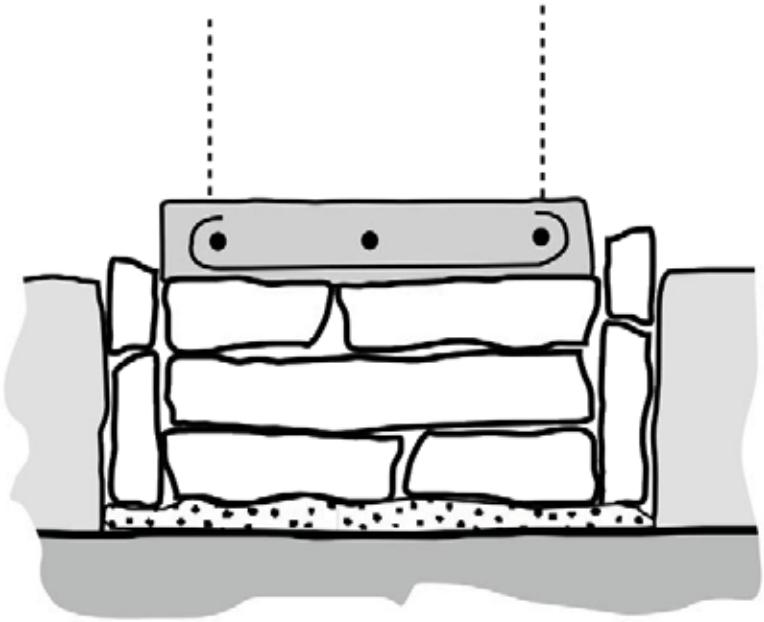
One can finish the foundations with a layer of the biggest and flattest stones possible.



Stability:	**Friction:**
The flat stones allow a good start of the walls with well aligned first layer, and a good distribution of the load on the foundations.	The wall is partly disconnected from the foundations and the flat surfaces allow a better dissipation of energy through friction.

A particular care will be taken concerning the interface between the foundations and the wall. A partial breakage or collapse of the foundation should not make the wall collapse.

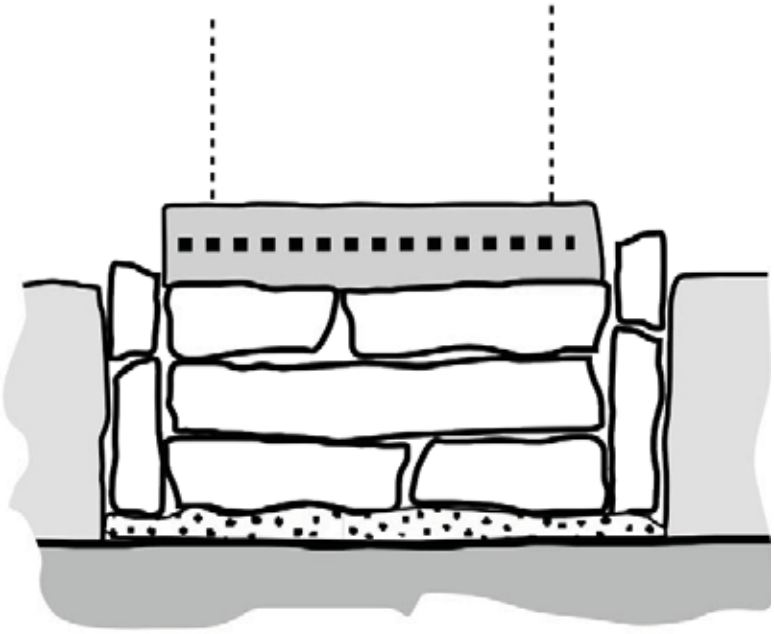
Finish the foundations with a layer of mortar. This layer must be perfectly horizontal and is let to set before building the wall.
The mortar can be reinforced with steel bars in a similar way as the DPC (damp proof course).



Stability:	**Friction:**
The mortar layer allow a good start of the walls with well aligned first layer, and a good distribution of the load on the foundations. It prevents a partial collapse of the foundations to affect the walls.	The wall is partly disconnected from the foundations and the flat surfaces allow a better dissipation of energy through friction. The mortar can dissipate some energy through breakage.

A particular care will be taken concerning the interface between the foundations and the wall. A partial breakage or collapse of the foundation should not make the wall collapse.

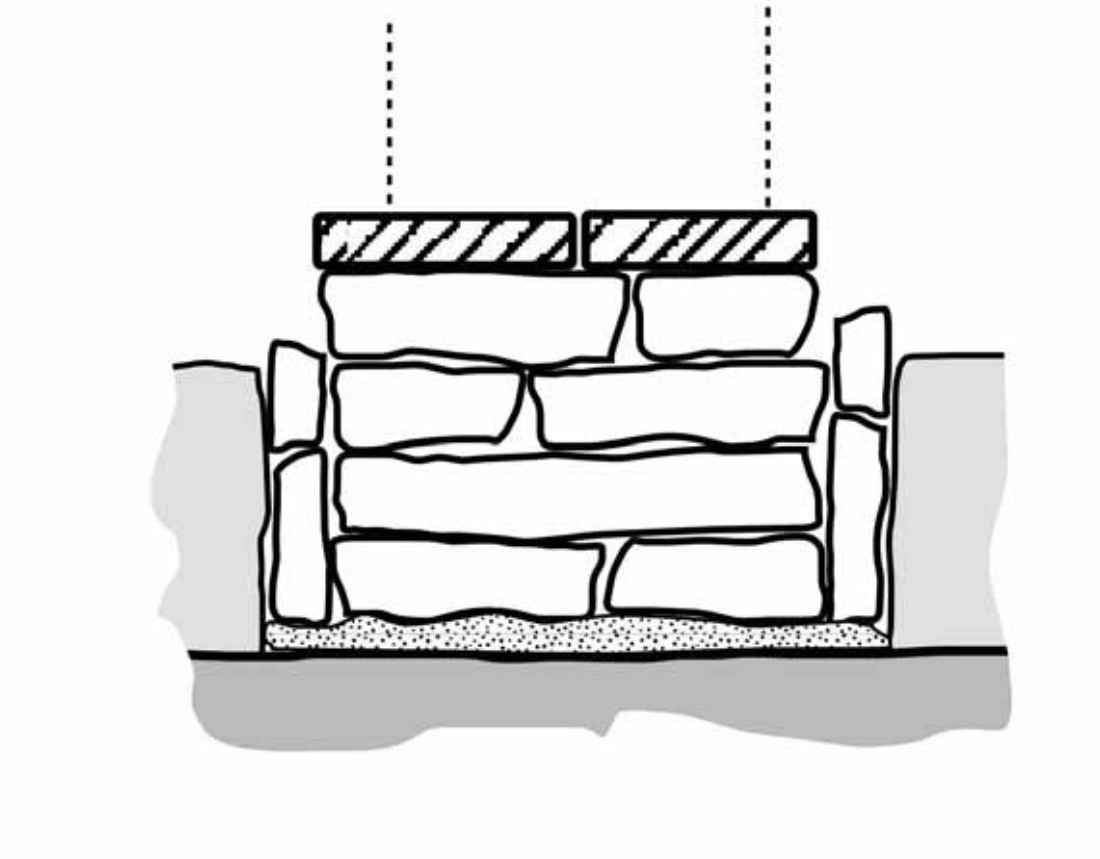
Finish the foundations with a layer of mortar. This layer must be perfectly horizontal and is let to set before building the wall.
The mortar can be reinforced with wire mesh cut at the width of the wall. The parts of wire mesh must be overlapping.



Stability:	**Friction:**
The mortar layer allow a good start of the walls with well aligned first layer, and a good distribution of the load on the foundations. It prevents a partial collapse of the foundations to affect the walls.	The wall is partly disconnected from the foundations and the flat surfaces allow a better dissipation of energy through friction. The mortar can dissipate some energy through breakage.

A particular care will be taken concerning the interface between the foundations and the wall. A partial breakage or collapse of the foundation should not make the wall collapse.

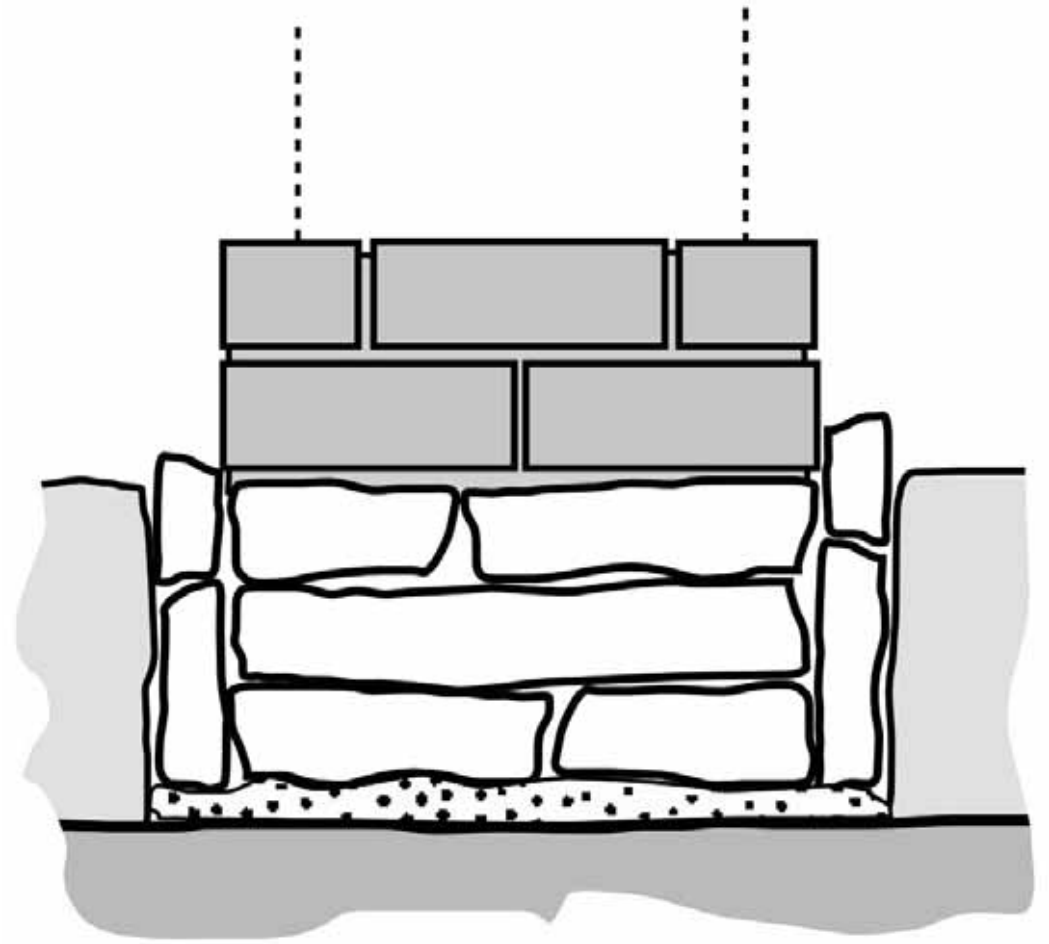
A layer of wooden planks can be used.



Stability:	**Friction:**
The planks allow a good start of the walls with well aligned first layer, and a good distribution of the load on the foundations. It prevents a partial collapse of the foundations to affect the walls.	The wall is partly disconnected from the foundations and the flat surfaces allow a better dissipation of energy through friction with higher friction between wood and stones than between stones.

A particular care will be taken concerning the interface between the foundations and the wall. A partial breakage or collapse of the foundation should not make the wall collapse.

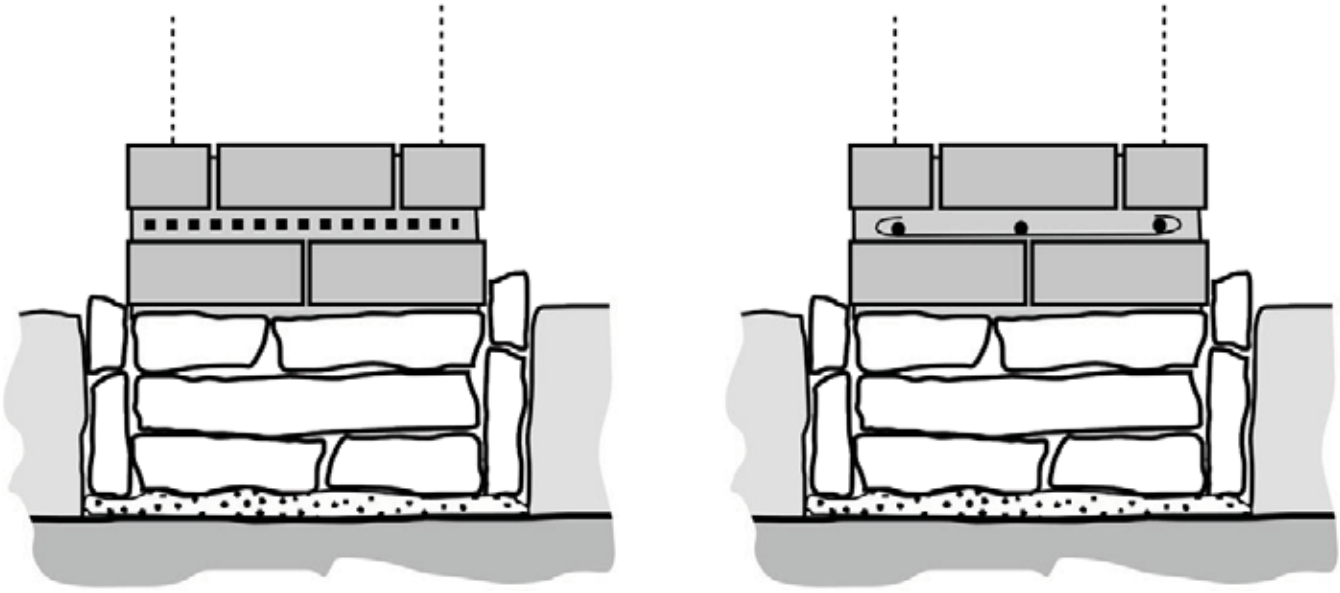
Finish the foundations with two layers of fired bricks laid on earth mortar. Those layers must be perfectly horizontal.



Stability:	**Friction:**
The bricks allow a good start of the walls with well aligned first layer, and a good distribution of the load on the foundations.	The wall is partly disconnected from the foundations and the flat surfaces allow a better dissipation of energy through friction. The mortar can dissipate some energy through breakage.

A particular care will be taken concerning the interface between the foundations and the wall. A partial breakage or collapse of the foundation should not make the wall collapse.

Finish the foundations with two layers of fired bricks laid on cement mortar. Those layers must be perfectly horizontal. They are reinforced with either steel bars or wire mesh.



Stability:	**Friction:**
The bricks allow a good start of the walls with well aligned first layer, and a good distribution of the load on the foundations. It prevents a partial collapse of the foundations to affect the walls.	The wall is partly disconnected from the foundations and the flat surfaces allow a better dissipation of energy through friction. The mortar can dissipate some energy through breakage.

LESSON PLAN

The stone wall

3-54

Session duration: 30 mn theorie; 1 day practice

Objectives: Understand the two concept; stability of the work and dissipation of the energy given by he earthquake. Through this understanding, help the artisans to be conscious of the good practice to apply when they will be on the job.

Give an overview of the worldwide knowledge (good practice and LSC) as well as the result of research that can help to improve stability of the wall, dissipation capacity of the wall, and security for the inhabitant.

Develop improved design that will integrate international LSC

Method: Discussion on existing local good practice for wall stability

Discussion on how to improve the stability of the wall (describe how problem occur, understand why, try to develop solution.

Discussion on local know how related energy dissipation

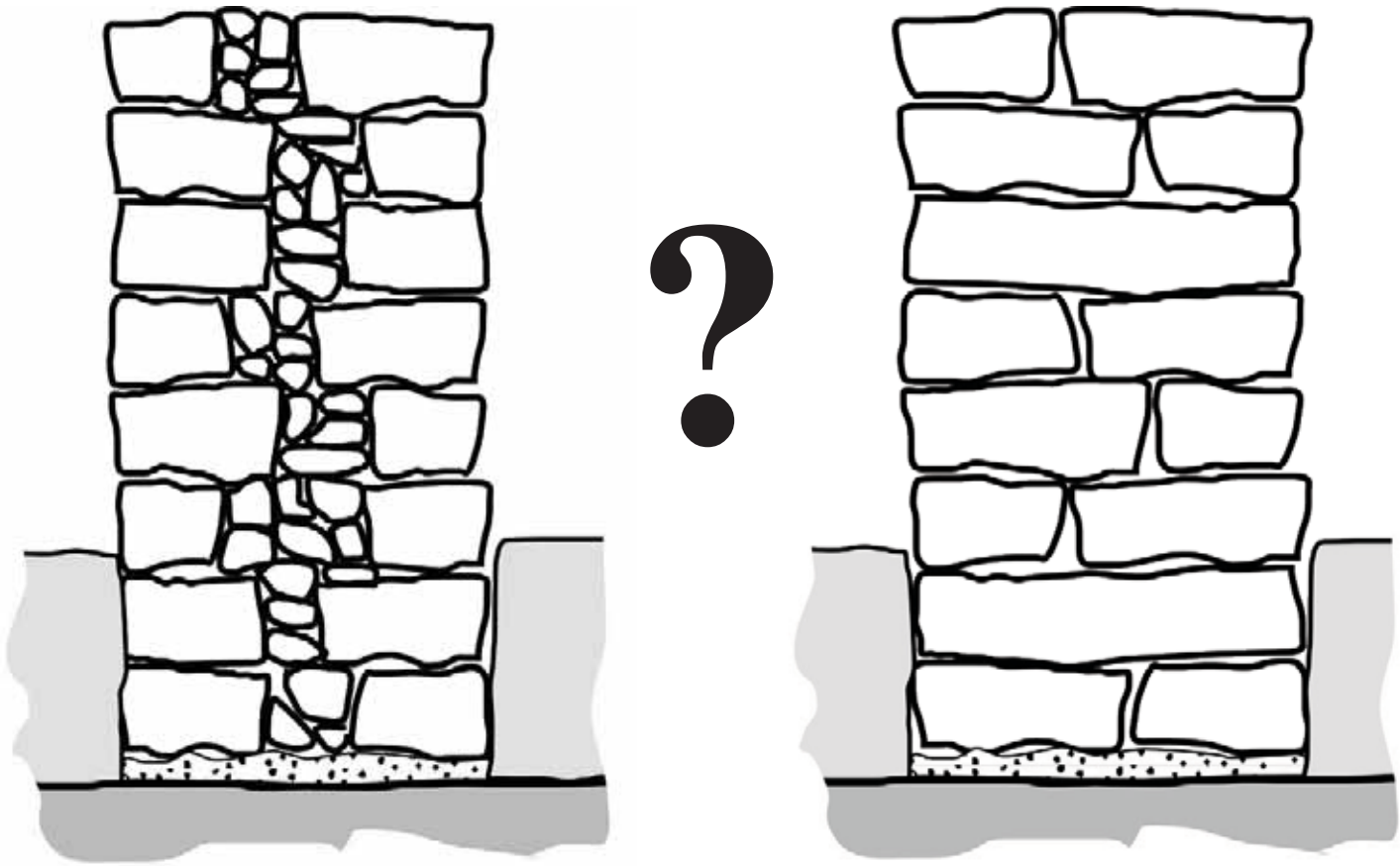
Discussion on how to improve the dissipation capacity of the wall (describes how phenomenon is happening, understand why, try to develop improvement on the existing).

Practise in the field

Trainer team	**Preparatory work** :	**Pedagogical support** :	**Tools** :
One trainer for 7 trainees on theorie One trainer for three group of 7 trainees on practice	Identified and document local good practice and LSC Illustrate local good practise and LSC with international good practice and LSC Illustrate international good practice and LSC in similar context and condition. **Session**: <u>Part 1; role in static condition; stability</u> Ask the masons to share together on the stone masonry good practice (they can illustrate physically what they are talking about using existing walls or stone). Ask them to identify main problems they are facing to apply good practice. Ask them to identify the main problems stone walls are facing and to give their understanding of the raison of these problems Ask trainees to develop potential improvement on the existing Illustrate some of the international good practise. Relation thickness / high Practice on site: <u>Part 2; behaviour in dynamic condition;</u> Trainees analysis: Ø Building comportment Ø Rigidity approach Ø Flexibility approach <u>Part 3; Dissipation; the LSC</u> Ask the masons to share together on local LSC (they can illustrate physically what they are talking about using existing walls or stone). Ask them to specify the reason of each detail they are talking about. Ask them to identify main problems they are facing to apply good practice. Ask them to identify the main problems stone walls are facing and to give their understanding of the raison of these problems Ask trainees to develop potential improvement on the existing Illustrate some of the international good practise. <u>Part 4; Discussion about the differents technical details developed in the guideline</u> Ask trainees to give their ideas on the variuos proposed technical details. Give the trainees an overview of potential improvement. <u>Part 5; Doors and windows anchorage</u> The existing The needs The main rules to be observed and why Anchorage of doors and windows	Demonstration Trainees guide	Massonry tools required for stone massonry

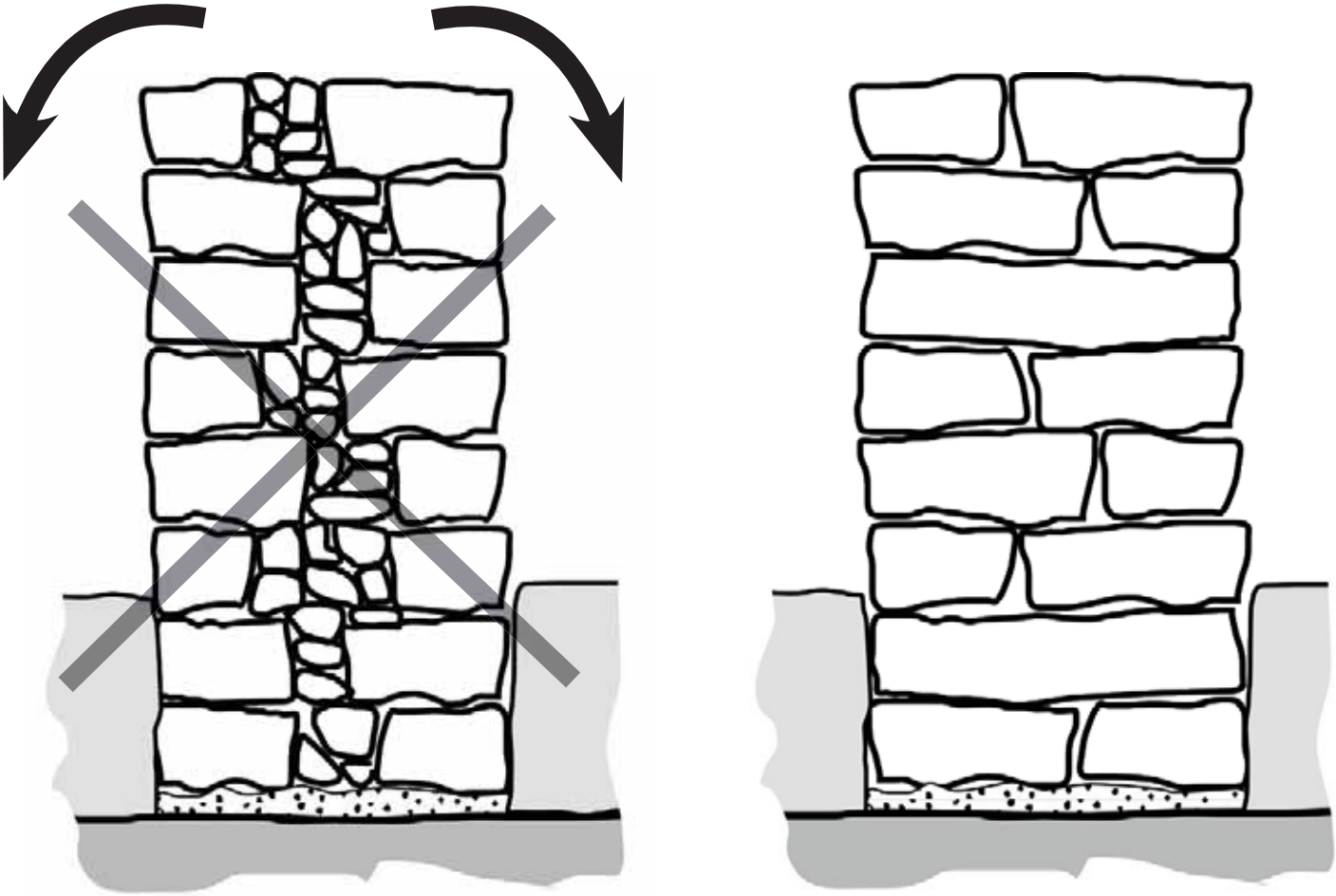
Planning
J- 5 weeks
Lecture
After lecture

Which of the following walls is the most resistant ?



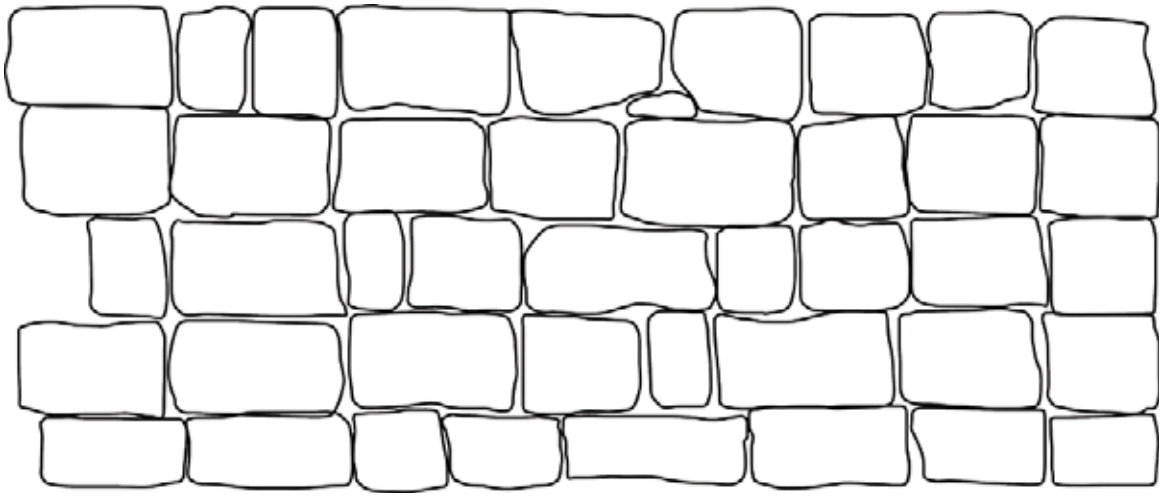
The two sides of the wall must be linked with long stones to prevent the opening of the wall. The more is the best.

Stones from one side should be as most as possible laid on stones of the other side.



Stability:	**Friction:**
The through stones ensure the stability of the wall by connecting the two faces.	The more link between stones, the more friction, allowing a better dissipation of energy.

Which of the following walls is the most resistant ?



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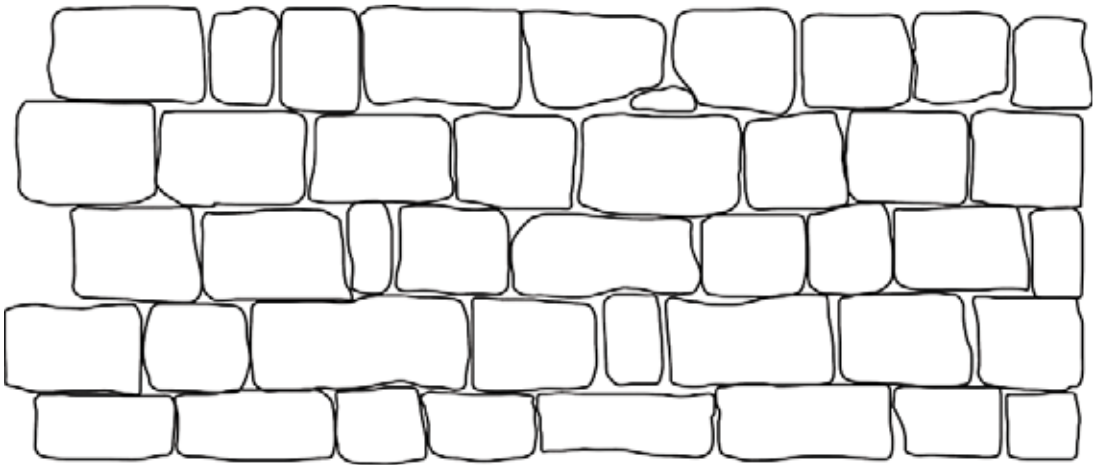
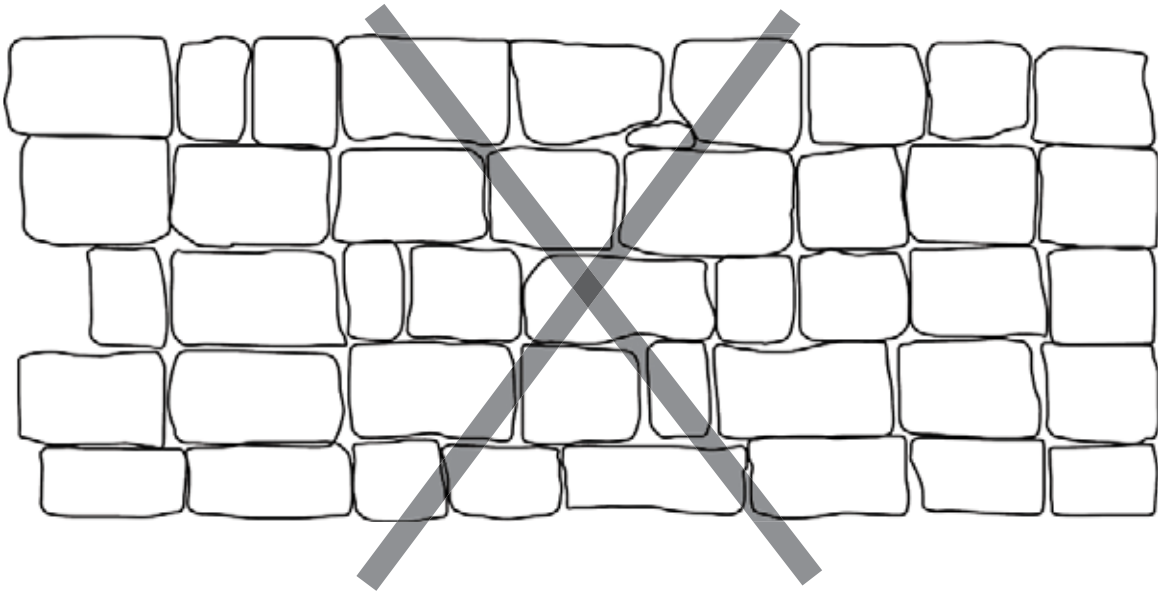
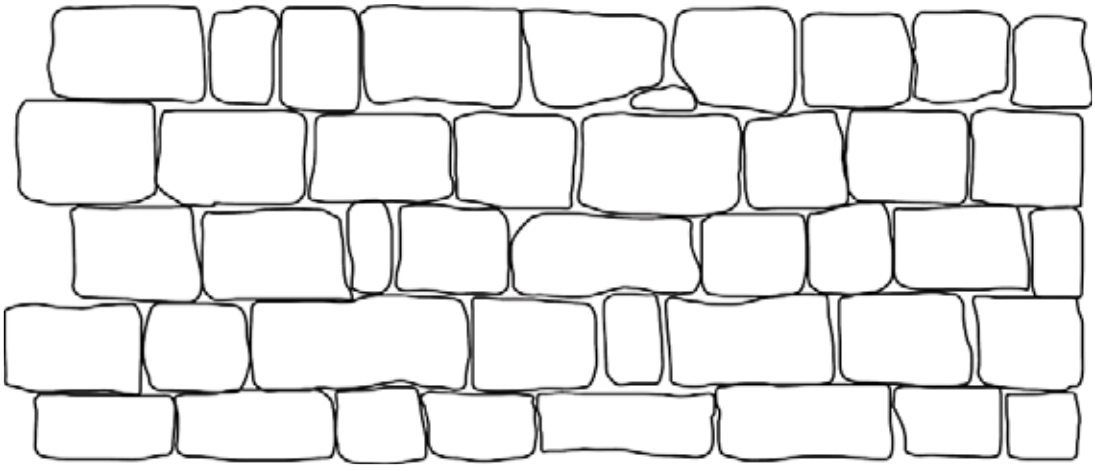


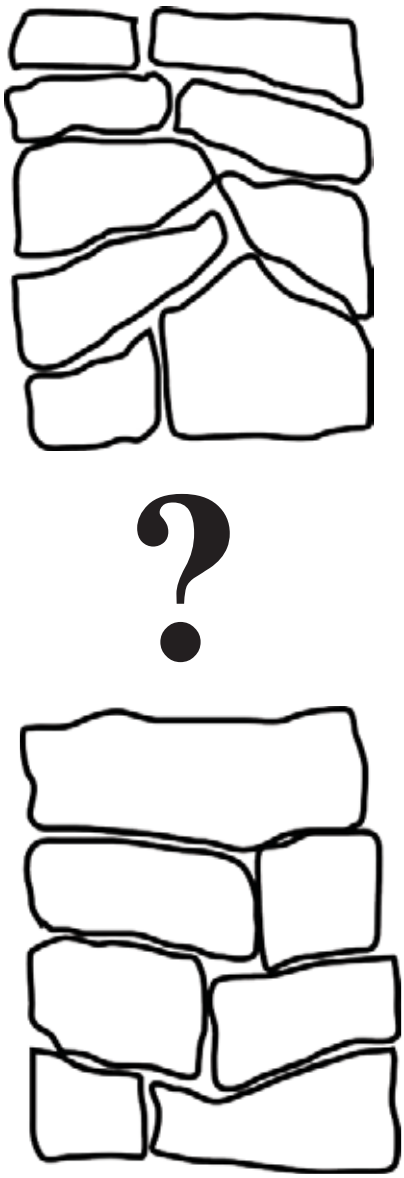
Joints between stones must not be on top of each other.





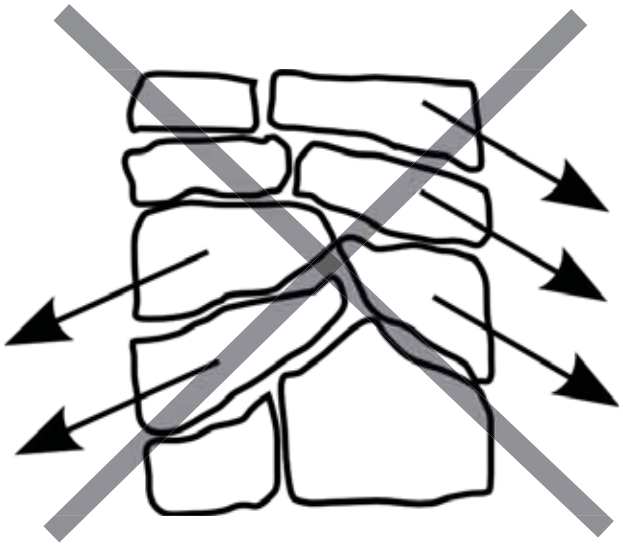
Stability:	**Friction:**
Discontinuity of the vertical joints ensure a good cohesion of the wall and prevents it to split.	The more link between stones, the more friction, allowing a better dissipation of energy.

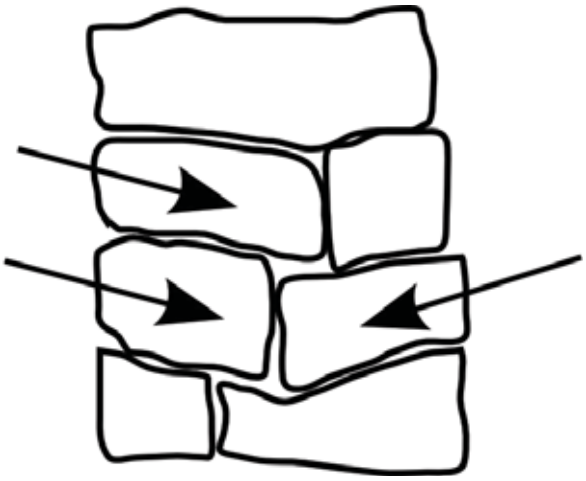
Which of the following walls is the most resistant ?



Dry stone wall: Inside leaning of stones

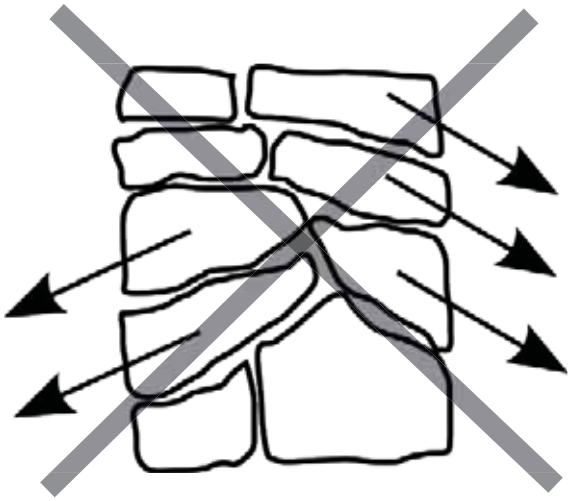
The stones should be slightly leaned to the center of the wall, to prevent them to fall out.

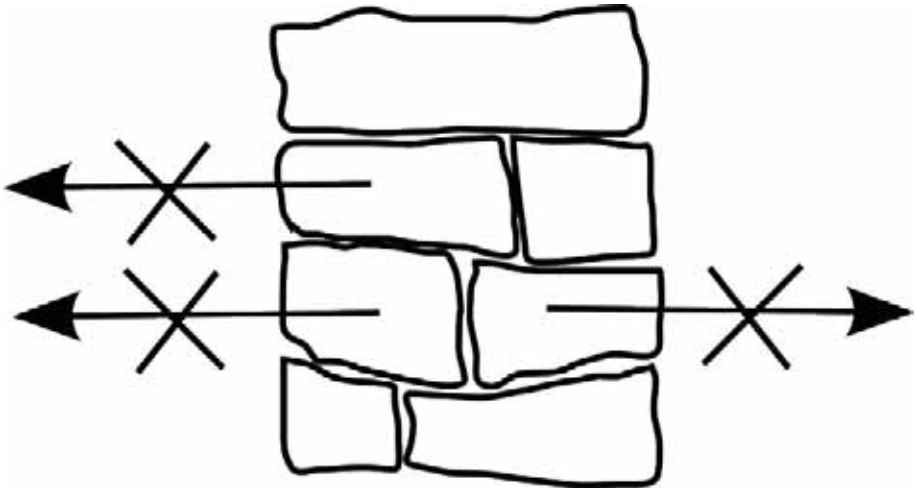




Stability:	**Friction:**
In case of slight movement of the stones under seismic stress, they tend to stay in place.	The fact that the stones remain in place longer under seismic stress allow them to dissipate energy through friction for a longer time.

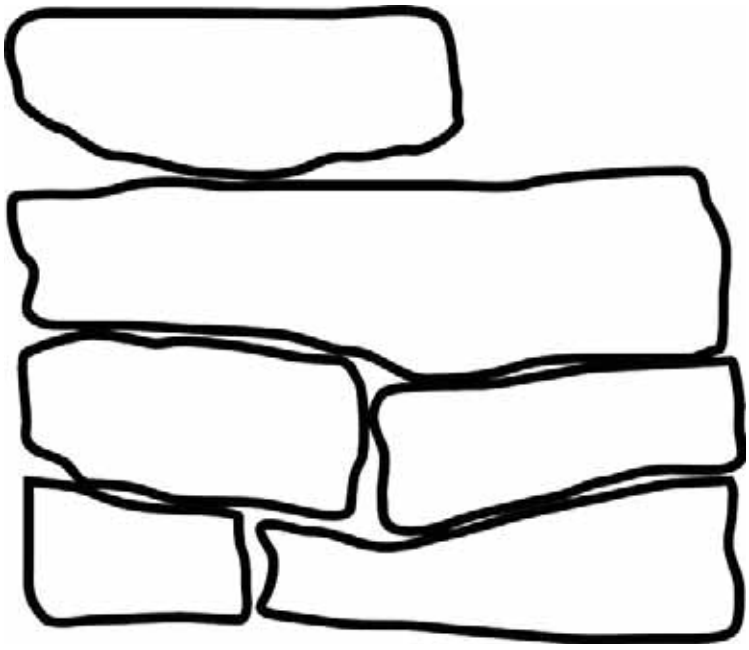
The aesthetic aspect is not the most important for the choice of the stone placing. The stones should be placed to be the most difficult possible to remove.



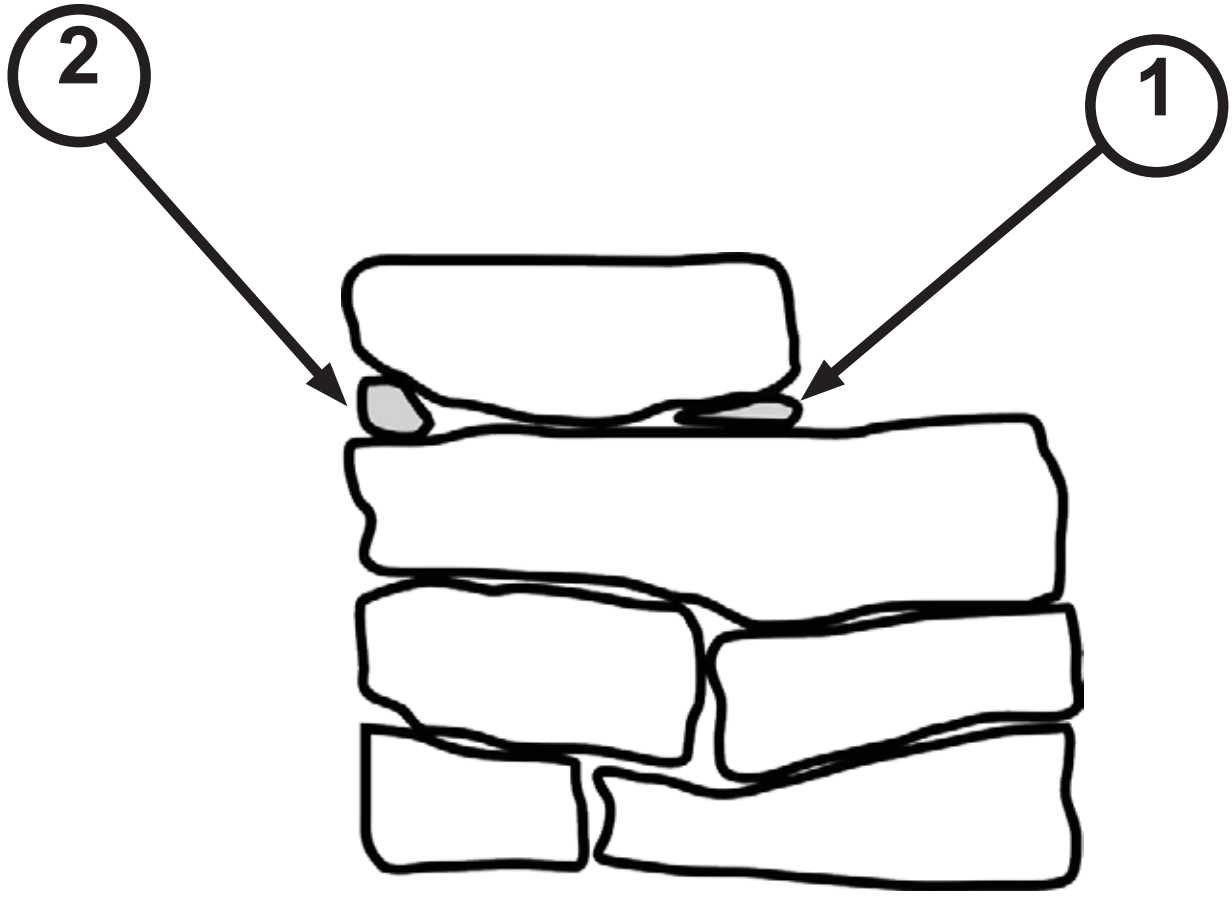


Stability:	**Friction:**
In case of slight movement of the stones under seismic stress, they tend to stay in place.	The fact that the stones remain in place longer under seismic stress allow them to dissipate energy through friction for a longer time.

Where to put the small stone first to block the big stone ?



The blocking stone must be inside the wall so that it cannot be removed or fall. The outside stone is putted after, but even if removed, the big stone must remain in place.

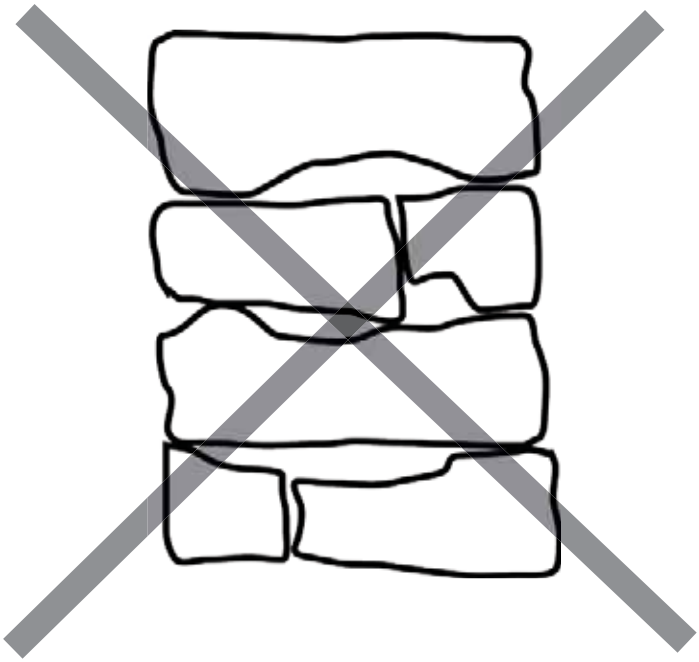


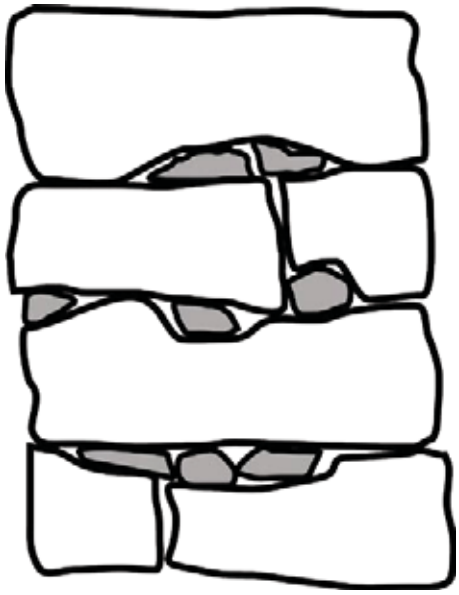
The contact surface between the stones must be as big as possible.

Small stones are used to fill the gaps and increase friction but big stones with flat sides are better.

Every stone must be blocked in all the directions.

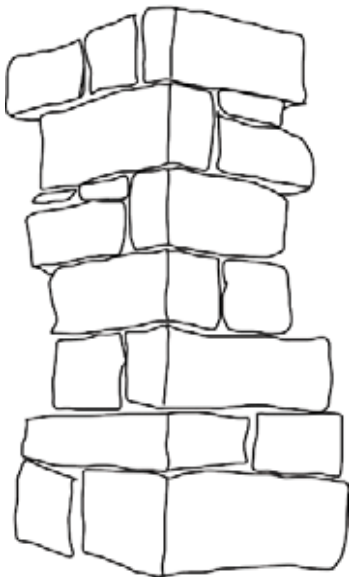
Once the wall finished, more small stones can be added on the faces of the wall to stabilize the bigger stones.



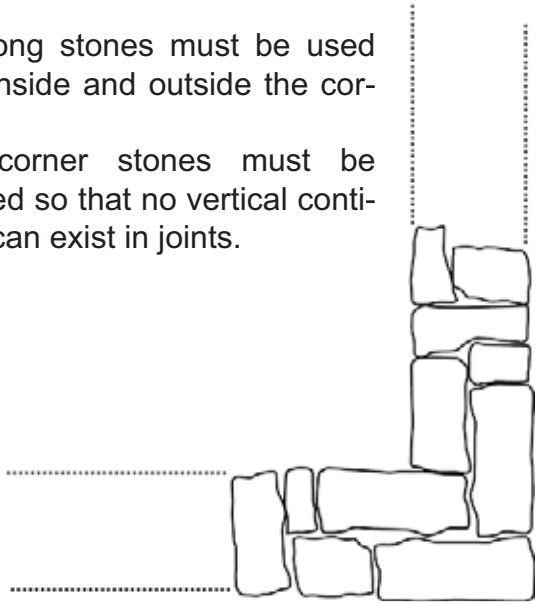


Stability:	**Friction:**
The more contacts between stones, the more each stone will be blocked and stable.	The more contacts between stones, the more friction and dissipated energy.

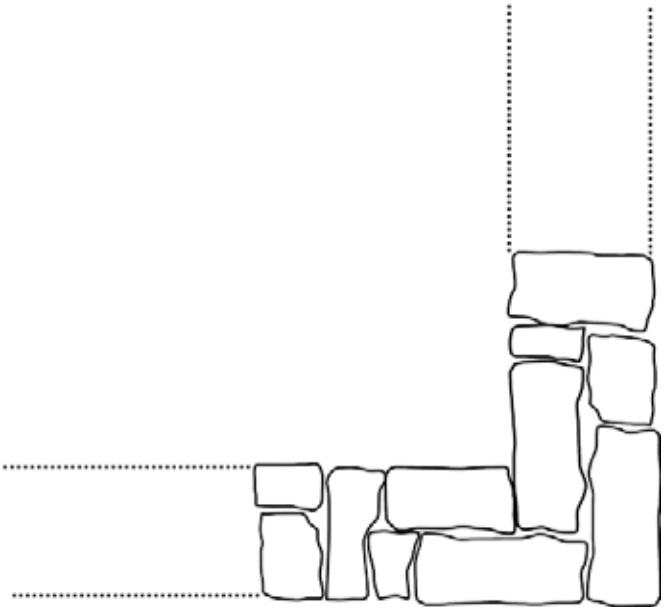
The corners of the walls are a weak part of the building, especially under seismic stress. Particular attention should be given to the laying of the corners. Big stone should be used as often as possible, at every course.



The long stones must be used both inside and outside the corner.
The corner stones must be crossed so that no vertical continuity can exist in joints.



FOUNDATIONS COURSE 1



FOUNDATIONS COURSE 2

Stability:	**Friction:**
The through stones in the corners prevent the wall to open.	The choice of the better stones with flat sides allow greater contact surfaces and therefore more friction and dissipation.

Structural
The wall support the roof's weight and eventualy the upper storeys.

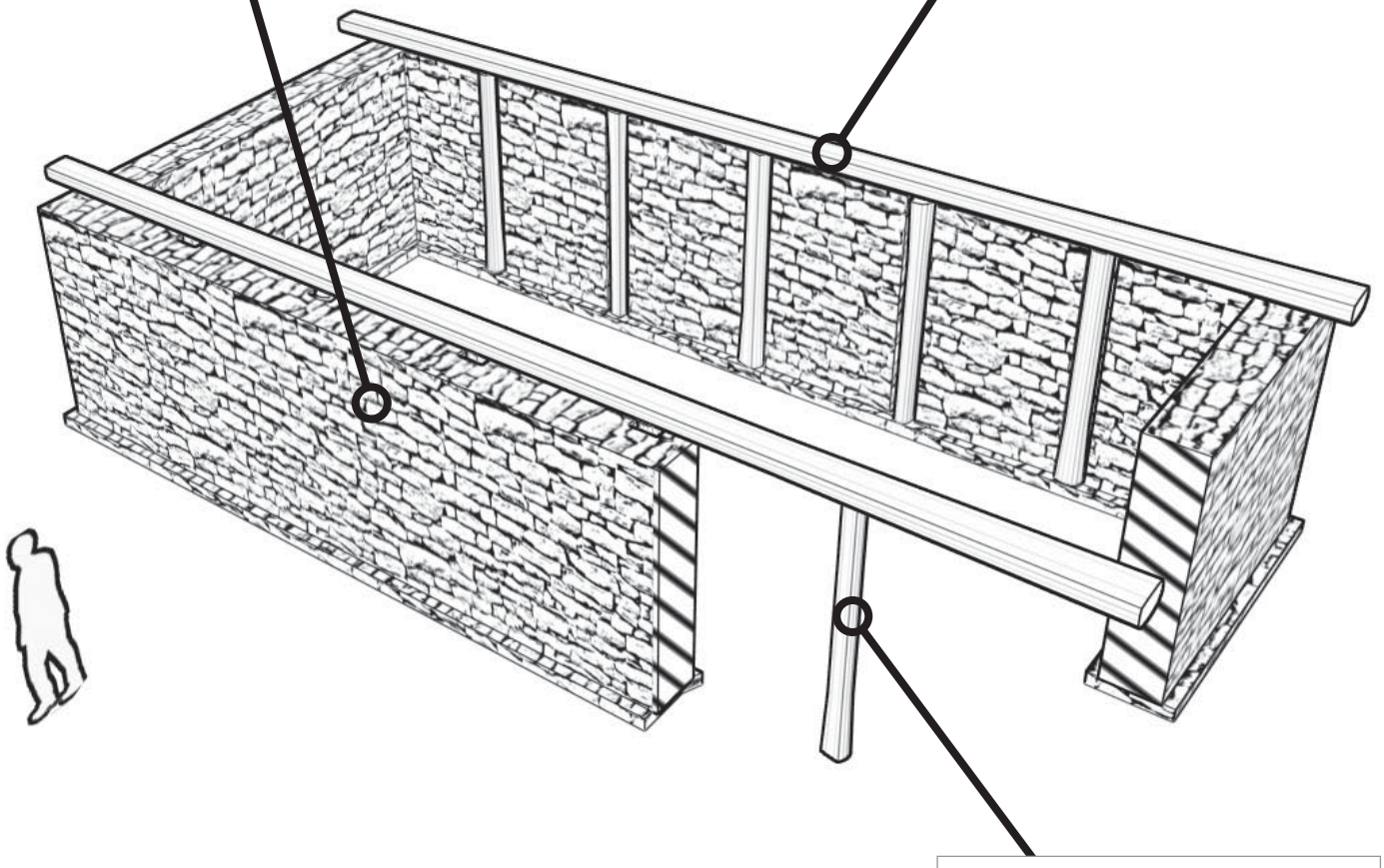
Thermal
The wall protects the inhabitants from the cold and the heat, and eventualy regulates the temperature variations.

Aesthetic
The form and look of the wall is of first importance for the general aesthetic of the building.

Social
The wall preserves the intimity of the inhabitant by separating the public and private spaces and separating the spaces devoted to the different functions.

In this structure, the resistance of the walls is reached through a flexible/ dissipative approach. The dry stone walls can have post-elastic deformation which dissipate a lot of energy through friction.

The ring-beam allows a good distribution of the roof load on the walls and let the roof slide on it.



The wooden posts bring containment to the masonry while improving the damping effects through friction (stone-wood friction is greater than stone-stone). They are braced by the masonry.

LESSON PLAN

WOODEN POSTS AND BEAMS

4-68

Session duration: theotie 30 mn; practice with stone massonry

Objectives:
In order to help trainees to improve on their actual building habits, the trainer will help the trainees to understand the interaction between the wooden structure and the walls massonry. Help the trainees to understand the stability limit of the wooden structure and how to improve its stability without reducing its flexibility.

Method:
Discussion about the behaviour of the wooden structure under earthquake movement. Ask trainees to identify problems and to develop their own solutions. Synthesis by the trainer who will make available potantial improvment if they have not been find by the trainees themselves.

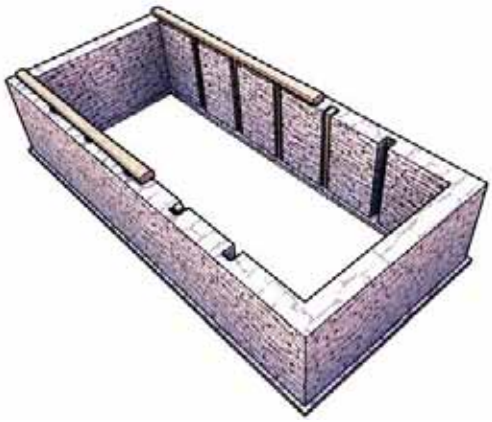
Trainer team	**Session**	**Pedagogical support** :	**Tools :**
Lecture One trainer for 7 participant Practice One trainer for three group of 7 trainees on practice	Preparatory work : It could be good to produce small scale models to illustrate the different risks taht are related to this wooden structure, and how to reduce these risks. Lecture: Use the model or an existing structure or some drawing to illustrate the way the wooden structure is commonly constructed in the area. Ask the trainees to list the role of each part of the wooden structure and how they interact together. Ask Trainees to give their feeling on how this structure will move under seismic movement and the different damage this structure can face during them. List the different risk and complete them if trainees do not cover everything. For each risk, ask trainees to develop their solution. Synthetise trainees ideas and add some more solutions if required.	Demonstration: Trainer guide: Small model of the wooden structure	

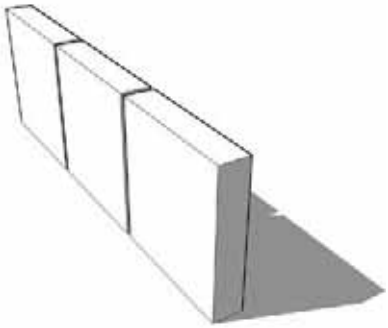
Planning

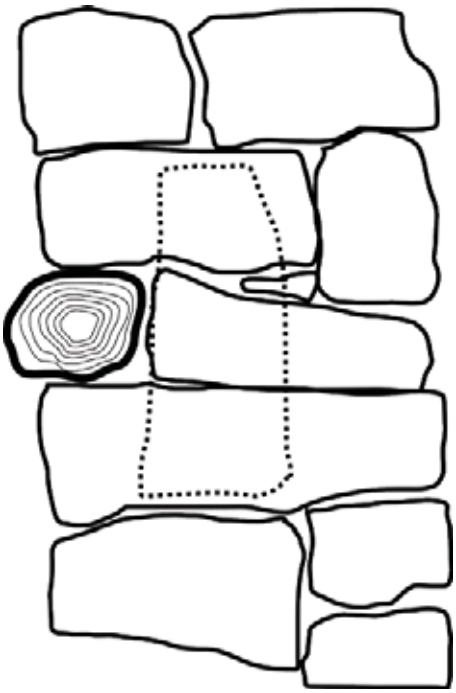
Before the session:

Lecture

After lecture



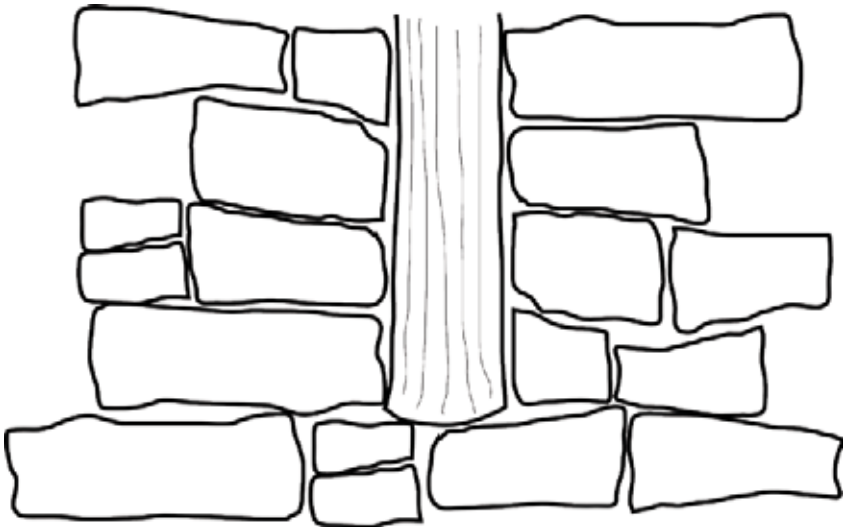




The wooden posts are incorporated inside the masonry but must remain visible from the inside of the house to ensure easy checking of rotting and maintenance.
The contact between the stones and the wood must be maximum.

Stability:	**Friction:**	**Maintenance:**
The wooden posts help confining the stone wall. The stone wall braces the posts.	The friction between wood and stone is greater than between stones, allowing more dissipation of energy.	The posts can be checked easily and eventually changed.

Which one of the following posts settlement is the most resistant ?



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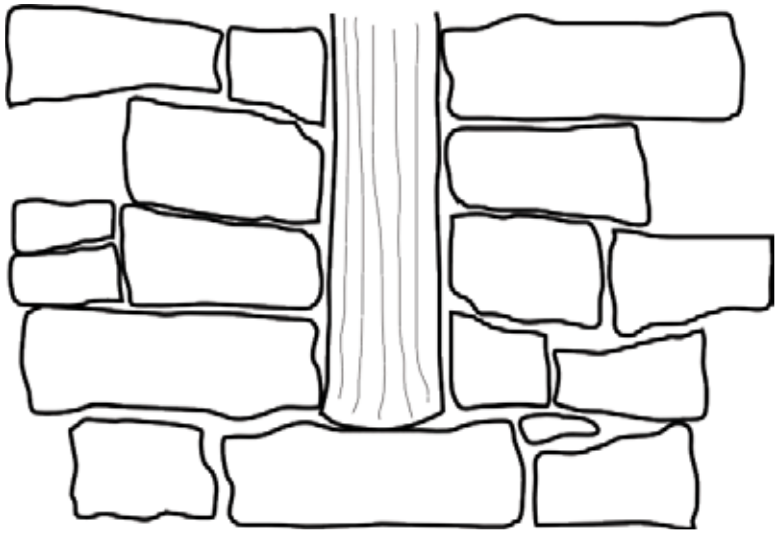
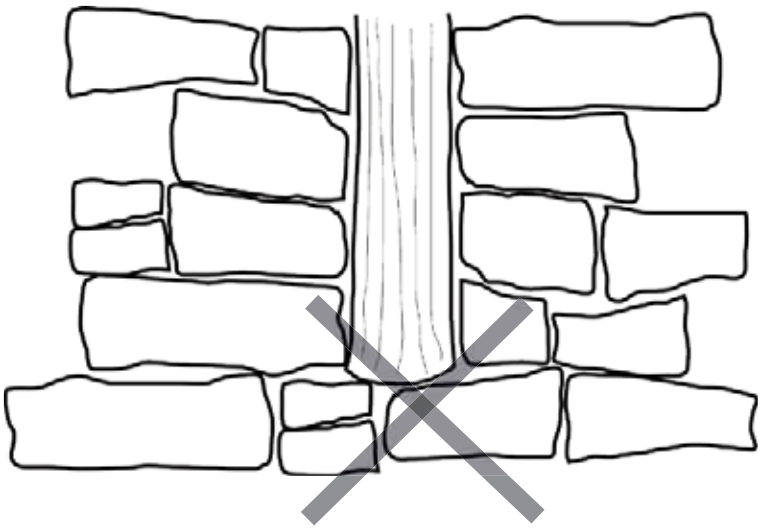
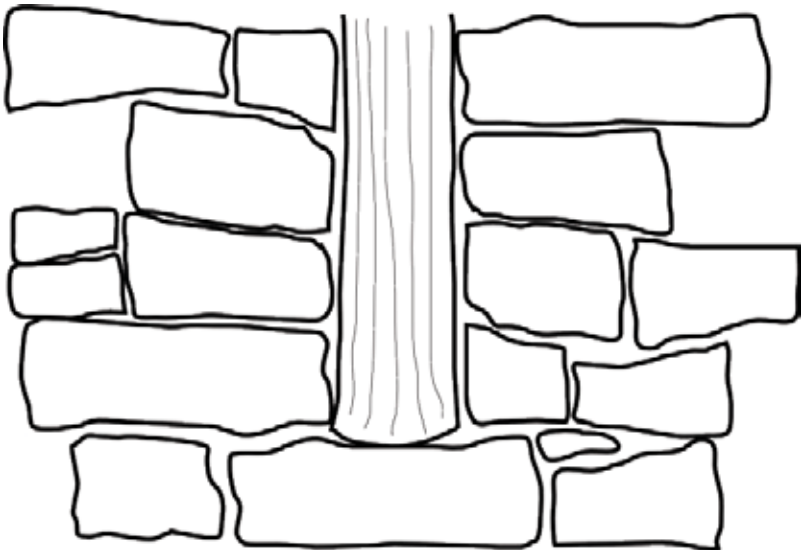
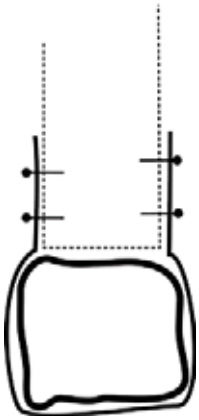


The posts must rest on a big flat stone.
The bottom of the post must be at least 4 inches higher than the ground to prevent moisture problems.

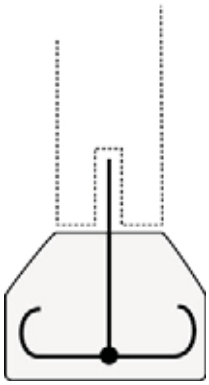




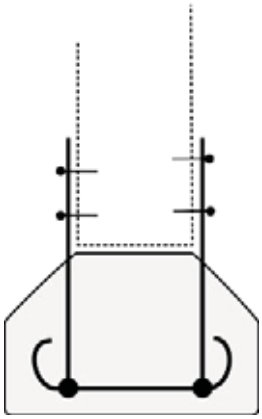
The post can be fixed with a metal part tight around the support stone.



As an alternative to the big stones, the support of the posts can be made of 20”x20” reinforced concrete blocks with a steel rod coming out. This steel rod allows lateral blocking of the wooden posts.

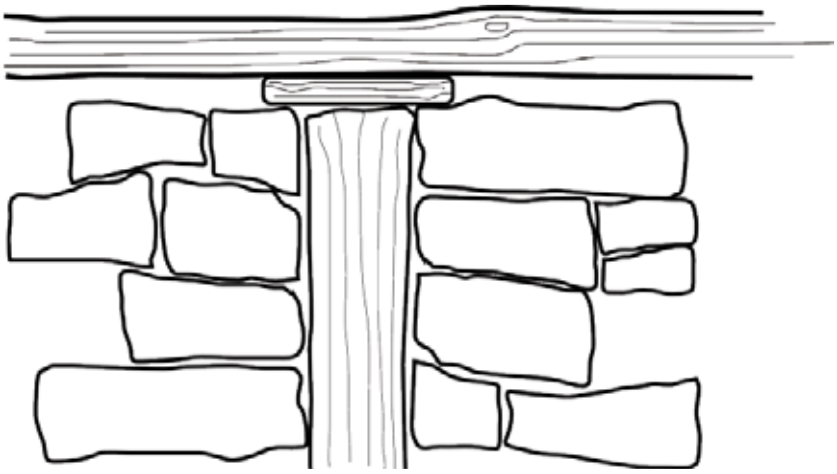


An other alternative is a concrete block with two steel parts fixed on each side of the post.



Stability:	**Friction:**
The wooden posts may move slightly but cannot come out from their support.	The friction between the post and the basement allows some dissipation of energy.

Which type of upper beam location is the best ?



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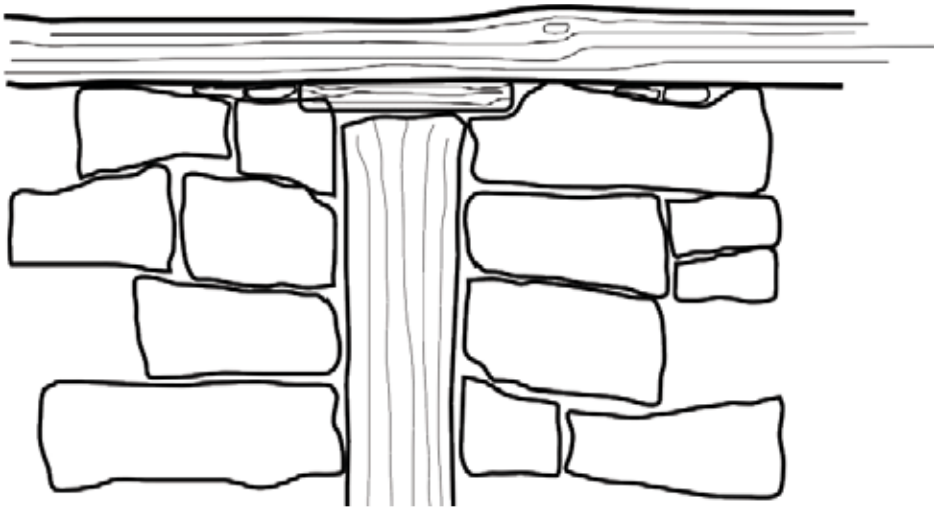
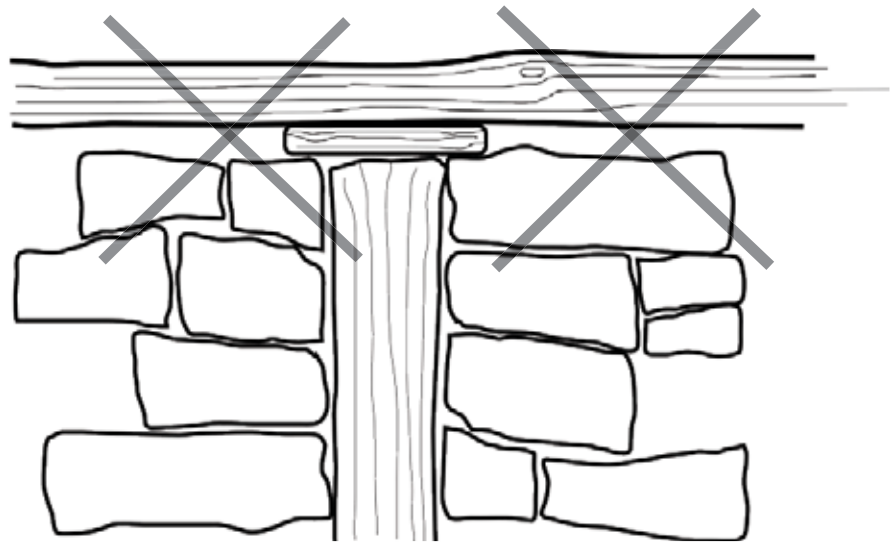
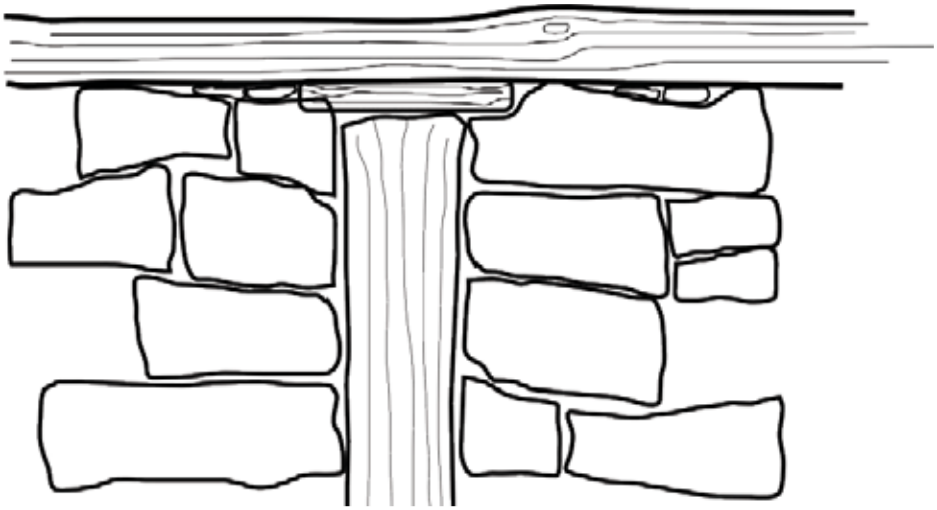


Upper beam

The upper beam must be set on the masonry with maximum contact. The use of small stones is necessary to ensure maximum contact.

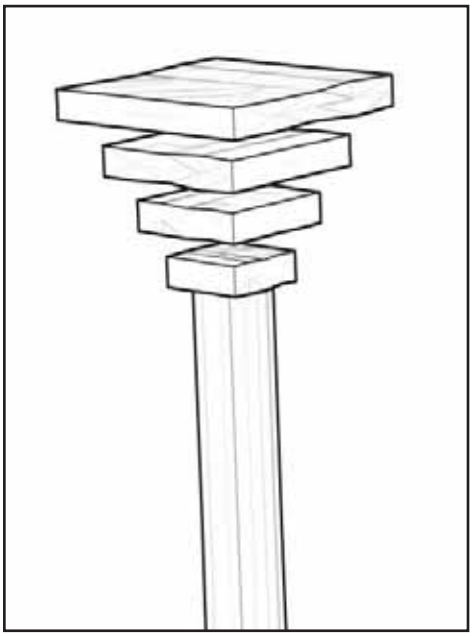


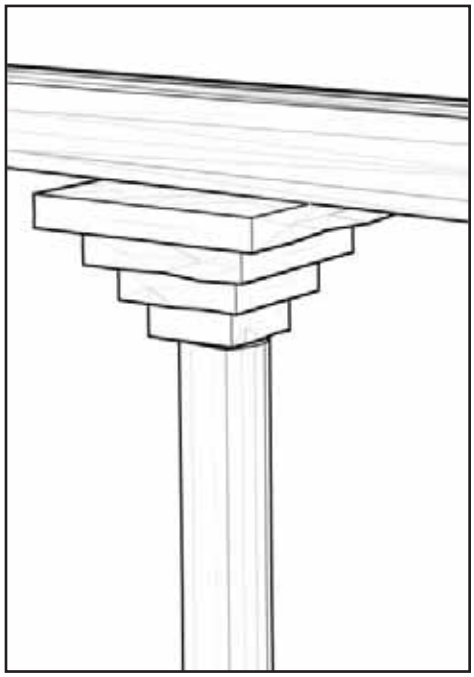


Stability:	**Friction:**
The wooden beam (with the weight of the roof) confine the stone wall. It allows even distribution of the load of the roof.	The friction between wood and stone allows dissipation of energy.

The beam is set on a stack of planks that allows it to come back in place in case of moves.

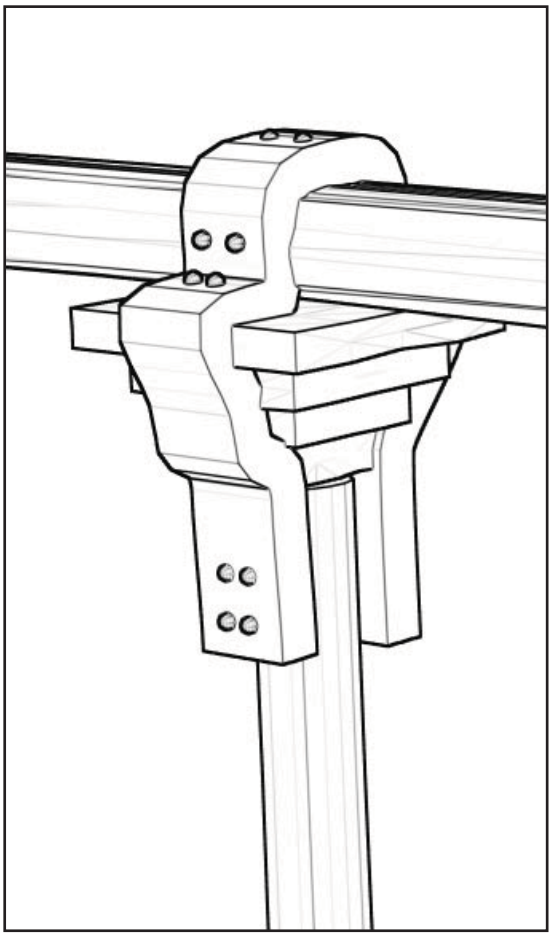
The ring beam must be fixed to the posts with barbed wires, nails or iron hoop.





Stability:	**Friction:**
It is more difficult for the beam to fall from the posts and loose its functions.	The friction between the planks of the capital dissipate energy

Which one of the following fixing system is the most adapted to eartquake prone areas ?



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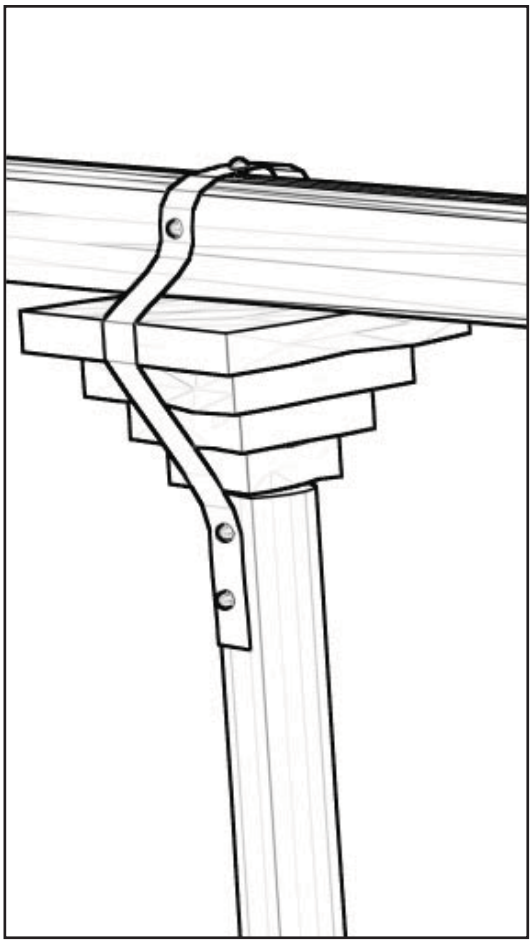
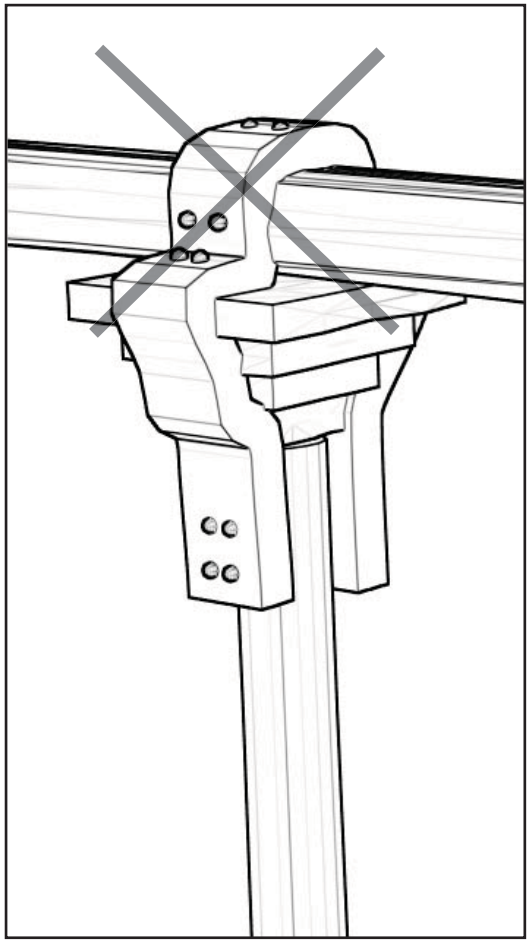
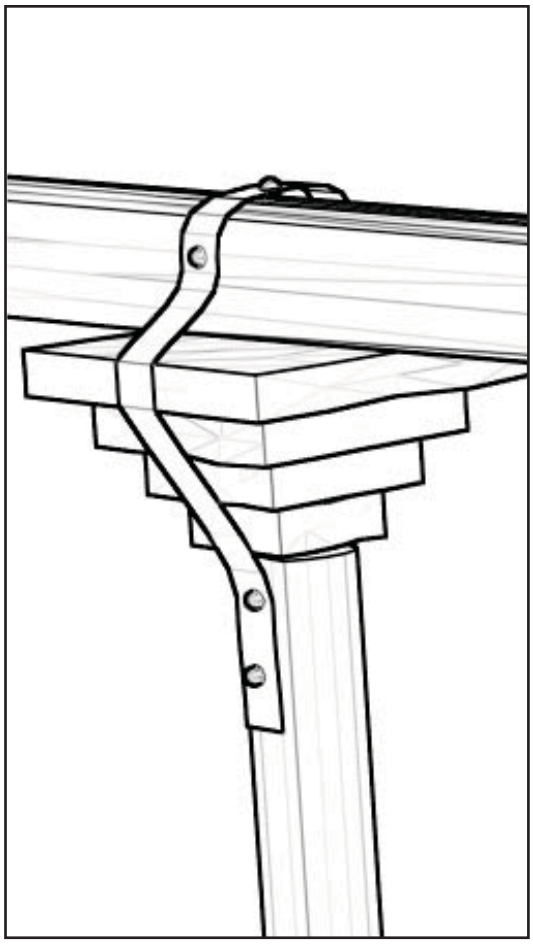


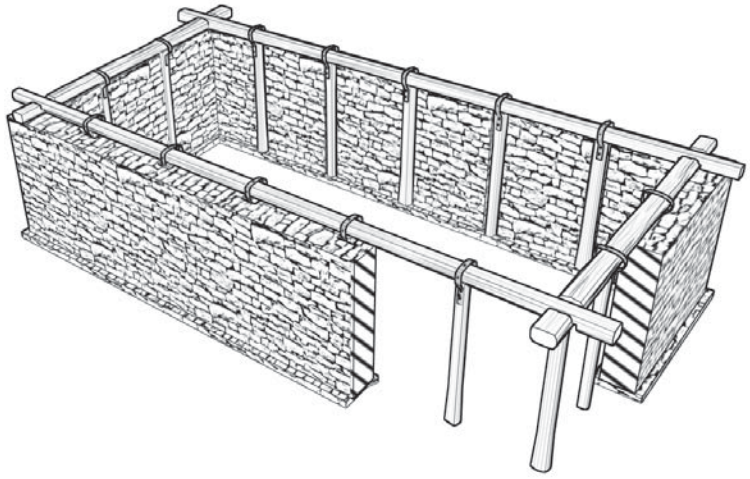
The ring beam must be fixed to the posts with barbed wires, nails or iron hoop, but the link must not be too rigid.





Stability:	**Friction:**
It is more difficult for the beam to fall from the posts and loose its functions	The deformation of the links absorb some energy (friction between nails and wood, deformation of the iron hoops).

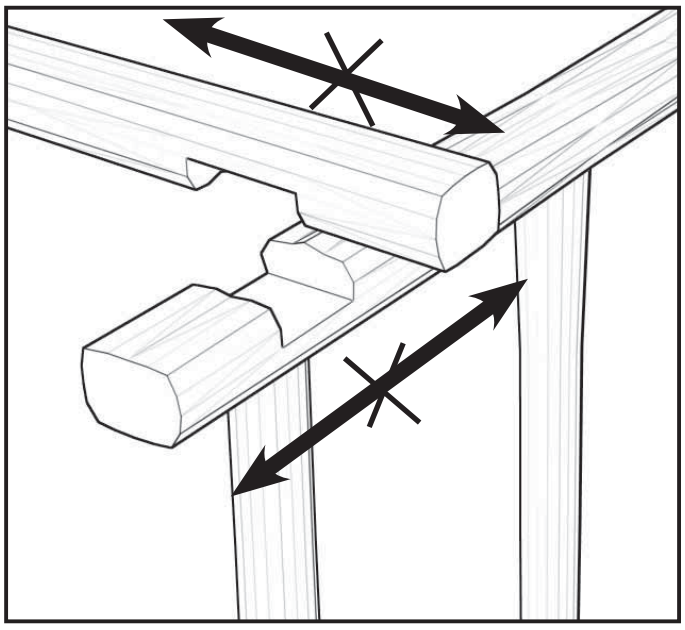
The upper beams are completed with two others beams to form a complete ring beam.



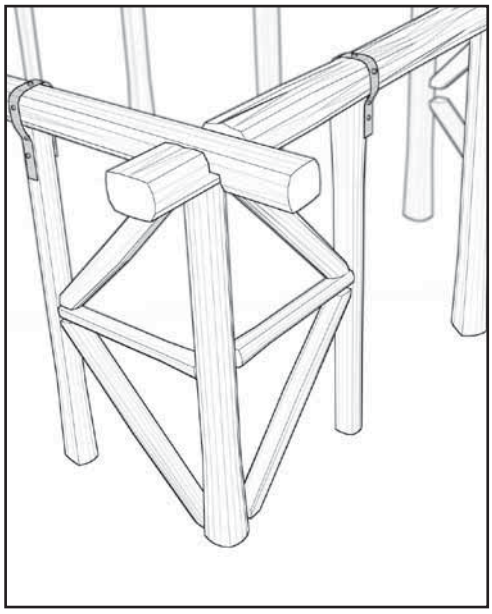
The wooden ring-beam must be resistant to tensile stress. The link between the beams is worked for that. The wood must not be removed on more than half of the beam.

The beams are fixed together with nails (at least 4, long enough), barbed wire or iron hoop.

The beams supporting the beams of the roof must be placed on top of the two other ones to ensure more friction.

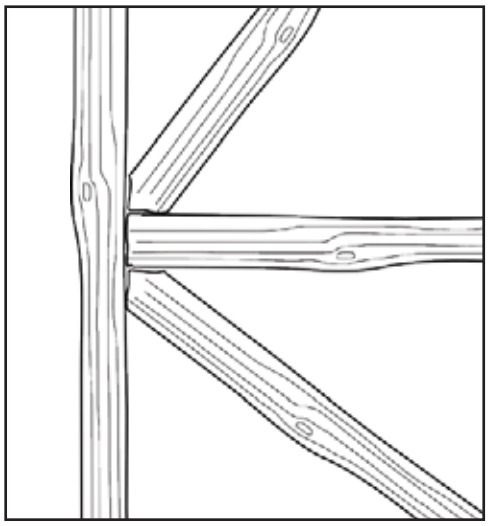


Stability:	**Friction:**
The ring beam (with the weight of the roof) confine the stone wall. It allows even distribution of the load of the roof. It prevents the corner to open. The extra-length of the beams prevent them to fall in case of a breakage of the wood assembly.	The friction between wood and stone is greater than between stones, allowing more dissipation of energy. The wood assembly can dissipate energy too (wood/wood friction and nail/wood friction).



The advantage of this type of bracing is that it uses short pieces of wood. But it may add some stress in the middle of the corner post.

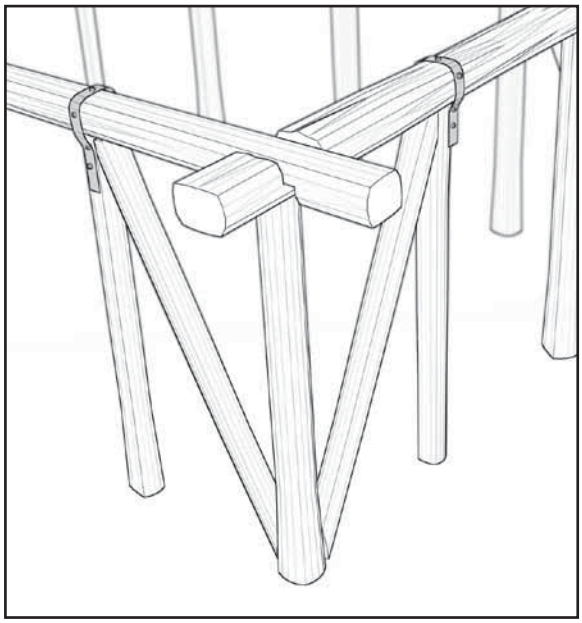
The distance between the poles in the corners must be less than 4 feets.



The struts are fixed both to the post and the ring beam or with other struts with crossed nails.
The strut must be cut at the end so that the surfaces in contact with the beam or the other struts and the post are maximal.

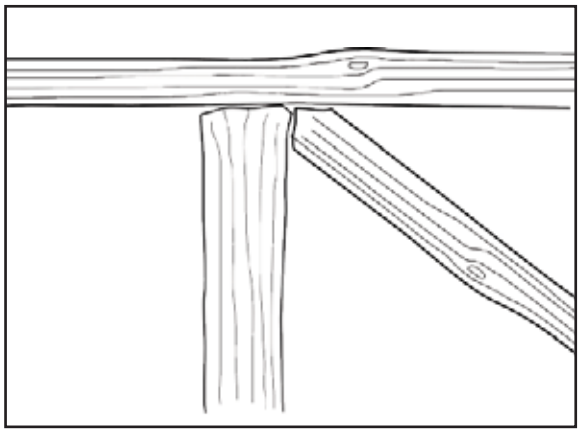
Stability: In case of a partial collapse of the wall, the braced wooden structure brings a safety support for the roof to prevent sudden collapse.	**Friction:** The friction between wood and stone is greater than between stones, allowing more dissipation of energy. The wood assembly can dissipate energy too (wood/wood friction and nail/wood friction).

© Randolph Lagenbach



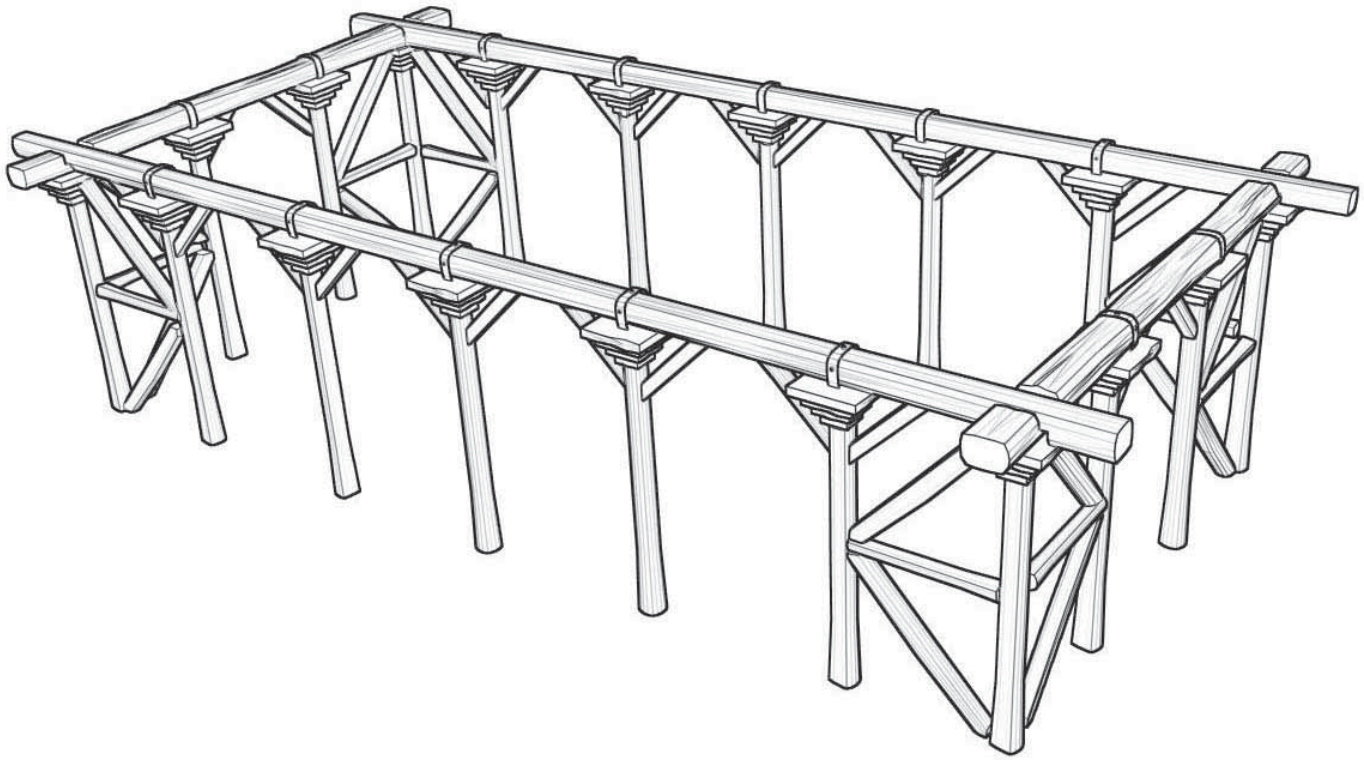
The distance between the poles in the corners must be less than 4 feets.

The struts are fixed both to the post and the ring beam with crossed nails.
The strut must be cut at the end so that the surfaces in contact with the beam and the post are maximal.



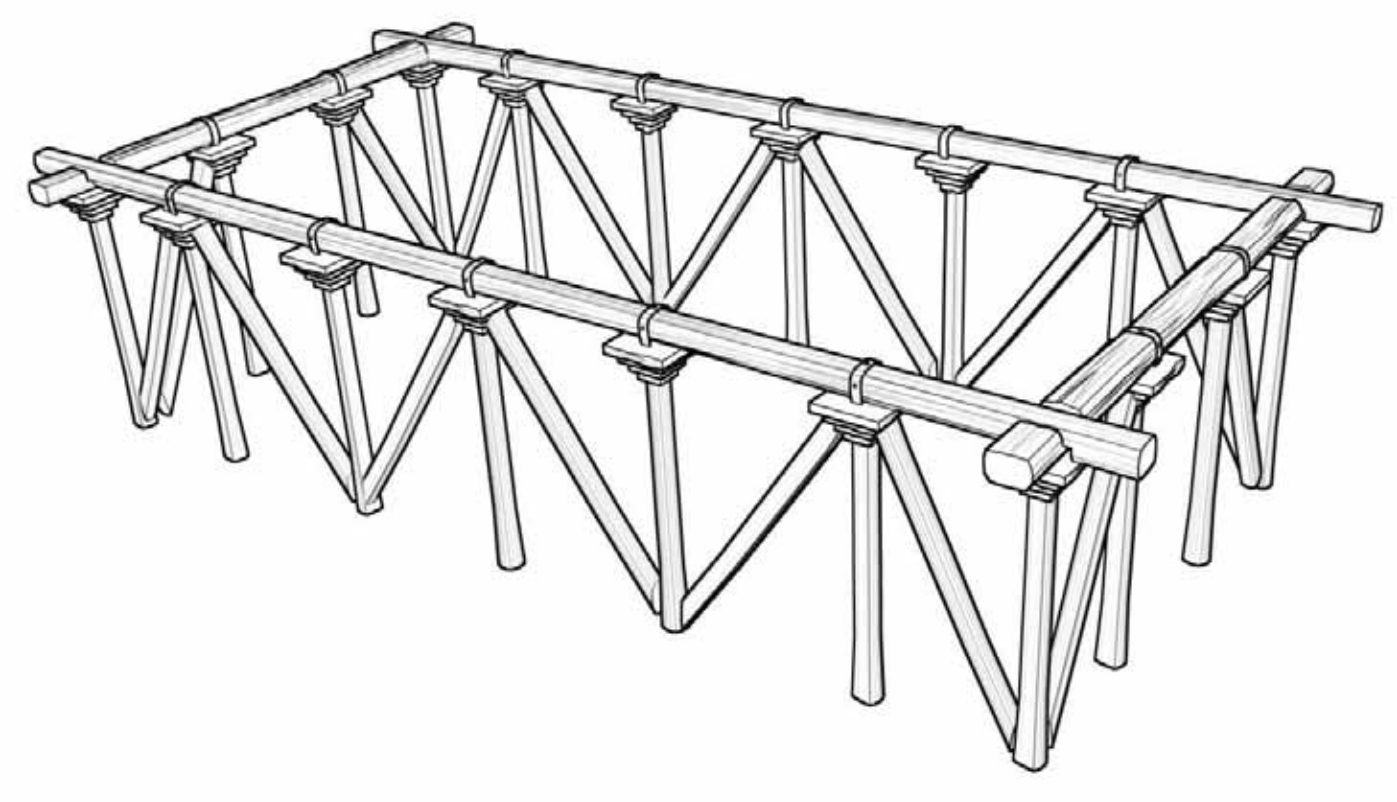
Stability:	**Friction:**
In case of a partial collapse of the wall, the braced wooden structure brings a safety support for the roof to prevent sudden collapse.	The friction between wood and stone is greater than between stones, allowing more dissipation of energy. The wood assembly can dissipate energy too (wood/wood friction and nail/wood friction).

Struts at the top of the post increases the stability of the wooden structure.



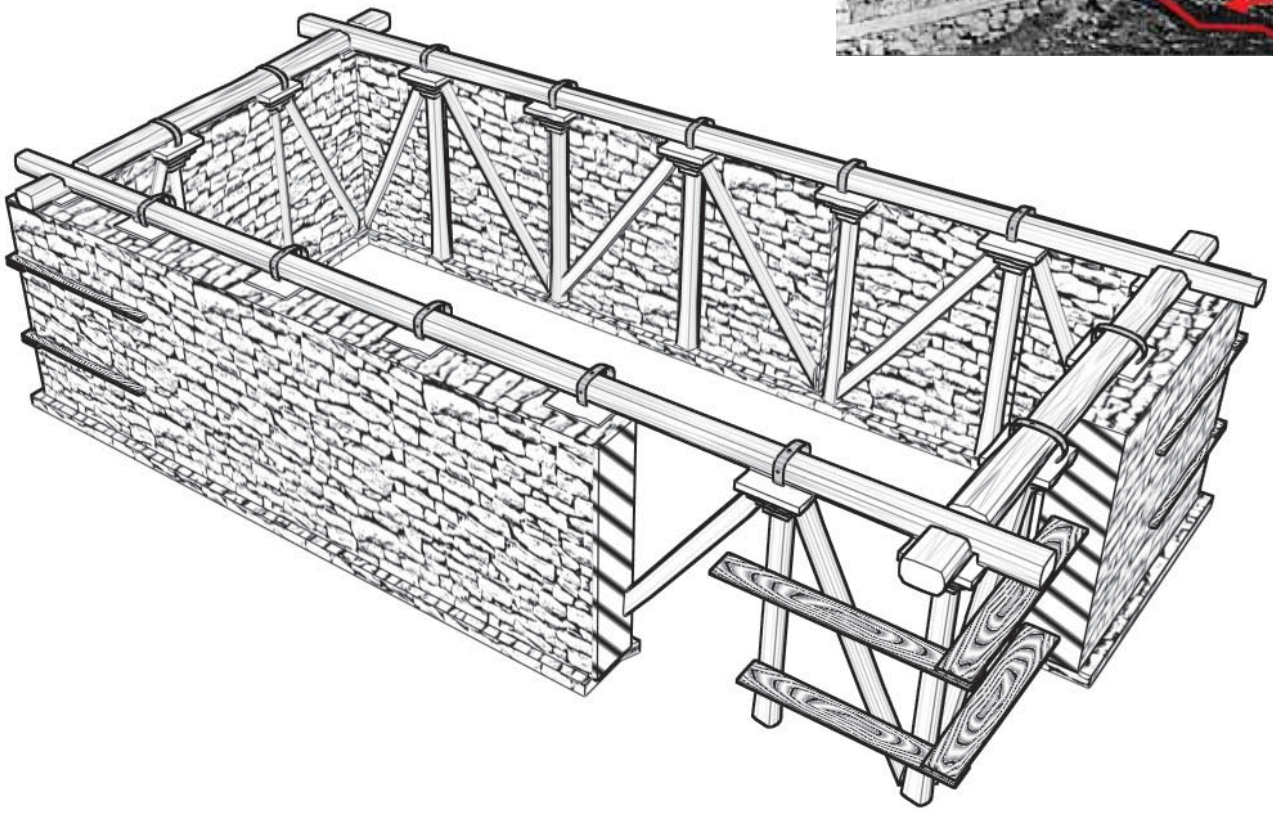
Stability:	**Friction:**
In case of a partial collapse of the wall, the braced wooden structure brings a safety support for the roof to prevent sudden collapse.	The friction between wood and stone is greater than between stones, allowing more dissipation of energy. The wood assembly can dissipate energy too (wood/wood friction and nail/wood friction).

Bracing all the frames of the wooden structure increases significantly the stability of the structure.



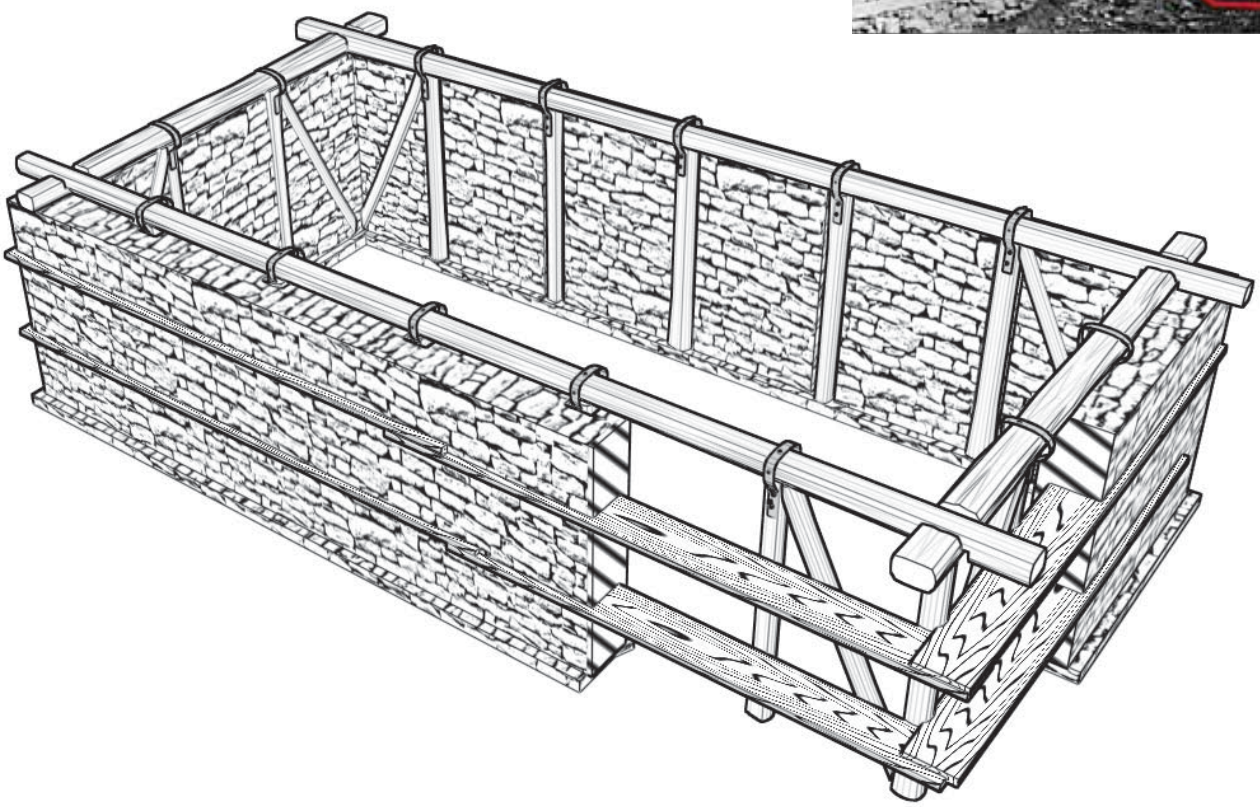
Stability:	**Friction:**
In case of a partial collapse of the wall, the braced wooden structure brings a safety support for the roof to prevent sudden collapse.	The friction between wood and stone is greater than between stones, allowing more dissipation of energy. The wood assembly can dissipate energy too (wood/wood friction and nail/wood friction).

The corners of the building are the most affected parts by the torsion stresses. It is therefore recommended to increase their tensil strength.



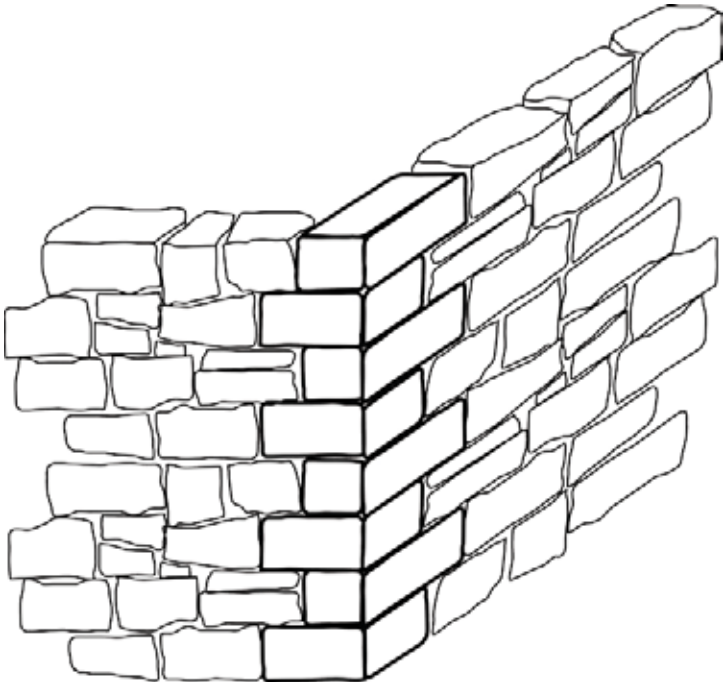
Stability:	**Friction:**
The planks maintain the corner together even in case of cracks or partial collapse.	The friction between wood and stones is high, allowing good dissipation of energy.

The wooden planks are continuous but they don't act as a rigid diaphragm. The wall is still able to deform.

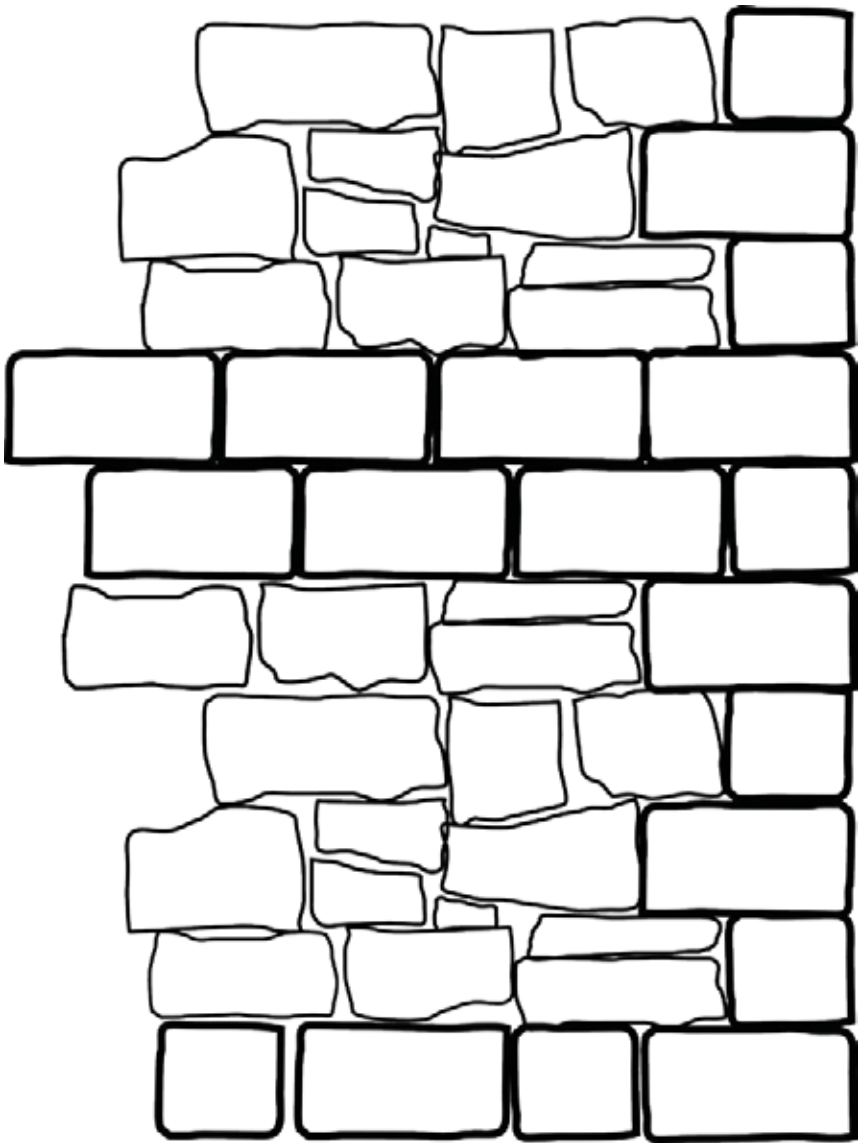


Stability:	**Friction:**
The planks maintain the walls together even in case of cracks or partial collapse.	The friction between wood and stones is high, allowing good dissipation of energy.

The corner stones can be replaced by reinforced concrete blocks made on the site.



Stability:	**Friction:**
The good connections between carved stones improve the stability of the corners, and therefore of the whole building.	The contact surface between carved stones is higher than between rough stones, increasing the friction.



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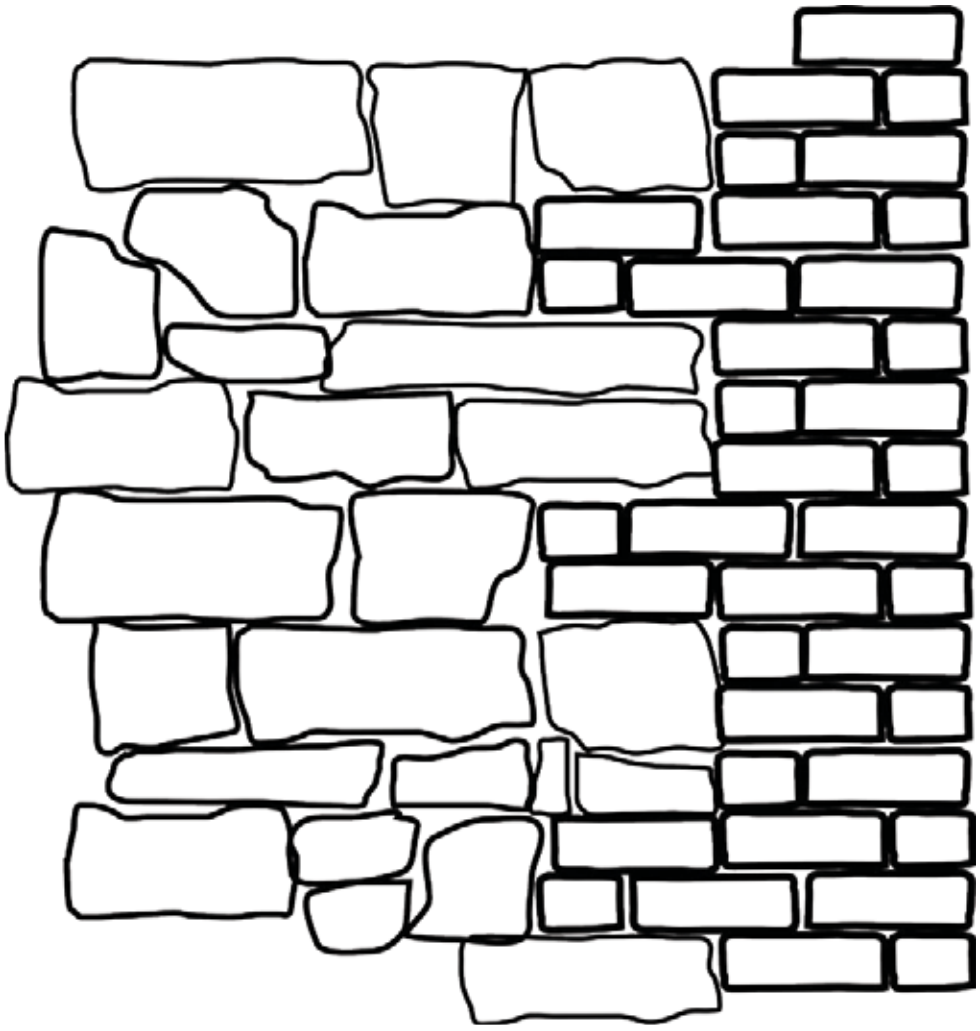
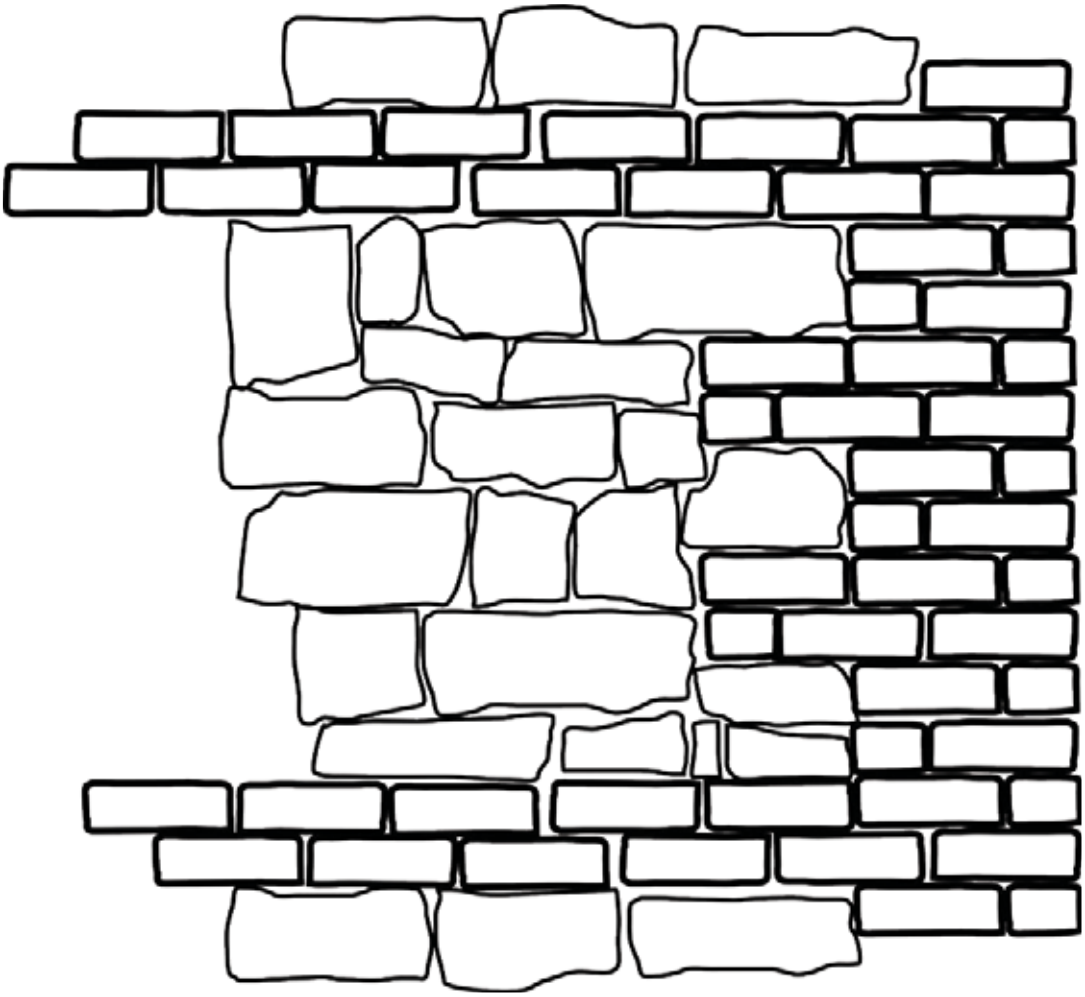
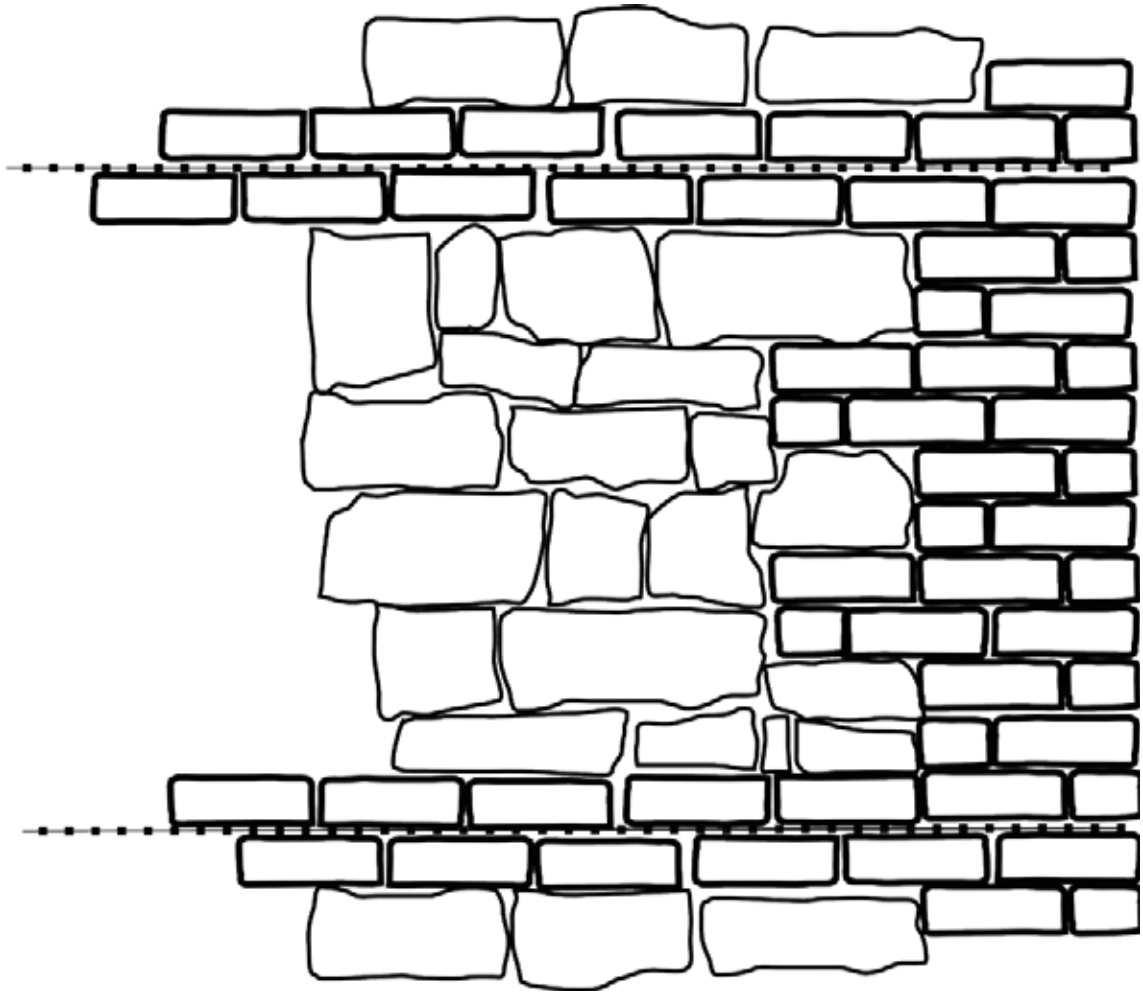


Stability:	**Friction:**
The strength of the brick masonry increases the corner's stability.	The friction between bricks is high, allowing good dissipation of energy.



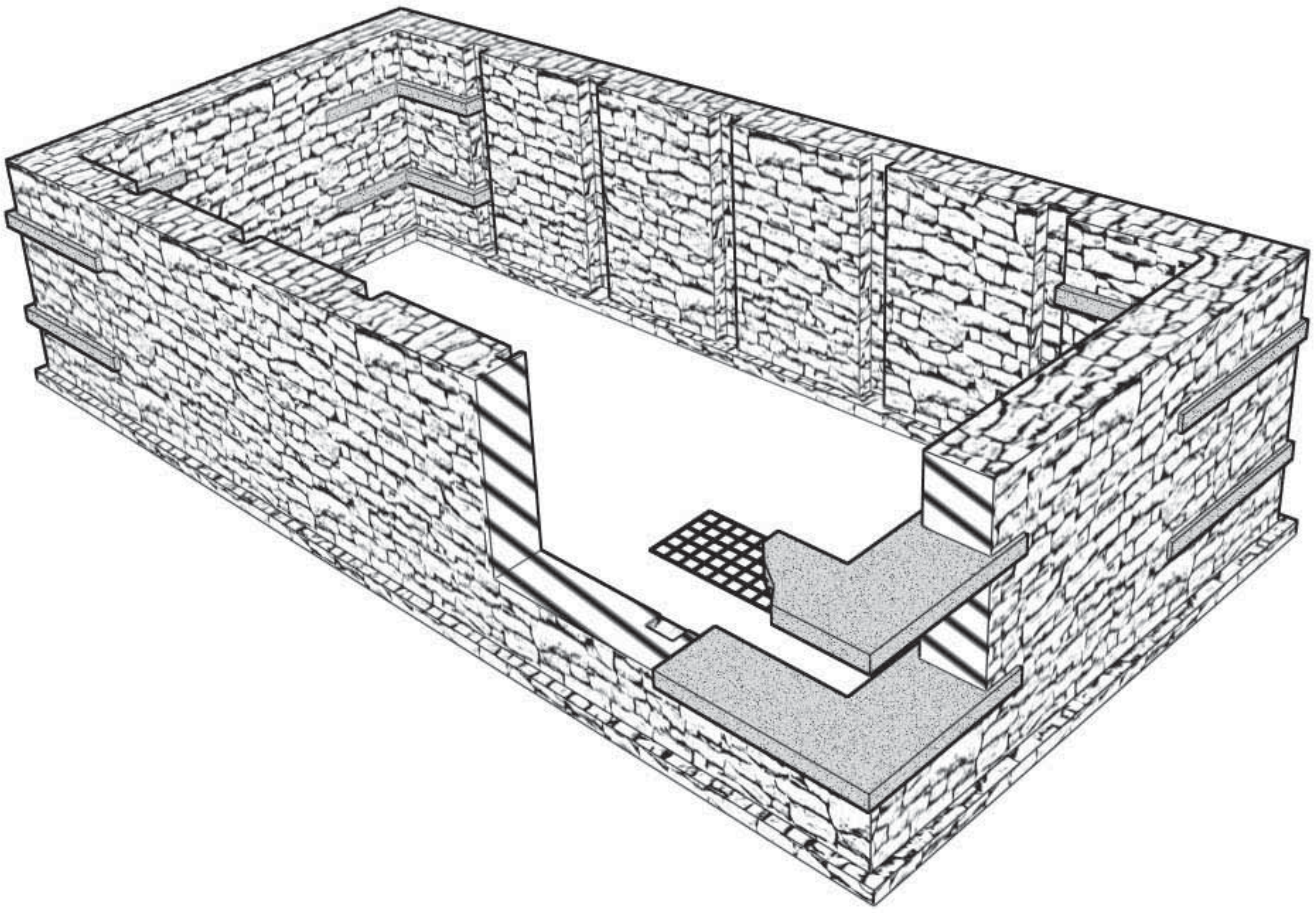
Stability:	**Friction:**
The strength of the brick masonry increases the corner's stability.	The friction between bricks is high, allowing good dissipation of energy.

The brick layers can be reinforced with a wire mesh. This mesh brings some confinement and some ductility to the wall.



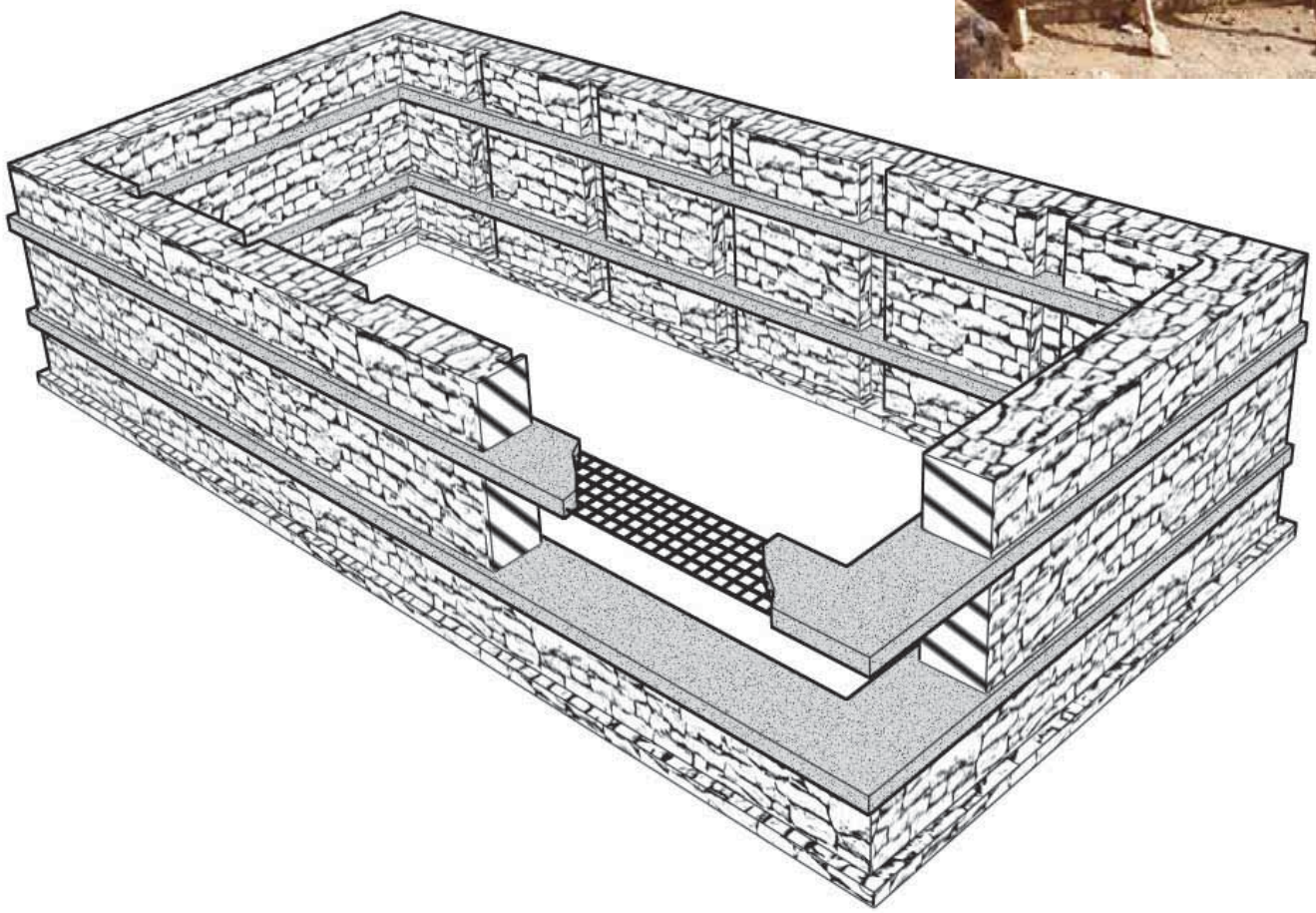
Stability:	**Friction:**
The wire mesh brings some ductility to the wall, improving shearing stress resistance. The mesh layers maintain the walls together even in case of cracks or partial collapse.	The friction between bricks is high, allowing good dissipation of energy.

The corners can be reinforced with concrete layers in which is set a wire mesh. The concret layer should be 4 inches thick.



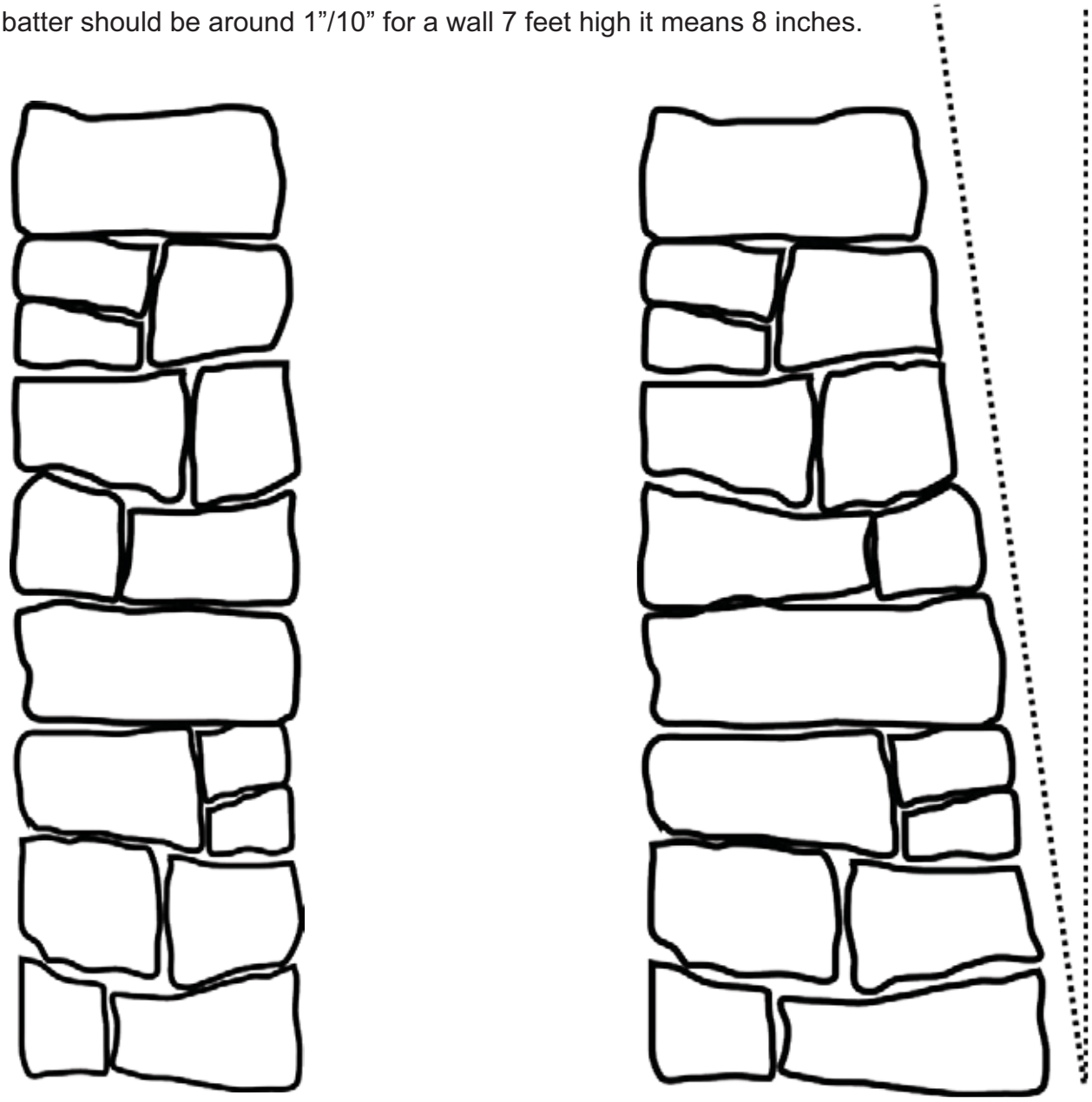
Stability:	**Friction:**
The wire mesh brings some ductility to the corners, improving shearing stress resistance. The mesh layers maintain the corners together even in case of cracks or partial collapse.	

This concrete layer can be used in the whole wall for better reinforcement.



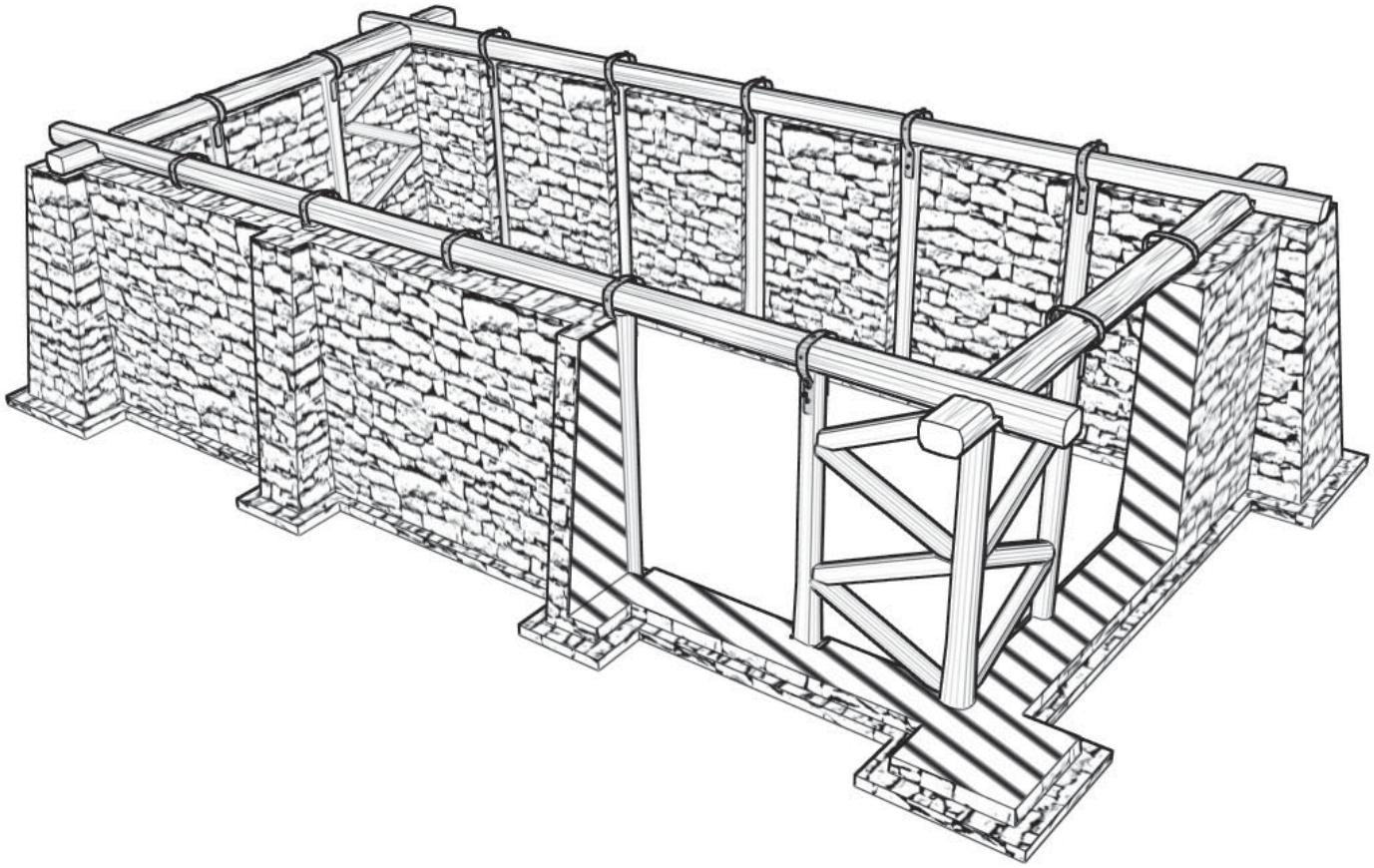
Stability:	**Friction:**
The wire mesh brings some ductility to the wall, improving shearing stress resistance. The mesh layers maintain the walls together even in case of cracks or partial collapse.	

The batter is added to the wall thickness: the top of the wall with batter must be as thick as the top of the wall without batter.
The batter should be around 1”/10” for a wall 7 feet high it means 8 inches.



Stability:
The batter decreases the height/thickness ratio of the wall without increasing the weight of the upper part. The smaller the slenderness, the greater the stability.

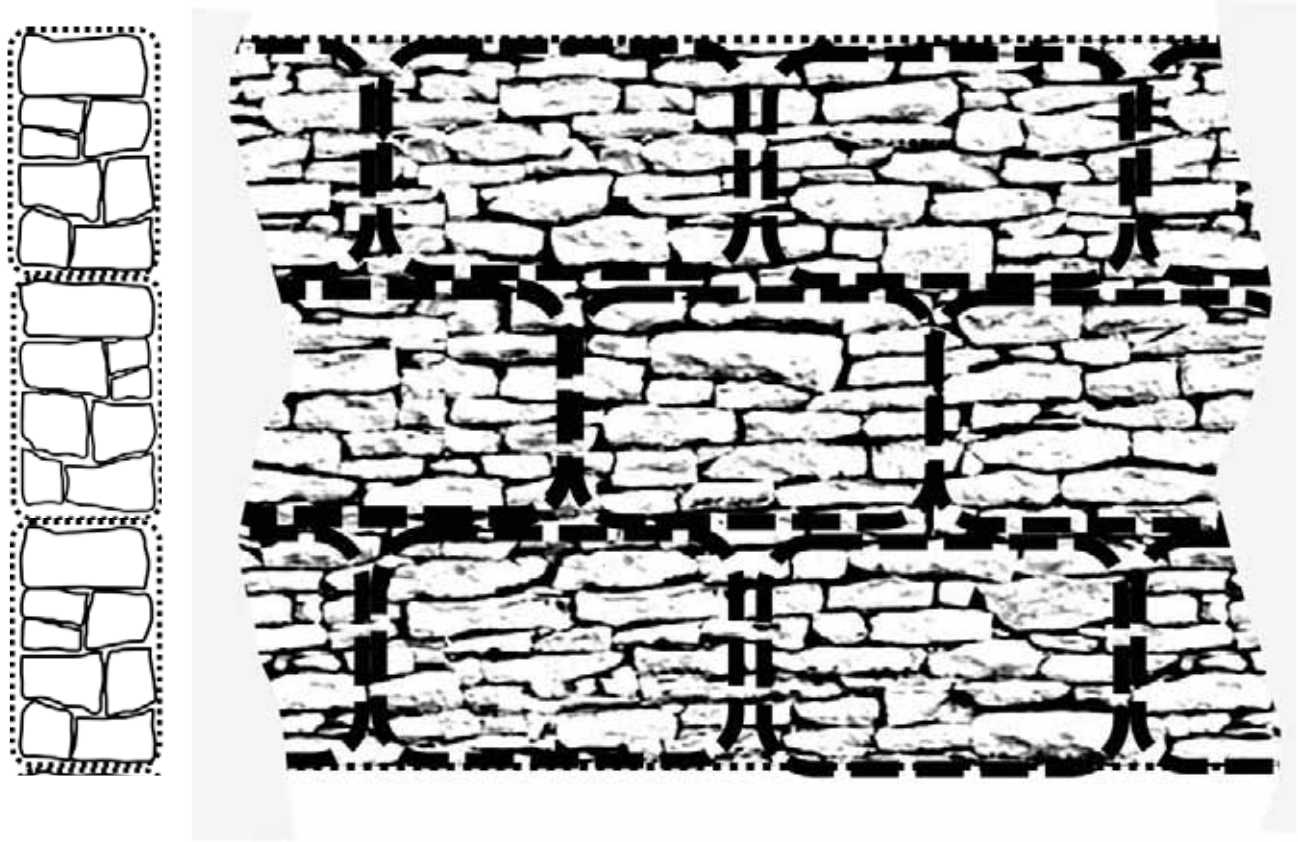
The distance between the buttresses should be less than 10 feets.



Stability:
The buttress decreases the height/thickness ratio of the wall without increasing the weight too much. The smaller the slenderness, the greater the stability.

The stones are confined in wire mesh. The wire meshes form “blocks”. This confinement prevent stones to fall and make the wall loose its integrity. The meshes bring some ductility too.

The mesh are not fixed one to each other, to prevent sudden collapse of the whole wall.



Stability: The confinement prevent stones to fall, improving the stability. The wire mesh brings some ductility to the wall, improving shearing stress resistance.	**Friction:** The stones staying together longer time, the dissipation through friction is ensured as well for a longer time.

Definition

The opening is the empty space of a door or a window created in the masonry of the walls.

Function

The openings permit to illuminate and to ventilate the inside of the building. They represent nevertheless a weak point in the structure of the building. It is often from the openings that appear many cracks. Therefore it is necessary to look after their solidity.

Dimensions

It is strongly recommended to respect some rules in the construction of openings:

Do not make openings too close one from another (minimum 1 meter) (3'4").
Do not place the openings less than 1 meter from an angle of the building.
Well anchorage the lintel in the wall: support it on a minimum of 20 cm (8") inside the wall on each side of the opening.

It is strongly recommended to avoid:

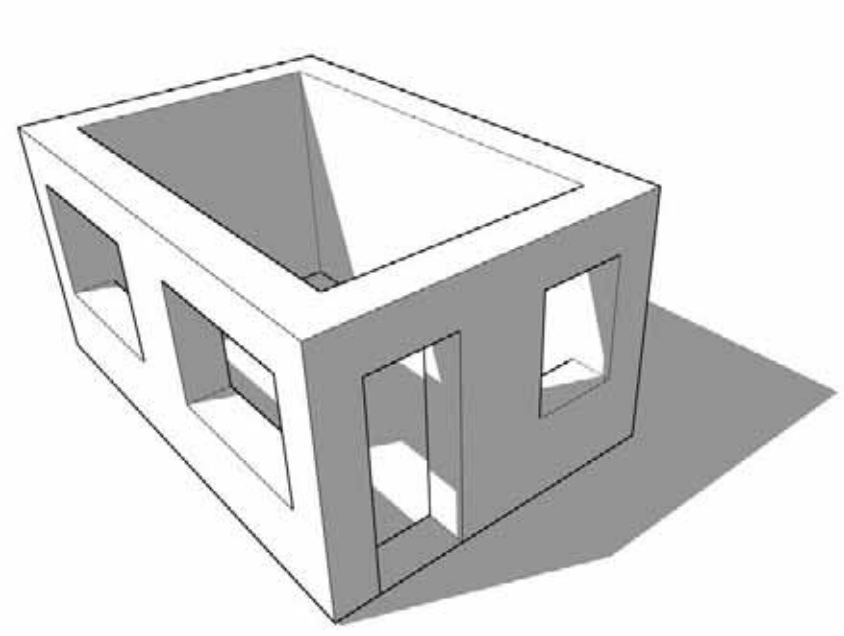
Too large openings (more than 1.20 meters) (4').
Too many openings on a same wall or openings badly equilibrated in the wall.

Lintel

The lintel is a horizontal crossbar above an opening which reports the load of the superior parts on the lateral points of support.

The lintel is very solicited by the load of masonry it supports and which it transmits toward the sill. To avoid the cracks, it is necessary to increase the length of support of the lintel in the wall.
The lintel must be in wood.

Which one of the following buildings will be the most resistant to earthquakes ?



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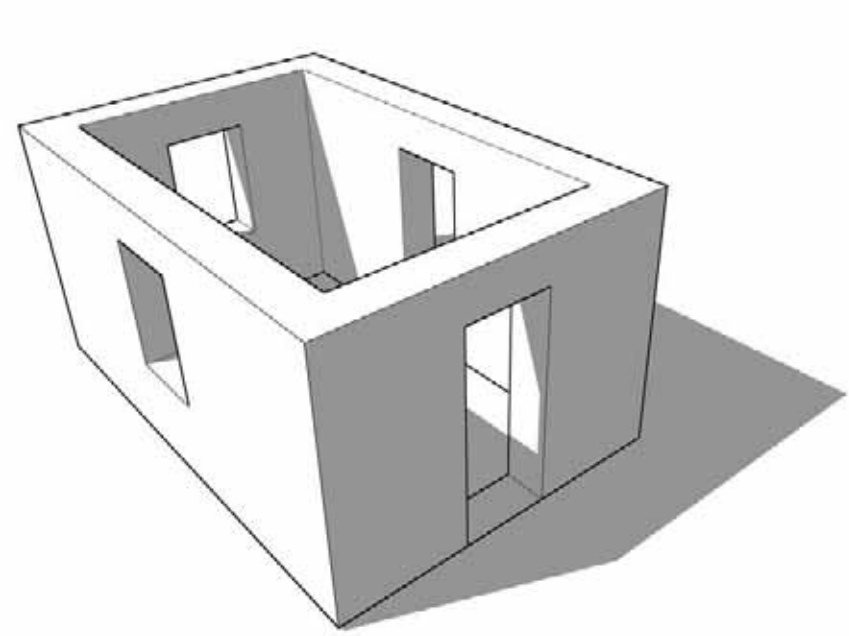
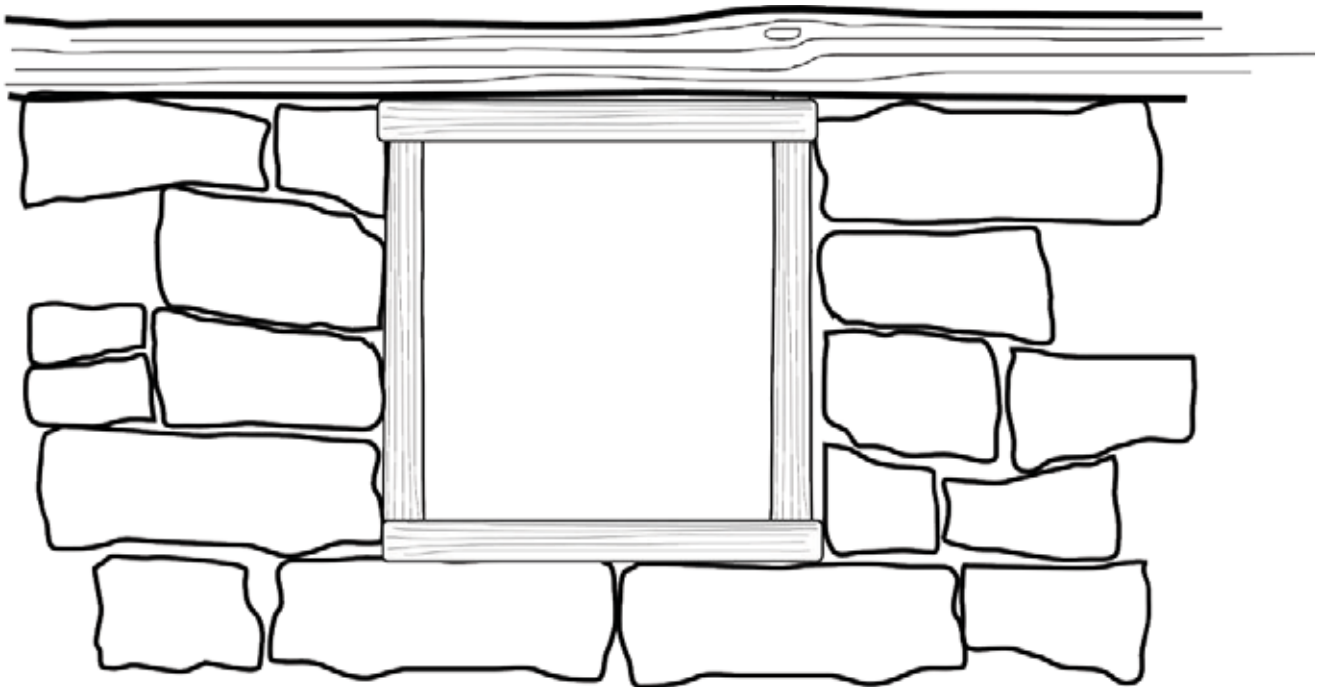


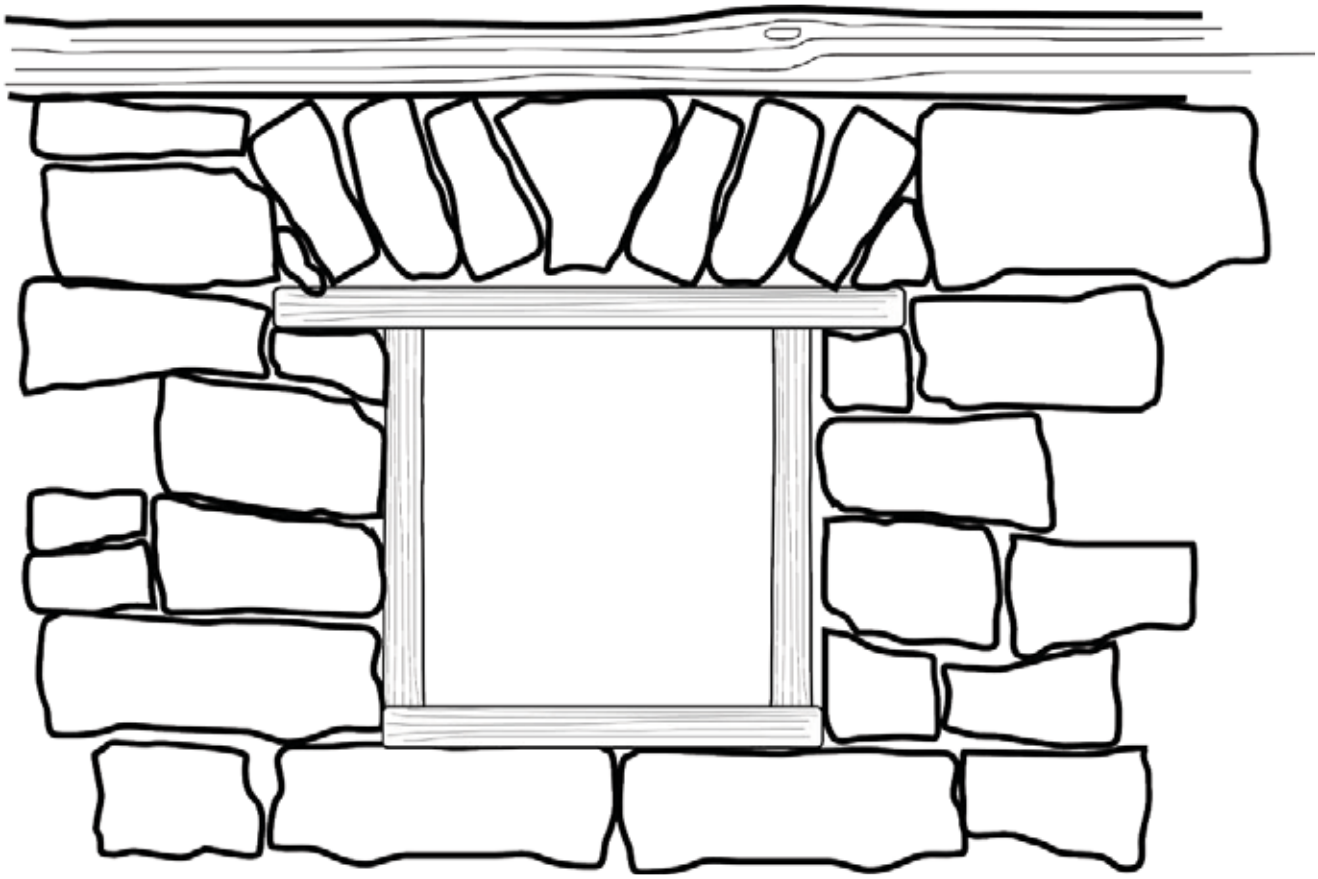
Wooden lintel



The borders of the opening must be treated as a corner of the building, with the most regular through stones

Stability:	**Friction:**
The wooden border of the window prevent the stones from the masonry to fall.	The friction between the wooden border and the stones can dissipate energy.

If the lintel cannot be just under the ring-beam, the stone filling must be a flat arch for it not to transmit load on the lintel. The masonry of the arch must be done with great care to prevent stones to fall.

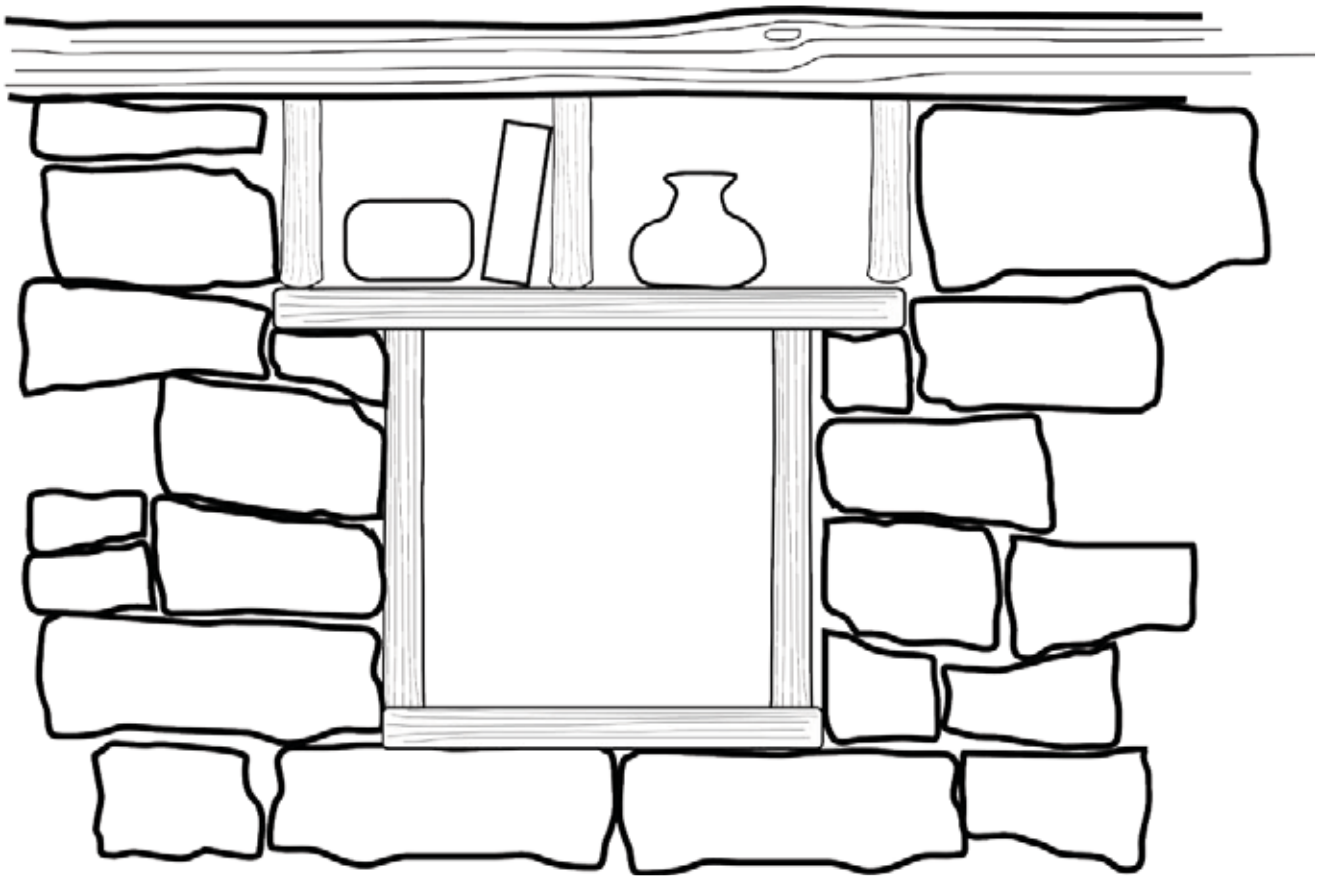


The borders of the opening must be treated as a corner of the building, with the most regular through stones.

Stability: The wooden border of the window prevent the stones from the masonry to fall.	**Friction:** The friction between the wooden border and the stones can dissipate energy.

Cupboard lintel

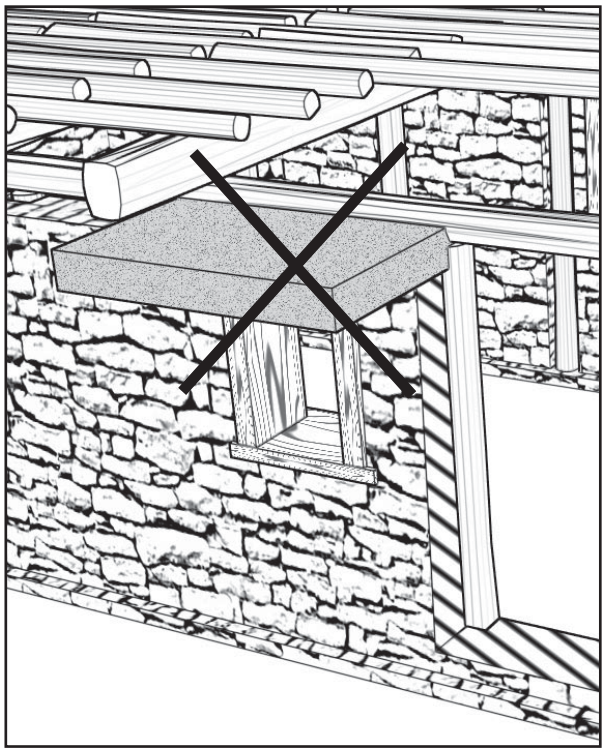
The part of the wall at the top of the lintel is made by a wooden cupboard. This will make it lighter and prevent stones to fall from this part. The cupboard should have a door to prevents objects to fall.



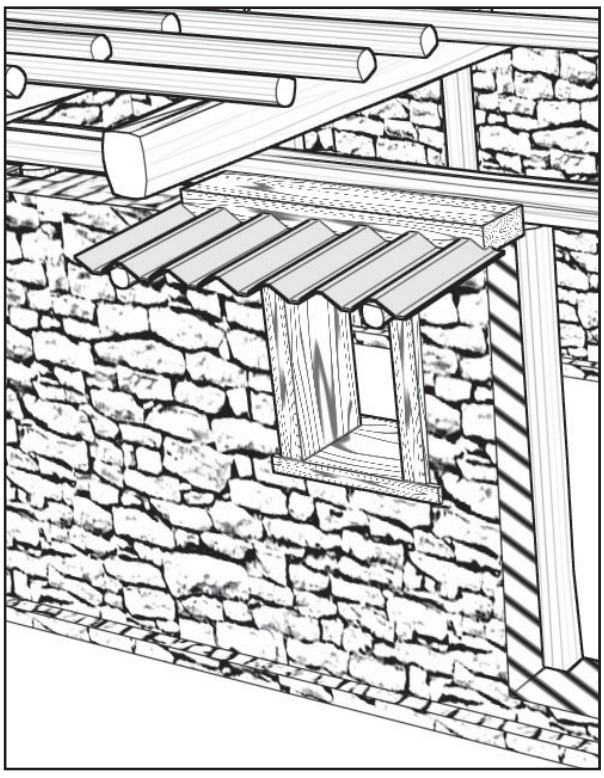
The borders of the opening must be treated as a corner of the building, with the most regular through stones.

Stability:	**Friction:**
The wooden border of the window prevent the stones from the masonry to fall.	The friction between the wooden border and the stones can dissipate energy.

The use of concrete for the protection of the openings as it is a cantilevered heavy structure that may collapse under vertical seismic loads.



It can be replaced by corrugated steel sheets on a wooden structure.



LESSON PLAN

ROOF

7-102

Session duration: theotie 30 mn; practice with stone massonry

Objectives:
In order to help trainees to improve on their actual building habits, the trainer will help the trainees to understand the behaviour of the roof and its different part under seismic movement. Help the trainees to understand the stability limit of the roof structure and how to improve its stability without reducing its flexibility. Specila focus will be done on maintenance (degradation of some struictural component) and risk link to the increasment of the roof load along the years.

Method:
Discussion about the behaviour of the wooden structure under earthquake movement. Ask trainees to identify problems and to develop their own solutions. Synthesis by the trainer who will make available potantial improvment if they have not been find by the trainees themselves.

Trainer team	**Session**	**Pedagogical support** :	**Tools :**
Lecture One trainer for 7 participant Practice One trainer for three group of 7 trainees on practice	Preparatory work : It could be good to produce small scale models to illustrate the different risks related to this roof structure, and how to reduce these risks. Lecture: Use the model or an existing structure or some drawing to illustrate the way the roof structure is commonly constructed in the area. Ask the trainees to list the role of each part of the roof structure and how they interact together. Ask Trainees to give their feeling on how this structure will move under seismic movement, how it will interact with the walls it is lasting on, Ask the trainees to list the different damage this structure can face during earthquake. List the different risk and complete them if trainees do not cover everything. For each risk, ask trainees to develop their solution. Synthetise trainees ideas and add some more solutions if required. Emphasis in the risk related to maintenance: ❋ Rooting of some wood ❋ Adding new layer of mud every year on top of the wall (for waterproofing) that results in increasing the load of this roof . Give trainees advices to redo the roof waterproofing at least every ten years (remove the mud, replace the spoiled peices of wood, redo the whole things).	Demonstration: Trainer guide: Small model of the roof structure	

Planning

Before the session:

Lecture

After lecture

Protection
The roof protects the building itself and the inhabitants from the rain, the snow and the sun.

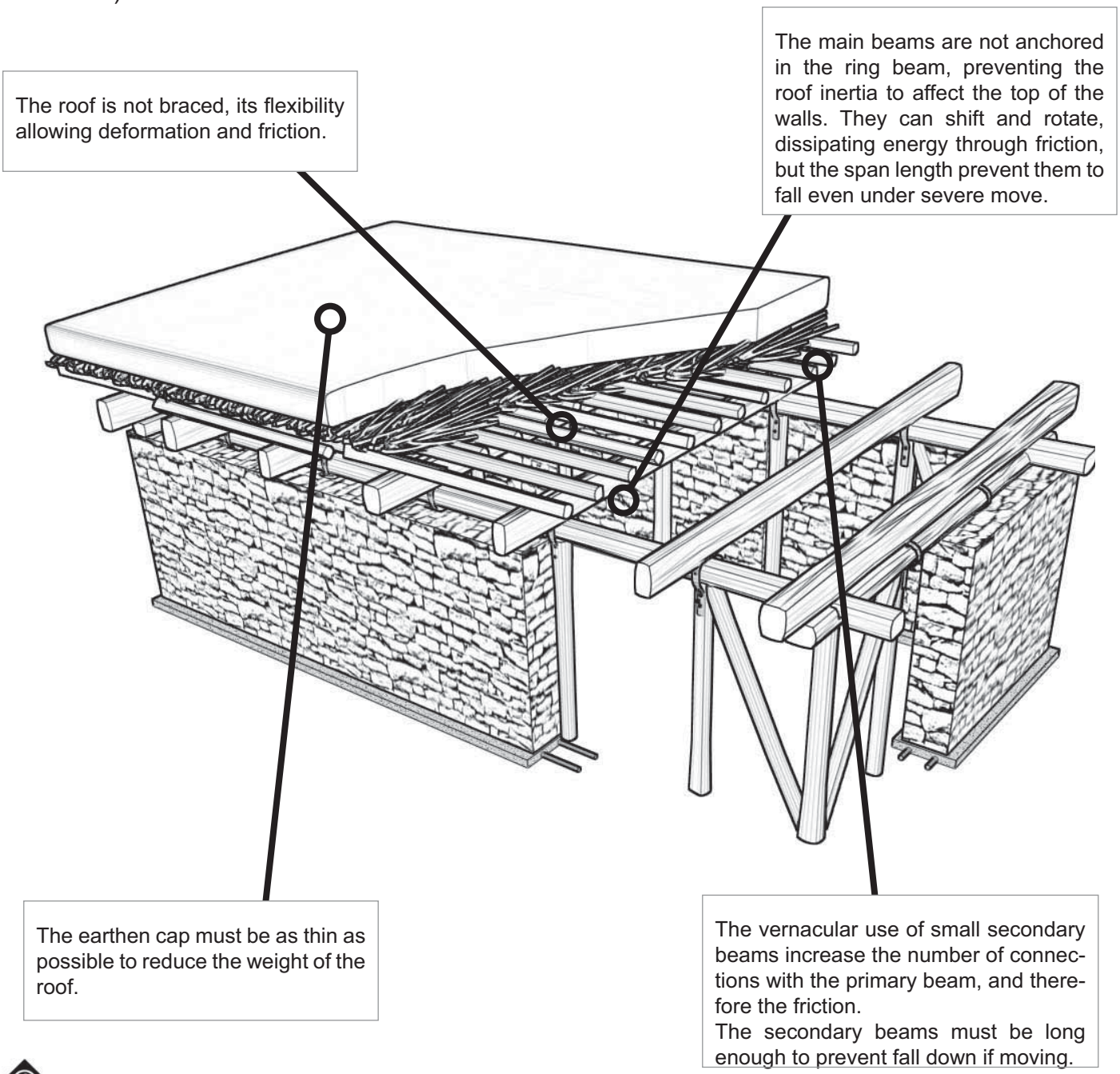
Thermal
The roof provide insulation to the building. An important part (around 30%) of the thermal losses appends through the roof. Its good insulation is therefore important.

Aesthetic
The form and look of the roof is of first importance for the general aesthetic of the building.

Social
The roof can be used as a terrace for various activities among which drying crops.

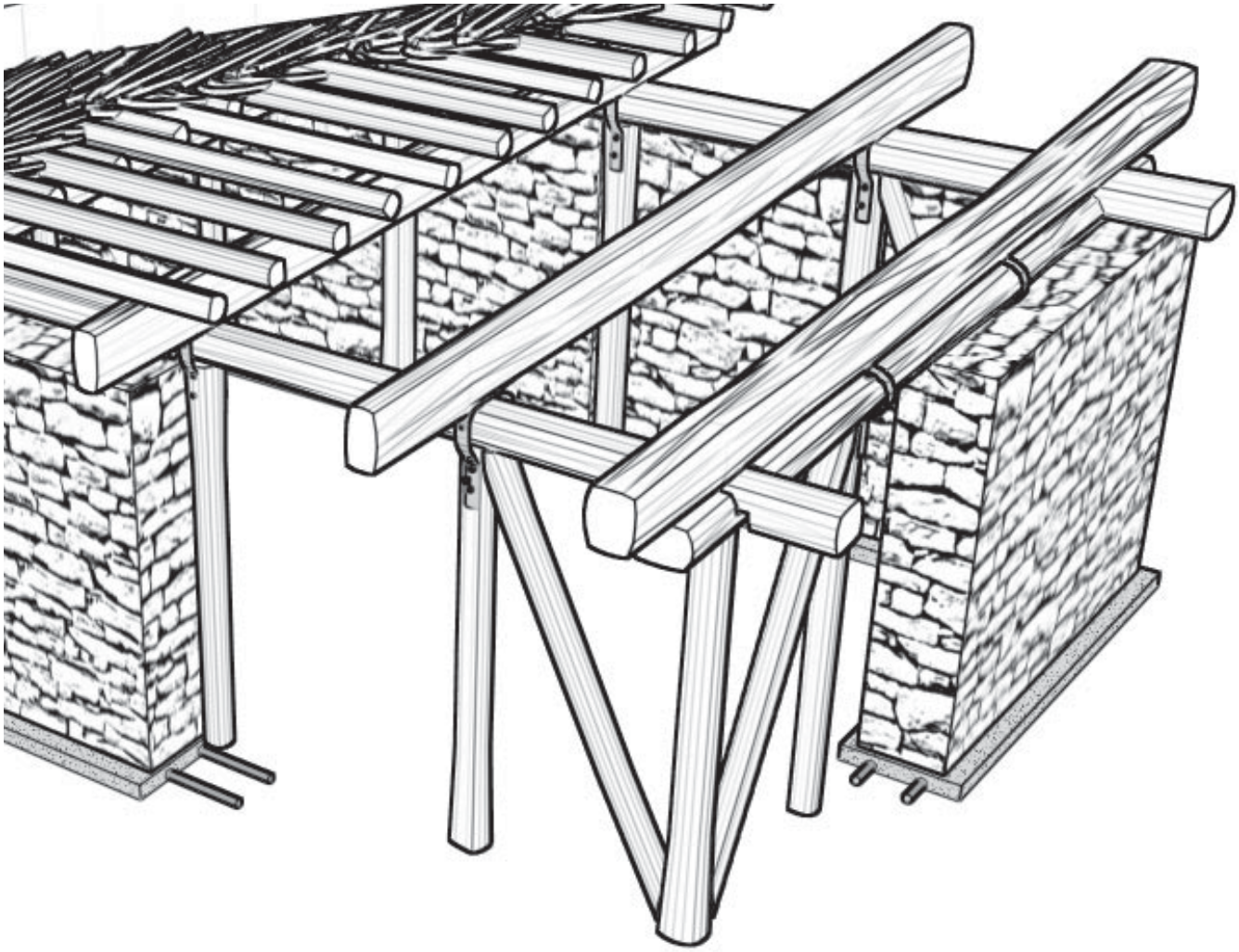
The earthen terrace roof is an important part of the architectural culture of the region. It is not only insulating and protecting but has an important paper in the everyday life of the people that use it for several purposes. It is necessary to keep it in spite of its big weight that can be problematic in earthquake prone areas.

The roof is separated of the walls to reduce interaction and therefore avoid that its movement pressure too much the corners. Energy can be dissipated at the interface between the ring beam and the roof and inside the roof mainly through friction in the assemble (friction between the wooden parts and between nails and wood).



The main beams

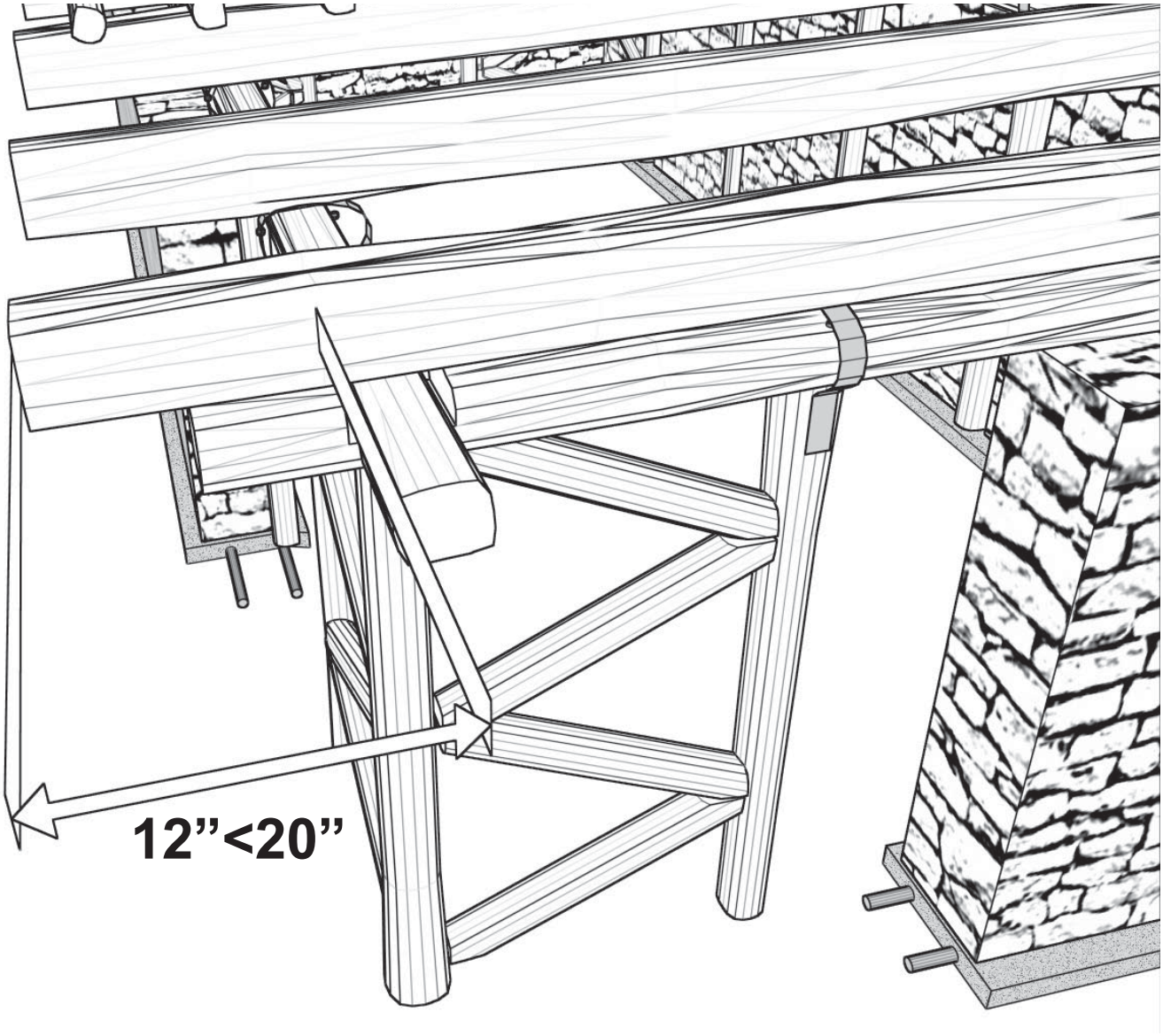
The main beams are set on the ring beam without anchorage.



Stability:	**Friction:**
The length of the beams prevent them to fall, even in case of severe moves.	The beams can shift and rotate on the ring beam, dissipating energy through friction.

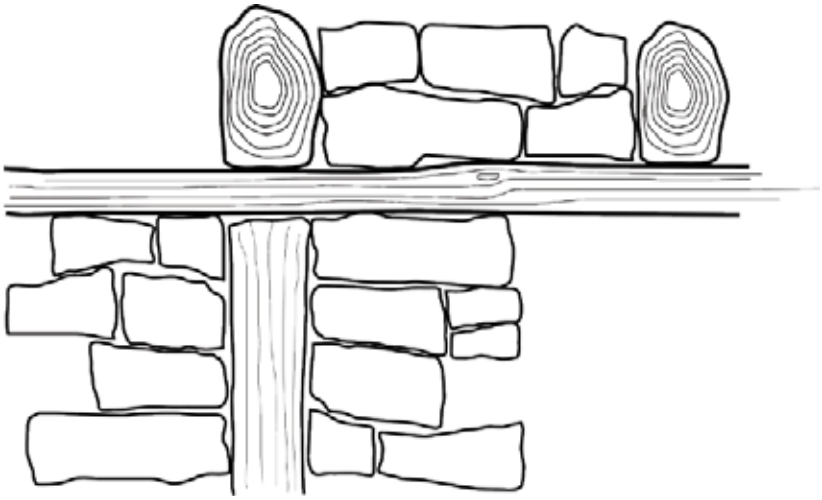
The main beams

The span of the primary beams must not be more than 20 inches, but not less than 12 inches to prevent them to fall in case of sliding.

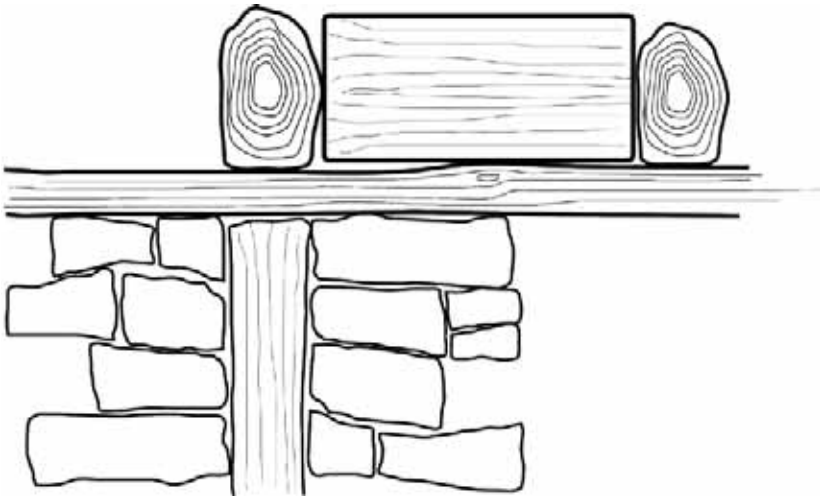


Stability:	**Friction:**
The length of the beams prevent them to fall, even in case of severe moves.	The beams can shift and rotate on the ring beam, dissipating energy through friction.

After setting the primary beams, the masonry is finished between them. The filling must be done carefully.
The use of wire mesh to prevent the stones to fall is strongly recommended.



To prevent the stones to fall, they can be replaced by wooden planks naild to the beams.



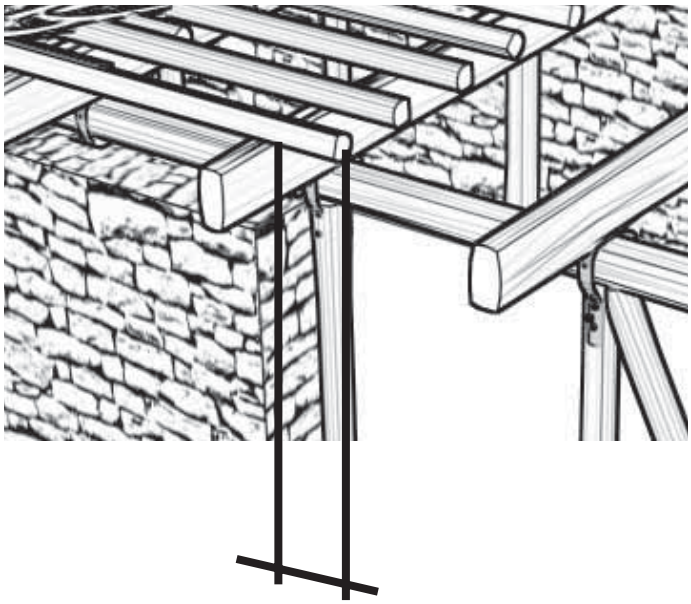
Stability:	**Friction:**
The masonry between the beams prevent them to slide independently laterally.	The stones increase the friction with the beam

The secondary beams

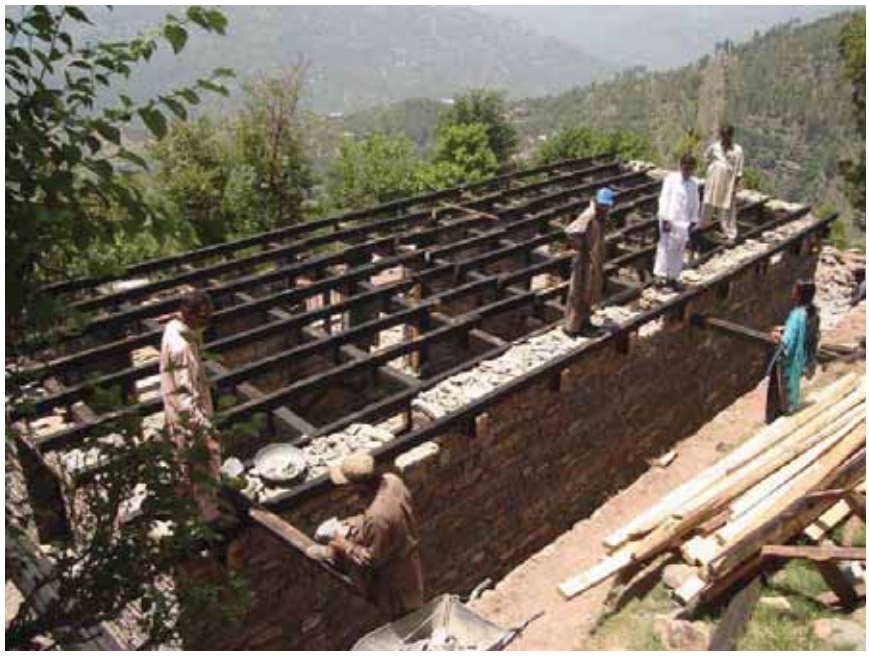
The secondary beams are nailed to the primary beams.

Two nails should be used for each.

The secondary beams must be longer of at least 30 cm on each side of the primary beam.

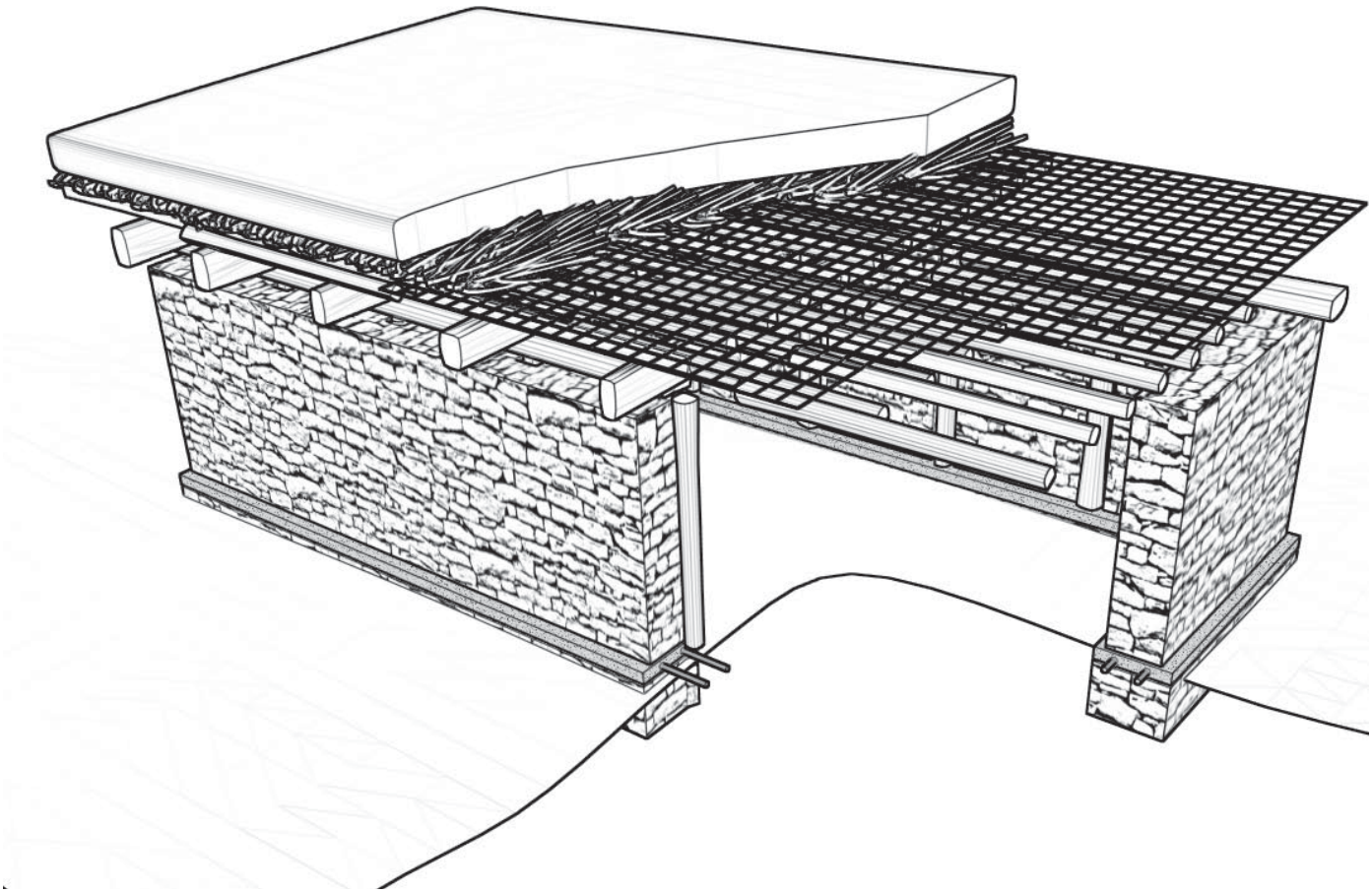


1 foot



Stability:	**Friction:**
The length of the beams prevent them to fall, even in case of severe moves.	The high number of secondary beams increase the friction. Energy can be dissipated by the nails too.

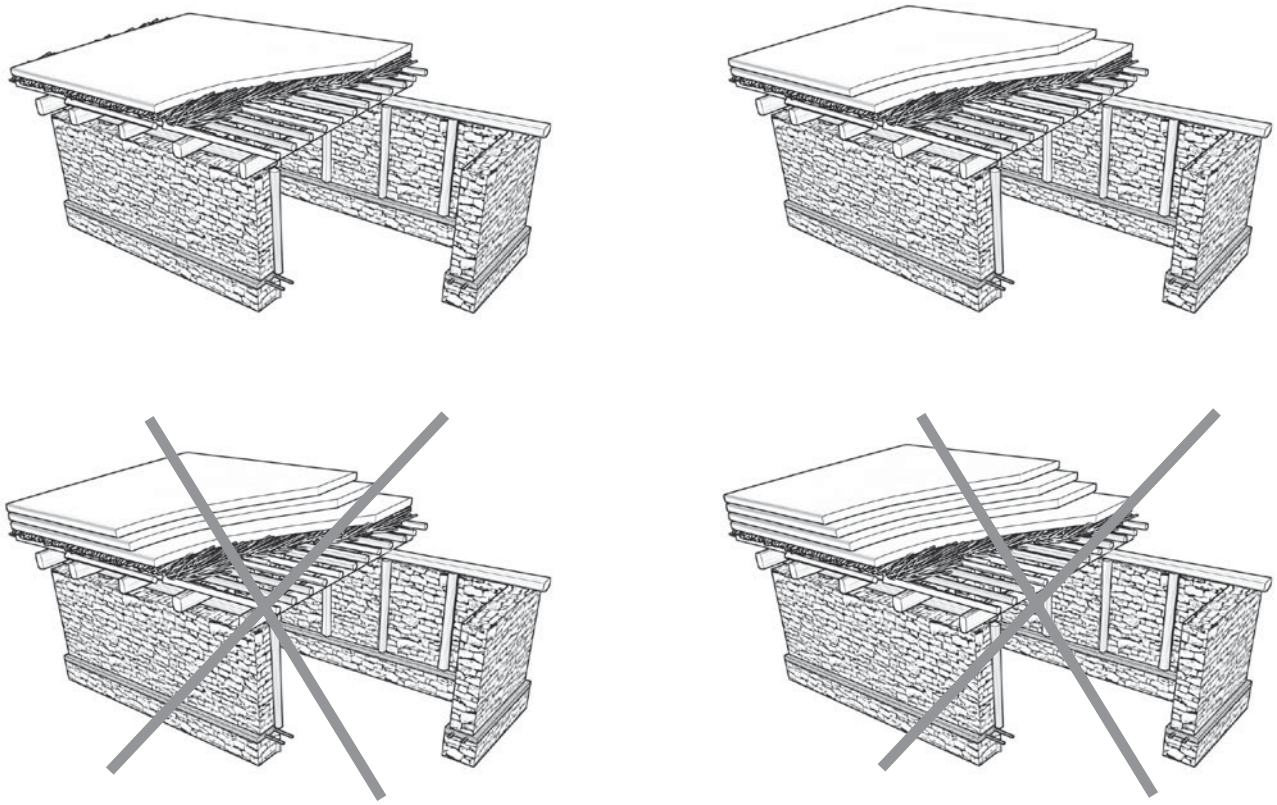
A wire mesh can be nailed to the secondary beam. Still allowing some deformation, the mesh reduces sliding and prevent the fall of wooden parts or earth blocks.



Stability:
Preventing the beams to slide too much, the mesh increases the stability of the roof.

Roof maintenance

The local way to maintain roofs is to add every year a new cap of earth plaster to ensure the water-proofness of the roof.
This leads to very heavy roofs after some years that increase the collapse risk in case of earth-quakes.



It is recommanded to remove the whole earth layers from the roof every 10 years and to build it again. This will prevent to thick roofs and will allow to check the conservation state of the wooden parts and eventualy change the dammaged ones.

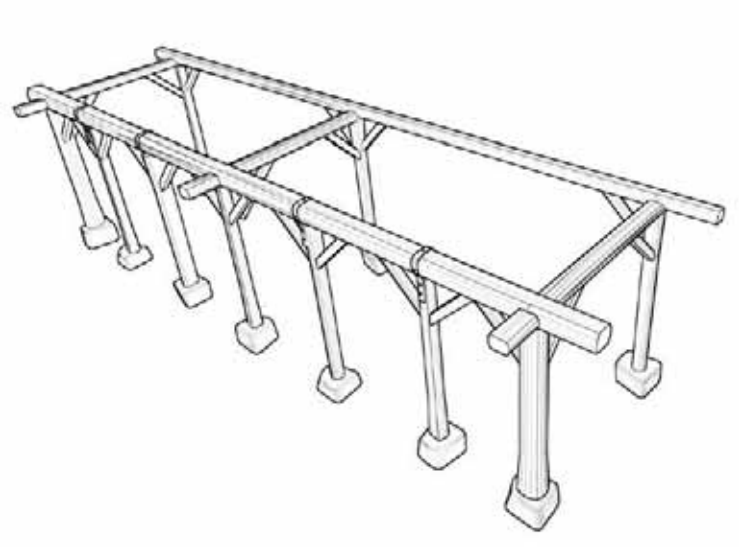
Thermal:
The veranda protects the southern facade from the direct sun, reducing the heat during summer.

Cultural:
The veranda is one of the typical elements of vernacular architecture of this region. Most of the houses have one.

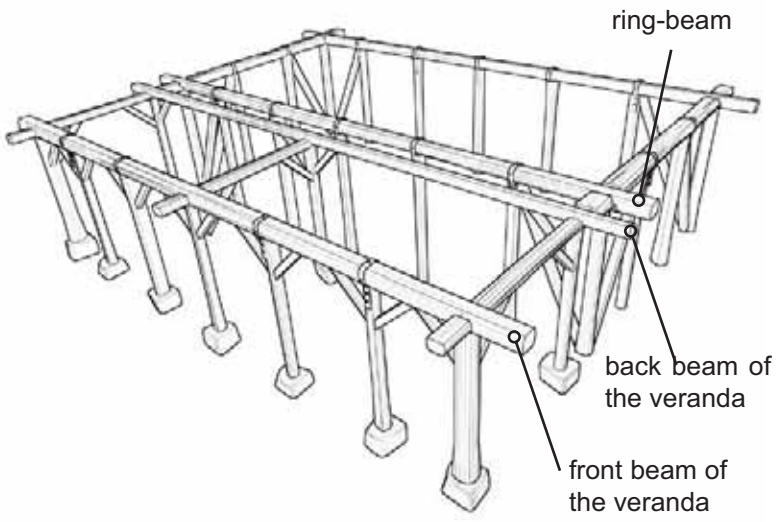
Social:
The veranda is a half public half private space. It is an outside place but protected from the sun and the rain.

The veranda is an independent wooden structure. It is stable in both direction.

The posts are set on big flat stones.
They support the beams.
They are braced by struts in both direction in some places.

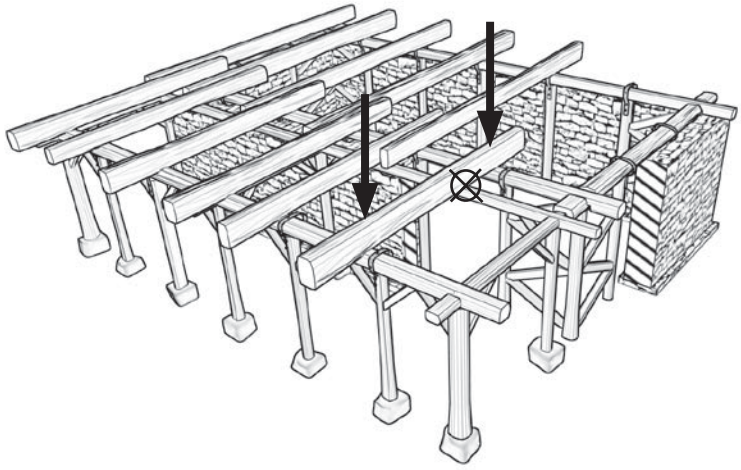


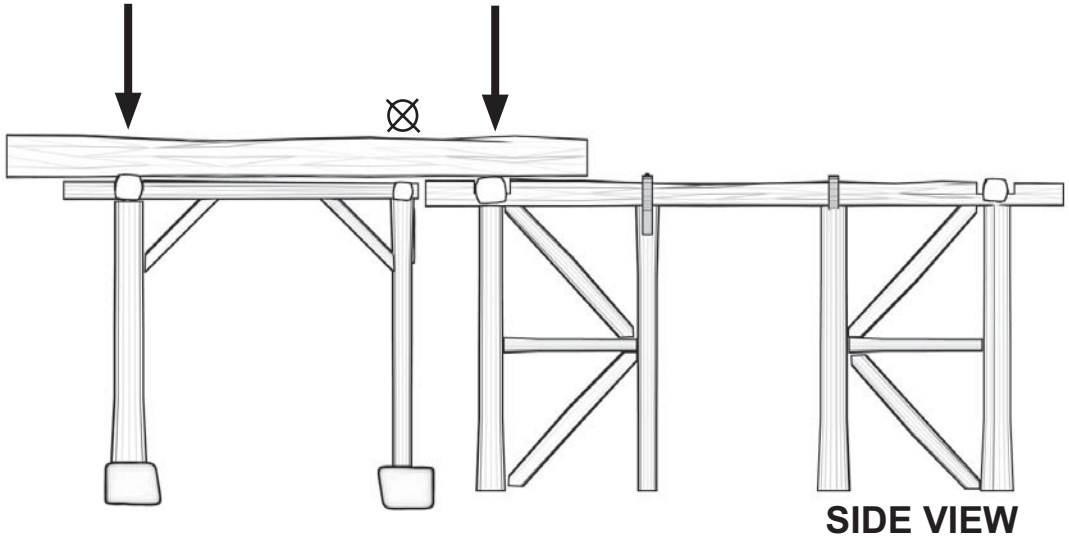
The veranda structure and the walls structure are not connected. It is necessary to allow them to move freely one from the other because of their different rigidity.



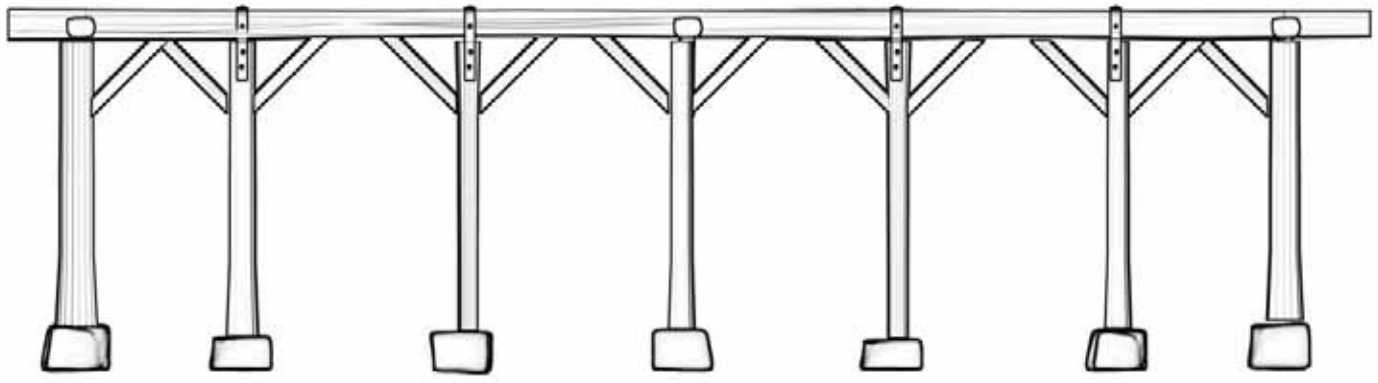
The primary beams of the veranda's roof are independent of the primary beams of the house's roof for the same reason. A eventual failure of the veranda must affect the least possible the walls.

The primary beams of the veranda roof rests on the front beam of the veranda and the ring-beam of the walls, but not on the back beam of the veranda.





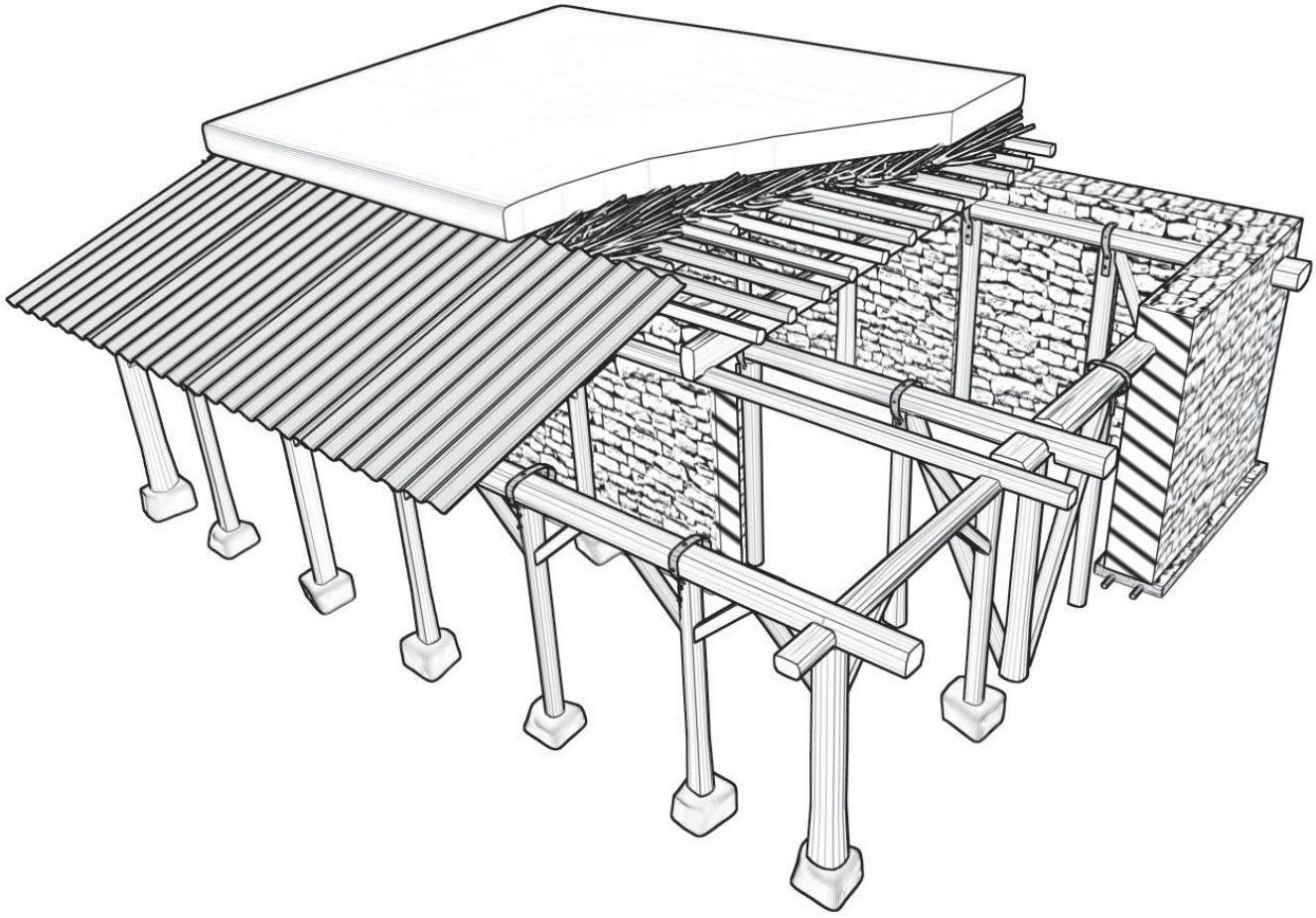
SIDE VIEW



FRONT VIEW

Stability: The struts in both direction increase the stability of the veranda.	**Friction:** The wood assembly can dissipate energy (wood/wood friction and nail/wood friction). The high number of assemblies increase the dissipation.

It is strongly recommended to cover the veranda with corrugated sheets to reduce its weight.



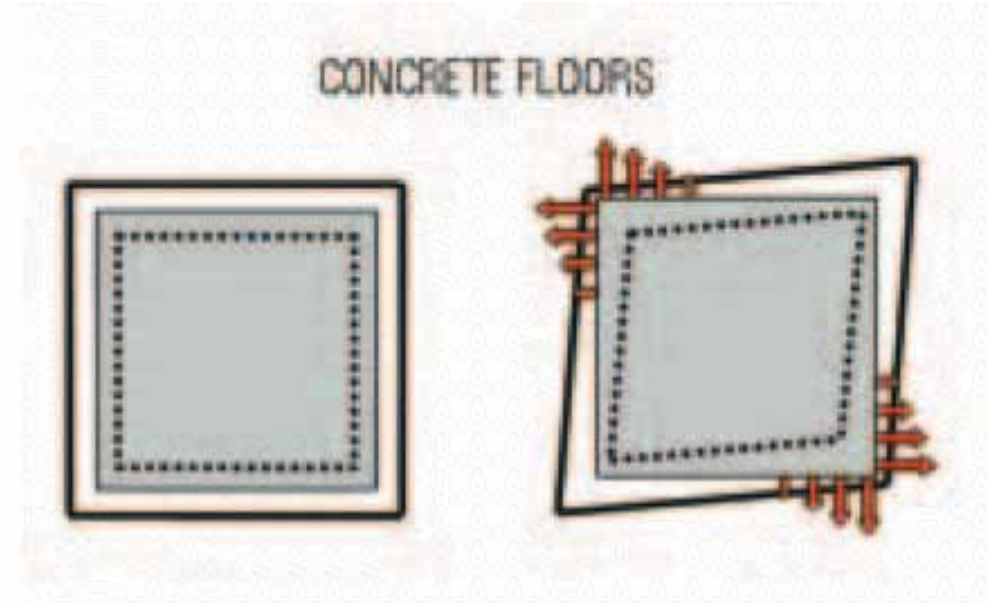
Definition
The slab is a large surface of hard material used as floor, cover, or artificial soil.

Function
The slab permit to distribute uniformly to the ground the load of people and furniture.

The slab is generally made of earth mixed with coal tar.

The floor slab must not act as a diaphragm and must not transmit stress to the walls.

If thick concrete slab is used, a gap of 2 inches between the borders of the slab and the walls is strongly recommended.



Plaster functions

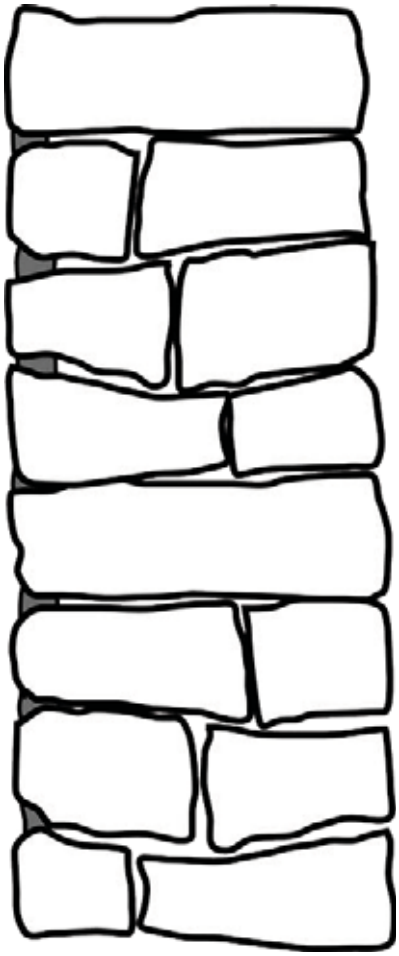
Aesthetic
The plaster brings good finish to the wall. It can bring an aspect of mortared wall which can be preferred by somme people.

Protection
The plaster prevents the rain and the snow to enter in the wall. It prevents animals and insects too.

Insulation
The plaster blocks the air circulation, improving the insulaton of the building.

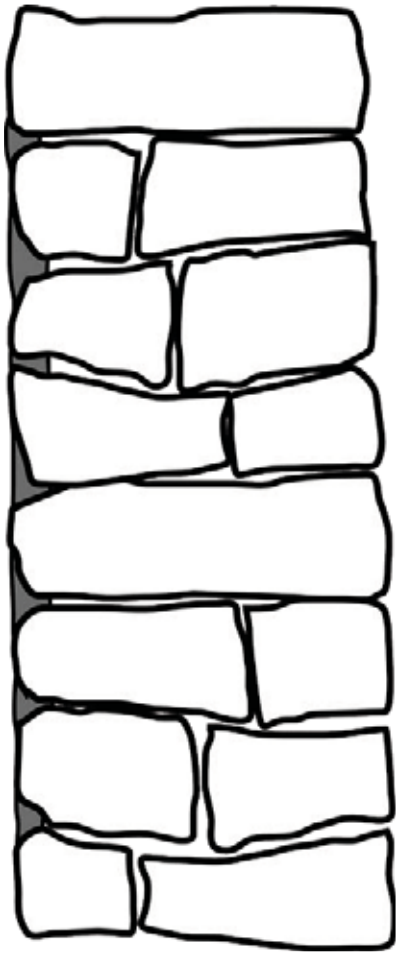
Stone blocking
The plaster increases the stone blocking, preventing them to move in case of defects in the masonry work.

The joints are filled with a cement-lime-sand plaster.



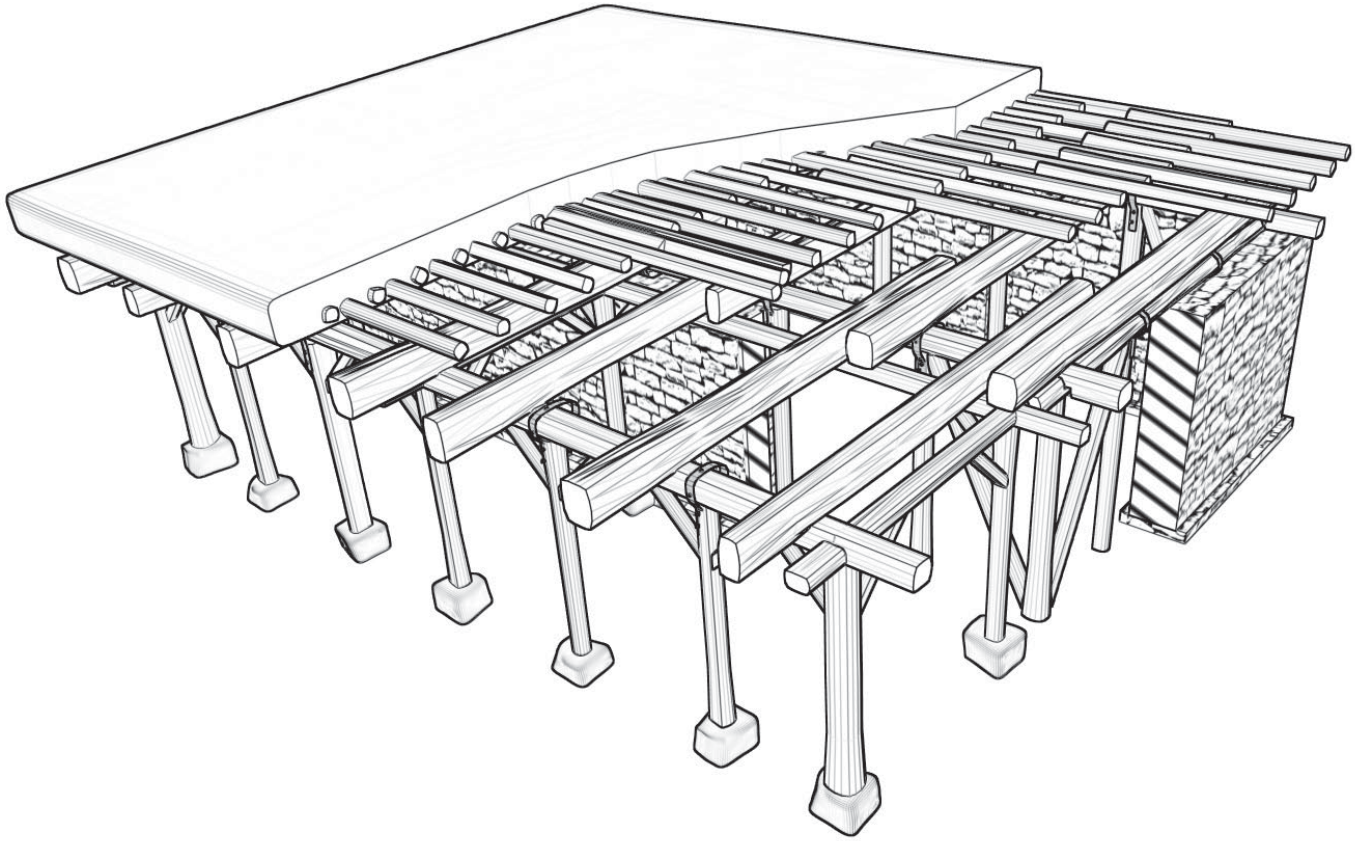
Stability:	**Friction:**	**Maintenance:**
By filling the gaps between the stones, the plaster can prevent them to fall and increase slightly the stability of the wall	The breakage of the plaster can dissipate energy	The plaster helps maintaining the wall and reduces the maintaining needs.

The joints are filled with a cement-lime-sand plaster and the surface of the wall is straightened.

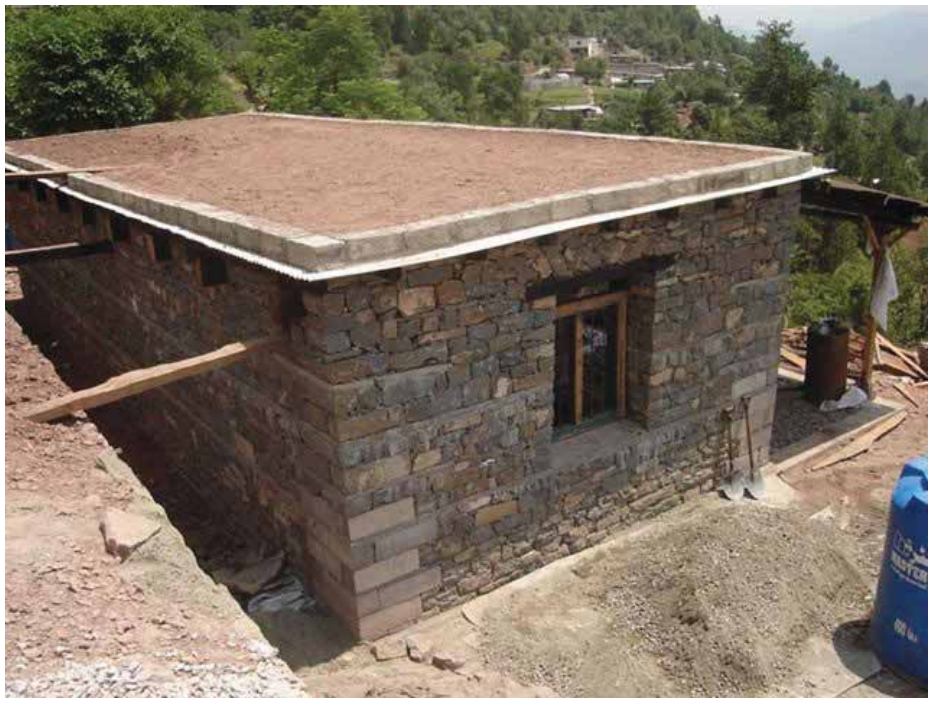


Stability:	**Friction:**	**Maintenance:**
By filling the gaps between the stones, the plaster can prevent them to fall and increase slightly the stability of the wall	The breakage of the plaster can dissipate energy	The plaster helps maintaining the wall and reduces the maintaining needs.

This is a general overview of the model based on the local seismic cultures and improved seismic cultures.



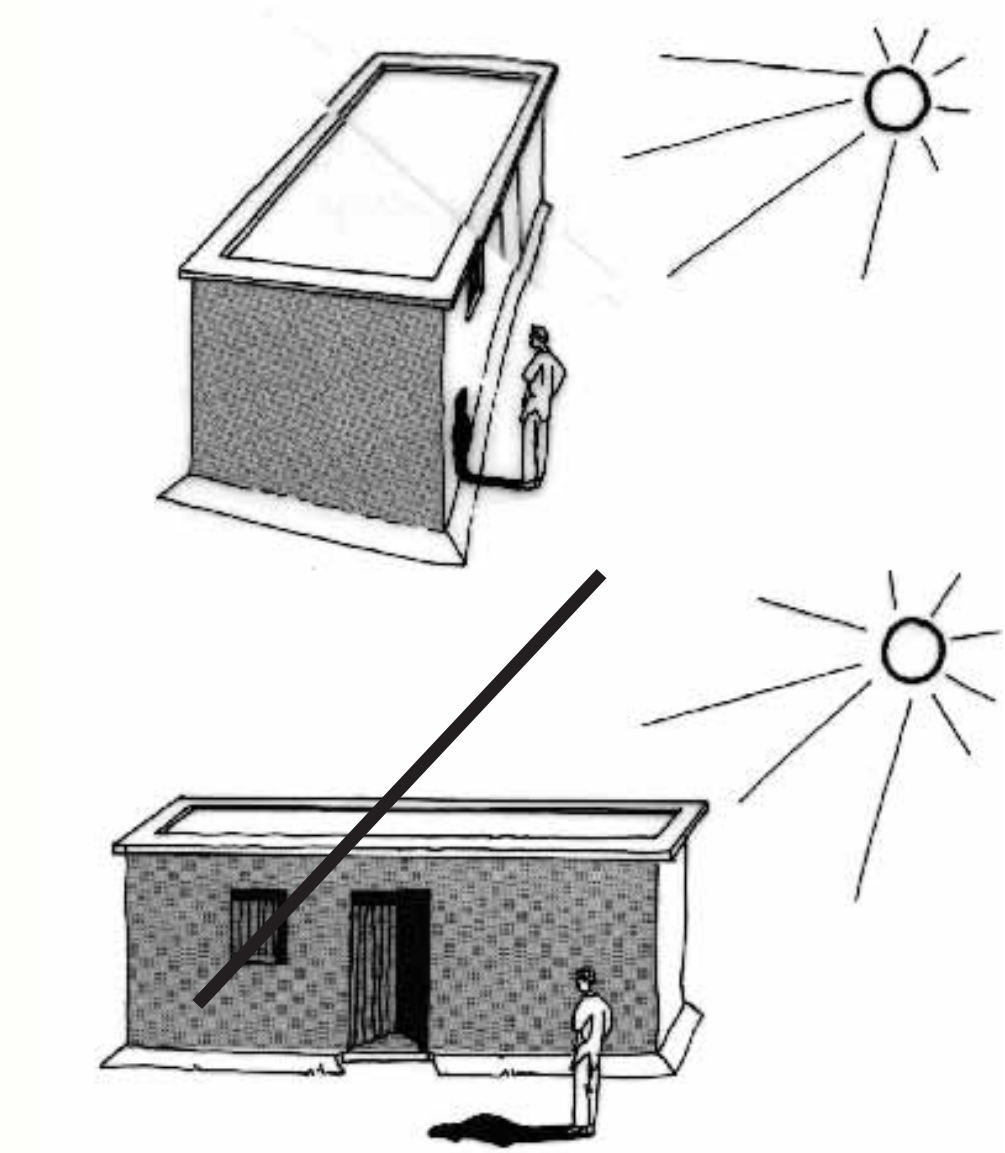
This is a picture of the first prototype based on the model with a corrugated sheet veranda.



General considerations

Orientation of the building is very important in term of thermal comfort.
With hot days and cold night, the best is to try to accumulate the sun heat during the day, for it to be redistributed during the night. The masonry wall inertia is here a good advantage.
Direct sunshine is stronger at the southern side. Therefore, the longest wall of the building should be on the southern side.

General considerations



General considerations

It is necessary to clear the site before any construction:

Vegetable earth should be removed up on the whole surface of the building.

It assists to set the building on a good and firm soil.

Extra allowance of about 2 meters (6 feet) should be given all over the perimeter of the proposed building.

The top soil consisting of vegetable matter when cleared could be used for agricultural purposes only, not for construction.

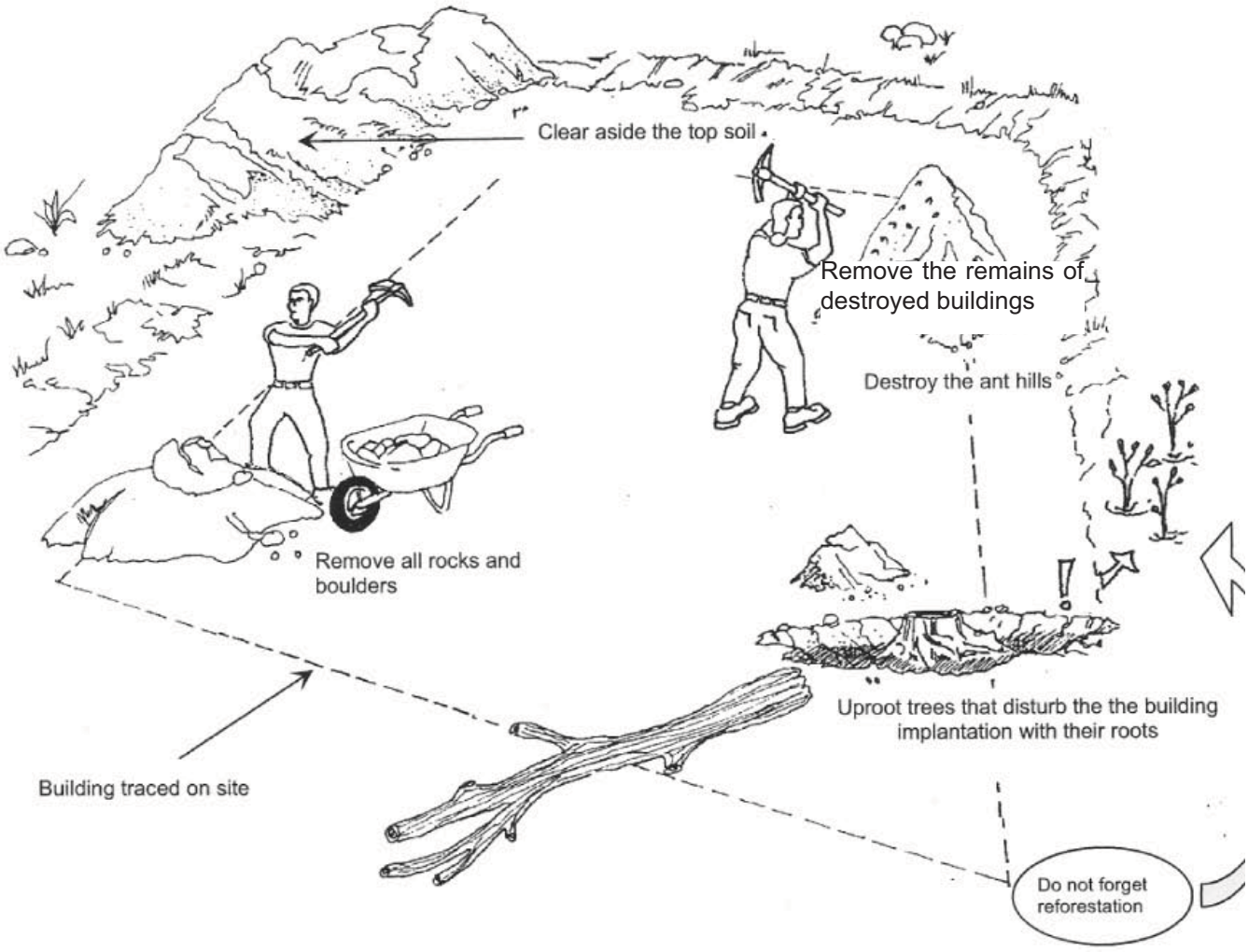
In case the land of a destroyed house is used, all the remains and debris should be removed.

Remember to remove stones, stumps and roots.

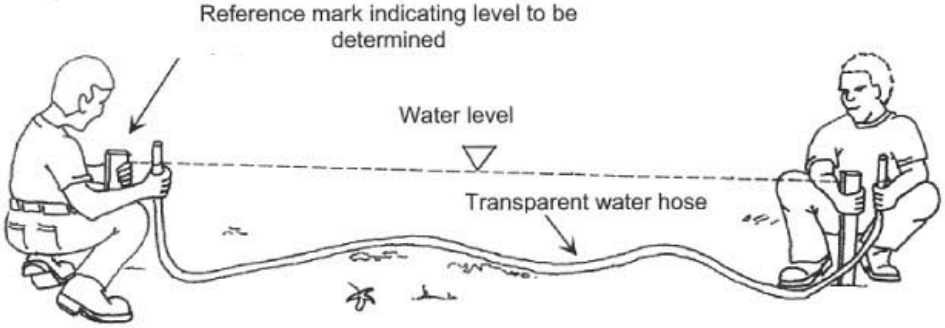
The presence of organic materials in the site of the building would encourage the presence of insects and rodents around the construction works.

Determine the slope and the levels of the site through locally known techniques, for example with the use of water level (hose pipe), boning rod or spirit level.

In the case of the water level, take the 2 ends of a transparent hose pipe of sufficient length, and put them at 2 points of the site. Fill the hose pipe with water while raising up in the air each end. When the water stabilizes, it will indicate the lower and higher points of the site. Measure height between water level and ground. Be careful, where the water rises up higher from the ground is the lower point of the site!



Before starting construction, the site must be cleaned and levelled,
Both to set out the building's position and store material



Once the water is stabilised at the reference height, Mark on the other side.

These two marks provide the horizontal level

It is very easy to transfer the reference height from the first peg to the others by using a transparent hose filled with water

Definition

The setting out of a building is the marking of its position (trenches, width of the walls, pillars…) on the site.

Function

This step is very important and requires a lot of precision in order to avoid further problems when connecting the walls or setting the roofing.

Method

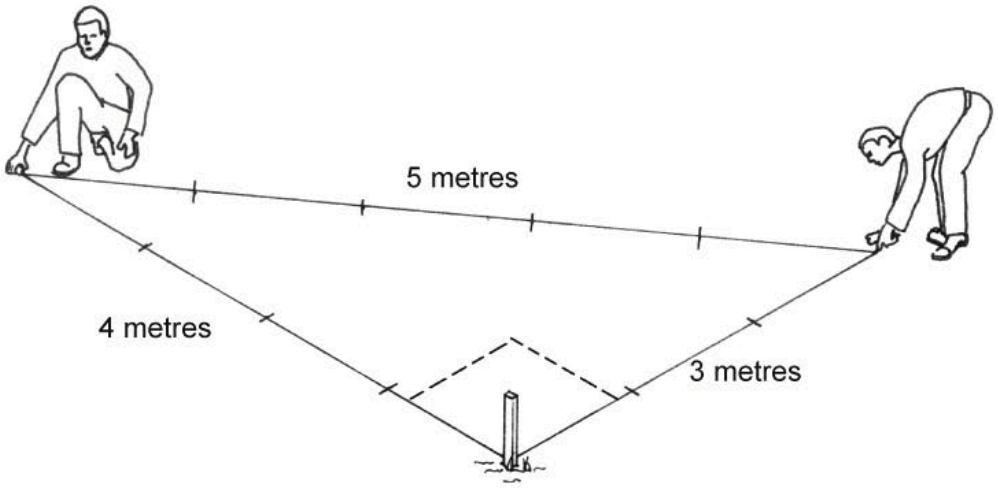
Set-out four (4) lines representing the axes of the walls.

Use the rule of the 3-4-5 for the right angles. Put the 0 of the tape on the 1st peg, and make a triangle, which angles are the numbers 3, 8 and 12.
When the 1st corner of building is correct, make the same thing with the 3 other corners.

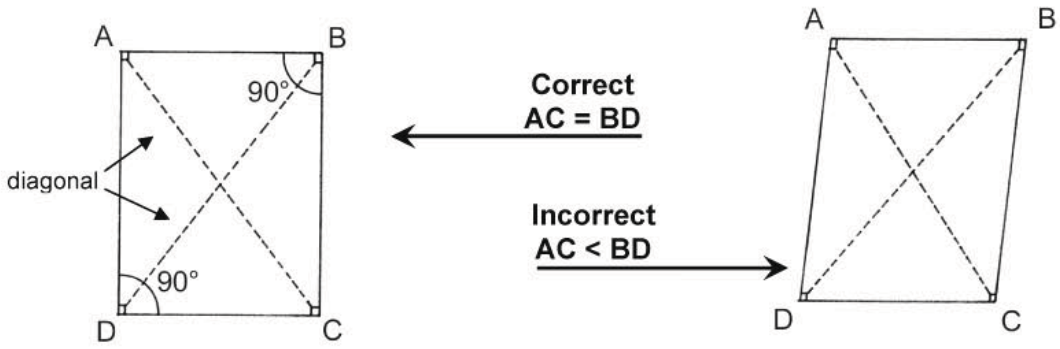
After defining the angles, check the lengths of the diagonals to be sure they have the same measurements.

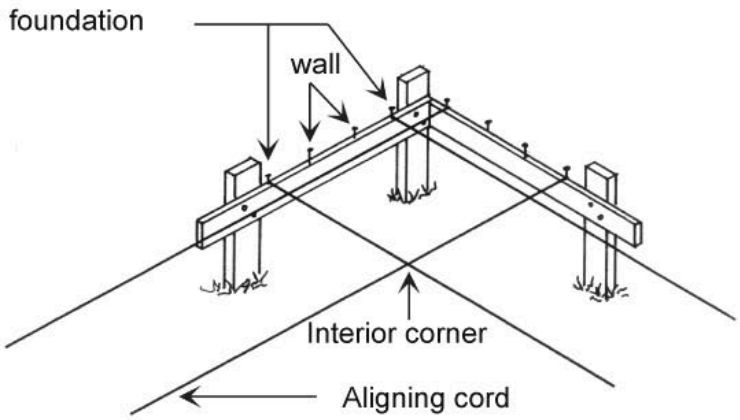
When the angles are correct (90°), extend the lines and fix the pegs far from the actual corner of the building.

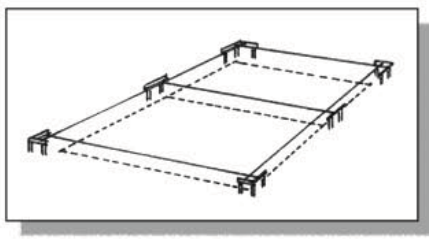
Around the 4 lines representing axes of walls, draw on the ground the limits of the excavations with a pick-axe or similar tool.



After fixing the four corners, check the diagonals.
Their lengths must be equal







Definition

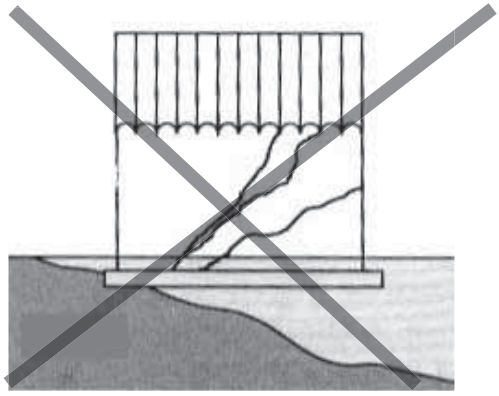
The excavation is the hole or trench made in the ground in order to receive the foundations of the building. The excavations are necessary for all external and internal walls, columns and piers of a building.
Excavation is needed if the stone is not reached during the clearance of the site process.

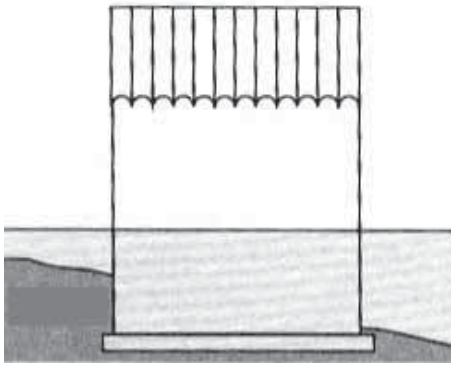
Function

Excavations serve the purpose of receiving the bases of the building on a good soil, a hard soil.

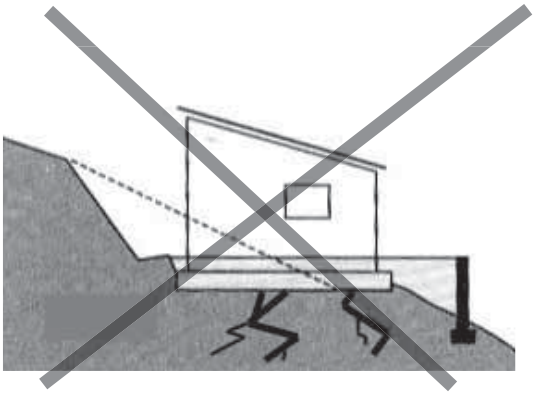
The ground can have differential displacements which are very bad for buildings.
Therefore it is strongly recommended to:

-avoid to build the house on different types of ground or non-homogeneous ground:

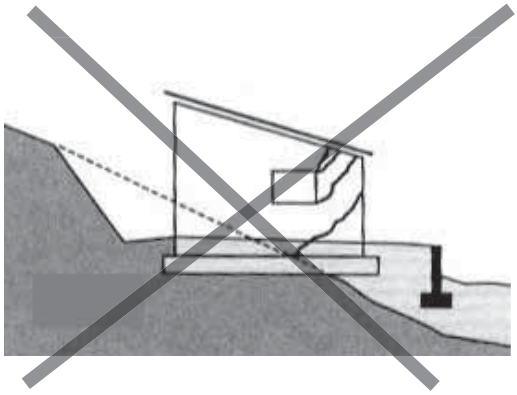


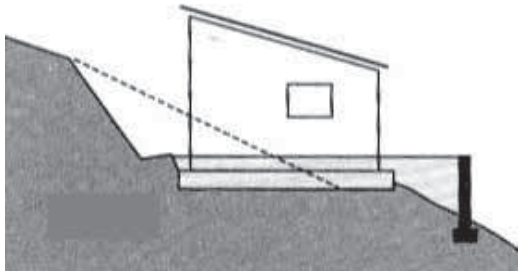


-avoid to build houses on ground with cracks:



-avoid to build foundations with different levels:





Method

The width of the excavations should be between 2 and 3 times the thickness of the wall.
The depth of the excavations should go deep until the good soil is reached (that means hard enough not to be dug easily), and depends on the weight of the building. It is necessary to dig always until the pick reaches a hard surface.

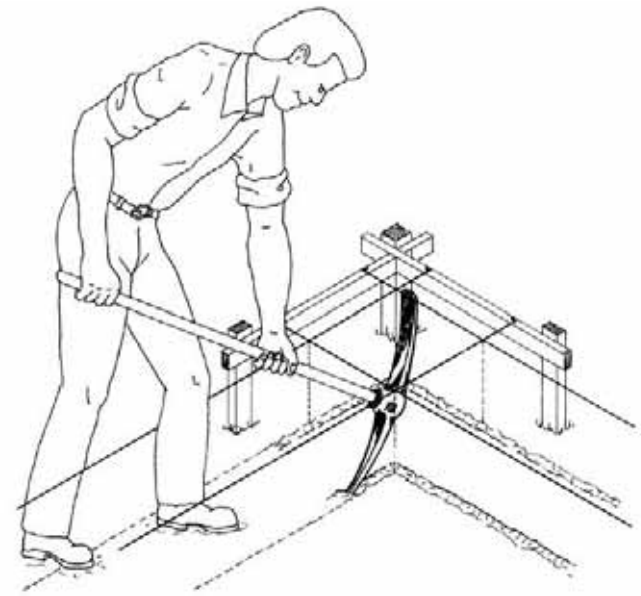
Mark the position of the trench with the pickaxe.

Dig vertically, and follow the alignment given by the line.

Use straight edge and levels to prepare level surfaces at the bottom of the trenches. Keeping the bottom of excavations damp and compacting it with a tamper or hammer is a good practice.

Evacuate away from the site all the top soil.

Stock the good soil near the site for future back filling and drainage works. Put aside the soil that doesn't contain organic matter and could be used for plaster.



Definition

Function

The drainage prevents the water from the rain to contact and affect the building.

It must be located between the slope and the building itself, at a distance of 50 cm from the building.

This prototype is not using all the technics described in this guide. It has been build in Kaffal Gahr too. Its structure is completely different, with self-stable wall elements, made of an heavy stone basement with a light hollow blocks upper part. Those hollow blocks may be replaced by wood, with earth infill for example.
The roof is a light 2 planes corrugated sheet roof.

A history of reinforced masonry construction designed to resist earthquakes: *1755-1907 / Tobriner, S. / In: Earthquake Spectra, Vol. 1, N°1, EERI, November 1984*

A strategy for developing indigenous building in earthquake regions – Case studies of the Bandar Abbas (1977) and the Zarand (1978) earthquakes */ Farokh Afshar, Allan Cain, Mohammad-Reza Daraie, John Norton / Development Workshop.*

Cabanes en pierres sèches de France */ Christian Lassure / Aix-en-Provence: Edisud*

Construction manual for earthquake-resistant houses built of earth */ Gernot Minke / Eschborn: Gate-Basin, 2001*

Construire parasismique */ Milan Zacek / Marseille: Editions Parenthèses, 1996*

Getty seismic adobe project, report of third year activities. Shaking table tests of large scale adobe structures */ W.S. Ginell, E.L. Tolles, P. Gavrilovic, L. Krestevska, V. Sendova, L. Taskov / Los Angeles: GCI, 2001*

Guide de construction parasismique. Adobe */ Wilfredo Carazas Aedo / Villefontaine: CRATerre, 2002*

International recommendations for design and erection of unreinforced and reinforced masonry structures */ Haseltine B.A., Rotterdam: CIB, 1987*

International workshop on earthen buildings in seismic areas. Conference report */ , In: Earthen buildings in seismic areas. Proceedings of the international workshop held at the university of new mexico, albuquerque, may 24-28, 1981 / Washington: National science foundation, 1981, p. 2-90*

Ancient buildings and earthquakes. The Local Seismic Culture approach*: principles, methods, potentialities/ F. Ferrigni, B. Helly, A. Mauro, L. Mendes Victor, P. Pierroti, A. Rideaud, P. Teves Costa et al ; Centro Universitario Europeo Per I Beni Culturali / Edipuglia, Bari 2005*

Traité de construction en terre */ Houben, Hugo; Guillaud, Hubert / CRATerre , Marseille: Editions Parenthèses, 1989*

A comprehensive Study on Earthquake Disasters in Turkey in View of Seismic Risk Reduction */ Sapporo: Departement of Architectural engineering, 1983*

Seismic Stabilization of historic adobe structures. Final report of the Getty seismic adobe project */ E Leroy Tolles, Edna E. Kimbro, Frederick A. Webster, William S. Ginell. Los Angeles: The Getty conservation institute. 2000*