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EARTHQUAKE RESISTANT AFFORDABLE HOUSES

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☐ S'autoritza la Universitat a incloure el meu treball en el Repositori Institucional per a la seva consulta en accés obert i difusió en línea, amb finalitats exclusivament acadèmiques i d'investigació

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Objective

The aim of the present work has been study a possibility of building houses for a targeted people, the underdeveloped countries people. In addition, the condition is obtain a structure resistant to earthquake hazard.

For this, have been selected two countries for the optimal conditions of poverty because of the society that is enveloped, the material wealth, the methodology constructive, placement and without exception, countries or cities were highly affected by earthquakes.

The chosen cities are Papua Nueva Guinea in Oceanian country and Bolivia in South America. The reason of this placements it's commented later.

This work has been totally realized by the author, Carlos Garcia Fluxà

Earthquakes

"Earthquake can be defined as the shaking of earth caused by waves moving on and below the earth's surface and causing: surface faulting, tremors vibration, liquefaction, landslides, aftershocks and/or tsunamis

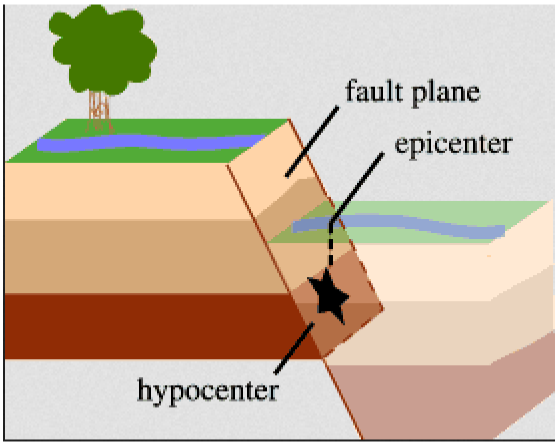
Aggravating factors are the time of the event and the number and intensity of aftershocks.

Compound hazards are fire, landslide, and tsunami."[1]

[1]http://www.who.int/hac/techguidance/ems/earthquakes/en/

"An earthquake is what happens when two blocks of the earth suddenly slip past one another. The surface where they slip is called the fault or fault plane. The location below the earth's surface where the earthquake starts is called the hypocenter, and the location directly above it on the surface of the earth is called the epicenter."[2]

[2]http://earthquake.usgs.gov/learn/kids/eqscience.php



Types of earthquakes

<u>Natural causes of earthquakes:</u>

"Tectonic earthquakes: The earth's crust consists of loose broken fragments of lands known as the tectonic plates. These tectonic plates have the ability to slowly and gradually move. Now, these plates can away from each other, towards each other, can collide or can slide past each other.

When the two tectonic plates slide over each other a huge tremor takes place, and that's how a tectonic earthquake occurs.

Tectonic earthquakes are the most common type of earthquake. It may be of small or of extremely high magnitude. Most of the mass destruction caused by an earthquake over the history is due to the tectonic earthquakes.

The tremors caused by tectonic earthquakes are mostly severe and if they are of high magnitude, they can completely destroy a whole city within seconds.

Volcanic earthquakes: Volcanic earthquakes are comparatively less common than the tectonic earthquakes and usually occur either before or after a volcanic eruption.

There are two types of volcanic earthquakes: Volcano tectonic earthquakes and L ong period volcanic earth quakes.

The volcanic tectonic earthquakes occur usually after a volcanic activity has taken place. The magma that erupts during an earthquake leaves a space, to fill the space left by the magma the rocks move towards the space to fill it in, causing severe earthquakes.

Most of the times after the release of lava, the lava falls on its vent blocking it, and not letting the pressure release. The retained pressure does not stay for long; it releases with a huge explosion. The explosion causes a severe earthquake, mostly of extremely high magnitude.

The long period volcanic earthquakes occur post a volcanic eruption. Few days before the great explosion, the change in heat of magma below the earth's surface creates seismic waves, causing an earthquake.

Parinacota Volcano

Collapse earthquakes: Collapse earthquakes are comparatively small earthquakes and they take place around underground gaps. The collapse earthquakes are caused by the pressure induced within the rocks”. [3]

[3]http://hubpages.com/education/Types-Of-Earthquakes

“The extraterrestrial or meteor earthquake: Every day tiny meteors hit the earth, as we move through space. The vast majority of them burn up in the atmosphere, leaving no more trace than a shooting star across the sky. Once in a while, a meteorite will reach the surface of the earth. Very rarely a great meteorite will hit, causing the ground to shake and creating a large crater. The Meteor Crater in Arizona is an excellent example of this type of crater

The moon is full of meteor craters that we can see because they have not eroded away. The earth also has been struck many times over its history. Erosion by wind and rain wear down the craters so we can't see most of them anymore. Scientists studying the earth have found traces of many meteor impacts around the world. Each impact creates an earthquake.” [4]

Meteor crater in Arizona.

[4]http://web.csulb.edu/~rodrigue/geog458558/lisbon/m03causes.html

<u>Antrophic causes (artificial, produced by human activity):</u>

"Earthquake by a dam: It has only recently been recognised that the pressure applied to often fragile geological structures by the vast mass of water impounded by a big dam can – and often does – give rise to earthquakes.

The first time that seismic activity was imputed to a reservoir was in California in the late 1930s. The reservoir in question was Lake Mead, which was impounded by the Boulder dam when it was closed in 1935.

Earthquakes can be induced by dams. Globally, there are over 100 identified cases of earthquakes that scientists believe were triggered by reservoirs (see Gupta 2002). The most serious case may be the 7.9-magnitude Sichuan earthquake in May 2008, which killed an estimated 80,000 people and has been linked to the construction of the Zipingpu Dam." [5]

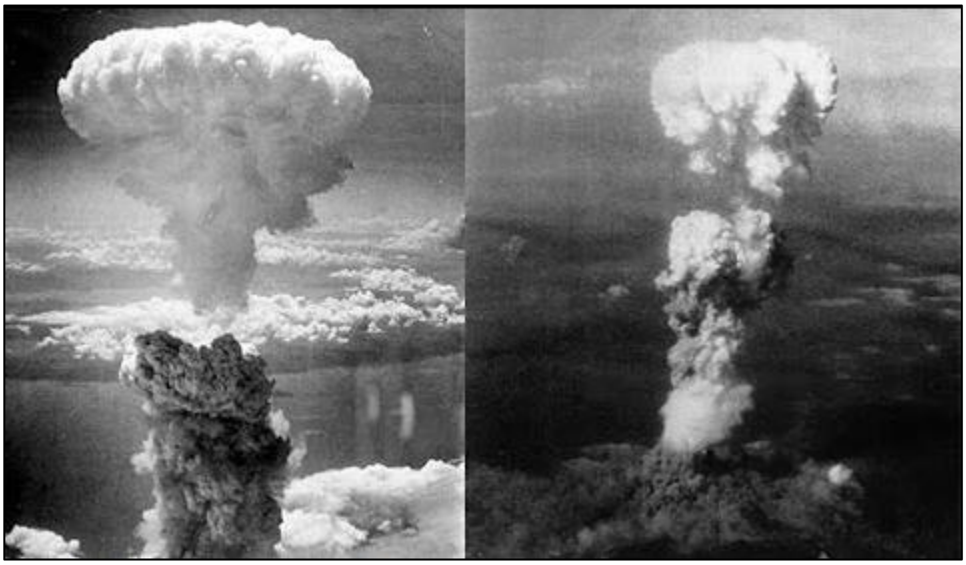
Zipingpu Dam, 2007.

[5]http://www.edwardgoldsmith.org/1020/dams-failures-and-earthquakes/

"Explosion earthquake: The explosion earthquakes are caused due to the nuclear explosions.

These man induced earthquakes are one of the biggest side effects of the modern nuclear war.

In the 1930s during the American nuclear tests many small villages and towns suffered through such tremors, many of them were completely destroyed due to this heinous act". [6]



Nagasaki and Hiroshima, Japan. Atomic bombing.

[6]http://hubpages.com/education/Types-Of-Earthquakes

"Earthquakes caused by explosions of mines and quarries: It results in the collapse of the roof of the mine which causes further tremors. Collapse earthquakes are common in small towns near these underground mines.

The seismicity triggered by the collapse of the Crandall Canyon Mine was hardly an unusual event. Mining-induced seismicity (MIS) occurs frequently in the state's central-eastern coalfields, where University of Utah seismograph stations detected more than 17,000 events between 1978 and August 2007." [7]

[7]http://www.earthmagazine.org/article/ground-shaking-research-how-humans-trigger-earthquakes

"Earthquakes induced by fluid injection: Earth's crust is pervasively fractured at depth by faults. These faults can sustain high stresses without slipping because natural "tectonic" stress and the weight of the overlying rock pushes the opposing fault blocks together, increasing the frictional resistance to fault slip. The injected wastewater counteracts the

frictional forces on faults and, in effect, "pries them apart", thereby facilitating earthquake slip". [8]

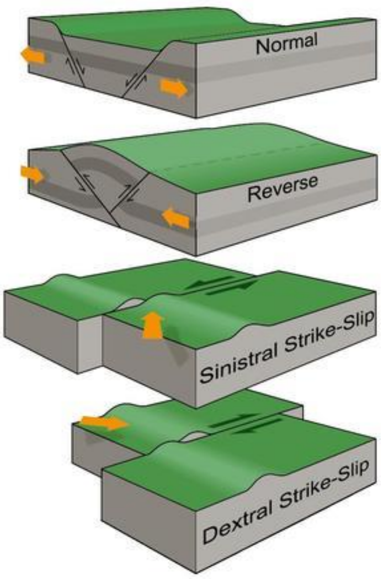
[8]http://www.gpwaho.org/info.php?pnum=21

Earthquake causes

The mechanical model to explain the crustal earthquakes is based on the "theory of elastic rebound" proposed by Reid (1911). According to this theory earthquakes occur in regions subject to deformation due to external causes, usually regional tectonic stresses caused by the movement of lithospheric plates. When efforts accumulated in a place beyond the rock strength rock fracturing and / or a displacement in areas of preexisting weakness occurs. The area is called seismic fault fracturing. Deformation tectonic stresses is due to terrestrial dynamics.

A fault is a fracture zone where shifts have occurred one side relative to the other plane or fracture surface. Tectonic earthquakes are caused by fracturing rock or shifts in existing areas of weakness.

"Types of movement of crustal blocks that can occur along faults during an earthquake:



Types of faults

Where the crust is being pulled apart, normal faulting occurs, in which the overlying (hanging-wall) block moves down with respect to the lower (foot wall) block.

Where the crust is being compressed, reverse faulting occurs, in which the hanging-wall block moves up and over the footwall block – reverse slip on a gently inclined plane is referred to as thrust faulting.

Crustal blocks may also move sideways past each other, usually along nearly-vertical faults. This 'strike-slip' movement is described as sinistral when the far side moves to the left, and dextral, when the far side moves to the right.

An oblique slip involves various combinations of these basic movements, as in the 1855 Wairarapa Fault rupture, which included both reverse and dextral movement. (COM pg. 100).

Faults can be as short as a few metres and as long as 1000km. The fault rupture from an earthquake isn't always a straight or continuous line. Sometimes there can be short offsets between parts of the fault, and even major faults can have large bends in them." [9]

[9]http://www.gns.cri.nz/Home/Learning/Science-Topics/Earthquakes/Earthquakes-and-Faults/Different-types-of-Faults

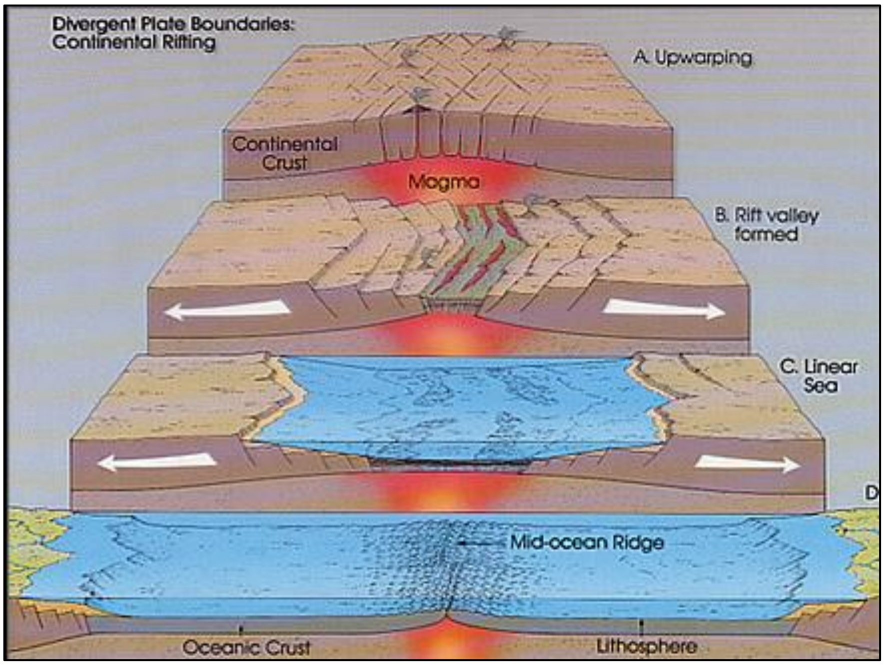
Seismicity and tectonics

Plate tectonics is a unifying hypothesis of work that provides a kinematic model of the upper layers of the Earth. There are a dozen large plates and some smaller plates. The movement between them is the resulting earthquakes.
The relative movement of the plates occurs, especially at the edges of the plates and in them a narrow deformation zone where seismic activity is concentrated.

"The plate edges reveal the type of movement that occur between the plates and consequently determines the type of seismic activity that originates. They are basically of 3 types:

Divergent boundaries (also called spreading zones). There are places on earth where two plates are separating or spreading apart, such as at oceanic ridges. Rift valleys and faults occur when the lithosphere is under tensional stress. At spreading zones, new magma comes up from the mantle, pushing two plates apart and adding new material at their edges. Spreading zones are usually found in oceans along with mid-ocean ridges. For example, the North American and Eurasian plates are spreading apart along the mid-Atlantic ridge.

As the new material flows out of the ridge, it pushes the existing ground floor out, until it eventually sinks under another plate, which leads us into a different type of boundary. Earthquakes with low Richter magnitudes along boundaries with normal fault motion tend to be shallow focus. These quakes can have focal depths of less than 20km.This indicates the brittle lithosphere must be thin along the diverging plate boundaries.



Magma up swelling from deep within the Earth occurs when divergent plates spread apart

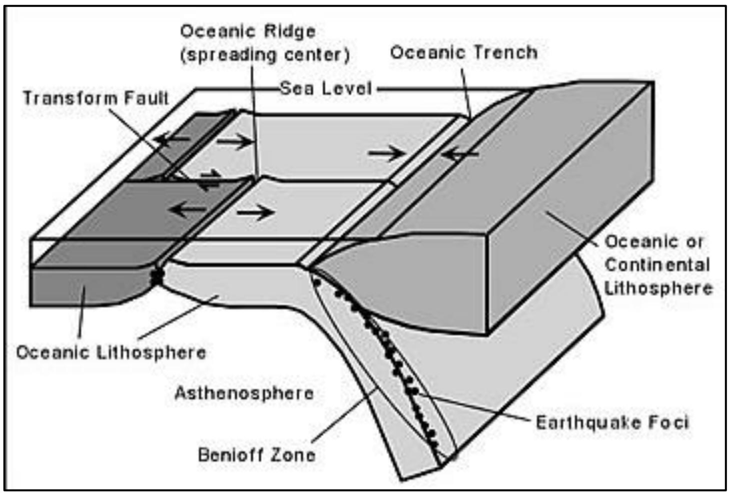
Transform boundaries (also called transform faults). These are found where plates slide past one another. The San Andreas Fault is an example of a transform -fault plate boundary along the north western Mexican and California coast. Earthquakes along transform boundaries show strike-slip motion on the faults, they form fairly straight linear patterns and tend to be shallow focus earthquakes with depths usually less than about 100 km. Richter magnitudes could be large.

The Fault of San Andreas

As seen in the image above, the trees (they look like small dots) in the aerial view of San Andreas fault have been offset by the slipping of the plates. The North American Plate to the right and the Pacific Plate to the left.

Convergent boundaries (also called transform faults). Convergent boundaries are the place where two tectonic plates converge. These zones tend to be where compressional stresses are active and this results in thrust or reverse faults being common. Converging plate boundaries are of two types:

- *Subduction boundaries occur where oceanic lithosphere is pushed beneath continental or oceanic lithospheres. Where two plates converge at an oceanic trench a subduction boundary is formed as cold oceanic lithospheres are pushed back down into the mantle. This happens because the oceanic plate is denser than the continental plate so, as they move together, the oceanic plate is forced underneath the continental plate. In this case, one plate overrides, or "subducts" the other, pushing it slowly downward into the mantle where it melts to form magma. A subducted lithosphere remains cold and brittle as it descends and can fracture under compressional stress. These fractures generate earthquakes that define a zone of quakes at increasing focal depth under the overriding plate. This zone is called the Benioff Zone.*



Earthquakes hazards risks

Collisional boundaries where two plates of continental lithosphere collide result in fold-thrust mountain belts. The continental crust is squashed together as the plates push together and is forced upwards. This is called folding. Fold mountains are created by this process of folding. Where two continental plates converge and push towards each other fold mountains can also be formed. This is how mountain ranges such as the Himalayas and the Alps were formed. Earthquakes occur due to the thrust faulting and range in depth from shallow to about 200 km. Examples are found along the Himalayan Belt into China, along the Northern edge of the Mediterranean Sea through Black Sea and Caspian Sea into Iraq and Iran". [10]

[10]http://www.sms-tsunami-warning.com/pages/tectonic-plates

Seismic wave

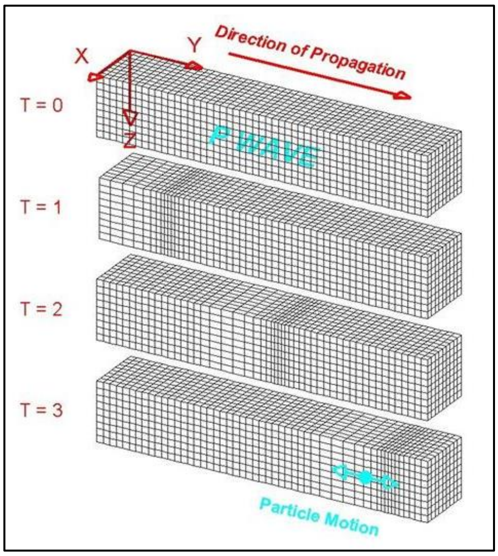
"Seismic waves are the waves of energy caused by the sudden breaking of rock within the earth or an explosion. They are the energy that travels through the earth and is recorded on seismographs.

There are several different kinds of seismic waves, and they all move in different ways. The two main types of waves are body waves and surface waves. Body waves can travel through the earth's inner layers, but surface waves can only move along the surface of the planet like ripples on water. Earthquakes radiate seismic energy as both body and surface waves.

Body waves: Traveling through the interior of the earth, body waves arrive before the surface waves emitted by an earthquake. These waves are of a higher frequency than surface waves.

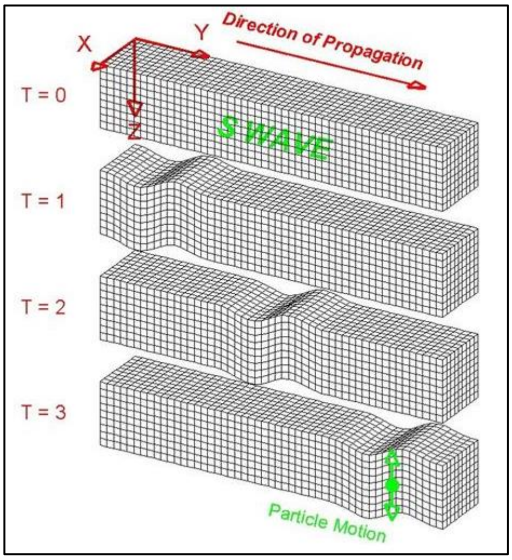
The first kind of body wave is the P wave or primary wave. This is the fastest kind of seismic wave, and, consequently, the first to 'arrive' at a seismic station. The P wave can move through solid rock and fluids, like water or the liquid layers of the earth. It pushes and pulls the rock it moves through just like sound waves push and pull the air. Usually people can only feel the bump and rattle of these waves.

P waves are also known as compressional waves, because of the pushing and pulling they do. Subjected to a P wave, particles move in the same direction that the the wave is moving in, which is the direction that the energy is traveling in, and is sometimes called the 'direction of wave propagation'.



P wave travels through a medium by means of compression and dilation.

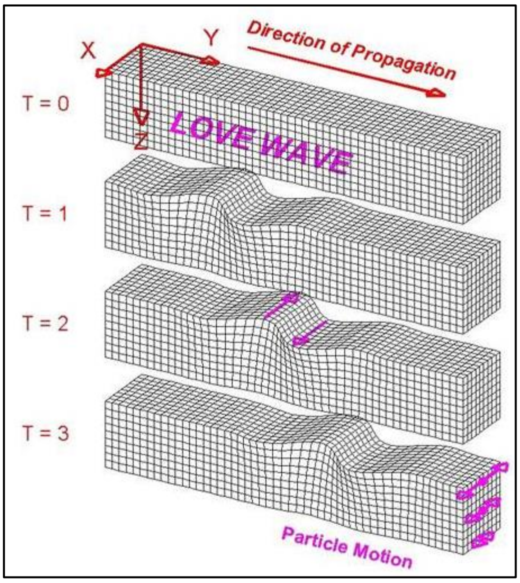
The second type of body wave is the S wave or secondary wave, which is the second wave you feel in an earthquake. An S wave is slower than a P wave and can only move through solid rock, not through any liquid medium. It is this property of S waves that led *seismologists to conclude that the Earth's outer core is a liquid. S waves move rock particles up and down, or side-to-side-perpindicular to the direction that the wave is traveling in (the direction of wave propagation).*



S wave travels through a medium. Particles are represented by cubes in this model.

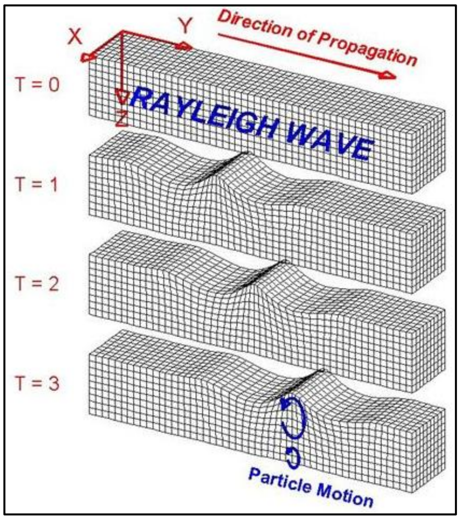
<u>Surface waves:</u> Travelling only through the crust, surface waves are of a lower frequency than body waves, and are easily distinguished on a seismogram as a result. Though they arrive after body waves, it is surface waves that are almost enitrely responsible for the damage and destruction associated with earthquakes. This damage and the strength of the surface waves are reduced in deeper earthquakes.

The first kind of surface wave is called a Love wave, named after A.E.H. Love, a British mathematician who worked out the mathematical model for this kind of wave in 1911. It's the fastest surface wave and moves the ground from side-to-side. Confined to the surface of the crust, Love waves produce entirely horizontal motion.



Love wave travels through a medium. Particles are represented by cubes in this model.

The other kind of surface wave is the Rayleigh wave, named for John William Strutt, Lord Rayleigh, who mathematically predicted the existence of this kind of wave in 1885. A Rayleigh wave rolls along the ground just like a wave rolls across a lake or an ocean. Because it rolls, it moves the ground up and down, and side-to-side in the same direction that the wave is moving. Most of the shaking felt from an earthquake is due to the Rayleigh wave, which can be much larger than the other waves."[11]



Rayleigh wave travels through a medium. Particles are represented by cubes in this model.

[11]http://www.geo.mtu.edu/UPSeis/waves.html

Measure

"*As has already been mentioned, seismic waves are the vibrations from earthquakes that travel through the Earth; they are recorded on instruments called seismographs. Seismographs record a zig-zag trace that shows the varying amplitude of ground oscillations beneath the instrument. Sensitive seismographs, which greatly magnify these ground motions, can detect strong earthquakes from sources anywhere in the world. The time, locations, and magnitude of an earthquake can be determined from the data recorded by seismograph stations.*

The Ritcher Magnitude: The Richter magnitude scale was developed in 1935 by Charles F. Richter of the California Institute of Technology as a mathematical device to compare the size of earthquakes. The magnitude of an earthquake is determined from the logarithm of the amplitude of waves recorded by seismographs. Adjustments are included for the variation in the distance between the various seismographs and the epicenter of the earthquakes. On the Richter Scale, magnitude is expressed in whole numbers and decimal fractions. For example, a magnitude 5.3 might be computed for a moderate earthquake, and a strong earthquake might be rated as magnitude 6.3. Because of the logarithmic basis of the scale, each whole number increase in magnitude represents a tenfold increase in *measured amplitude; as an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value.*

At first, the Richter Scale could be applied only to the records from instruments of identical manufacture. Now, instruments are carefully calibrated with respect to each other. Thus, magnitude can be computed from the record of any calibrated seismograph.

The Richter Scale is not commonly used anymore, as it has been replaced by another scale called the moment magnitude scale which is a more accurate measure of the earthquake size.

Magnitud: Modern seismographic systems precisely amplify and record ground motion (typically at periods of between 0.1 and 100 seconds) as a function of time. This amplification and recording as a function of time is the source of instrumental amplitude and arrival-time data on near and distant earthquakes. Although similar seismographs have existed since the 1890's, it was only in the 1930's that Charles F. Richter, a California seismologist, introduced the concept of earthquake magnitude. His original definition held only for California earthquakes occurring within 600 km of a particular type of seismograph (the Woods-Anderson torsion instrument). His basic idea was quite simple: by knowing the distance from a seismograph to an earthquake and observing the maximum signal amplitude recorded on the seismograph, an empirical quantitative ranking of the earthquake's inherent size or strength could be made.

Richter's original magnitude scale (ML) was then extended to observations of earthquakes of any distance and of focal depths ranging between 0 and 700 km. Because earthquakes excite both body waves, which travel into and through the Earth, and surface waves, which are constrained to follow the natural wave guide of the Earth's uppermost layers, two magnitude scales evolved - the mb and MS scales. The standard body-wave magnitude formula is

$$m_b = \log10(A/T) + Q(D,h) ,$$

where A is the amplitude of ground motion (in microns); T is the corresponding period (in seconds); and Q(D,h) is a correction factor that is a function of distance, D (degrees), between epicenter and station and focal depth, h (in kilometers), of the earthquake. The standard surface-wave formula is

$$M_S = \log10 (A/T) + 1.66 \log10 (D) + 3.30 .$$

There are many variations of these formulas that take into account effects of specific geographic regions, so that the final computed magnitude is reasonably consistent with Richter's original definition of ML. Negative magnitude values are permissible.

A rough idea of frequency of occurrence of large earthquakes is given by the following table:

M_S	Earthquakes per year
8.5 – 8.9	0.3
8.0 – 8.4	1.1
7.5 – 7.9	3.1
7.0 – 7.4	15
6.5 – 6.9	56
6.0 – 6.4	210

This table is based on data for a recent 47 year period. Perhaps the rates of earthquake occurrence are highly variable and some other 47 year period could give quite different results.

The original m_b scale utilized compressional body P-wave amplitudes with periods of 4-5s, but recent observations are generally of 1 s-period P waves. The M_S scale has consistently used Rayleigh surface waves in the period range from 18 to 22 s.

When initially developed, these magnitude scales were considered to be equivalent; in other words, earthquakes of all sizes were thought to radiate fixed proportions of energy at different periods. But it turns out that larger earthquakes, which have larger rupture surfaces, systematically radiate more long-period energy. Thus, for very large earthquakes, body-wave magnitudes badly underestimate true earthquake size; the maximum body-wave magnitudes are about 6.5 - 6.8. In fact, the surface-wave magnitudes underestimate the size of very large earthquakes; the maximum observed values are about 8.3 - 8.7. Some investigators have suggested that the 100s mantle Love waves should be used to estimate magnitude of great earthquakes. However, even this approach ignores the fact that damage to structure is often caused by energy at shorter periods. Thus, modern seismologists are increasingly turning to two separate parameters to describe the physical effects of an earthquake: seismic moment and radiated energy.

<u>Fault Geometry and Seismic Moment, M_O :</u> The orientation of the fault, direction of fault movement, and size of an earthquake can be described by the fault geometry and seismic moment. These parameters are determined from waveform analysis of the seismograms produced by an earthquake. The differing shapes and directions of motion of the waveforms recorded at different distances and azimuths from the earthquake are used to determine the fault geometry, and the wave amplitudes are used to compute moment. The seismic moment is related to fundamental parameters of the faulting process.

$$M_O = \mu S \langle d \rangle ,$$

where μ is the shear strength of the faulted rock, S is the area of the fault, and $\langle d \rangle$ is the average displacement on the fault. Because fault geometry and observer azimuth are a part of the computation, moment is a more consistent measure of earthquake size than is magnitude, and more importantly, moment does not have an intrinsic upper bound. These factors have led to the definition of a new magnitude scale M_W, based on seismic moment, where

$$M_W = 2/3 \log_{10}(M_O) - 10.7 .$$

The two largest reported moments are 2.5 X 10^{30} dyn·cm (dyne·centimeters) for the 1960 Chile earthquake (M_S 8.5; M_W 9.6) and 7.5 X 10^{29} dyn·cm for the 1964 Alaska earthquake (M_S 8.3; M_W 9.2). M_S approaches its maximum value at a moment between 10^{28} and 10^{29} dyn·cm.

Energy: *The amount of energy radiated by an earthquake is a measure of the potential for damage to man-made structures. Theoretically, its computation requires summing the energy flux over a broad suite of frequencies generated by an earthquake as it ruptures a fault. Because of instrumental limitations, most estimates of energy have historically relied on the empirical relationship developed by Beno Gutenberg and Charles Richter:*

$$\log_{10}E = 11.8 + 1.5M_S$$

where energy, E, is expressed in Ergs. The drawback of this method is that M_S is computed from an bandwidth between approximately 18 to 22 s. It is now known that the energy radiated by an earthquake is concentrated over a different bandwidth and at higher frequencies. With the worldwide deployment of modern digitally recording seismograph with broad bandwidth response, computerized methods are now able to make accurate and explicit estimates of energy on a routine basis for all major earthquakes. A magnitude based on energy radiated by an earthquake, M_e, can now be defined,

$$M_e = 2/3 \log_{10}E - 2.9.$$

For every increase in magnitude by 1 unit, the associated seismic energy increases by about 32 times.

Although M_w and M_e are both magnitudes, they describe different physical properites of the earthquake. M_w, computed from low-frequency seismic data, is a measure of the area ruptured by an earthquake. M_e, computed from high frequency seismic data, is a measure of seismic potential for damage. Consequently, M_w and M_e often do not have the same numerical value.

Intesity: *The increase in the degree of surface shaking (intensity) for each unit increase of magnitude of a shallow crustal earthquake is unknown. Intensity is based on an earthquake's local accelerations and how long these persist. Intensity and magnitude thus both depend on many variables that include exactly how rock breaks and how energy travels from an earthquake to a receiver. These factors make it difficult for engineers and others who use earthquake intensity and magnitude data to evaluate the error bounds that may exist for their particular applications.*

With the aim of this Project, an example of how local soil conditions can greatly influence local intensity is given by catastrophic damage in Mexico City from the 1985, M_S 8.1 Mexico earthquake centered some 300 km away. Resonances of the soil-filled basin under parts of Mexico City amplified ground motions for periods of 2 seconds by a factor of 75 times. This shaking led to selective damage to buildings 15 - 25 stories high (same resonant period), resulting in losses to buildings of about $4.0 billion and at least 8,000 fatalities.

The occurrence of an earthquake is a complex physical process. When an earthquake occurs, much of the available local stress is used to power the earthquake fracture growth to produce heat rather than to generate seismic waves. Of an earthquake system's total energy, perhaps 10 percent to less that 1 percent is ultimately radiated as seismic energy. So the degree to which an earthquake lowers the Earth's available potential energy is only fractionally observed as radiated seismic energy.

Determining the Depth of an Earthquake: *Earthquakes can occur anywhere between the Earth's surface and about 700 kilometers below the surface. For scientific purposes, this earthquake depth range of 0 - 700 km is divided into three zones: shallow, intermediate, and deep.*

Shallow earthquakes are between 0 and 70km deep; intermediate earthquakes, 70 - 300km deep; and deep earthquakes, 300 - 700km deep. In general, the term "deep-focus earthquakes" is applied to earthquakes deeper than 70km. All earthquakes deeper than 70km are localized within great slabs of shallow lithosphere that are sinking into the Earth's mantle.

The evidence for deep-focus earthquakes was discovered in 1922 by H.H. Turner of Oxford, England. Previously, all earthquakes were considered to have shallow focal depths. The existence of deep-focus earthquakes was confirmed in 1931 from studies of the seismograms of several earthquakes, which in turn led to the construction of travel-time curves for intermediate and deep earthquakes.

The most obvious indication on a seismogram that a large earthquake has a deep focus is the small amplitude, or height, of the recorded surface waves and the uncomplicated character of the P and S waves (can observe the different between the waves in the last themes of this Project). Although the surface-wave pattern does generally indicate that an earthquake is either shallow or may have some depth, the most accurate method of determining the focal depth of an earthquake is to read a depth phase recorded on the seismogram. The most characteristic depth phase is pP. This is the P wave that is reflected from the surface of the Earth at a point relatively near the epicenter. At distant seismograph stations, the pP follows the P wave by a time interval that changes slowly with distance but rapidly with depth. This time interval, pP-P (pP minus P), is used to compute depth-of-focus tables. Using the time difference of pP-P as read from the seismogram and the distance between the epicenter and the seismograph station, the depth of the earthquake can be determined from published travel-time curves or depth tables.

Another seismic wave used to determine focal depth is the sP phase - an S wave reflected as a P wave from the Earth's surface at a point near the epicenter. This wave is recorded after the pP by about one-half of the pP-P time interval. The depth of an earthquake can be determined from the sP phase in the same manner as the pP phase by using the appropriate travel-time curves or depth tables for sP.

If the pP and sP waves can be identified on the seismogram, an accurate focal depth can be determined, and we need this conclusion for will be prepared against the earthquake damage in the future." [12]

[12]http://earthquake.usgs.gov/learn/topics/seismology/determining_depth.php

EARTHQUAKES AND STRUCTURES

To the next point it's for expand the theme of impact of earthquakes on structures. All the section about "earthquakes and structures" is obtained from the book "Dynamics of Structures ".

Equations of motion, problem statement

"Simple structures: We call structures simple to the structures can be idealized as a concentrated or lumped mass m supported by a massless structure with stiffness k in the lateral direction. Such an idealization is appropriate ,for exemple a pergola, with a heavy concrete roof supported by light-steel-pipe columns, which can be assumed as massless. The concrete roof is very stiff and the flexibility of the structure in lateral (or horizontal) motion is provided entirely by the columns. This system has a lumped mass *m* equal to the mass of the roof, and its lateral stiffness *k* is equal to the sum of the stiffnesses of individual pipe columns.

Intuition suggests that if the roof of the pergola were pulled laterally by a rope and the rope were suddenly cut, the structure would oscillate with ever-decreasing amplitude and eventually come to rest. Such experiments were performed on laboratory models of one-story frames, and measured records of their free vibration response are presented in Fig. 1.1.4.. As expected, the motion of these model structures decays with time, with the decay being more rapid for the plexiglass model relative to the aluminum frame.

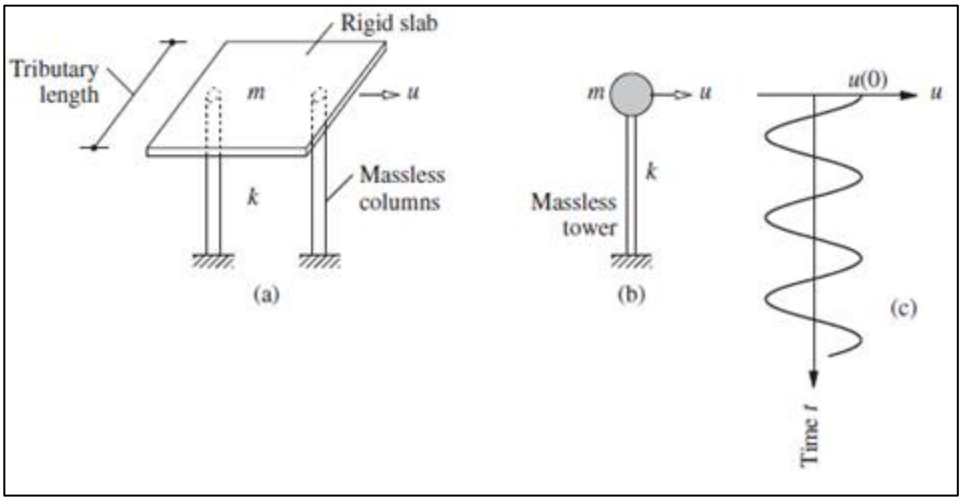


Fig. 1.1.3 a) Idealized pérgola b) idealized water tank c) free vibration fue to initial diplacement

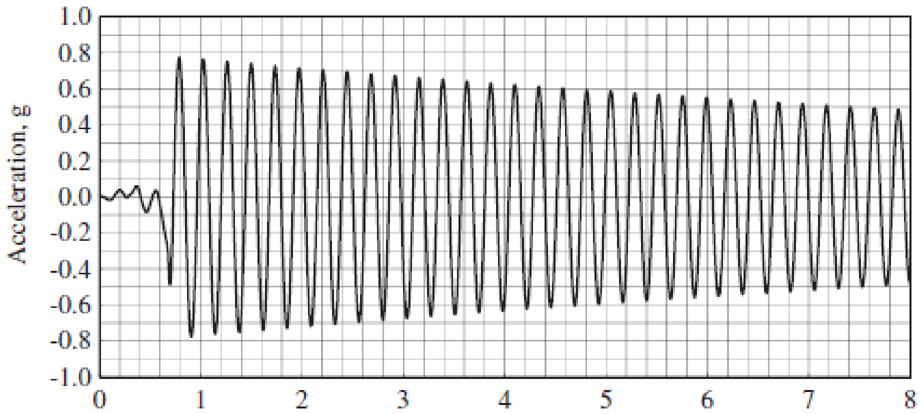


Fig. 1.1.4. free vibration record of aluminium model.

The process by which vibration steadily diminishes in amplitude is called damping.

<u>Single degree of freedom system: </u>This system may be considered as an idealization of a one-story structure. Each structural member (beam, column, wall, etc.) of the actual structure contributes to the inertial (mass), elastic (stiffness or flexibility), and energy dissipation (damping) properties of the structure. In the idealized system, however, each of these properties is concentrated in three separate, pure components: mass component, stiffness component, and damping component.

The number of independent displacements required to define the displaced positions of all the masses relative to their original position is called the number of degrees of freedom (DOFs) for dynamic analysis. More DOFs are typically necessary to define the stiffness properties of a structure compared to the DOFs necessary for representing inertial properties.

<u>Force displacement relation:</u>For a linear system the relationship between the lateral force f_S and resulting deformation u is linear, that is,

$$f_S = ku$$

where k is the lateral stiffness of the system; its units are force/length. Implicit in this equation is the assumption that the linear fS–u relationship determined for small deformations of the structure is also valid for larger deformations. This linear relationship implies that f_S is a single-valued function of u (i.e., the loading and unloading curves are identical). Such a system is said to be elastic; hence we use the term linearly elastic system to emphasize both properties.

Consider the frame of next figure with bay width L, height h, elastic modulus E, and second moment of the cross-sectional area (or moment of inertia)† about the axis of bending = Ib and Ic for the beam and columns, respectively; the columns are clamped (or fixed) at the base. The lateral stiffness of the frame can readily be determined for two extreme cases: If the beam is rigid [i.e., flexural rigidity E Ib =∞(Figure (b))],

$$k = \sum_{\text{columns}} \frac{12EI_c}{h^3} = 24\frac{EI_c}{h^3}$$

On the other hand, for a beam with no stiffness [i.e., E Ib = 0 (Figure (c))],

$$k = \sum_{\text{columns}} \frac{3EI_c}{h^3} = 6\frac{EI_c}{h^3}$$

Observe that for the two extreme values of beam stiffness, the lateral stiffness of the frame is independent of L, the beam length or bay width.

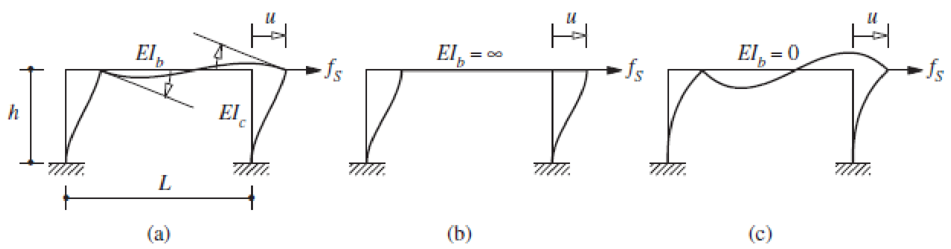


Fig. 1.1.5 differents beam's values

When the initial loading curve is nonlinear at the larger amplitudes of deformation, and the unloading and reloading curves differ from the initial loading branch; such a system is said to be inelastic. This implies that the force–deformation relation is path dependent, i.e., it depends on whether the deformation is increasing or decreasing. Thus the resisting force is an implicit function of deformation:

$$f_S = f_S(u)$$

The force–deformation relation for the idealized one-story frame deforming into the inelastic range can be determined in one of two ways. One approach is to use methods of nonlinear static structural analysis.

<u>Damping force:</u> The process by which free vibration steadily diminishes in amplitude is called damping. In damping, the energy of the vibrating system is dissipated by various mechanisms. Most of the energy dissipation presumably arises from the thermal effect of repeated elastic straining of the material and from the internal friction when a solid is deformed. In actual structures, however, many other mechanisms also contribute to the energy dissipation. In a vibrating building these include friction at steel connections, opening and closing of microcracks in concrete, and friction between the structure itself and nonstructural elements such as partition walls.

Figure 1.1.6a shows a linear viscous damper subjected to a force f_D along the DOF u. The internal force in the damper is equal and opposite to the external force f_D (Fig. 1.6b). As

shown in Fig. 1.1.6c, the damping force f_D is related to the velocity $\dot{u}$ across the linear viscous damper by

$$f_D = c\dot{u}$$

where the constant c is the viscous damping coefficient; it has units of force × time/length.

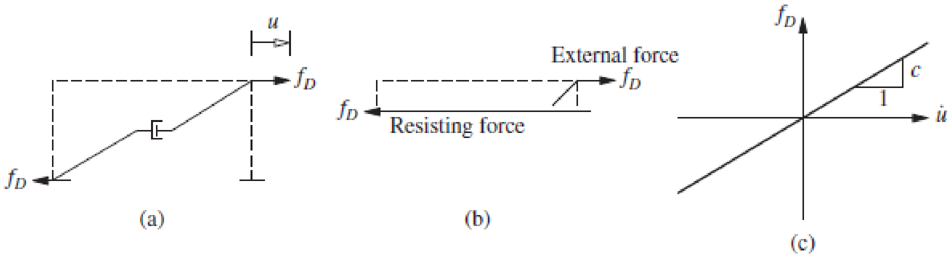


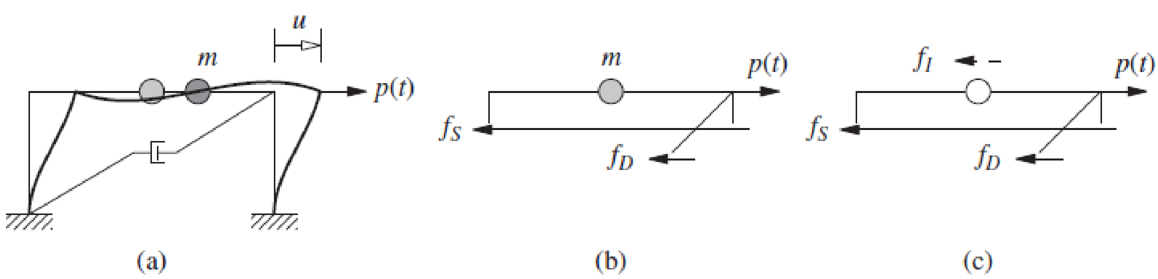
Fig. 1.1.6. linear viscus damper

Instead, the most common, direct, and accurate approach to account for the energy dissipation through inelastic behavior is to recognize the inelastic relationship between resisting force and deformation.

<u>Equation of motion: external force:</u>

Using Newton's Second Law of Motion

The external force is taken to be positive in the direction of the x-axis, and the displacement u(t), velocity $\ddot{u}$(t), and acceleration $\dot{u}$(t) are also positive in the direction of the x-axis. The elastic and damping forces are shown acting in the opposite direction because they are internal forces that resist the deformation and velocity, respectively.



The resultant force along the x-axis is p – fS – fD, and Newton's second law of motion gives

$$p - f_S - f_D = m\ddot{u} \quad \text{or} \quad m\ddot{u} + f_D + f_S = p(t)$$

For such systems, therefore, the equation of motion is

$$m\ddot{u} + c\dot{u} + ku = p(t)$$

assumed to be linearly elastic, subjected to an external dynamic force p(t). The units of mass are force/acceleration.

Dynamic equilibrium: Having been trained to think in terms of equilibrium of forces, structural engineers may find D'Alembert's principle of dynamic equilibrium particularly appealing. This principle is based on the notion of a fictitious inertia force, a force equal to the product of mass times its acceleration and acting in a direction opposite to the acceleration. It states that with inertia forces included, a system is in equilibrium at each time instant. Thus a freebody diagram of a moving mass can be drawn, and principles of statics can be used to develop the equation of motion.

Stiffness, damping, and mass components

Now visualize the system as the combination of three pure components: (1) the stiffness component: the frame without damping or mass (Fig. 1.1.7b); (2) the damping component: the frame with its damping property but no stiffness or mass (Fig. 1.1.7c); and (3) the mass component: the roof mass without the stiffness or damping of the frame (Fig. 1.1.7d).

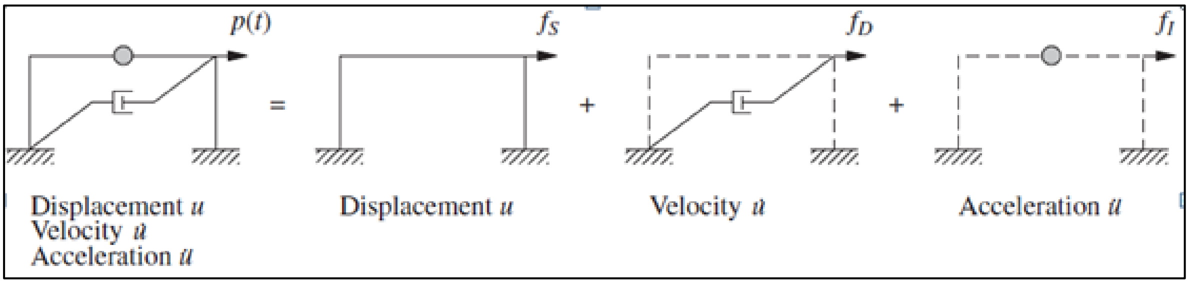


Fig. 1.1.7. a) System b) stiffness component c) damping component d) mass component.

The external force f_S on the stiffness component is related to the displacement u if the system is linearly elastic, the external force f_D on the damping component is related to the velocity $\dot{u}$ by, and the external force fI on the mass component is related to the acceleration by $f_I = m \cdot \dot{u}$. The external force p(t) applied to the complete system may therefore be visualized as distributed among the three components of the structure, and $f_S + f_D + f_I$ must equal the applied force *p(t).*

Equation of motion: earthquake excitation: In earthquake-prone regions, the principal problem of structural dynamics that concerns structural engineers is the behavior of structures subjected to earthquake-induced motion of the base of the structure. The displacement of the ground is denoted by u_g, the total (or absolute) displacement of the mass by u^t, and the relative displacement between the mass and ground by u. At each instant of time these displacements are related by

$$u^t(t) = u_g(t) + u(t)$$

Both u^t and u_g refer to the same inertial frame of reference and their positive directions coincide.

Here we choose to use the concept of dynamic equilibrium. From the free-body diagram including the inertia force f_I, shown in Fig. 1.1.8, the equation of dynamic equilibrium is

$$f_I + f_D + f_S = 0$$

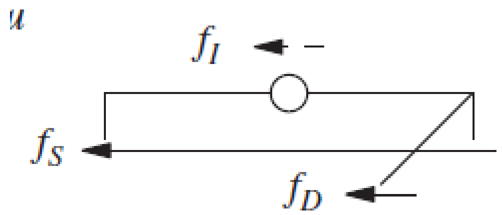


Fig. 1.1.8. free-body diagram

Only the relative motion u between the mass and the base due to structural deformation produces elastic and damping forces. The inertia force f_I is related to the acceleration $\ddot{u}^t$ of the mass by

$$f_I = m\ddot{u}^t$$

Substituting

$f_S = ku$, $f_D = c\dot{u}$, $f_I = m\ddot{u}^t$, in $f_I + f_D + f_S = 0$

and using

$$u^t(t) = u_g(t) + u(t)$$

gives

$$m\ddot{u} + c\dot{u} + ku = -m\ddot{u}_g(t)$$

This is the equation of motion governing the relative displacement or deformation *u(t)* of the linearly elastic structure of Fig. 1.1.9 subjected to ground acceleration $\ddot{u}_g(t)$.

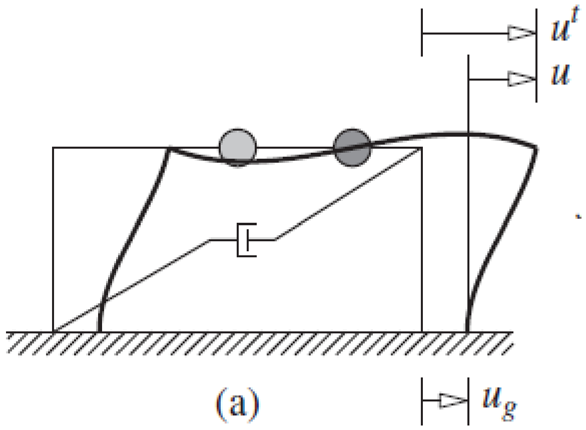


Fig. 1.1.9. linearly elastic structure

For inelastic systems, the resulting equation of motion is

$$m\ddot{u} + c\dot{u} + f_S(u) = -m\ddot{u}_g(t)$$

The relative displacement or deformation *u(t)* of the structure due to ground acceleration $\ddot{u}_g(t)$ will be identical to the displacement *u(t)* of the structure if its base were stationary and if it were subjected to an external force = $-m\,\ddot{u}_g(t)$. As shown in Fig. 1.1.10, the ground motion can therefore be replaced by the effective earthquake force (indicated by the subscript "$_{\text{eff}}$"):

$$p_{\text{eff}}(t) = -m\ddot{u}_g(t)$$

This force is equal to mass times the ground acceleration, acting opposite to the acceleration. It is important to recognize that the effective earthquake force is proportional to the mass of the structure. Thus the structural designer increases the effective earthquake force if the structural mass is increased.

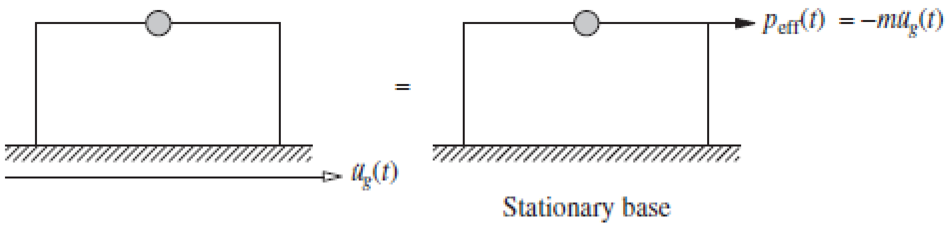
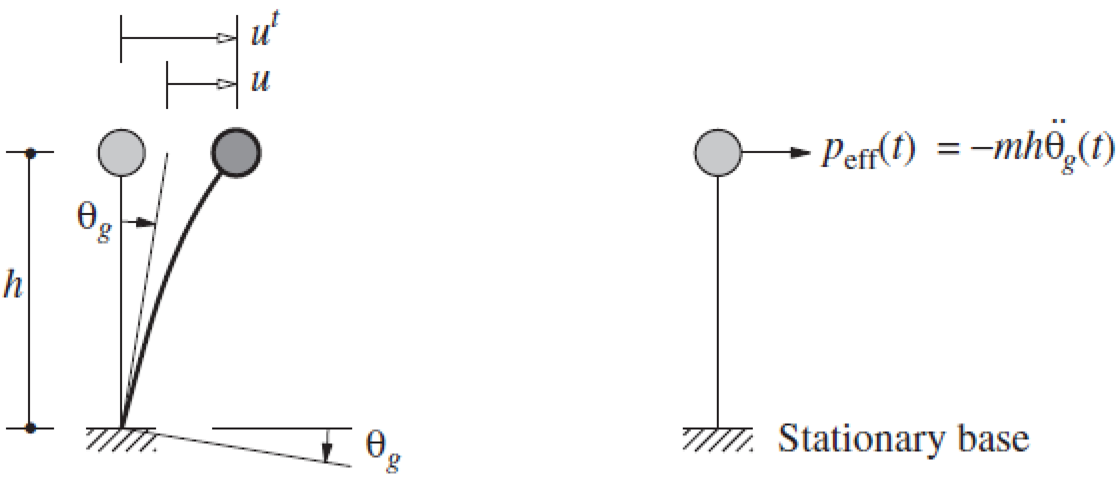


Fig. 1.1.10 Effective earthquake force: horizontal ground motion.

Although the rotational components of ground motion are not measured during earthquakes, they can be estimated from the measured translational components and it is of interest to apply the preceding concepts to this excitation. The total displacement u_t of the mass is made up of two parts: *u* associated with structural deformation and a rigid-body component $h\vartheta_g$, where *h* is the height of the mass above the base. At each instant of time these displacements are related by

$$u^t(t) = u(t) + h\theta_g(t)$$



the total acceleration $\ddot{u}_t$ *(t)* must now be determined from the last equation. Putting all these equations together leads to

$$m\ddot{u} + c\dot{u} + ku = -mh\ddot{\theta}_g(t)$$

The effective earthquake force associated with ground rotation is

$$p_{\text{eff}}(t) = -mh\ddot{\theta}_g(t)$$

Study of sdf systems: The time variation of response *r (t)* to these various excitations will be of interest. For structural design purposes, the maximum value (over time) of response r contains the crucial information, for it is related to the maximum forces and deformations that a structure must be able to withstand. We will be especially interested in the peak value of response, or for brevity, peak response, defined as the maximum of the absolute value of the response quantity:

$$r_o \equiv \max_t |r(t)|$$

By definition the peak response is positive; the algebraic sign is dropped because it is usually irrelevant for design.

Free vibration

A structure is said to be undergoing free vibration when it is disturbed from its static equilibrium position and then allowed to vibrate without any external dynamic excitation.

Free vibration is initiated by disturbing the system from its static equilibrium position by imparting the mass some displacement *u(0)* and velocity *ŭ(0)* at time zero, defined as the instant the motion is initiated:

$$u = u(0) \qquad \dot{u} = \dot{u}(0)$$

Subject to these initial conditions, the solution to the homogeneous differential equation is obtained by standard methods:

$$u(t) = u(0)\cos\omega_n t + \frac{\dot{u}(0)}{\omega_n}\sin\omega_n t$$

This motion is known as simple harmonic motion.

Where

$$\omega_n = \sqrt{\frac{k}{m}}$$

The last equation is plotted in Fig. 1.2.1. It shows that the system undergoes vibratory (or oscillatory) motion about its static equilibrium (or undeformed, *u* = 0) position; and that this motion repeats itself after every 2π/ωn seconds.

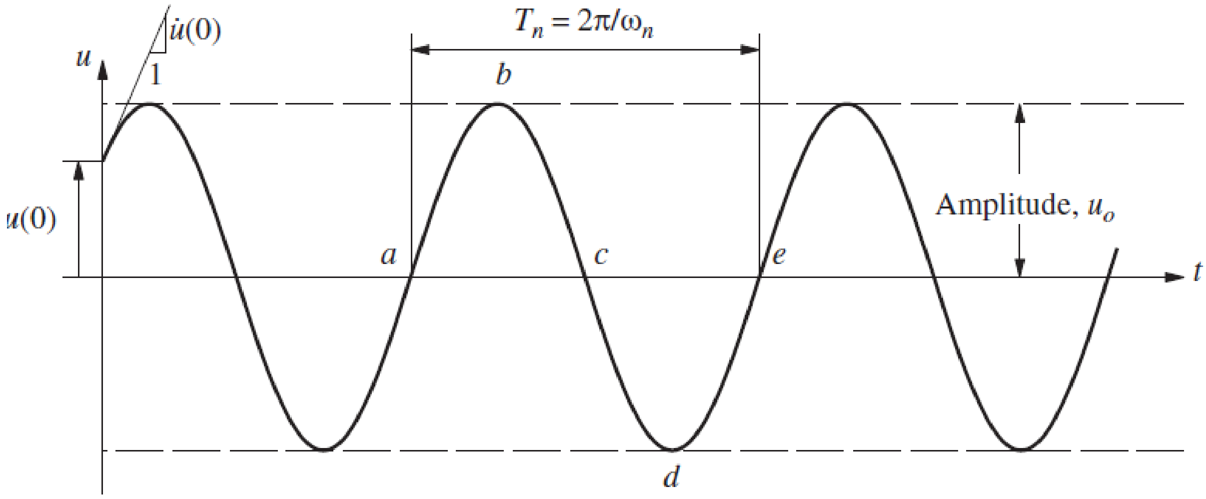


Fig. 1.2.1 Harmonic motion equation.

The undamped system oscillates back and forth between the maximum displacement u_o and minimum displacement $-u_o$. The magnitude u_o of these two displacement values is the same; it is called the amplitude of motion and is given by

$$u_o = \sqrt{[u(0)]^2 + \left[\frac{\dot{u}(0)}{\omega_n}\right]^2}$$

The amplitude u_o depends on the initial displacement and velocity. Cycle after cycle it remains the same; that is, the motion does not decay. We had mentioned in the last section, this unrealistic behavior of a system if a damping mechanism to represent dissipation of energy is not included.

The natural frequency of the one-story frame of Fig. 1.2.2a with lumped mass m and columns clamped at the base is

$$\omega_n = \sqrt{\frac{k}{m}} \qquad k = \frac{24EI_c}{h^3}\frac{12\rho + 1}{12\rho + 4}$$

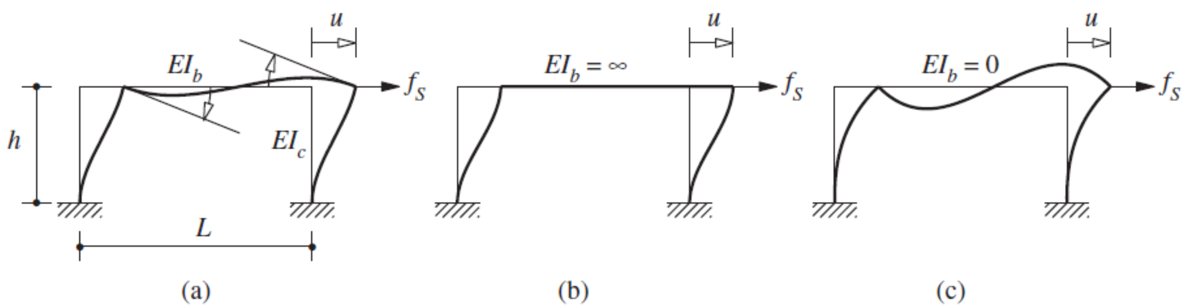


Figure 1.3.2

Fig. 1.2.2 Natural frequency in a structure.

where ρ = (E Ib/L) ÷ (2E Ic/h). For the extreme cases of a rigid beam, ρ = ∞, and a beam with no stiffness, ρ = 0, and the natural frequencies are

$$(\omega_n)_{\rho=\infty} = \sqrt{\frac{24EI_c}{mh^3}} \qquad (\omega_n)_{\rho=0} = \sqrt{\frac{6EI_c}{mh^3}}$$

The natural frequency is doubled as the beam-to-column stiffness ratio, ρ, increases from 0 to∞; its variation with ρ is shown in Fig. 1.2.2. The natural frequency is similarly affected by the boundary conditions at the base of the columns. If the columns are hinged at the base rather than clamped and the beam is rigid, $w_n = \sqrt{6 \cdot E \cdot \frac{I_c}{m \cdot h^3}}$, which is one-half of the natural frequency of the frame with clamped-base columns.

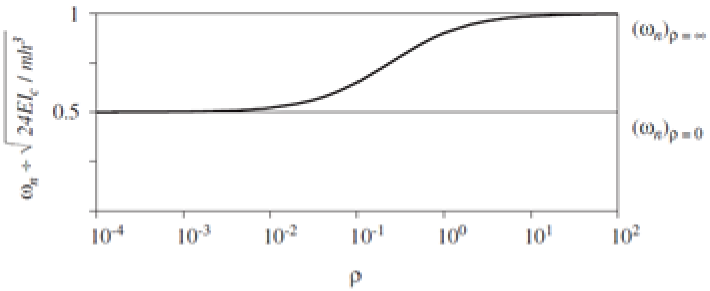


Fig. 1.2.2 Variation of natural frequency, w_n, with beam-to-column sitffness ratio, p.

<u>Viscously damped free vibration:</u> Setting *p(t) = 0* gives the differential equation governing free vibration of SDF systems with damping:

$$m\ddot{u} + c\dot{u} + ku = 0$$

Dividing by *m* gives

$$\ddot{u} + 2\zeta\omega_n\dot{u} + \omega_n^2 u = 0$$

where

$$\omega_n = \sqrt{\frac{k}{m}}$$

$$\zeta = \frac{c}{2m\omega_n} = \frac{c}{c_{cr}}$$

We will refer to

$$c_{cr} = 2m\omega_n = 2\sqrt{km} = \frac{2k}{\omega_n}$$

as the critical damping coefficient, for reasons that will appear shortly; and ζ is the *damping ratio* or *fraction of critical damping*. The damping constant *c* is a measure of the energy dissipated in a cycle of free vibration or in a cycle of forced harmonic vibration."

<u>All this section it's for help to understand a little bite the action of the earthquakes in the structures. With a idea before to work the construction details is better for evaluate the next part.</u>

AFFORDABLE HOUSES AND UNDERDEVELOPED COUNTRIES

Affordable houses description

"*People with disabilities face a severe housing affordability crisis in many countries. HUD's 2015 Worst Case Housing Needs Report to Congress found that in 2013, as many as 7.7 million renter households had worst case housing needs —defined as renters with acute needs for housing assistance, or unassisted renters with incomes below half of their area's median income who pay more than half of their income for housing or live in severely substandard housing. About one in seven, or 14%, of renter households with worst case housing needs included a nonelderly person with disabilities. According to Priced Out in 2014, a biennial report published by TAC and the Consortium for Citizens with Disabilities (CCD) Housing Task Force, the national average rent for a modestly priced one-bedroom apartment is more than the entire amount of Supplemental Security Income (SSI) received by people with disabilities*."[13]

[13]http://www.tacinc.org/knowledge-resources/topics/affordable-housing/

The definition of affordable houses is defined in various ways according to different authors.

"A standard definition for affordability is that households should pay no more than 30% of their income for housing, including utilities (O'Delletal.2004). Families that pay more, especially lower income families, are considered cost burdened because they may have difficulty paying for non-
Housing needs such as food, clothing, transportation, childcare, and medical care. The 30% standard can be applied to any income group. It is mostly used, however, to assess housing available to families earning less than the area median income. Those families are typically classified into "very low income" families earning less than 50% of area median income (AMI), "low income" families earning 50 to 80% of AMI, and "moderate income" families earning 80 to 100% of AMI.

One criticism of the 30% rule is that lower oncime gousegolds may not be able t pay 30% of their income for housing and still have enough money left to purchase other basic needs for food, transportation, healthcare, and so on. A second criticism of the 30% criterion is that it simply compares direct housing costs to income and ignores differences in costs related to neighborhood quality or accessibility (area affordability). A third criticism, is that ignores physical or structural housing conditions. If most condition problems occur in units occupied by lower income families, then physical conditions and affordability to lower income households may be realated".[14]

[14]http://fanniemae.com/resources/file/fundmarket/pdf/hoytpivo_mfhousing_affordablehousingdef_122013.pdf

An other definition, more elementary, is that affordable housing refers to housing units that are affordable by that section of society whose income is below the median household income.

“Last example, by London Assembly, “*the affordable housing is social rented, affordable rented and intermediate housing (see para 3.61), provided to eligible households whose needs are not met by the market. Eligibility is determined with regard to local incomes and local house prices. Affordable housing should include provisions to remain at an affordable price for future eligible households or for the subsidy to be recycled for alternative affordable housing provision.*

3.61 Within this overarching definition:

- *social rented housing should meet the criteria outlined in Policy 3.10 and be owned by local authorities or private registered providers, for which guideline target rents are determined through the national rent regime. It may also be owned by other persons and provided under equivalent rental arrangements to the above, as agreed with the local authority or with the Mayor.*
- *affordable rented housing should meet the criteria outlined in Policy 3.10 and be let by local authorities or private registered providers of social housing to households who are eligible for social rented housing. Affordable Rent is subject to rent controls that require a rent of no more than 80% of the local market rent (including service changes, where applicable)[1]. In practice, the rent required will vary for each scheme with levels set by agreement between developers, providers and the Mayor through his housing investment function. In respect of individual schemes not funded by the Mayor, the London boroughs will take the lead in conjunction with relevant stakeholders, including the Mayor as appropriate, but in all cases particular regard should be had to the availability of resources, the need to maximise provision and the principles set out in policies 3.11 and 3.12.*
- *intermediate housing should meet the criteria outlined in Policy 3.10 and be homes available for sale or rent at a cost above social rent, but below market levels. These can include shared equity (shared ownership and equity loans), other low cost homes for sale and intermediate rent, but not affordable rent. Households whose annual income is in the range £18,100–£66,000 should be eligible for new intermediate homes. For homes with more than two bedrooms, which are particularly suitable for families, the upper end of this eligibility range will be extended to £80,000. These figures will be updated annually in the London Plan Annual Monitoring Report.*

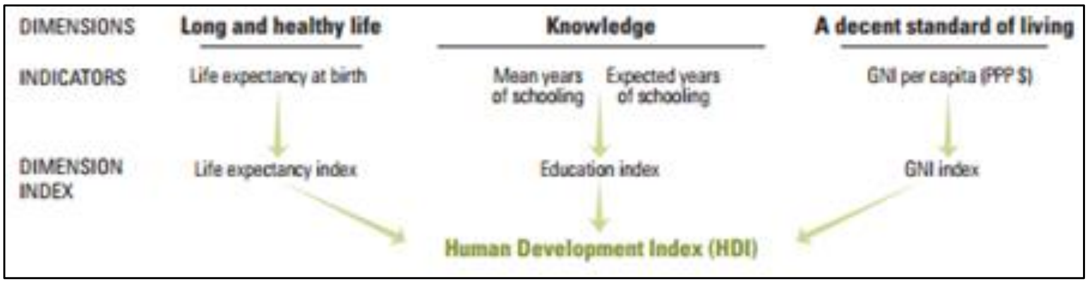
Market housing is defined separately as private housing for rent or sale where the price is set in the open market.”.[15]

[15]https://www.london.gov.uk/what-we-do/planning/london-plan/current-london-plan/london-plan-chapter-3/policy-310-definition

Underdeveloped countries

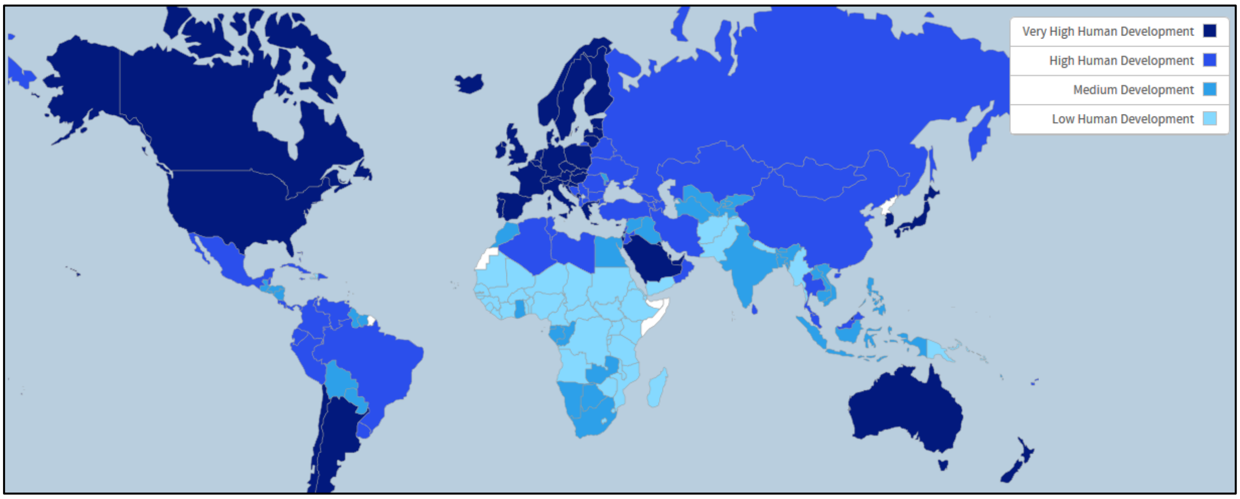
"According to United Nations Development Programme, the The Human Development Index (HDI) is a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and have a decent standard of living. The HDI is the geometric mean of normalized indices for each of the three dimensions.

The HDI simplifies and captures only part of what human development entails. It does not reflect on inequalities, poverty, human security, empowerment, etc.



The Human Development Index is divided into four divisions, very high, high, medium and low, therefore all those countries whose HDI is lower are considered underdeveloped, thus, are those that don't have minimum both social levels, and economic and cultural. Usually they associated with the called third world, in the opposite to the first world and extreme poverty." [16]

[16] http://hdr.undp.org/en/content/human-development-index-hdi



For exemple, some countries of that we know it are:

COUNTRY	INDEX HDI	RANK
Norway	0944	1
United Kingdom	0.907	14
Japan	0891	20
Spain	0.876	26
Bolivia	0.662	119
Papua New Guinea	0.505	158

We can observe the difference between Spain and Norway in the same continent, Europe, therefore in other countries as Bolivia or Papua New Guinea that are really low position for the people that tries survive all the days with the minimum, if we apply the risk of the earthquake, will be a unsustainable life for the community in the country.

The last countries of the table will be the aim of this project, Bolivia and Papua New Guinea.

BOLIVIA

+ Health	Life expectancy at birth	68.3
+ Education	Expected Years of Schooling (years)	13.2
+ Income/Composition of Resources	Gross national income (GNI) per capita (2011 PPP$)	5,760.1
+ Inequality	Inequality-adjusted HDI (IHDI)	0.472
+ Gender	Gender Development Index (GDI)	0.931
+ Poverty	Multidimensional Poverty Index (MPI), HDRO specifications	0.097
+ Work, employment and vulnerability	Employment to population ratio (% ages 15 and older)	70.6
+ Human Security	Homicide rate (per 100,000 people)	12.1

“The report analyzes the survival and accumulation strategies adopted by the Bolivian population over the past three decades, and characterizes the processes of individual and collective mobility, in many cases originated outside the state. Social change reflects a construction in which historical inequalities -of ethnicity, gender persist, and between urban and rural areas-, to which the new inequalities from a labor market segmented and new urban identities based on styles of life. These inequalities delays the development and limit the coexistence, because they occur in a context of high poverty and produce practices of exclusion and discrimination. At the same time they pose new challenges for action.

Between 1975 and 2007, Bolivia went from the post 57 of 82 countries, 113th among 177 countries in the world ranking of the Human Development Index (HDI). In this period the HDI went from a medium low human development (0.512) at a level high medium human development (0.729). At the same time, life expectancy increased from 45 to 65 years, and substantially improved indicators of educational attainment of the population that result, for example, in increasing the literacy rate of 63-91%.

However, this trend of increasing human development in the country, suggesting a fall of social achievements. In the field of social policy, further improvements in the social components of human development will be marginal due to reach scattered rural areas with the provision of basic services and improve their quality in urban and rural areas requires greater efforts which meant the expansion of services in the cities during the urbanization process.

Three results alert about the slowdown of social progress in recent years.
First, the gradual reduction in gains from migration field-City is observed; Second, the depletion of social reforms initiated in the nineties, focusing on increasing the supply of basic services, education and health through higher levels of public investment and current expenditure, but not necessarily translated into substantial improvements in quality and efficiency in the provision of such services; And third, it highlights important progress in decreasing the percentage of people living below the poverty line in the last decade".[17]

[17]Los cambios detrás del cambio

PAPUA NEW GUINEA

+ Health	Life expectancy at birth	62.6
+ Education	Expected Years of Schooling (years)	9.9
+ Income/Composition of Resources	Gross national income (GNI) per capita (2011 PPP$)	2,462.8
+ Inequality	Inequality-adjusted HDI (IHDI)	n.a.
+ Gender	Gender Development Index (GDI)	n.a.
+ Poverty	Multidimensional Poverty Index (MPI), HDRO specifications	n.a.
+ Work, employment and vulnerability	Employment to population ratio (% ages 15 and older)	70.7
+ Human Security	Homicide rate (per 100,000 people)	10.4

"Papua New Guinea's 40 year history of Independence has been dominated by the extractives sector. Large-scale mine and oil production (worth at least K150billion since

Independence) has driven formal sector growth, underpinned budgets that have improved health and education outcomes, as well as provided significant improvements in incomes and livelihoods for some. At the same time however, this production has sparked civil strife, caused massive environmental damage, arguably distorted the economy, and brought about a range of negative impacts on communities. Valuable lessons are being learnt (and have potential international relevance), but still the risk remains that the existing model of economic growth in the country will not deliver sustained improvements in wellbeing for the majority of the population". [18]

[18]http://hdr.undp.org/en/content/human-development-index-hdi

PROJECT

The aim is to design a build a shelter that is consistent with the income of the future users. Regarding this aspect, evolutive systems that allow growth from very simple constructions are especially interesting.

"*Housing is a basic need and like any basic human need will be constantly in demand. The concept of live ability of a house is usually framed in terms of activities in a house. The human requirements for space differ widely depending upon the geographic location and the climatic conditions of the site and upon the socio-economic and cultural standards of the population.*

Certain principles must be observed and minimum specifications must be followed without violating code rules for foundations, superstructure, plastering, painting, doors, windows and roofs.

Geographical situation, and the climate which goes along with it, is relevant for the needs in these kinds of buildings. Affordable housing should take local climatic conditions into account and be designed to minimize the use of energy. Insulation of all external walls and roof is important to minimize energy demand and provide internal comfort for the occupants.

To meet minimum health standards, certain household services and facilities are required. These include water supply, sanitary means for the disposal of household wastes including domestic sewage, facilities for washing clothes and cleaning household utensils, for bathing…

Ventilation is a key factor when building affordable housing. Therefore proper windows in the walls, protected by trusses, as well as roof ventilation to create natural ventilation, are relevant.

Seismic action is a significant factor when building housing. Some relevant ones are to tie different parts of foundations and walls or structural parts of the structure, so that a local *failure does not lead to an absolute ruin, or let the structure have deformations without leading to collapse.*

Access to the working site might also be relevant when deciding what system is to be used. Often transportation and lifting capabilities are defining the length and weight of the elements. Therefore in many cases it's only possible to use elements that can be lifted by two persons.

Precast elements are generally constructed under factory conditions, as the quality of the work is easier to control than on a construction site. The main essentials and advantages of prefabricated production will be: avoiding waste, standardization of repetitive work, reduction of resource idleness, reduction of average waiting time, decrease in time for processing parts to traverse the system; reducing inventor, increase in production rate…

Production units require storage of raw material such as cement, steel, lime, timber, etc., and hence extensive storage is done in stockpiles, yards, silos and warehouses. A machinery yard is also necessary to house the various cranes, concreting and material handling equipment. Storage arrangement becomes one of the primary functions of the production.

Next in importance are industrial sheds, wherein the prefabrication company will manufacture the various building components. These industrial sheds may have gantries and other such facilities.

The transportation branch is another important area for the transportation of the finished products to the building sites. A large vehicle parking lot in front of the industrial estate can also be envisaged.

The production of light elements, as ferro-cements wall panels, that can be moved and erected by few non-specialized people, without the help of machinery, may play an important role in developing countries.

The size of the panels and slabs are limited by the transportation used to deliver them. By limiting the lengths of the panels and slabs according to standard trailers can be used, assuming there are good road conditions. Larger size panels and slabs may be used but special permitting and routing to the construction site may be needed, adding to the cost of construction.

In developing contexts the erection process will be a key point for the design of prefabricated elements. The maximum weight that can be manipulated without cranes, for a normal crew, could be around 100 – 160 kg.

A shelter's "thermal envelope" separates outside conditions from inside conditions. This envelope consists of the components of all six sides of the house: the four walls, roof, and foundation. The roof is the most important part of the home to insulate in all climates. In hot weather, the sun beats directly on the roof. Even though heat moves in all directions by *radiation, in cold weather, heat loss out of the roof or attic is a particular problem because hot air rises. Wall insulation is far more important in a cold climate than a hot one. Floor insulation is very important in areas where the ground freezes.*

Adequate ventilation shall be provided to maintain a healthy environment inside the house and to limit the risk of transmission of diseases. Ventilation should be maximized in hot-climates to reduce inside temperature, and minimized in cold-climates to retain heat within the shelter.

In wet climates, draining water be the principal consideration, therefore:

- *Construction in sites with slope to provide adequate surface drainage;*
- *Roof with sufficient pitch for water drainage. Drains connect to reservoir to harvest rainwater.*
- *Roof overhang to protect walls and openings from water during rainy seasons and from sun in hot weather;*
- *Compacted plinth, with raised floor to protect from flooding;*
- *Provide sufficient openings (with small windows) for good ventilation and air convection, but looking the simetric structure for a correct resistant against earthquakes.*

In any case, all cultures have developed adequate and affordable housing solutions; if these are used as a starting-point, appropriate housing is easier and cheaper to provide.

Affordable housing when initially constructed may not always include services (plumbing, ductwork, wiring…). If this is the case the selected construction system should allow for future installation and integration of services.

The plumbing system is a one-pipe system in which the wastes from botch the kitchen and toilet are carried out of the building in a single stack. The service stack itself serves the purpose of a ventilation pipe and eliminates the need for a separate ventilation stack.

Looking for rigidity, sufficient rigidity is easily obtained in low rise buildings without the need for ductility the households are design with one floor.

Water supply is vital in all housing and this can be provided by installation of a water tank to collect rainwater from the roof. Water distribution can be collected direct from the tank or piped by gravity or pumped systems to within the house".[19]

[19]http://www.citopmadrid.es/actualidad/noticias/boletin60.pdf

PAPUA NEW GUINEA

"*Papua New Guinea, with capital Port Moresby, situated to the north of Australia, Papua New Guinea has a total land area of 462,840 km^2, including the large islands of New Britain, New Ireland, and Bougainville and hundreds of smaller islands. It's situated between the stable continental mass of Australia and the deep ocean basin of the Pacific. The largest section is the eastern half of the island of New Guinea, which is dominated by a massive central cordillera, or system of mountain ranges, extending from Indonesia's Irian Jaya to East Cape in Papua New Guinea at the termination of the Owen Stanley Range, and including the nation's highest peak, Mt. Wilhelm.*

The climate of Papua New Guinea is chiefly influenced by altitude and by the monsoons. The northwest or wet monsoon prevails from December to March, and the southeast or dry trade winds from May to October. Annual rainfall varies widely with the monsoon pattern, ranging from as little as 127cm at Port Moresby. Most of the lowland and island areas have daily mean temperatures of about 27°c, while in the highlands temperatures may fall to 4°c,at night and rise to 32°c in the day. Relative humidity is uniformly high in the lowlands at about 80% and averages between 65 and 80% in the highlands.

The flora of Papua New Guinea is rich and varied, with habitats ranging from tidal swamps at sea level to alpine conditions. In low-lying coastal areas, various species of mangroves form the main vegetation, together with the casuarina, sago, and palm. Most of the country is covered by tropical and savanna rain forest, in which valuable trees such as kwila and cedar are found.

Papua New Guinea's environmental concern includes pollution, global warming, and the loss of the nation's forests. Coastal waters are polluted with sewage and residue from oil spills. Only 88% of the nation's city dwellers and 32% of the rural population have access to improved water sources. The country's cities have produced an average of 0.1 million tons of solid waste per year. Global warming and the resulting rise in sea level are a threat to Papua New Guinea's coastal vegetation and water supply.

Transportation is a major problem in Papua New Guinea because of the difficult terrain. Major population centers are linked chiefly by air and sea, although road construction has increased to supplement these expensive means of transport. There are 10,940 km of waterways.

In the history New Guinea was first sighted by Spanish and Portuguese sailors in the early 16th century and was known prophetically as "Isla del Oro" (Island of Gold). The western part of the island was claimed by Spain in 1545 and named New Guinea for a fancied resemblance of the people to those on the West African coast." [20]

[20]http://www.encyclopedia.com/topic/Papua_New_Guinea.aspx

"*It was not until 1884, after an abortive Australian annexation attempt and under fear of German ambitions in the area, that Britain established a protectorate over the southern coast of New Guinea and adjacent islands. Germany took control of the northeastern portion of the island, as well as New Britain, New Ireland, and Bougainville, while Britain took possession of the southern portion and the adjacent islands.*

British New Guinea passed to Australian control in 1902 and was renamed the Territory of Papua in 1906. A Legislative Council, established in 1953, was replaced by the House of Assembly in 1964. Eight years later, the territory was renamed Papua New Guinea, and on 1 December 1973, it was granted self-government

Now, in time, Papua New Guinea is an independent, parliamentary democracy in the Commonwealth of Nations, with a governor-general representing the British crown.

Traditional housing in rural areas appears to be adequate, but in urban areas there are acute shortages because of migration. In most urban areas, squatter settlements have been established. New housing has generally fallen far short of meeting the demand, especially for medium- and low-cost units.

There is a high level of serious crime. Law and order is poor or very poor in many parts of the country. On 8 June 2016 protests at the University of PNG campus in Waigani, Port Moresby, resulted in an unconfirmed number of deaths and serious injuries. There are also reports of unrest in other parts of Port Moresby and elsewhere. Others risks, Papua New Guinea is prone to seasonal natural disasters including tropical cyclones and flash flooding.

PNW is a country with a great history, culture and natural wealth, but the industrial exploitation, government and natural disasters have led to the society to a serious condition. Overcrowding and poverty have made part of society to violence. Theft and crime is common, especially in Port Moresby.
This project aims to make a complex type of single-family affordable houses for the Papua New Ginea's community ". [21]

[21]http://www.nationsencyclopedia.com/Asia-and-Oceania/Papua-New-Guinea-HISTORY.html

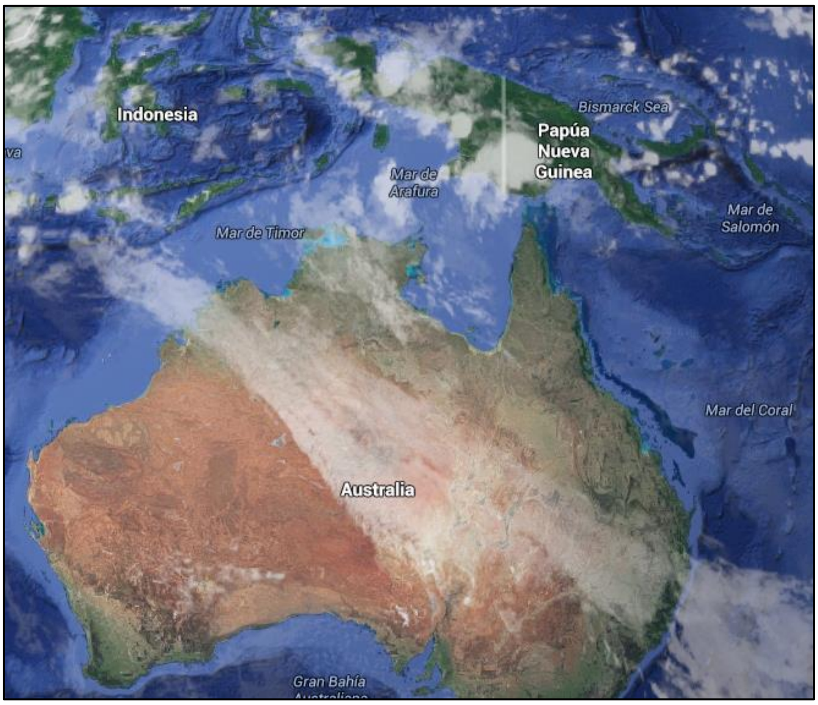
Papua new guinea project location

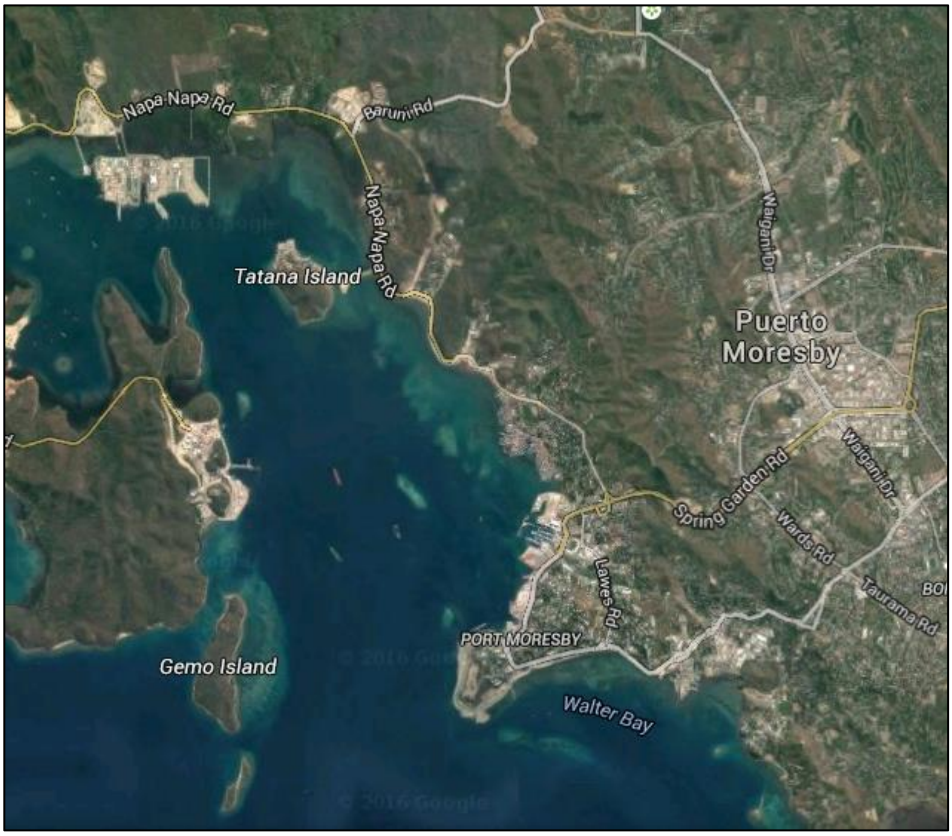
Independent State of Papua New Guinea belongs to the oceanic continent that occupies the eastern half of the island of New Guinea and its offshore islands in Melanesia, a region of the southwestern Pacific Ocean north of Australia.

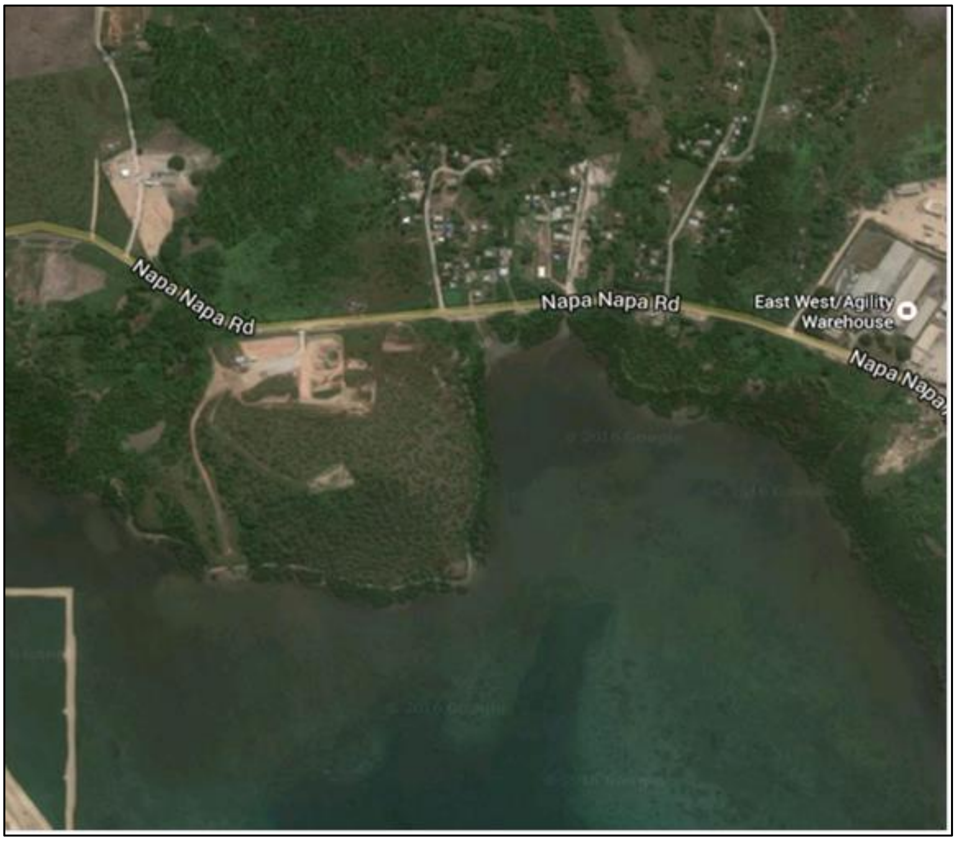
Port Moresby (9°30'49.1"S 147°13'7.7"E) is the capital and largest city of Papua New Guinea. It is located on the shores of the Gulf of Papua, on the south-eastern coast of the Papuan Peninsula of the island of New Guinea.

The big problem of this city is the high rate of crime. If we build houses on this site, for statistics (previously cases), materials can be stolen, deteriorate homes and the houses can be assaulted causing damage to occupants. Otherwise, the city has the features needed for a family such as: supermarkets, schools, hospitals, jobs, etc. Thus, the best option is to create a site near the city but not in it, where it already has services of other communities, building materials and workers from this area.

The chosen area is exactly on 9°24’59.4”S 147°07’11.5”E.

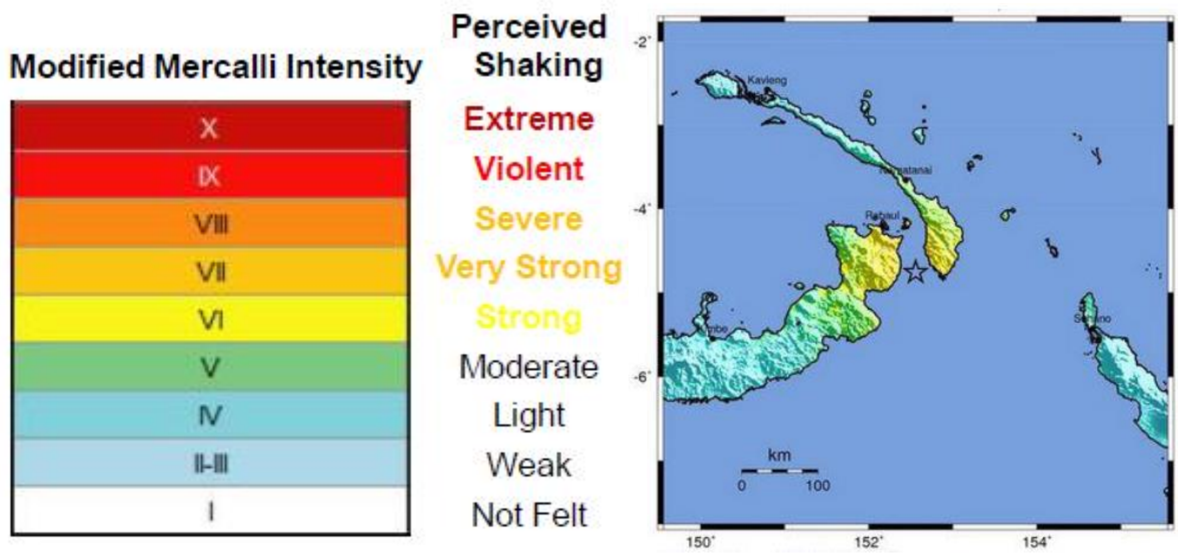



Napa Napa Rd
Baruni Rd
Napa Napa Rd
Tatana Island
Waigani Dr
Puerto Moresby
Spring Garden Rd
Waigani Dr
Wards Rd
Lawes Rd
Taurama Rd
PORT MORESBY
Gemo Island
Walter Bay


Napa Napa Rd
Napa Napa Rd
East West/Agility Warehouse

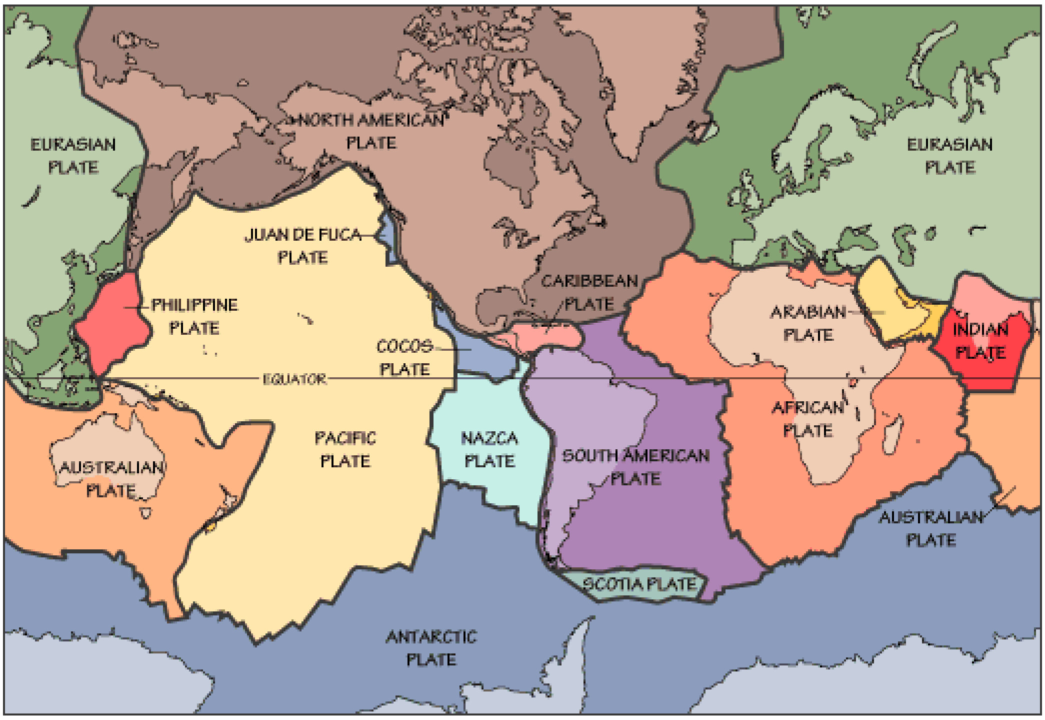
Report : "*A magnitude 7.5 earthquake struck off the eastern coast of Papua New Guinea on 29 March, 2015, approximately 54 km (33 miles) southeast of Kokopo. Residents reported strong ground shaking for about five minutes. The Pacific Tsunami Warning Centre reported that tsunami waves reaching 1 to 3 meters above the tide level were possible along some coasts of Papua New Guinea.*

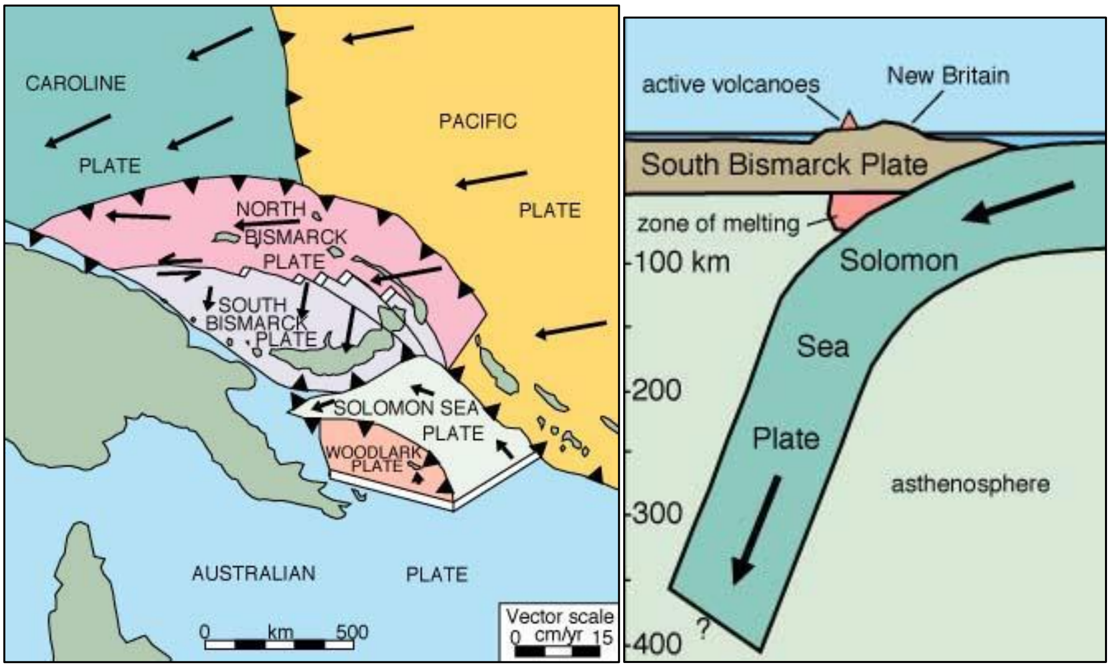
The Modified-Mercalli Intensity scale is a twelve-stage scale, from I to XII, that indicates the severity of ground shaking.
The nearest islands experienced very strong shaking from this earthquake.



In this region of the Pacific, the Australian Plate is subducting under the overriding Pacific Plate.

In detail, there are numerous microplates (fragments of larger plates). Arrows show net plate motion relative to the Australian Plate.





This region of tectonic microplates accommodate convergence between the larger Australia and the Pacific Plates.The Solomon Sea Plate moves slightly faster and more northeasterly with respect to the Pacific Plate than does the Australia Plate due to sea-floor spreading in the Woodlark Basin."[22]

[22]http://www.iris.edu/hq/files/programs/education_and_outreach/retm/tm_150505_papua/150505papua.pdf

Material

“The tree and its wood have played a prominent role in human life throughout history. Wood has been one of our most important building materials from early Paleolithic times, both for building and for the manufacture of tools, weapons, and furniture.

Early humans used wood because it was available and no elaborate tools were needed to work it. In the early days, however, the quality of the products depended more on the quality of the wood and the skill of the workman than on the tools available for woodworking. The development of copper tools by about 5000 BC opened new opportunities for craftsmanship – opportunities that have been carried forward to this day.
From the tenth to the eighteen the centuries in Europe, wood was the material primarily used for buildings, tools, machines, mills, carts, buckets, shoes, furniture and barrels, to name just a few of the thousands of kinds of wood products of the time. In Europe, wood use reached a peak during the sixteenth century, then began to diminish, not due to the limitations of wood, but due to limits on its accessibility as a result of increasing demands for fuel and materials and the expansion of agriculture into formerly forested lands. Wood use in North America continued to expand long after the decline of use in Europe and continues to increase today as part of the general world trend toward increasing wood use.

Wood has been a most versatile and useful construction material for thousands of years and is still used more than any other construction material. The style and durability of structures built at various times and places have depended on the type and quality of timber available and the conditions of use, as well as the culture and way of life of the people concerned. In forested zones, where timber was plentiful, solid walls were built of tree trunks or heavy timbers. Timber houses in Neolithic Europe were frequently made by splitting logs and setting them vertically in the ground or on a sill plate on the ground.

The architecture of the early colonists from Europe used wood intensively, adapting the concepts used in their homelands to the cultural conditions of the times and the availability of materials. Wood remained the principal construction material in North America well into the nineteen the century and remains so for housing today.

The most suitable material for this project is Cedar Wood, common name Cedar, pencil; scientific name Palaquium warburgianum spp.; and family group, the Sapotaceae.”[23]

[23]http://www.eolss.net/Sample-Chapters/C10/E5-03-03-01.pdf

“Pencil Cedar is a high quality hardwood. The timber works well with both machine and hand tools and has excellent moulding characteristics, producing a smooth, high class surface. Timber with silica present is harder to work with and can cause moderate blunting of cutting edges, but a good smooth finish can always be obtained.”[24]

[24]http://www.lumberbank.co.nz/products/pencil-cedar/

Properties	
Density	540-720 Kg/m3 @ 12% m.c
Durability	*Class 4: Non-durable.*
Texture	*Moderately fine and even; lustrous sheen.*
Permeability	*Class 4: Highly resistant.*

Workability	
General	Dependant on silican presents.
Sawing	*Readily sawn with little dulling effect.*
Planing	*Excellent characteristics.*
Blunting	*Moderate*
Boring	*Excellent characteristics.*
Nailing	*Easy to nail.*
Gluing	*Glues very well with all adhesives.*
Finishing	*Takes a high polish.*

Mechanical properties	
Strenght	*SD6*
Structural Grade	*F14 (select grade)*
Hardness	*4,0kN*
Modulus of Elasticity	*12GPa*
Modulus of Rupture	*70MPa*

Values:

- That equal weight, flawless wood is 3.6 times stronger than steel at break values.

- That the energy required to produce one ton of wood or steel is 60 times lower in the case of lumber.

- Three wooden centimeters equals 1 cm insulation.

-That maintaining that equal weight if the criterion of deformation (rigidity to flexion) is one is used wood it is 1.31 times stiffer than steel.

The chosen wood is the most abundant in the area with 28’5 hectares. The goal is build a house which the population can serve this material, that they already know and are more accustomed to their use.

We can say that wood is a material structurally advantaged every way.

In addition, safety criterion, the wood has been equated with other structural materials, the relatively recent rules of calculation, which means that there are no final differences between materials security.

The evolution of this material has experienced in recent times, in structural use, has made the wood is not only a material nature, but, now, wood has gone further and is a completely technological product.

Design

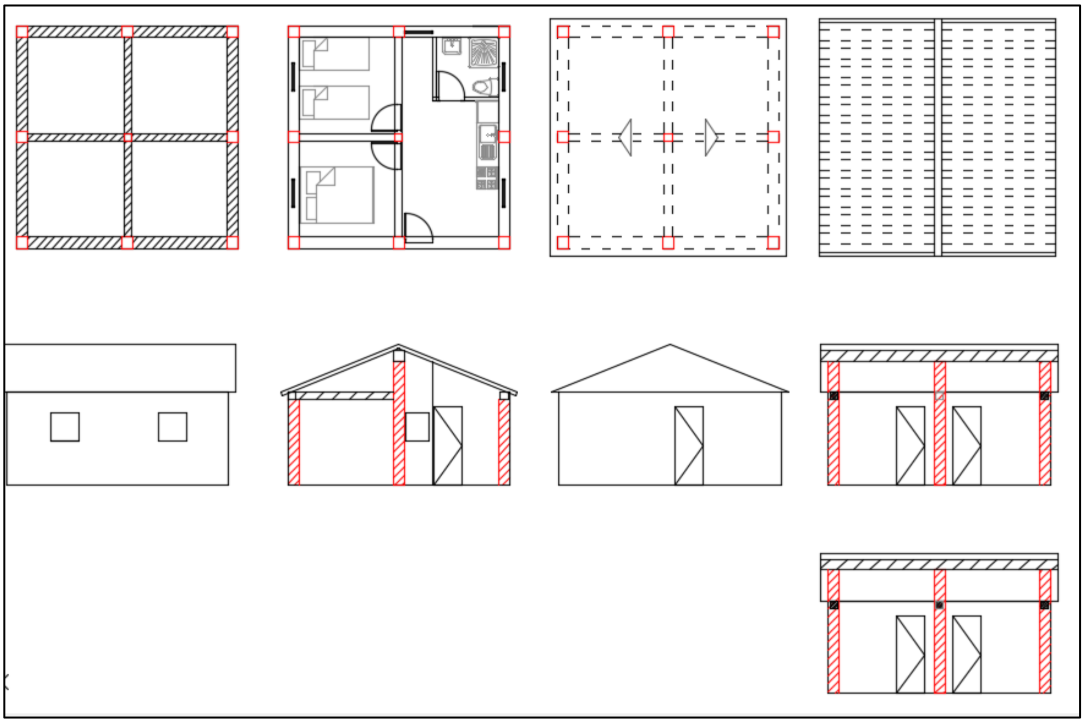
The design of a house resistance to earthquake can be of two ways: One structure design that allow to the build move with the movement of the earthquake waves or a design with a structure really static in the base and without movement.

The wood it’s a flexible material and will be the base for the foundation of the house.

We need a home where you can live in a large family of Papua New Guinea. The solution adopted is a house with two bedrooms, a living room, a kitchen and bathroom. It takes into account that the facilities are not the best, so the slope with the downspouts will spend the bathroom to the kitchen and end up in the sea. With this idea we direct the orientation of the house.

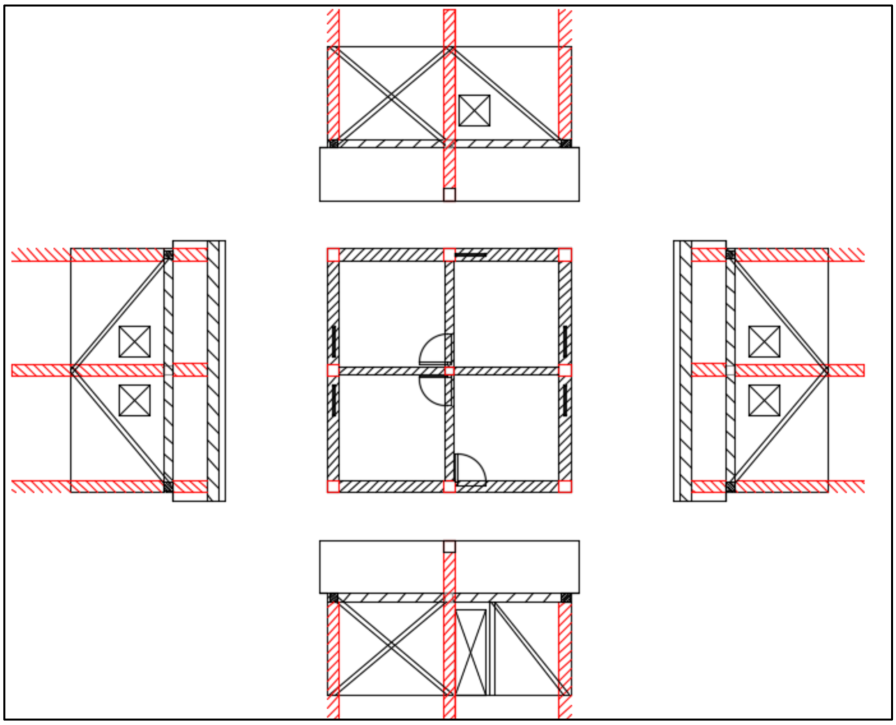
To see how work a wooden house against earthquakes we have chosen the STAAD (3D Structural Analysis and Design Software),a program of finite elements (a beam made it with little triangles), this point allow check all the parts of the structure. The process followed to obtain the results is iterative. The process is the next:

<u>Creat the geometry of the structure:</u> The first choice was a simple structure, with columns and beams with mechanical connections and bid dimensions. The house was designed to be affordable, but not resistant to earthquakes.



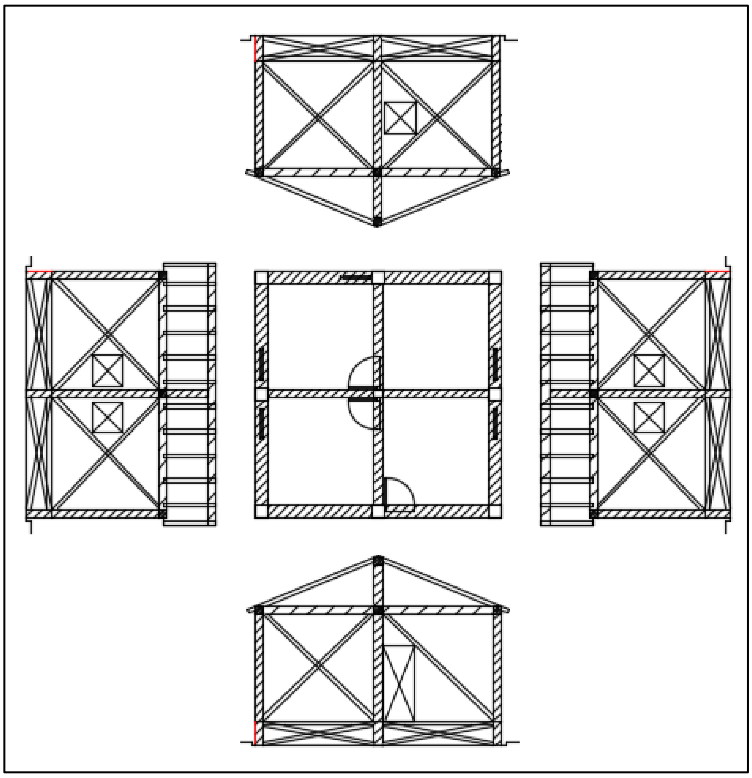
The main problem is that the strength of the earthquake creates loads in the X axis and Y axis that are not shared between connections elements (nodes) then the displacement is totally arbitrary. The structure collapses without warning.

In the second design it was created with a height different from the floor of the house foundation. The design of the house separate terrain is typical of the area, because of the moisture, streams, wild animals, etc. To solve the problems of the thrusts of the earthquake, you need to join nodes to distribute the load. The option chosen are crosses of St. Andrew from node to node.



In this design, the walls was a unic element, but the cover rised with each thrusts, because the foundation moves in other rhythm that the rest of the structure.

The final design is created with St. Andrew's crosses also the foundation, columns and profiles smaller (30cm to 20cm change) and material Bamboo (Guadua 10cm) for St. Andrew's crosses.



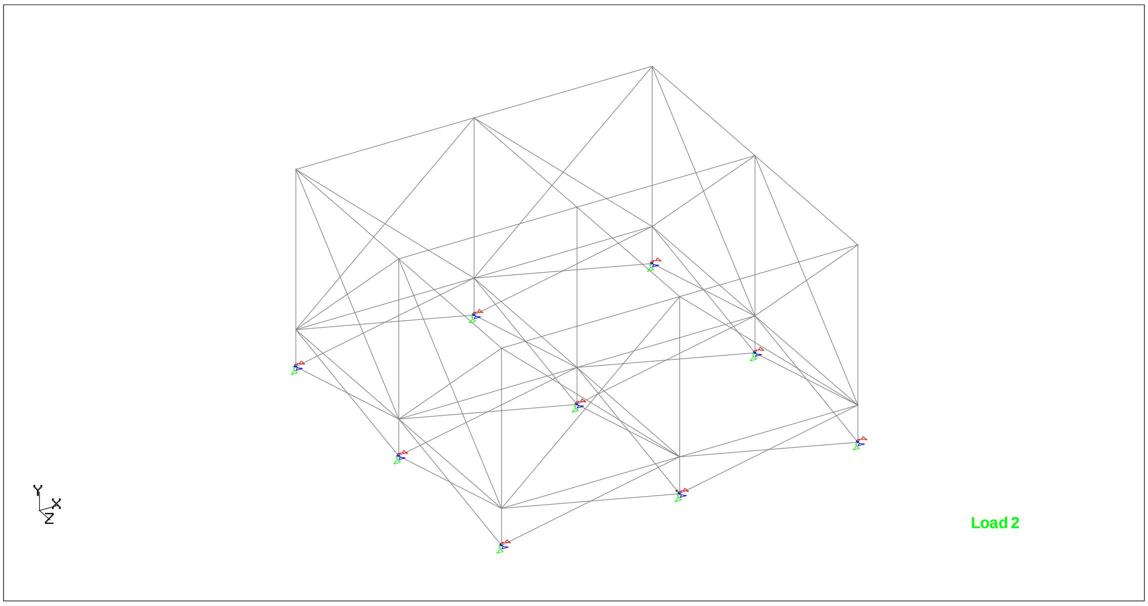
The best system is to include the diagonals to absorb copresiones and tractions. For the program, the required spaces (for bedroom, bathroom, kitchen, ...) are defined. The crosses of St. Andrew in the foundation pillars help stiffen the tensions and compressions.

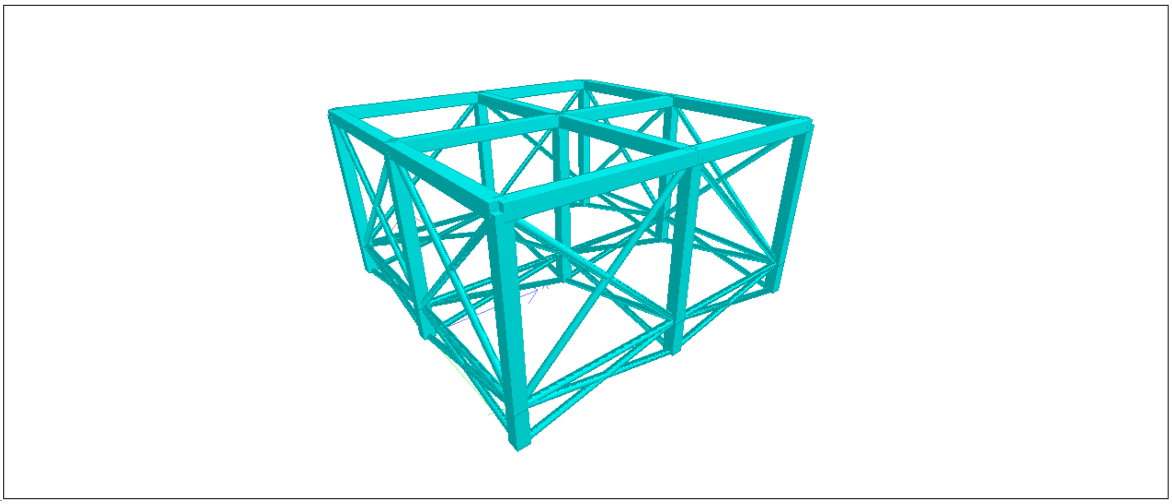
With the designed structure, we need to introduce the chosen values wood. Order values are: Elastic modulus, Poisson's ratio, density, modulus of rupture and shear modulus. As an orthotropic material must differ axes.

The data are verified with wooden Eurocode (Eurocode 5).

Now can introduce the columns, beams, diagonals… all the elements of the structure.

We have the structure:





And now we can continue with the foundation conditions. To represent seismic actions, we considered that the foundation is not rigid (as explained above is the option we have chosen) so underrun change it to a system of springs, where the X-axis and Z-axis we have introduced values to move horizontally and the Y axis have applied a load large enough to be totalemente immovable. The load apply in this system is of 600kN/m (type of Clay, from the “Modeling of soil-foundation-structure system” by Shrabony Adhikay) for X and Z axis. It considers that if the spring exceeds 600 kN / m, the plasticized dock and not regains its original form. Rotations choose them free, so that the displacement is natural.

Now we will make the rigid joints. If there are mechanically connected to transmit moments, which is the key to analyzing the loads transmitted by the earthquake.

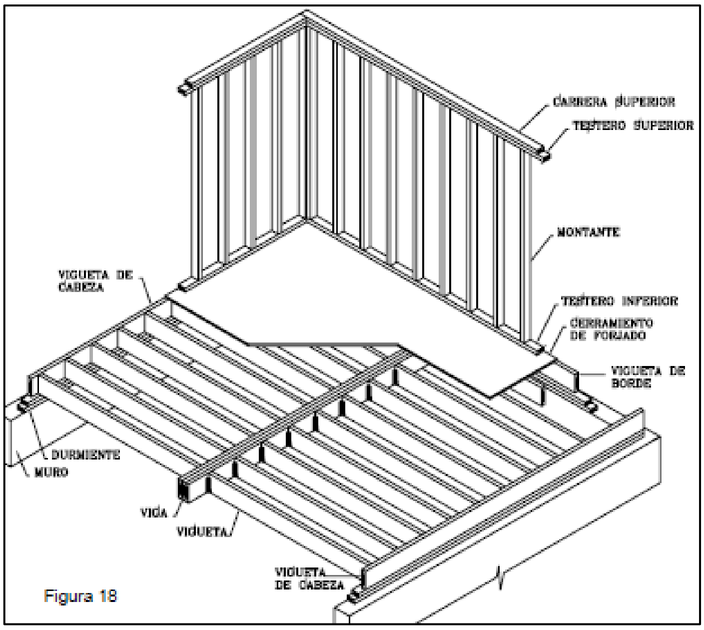
The loads applied are of a type earthquake (earthquake according to IB2 Spectrum 200 standard with Eurocode 8) offered by the program and more similar to earthquakes documented in the area.
Mass must be assigned to the axes to be accelerated and applied to the bars.
To simplify the model and knowing that the data are enough approximate to the condition of work loads are not considered as flooring, finishes, etc.
Only the infrastructure that is cosotoso the project is analyzed.

Analyzing the results we must check that the tensions that appear are smaller than the elastic modulus.
Appraisal: If the time is 0 is because it has not been applied to have free movement.

Annexed 1. Staad Report.

Construction system

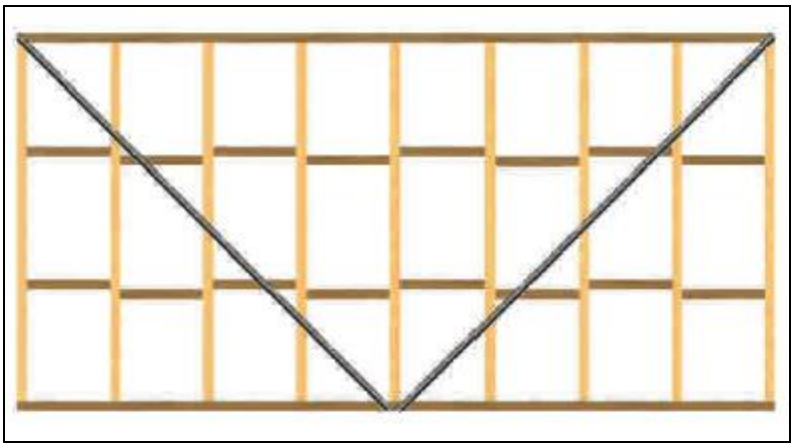
For the cover has chosen the lightest possible but dignified housing. With a network of bamboo and galvanized sheet finish. The floor is made of a timber-framed 10cm thick and finished dithering straw (as a tatami).



example floor framing

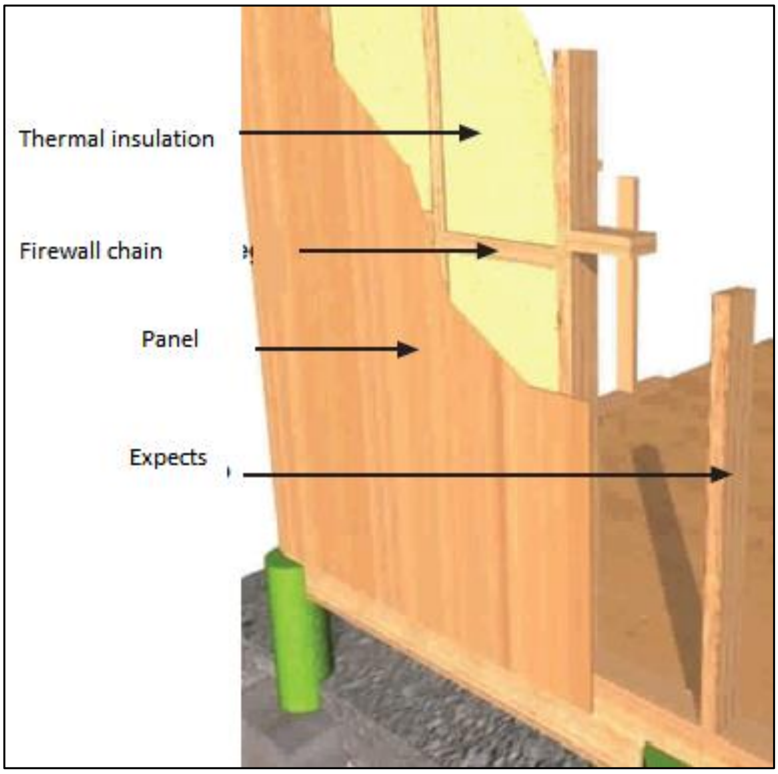
It is all vertical elements that performs functions of separation between the interior rooms of a house and can only receive loads of limited magnitude. Although it not required arriostrantes parts, it is advisable to incorporate those components that support proper fastening furniture hanging wall type, media closet, appliances, pipes and ducts basic facilities in housing.

Self-supporting Wall



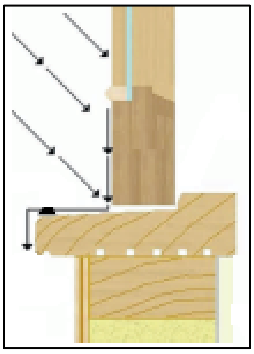
Correct form between diagonals and walll

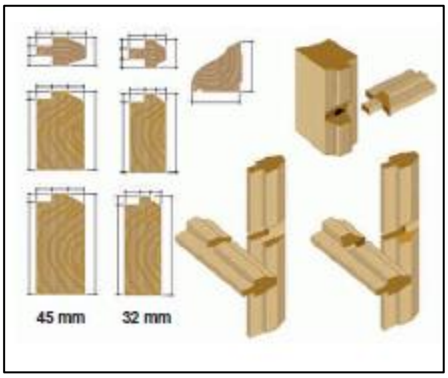
An important part is the isolation. In Papua New Guinea nueba there is a very high humidity and sometimes meets the monsoon and causes discomfort within the housing. But the available materials are not always adequate. For these cases the insulating material chosen is treated straw.

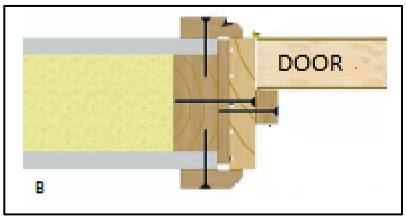


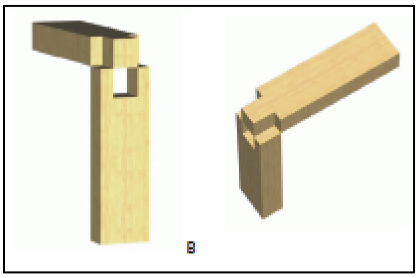
For junctions of the structure it has been used in mechanical fastening systems an assembly and a nail. It has been discarded chemical bonds to be more costly to achieve and perform.

Enclosures windows and doors are designed as simple as possible so that the cost is not higher, but satisfy the conditions for which they are designed.

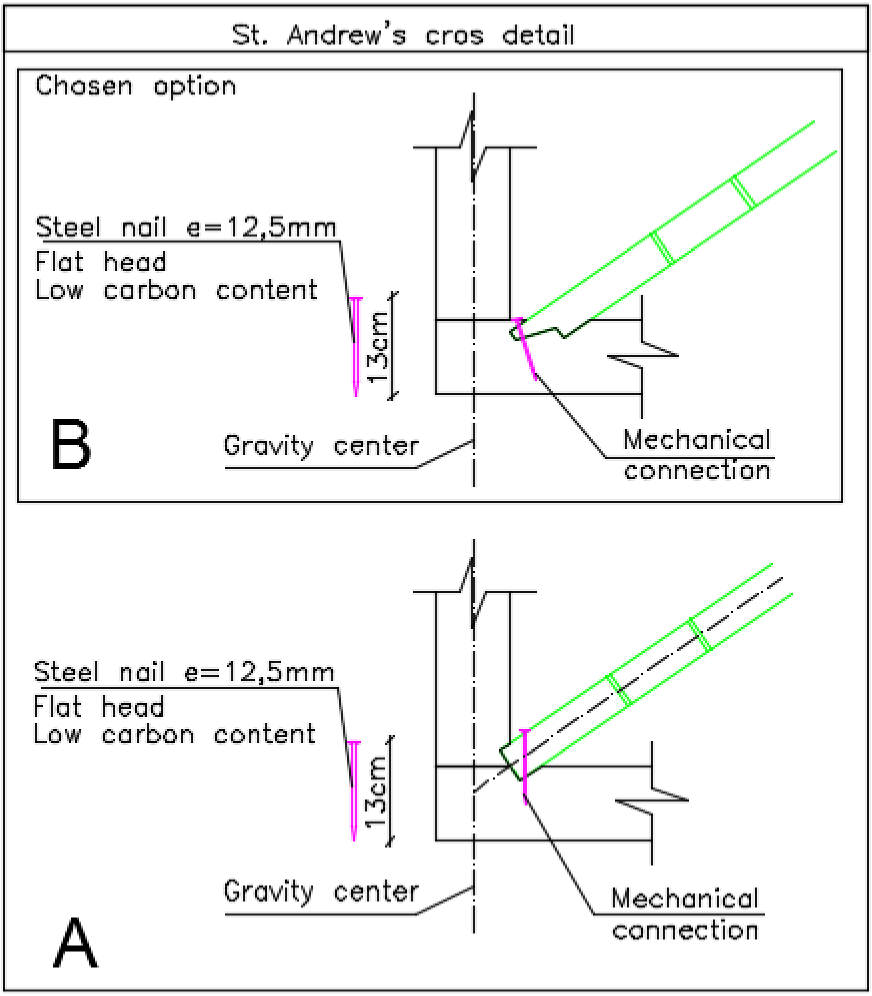








For the diagonals have two possible systems. The correct placement of the diagonal correction should be with the axis of the center of gravity of the structural member that joins, union A. But as the design and finishes are difficult, Opted by union B which is simpler.



The rest of details about this project such as structure, unions, etc. are in *Annexed 2. Papua New Guinea's Project*

BOLIVIA

"*Bolivia, surrounded by possibility, limps along as South America's poorest, least developed and most politically unstable country.*

Bolivian culture has been defined by its geographical layout, the predominant indigenous population and the mix of ancient traditions with European cultural elements that were imported during the period of Spanish colonialism. The amalgamation of all these elements have produced a rich and varied culture unlike any of the rest of the world. Bolivia is one of the poorest countries in Latin America. Nonetheless, it has great geopolitical importance in South America due to its geographical position at the center of the continent and its potential impact on the stability of the entire region. Bolivia has been for centuries one of the countries with the largest indigenous population in the area. Almost half of the population identifies with the native peoples -- mainly the Aymara and Quechua -- who consider the moderate use of coca leaf as a sacred element in their culture.

Famous since Spanish colonial days for its mineral wealth, modern Bolivia was once a part of the ancient Inca empire. After the Spaniards defeated the Incas in the 16th century, Bolivia's predominantly Indian population was reduced to slavery.

In 1965, a guerrilla movement mounted from Cuba and headed by Maj. Ernesto (Ché) Guevara began a revolutionary war. With the aid of U.S. military advisers, the Bolivian army smashed the guerrilla movement, capturing and killing Guevara on Oct. 8, 1967.

In June 1993, free-market advocate Gonzalo Sánchez de Lozada was elected president. He was succeeded by former general Hugo Bánzer, an ex-dictator turned democrat who became president for the second time in Aug. 1997. Bánzer made significant progress in wiping out illicit coca production and drug trafficking, which pleased the United States. However, the eradication of coca, a major crop in Bolivia since Incan times, plunged many Bolivian farmers into abject poverty. Although Bolivia sits on South America's second-largest natural gas reserves as well as considerable oil, the country has remained one of the poorest on the continent.

Bolivian Indian activist Evo Morales of the Movement Toward Socialism (MAS) won 54% of the vote in Dec. 2005 presidential elections, becoming the country's first indigenous president. He carried out two of his three major initiatives in 2006: nationalizing Bolivia's energy industry, which is expected to double the country's annual revenues; and forming in August a constituent assembly to rewrite the constitution, which will ensure greater rights for indigenous Bolivians. His third major initiative is to legalize the growing of coca, which many Bolivians consider an integral part of their culture.

In November, 2008, relations between Bolivia and the United States deteriorated further—the U.S. suspended duty-free access for Bolivian exports and President Morales suspended U.S. Drug Enforcement Administration operations, accusing its agents of espionage.

A new constitution that extended the rights of the indigenous majority, granted increased autonomy to the states, and allowed the president to run for a second five-year term was passed in a national referendum in January 2009 despite widespread protests.

As Bolivia country a zone of high seismic risk, we note that the most affected are the lack of decent housing, which promotes research for improvement and innovation in building low-cost housing, and not because of the use of materials alternative to concrete, as ferrocement.
Part of the problem is the time it takes to give decent housing to these families, so our proposal is to introduce a functional and quick solution for families after the disaster last significant in getting a place to live time."[25]

[25]http://www.oieduca.com.br/biblioteca/que-dia-e-hoje/dhoje-detail14.cfm?id=2729

Bolivia project location

"*Bolivia it's a country from South America with 1,098,580 km^2 and 10,631,486 population. Brazil forms its eastern border; its other neighbors are Peru and Chile on the west and Argentina and Paraguay on the south. The western part, enclosed by two chains of the Andes, is a great plateau—the Altiplano, with an average altitude of 12,000 ft (3,658 m). Almost half the population lives on the plateau. At an altitude of 11,910 ft (3,630 m), La Paz is the highest administrative capital city in the world. The Oriente, a lowland region ranging from rain forests to grasslands, comprises the northern and eastern two-thirds of the country. Lake Titicaca, at an altitude of 12,507 ft (3,812 m), is the highest commercially navigable body of water in the world."*[26]

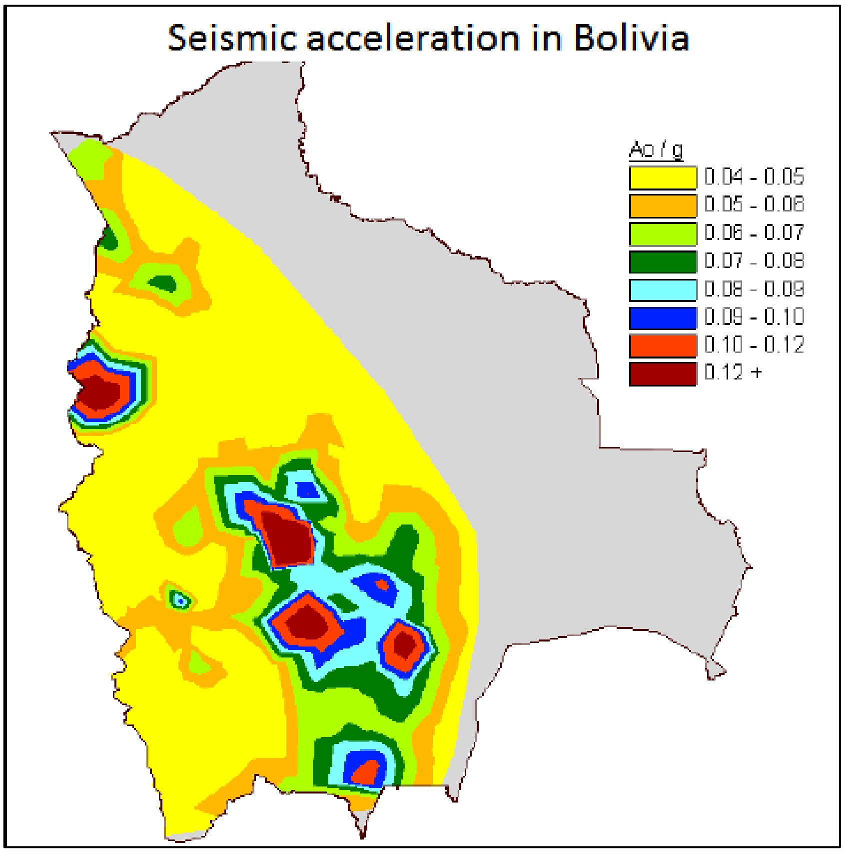
[26]http://www.infoplease.com/country/bolivia.html

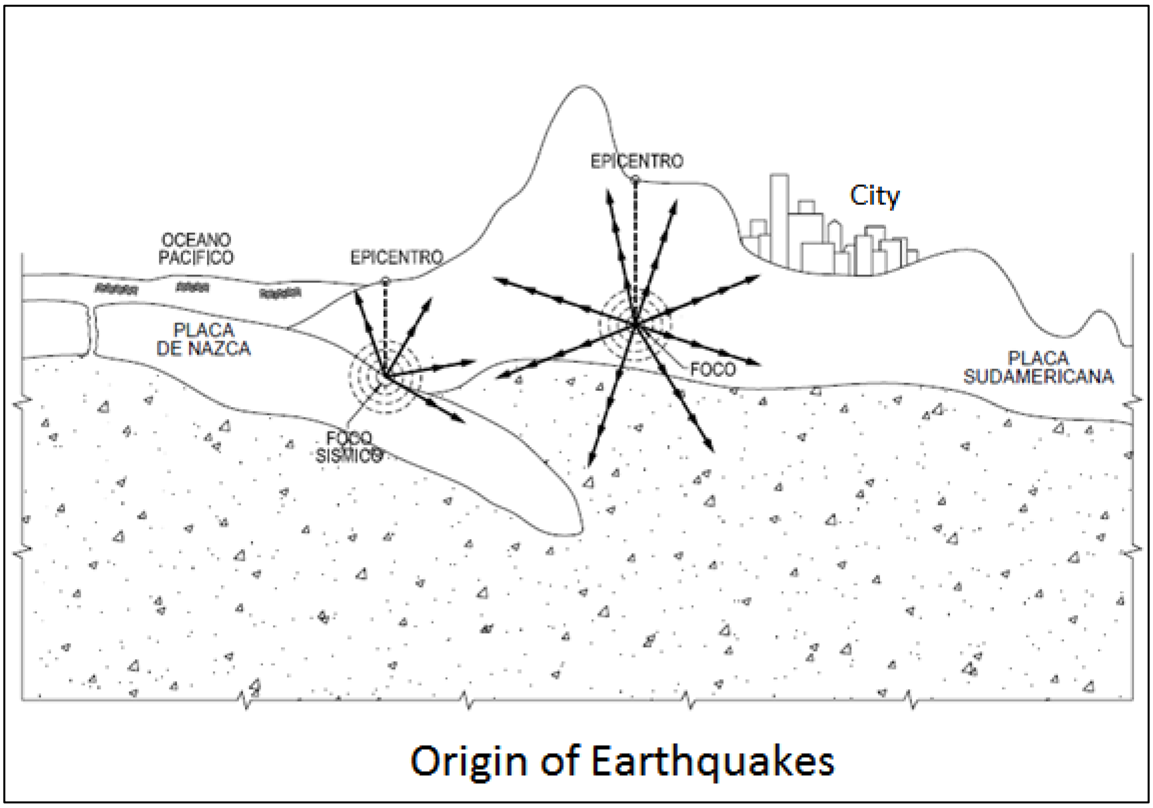
The aim of the Project is to attract the housing near to the capital city, but without insert the society in the center. The position at outside of the city allow, to the community, continue working in the agricultura (with a form of self-sufficiency and subsistence) and can sell it them crafty products in the city or the neighbooring villages. Thus the position of Bolivia, "La Paz", (-16.518752, -68.247751) we can find a worthy and suitable location for these families.

The main sources of earthquakes in Bolivia are:

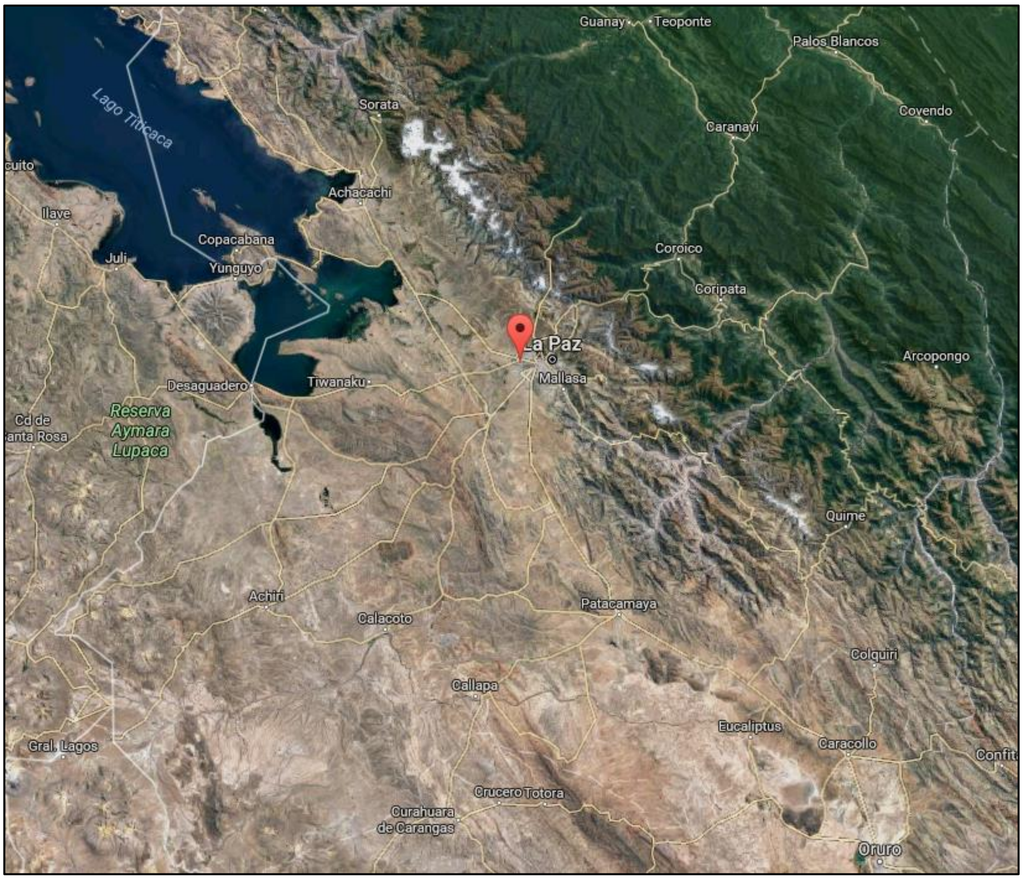
- Center of Bolivia (Cochamba, Chuquisaca, Santa Cruz and Tarija) manifesting type surface earthquakes, very destructives, not so much by its magnitude, because its low depth.
- The "Consta-Mapiri" zone in the northern part of the Department of La Paz, also with surface and destroyers earthquakes.
- The northern coastal área of Chile and South of Peru, where strong earthquakes that are felt in Bolivia, especially in the city La Paz. Also a part of that zone exists in a "vacuum" or "lagoon seismic" more tan 120 years, that means that in all those years there has been a major earthquake ocurred more tan 120 years ago, so the seismic

energy is accumulating and can suddenly release is generating an incredible earthquake.






AMAZONAS
PAR
ACRE
Brasil
Perú
RONDONIA
MATO GROSSO
Bolivia
MATO GROSSO
DEL SUR
Paraguay


Guanay
Teoponte
Palos Blancos
Lago Titicaca
Sorata
Covendo
Caranavi
Achacachi
Ilave
Copacabana
Coroico
Juli
Yunguyo
Coripata
La Paz
Arcopongo
Mallasa
Desaguadero
Tiwanaku
Reserva
Aymara
Lupaca
Quime
Achiri
Calacoto
Patacamaya
Colquiri
Callapa
Eucaliptus
Gral. Lagos
Caracollo
Crucero Totora
Curahuara
de Carangas
Oruro

Report: "*A strong and very deep earthquake registered by the USGS as M6.1 hit Bolivia at 03:25 UTC on January 14, 2016. The agency is reporting a depth of 582.4 km (361.9 miles).*

The South American arc extends over 7,000 km, from the Chilean margin triple junction offshore of southern Chile to its intersection with the Panama fracture zone, offshore of the southern coast of Panama in Central America. It marks the plate boundary between the subducting Nazca plate and the South America plate, where the oceanic crust and lithosphere of the Nazca plate begin their descent into the mantle beneath South America. The convergence associated with this subduction process is responsible for the uplift of the Andes Mountains, and for the active volcanic chain present along much of this deformation front.

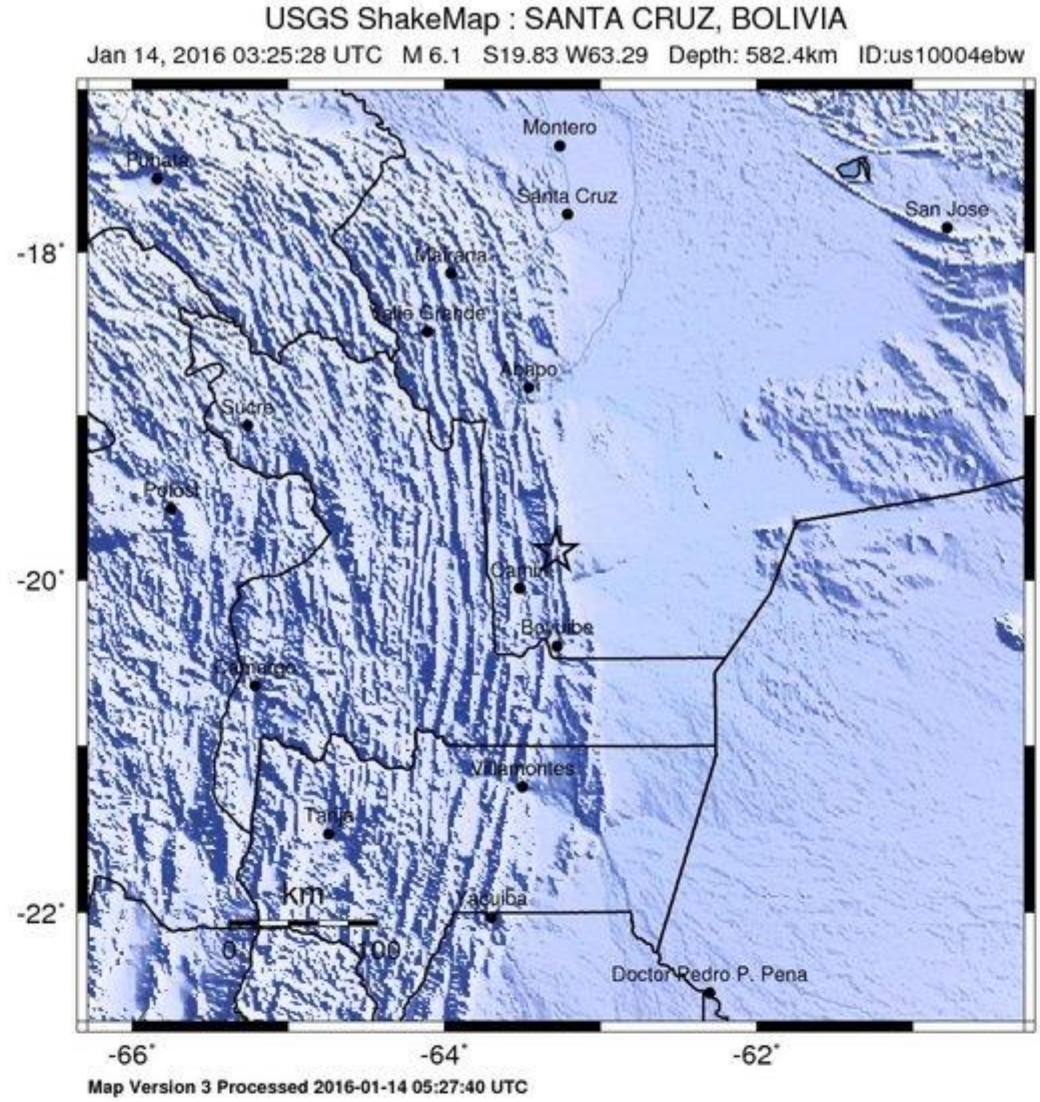
Most of the large earthquakes in South America are constrained to shallow depths of 0 to 70 km resulting from both crustal and interplate deformation. Crustal earthquakes result from deformation and mountain building in the overriding South America plate and generate earthquakes as deep as approximately 50 km. Interplate earthquakes occur due to slip along the dipping interface between the Nazca and the South American plates. Interplate earthquakes in this region are frequent and often large, and occur between the depths of approximately 10 and 60 km.

The epicenter was located 7 km (4 miles) WSW of Charagua, 34 km (21 miles) NE of Camiri, 159 km (99 miles) N of Villamontes, 204 km (127 miles) S of Santiago del Torno, 632 km (393 miles) SE of La Paz, Bolivia.

There are about 103 731 people living within 100 km (62 miles) radius.

Overall, the population in this region resides in structures that are vulnerable to earthquake shaking, though some resistant structures exist."

[27]http://www.starfiretor.com/CoreMatrix/2013-09-01_TSA.html



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	*<0.02*	*0.1*	*1.4*	*4.7*	*9.6*	*20*	*41*	*86*	*>178*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden et al. (2012)

Material

Ferrocement is feasible to build low-cost housing , in a short time and earthquake resistant material.

Ferrocement as a building material dates back to the times of the Sumerians and Romans, when they used mortars reinforced with fibers.

"*A Frenchman, Joseph Monier (1823 - 1906), produced flower pots made of cement mortar reinforced with chicken wire and showed this product at the world exhibition held in Paris in 1867. J. Monier became known as the father of reinforced concrete. In Germany for many years reinforcement steel was called "Monier iron". In 1847, another Frenchman, Joseph-Luis Lambot, filed a patent for producing a cement boat, wire-reinforced, not long after the development of Portland cement. Which of the two men first had the idea of combining wire with cement mortar is of no interest. Probably the discovery technique happened by chance. At that time, the commonly known chicken wire was a handmade product and therefore soon too expensive in the fast growing industrial era. But the knowledge of the steel-concrete combination resulted in the development of reinforced concrete using large steel rods. During the First and also later during the Second World War, the technique of Lambot's ferro-cement boat was remembered in the U.S. and the U.K. and shipbuilders were encouraged to construct barges like this in order to save shipbuilding materials such as steel plates and timber. Although some of the boats built during the Second World War had an amazingly long life span, the technique did not really became widespread*."[28]

[28]http://wgbis.ces.iisc.ernet.in/energy/water/paper/drinkingwater/rainwater/ferro-cement.html

"*It was the famous Italian engineer and architect, Pier Luigi Nervi, who first undertook real research into ferro-cement technology. He observed that reinforcing concrete with layers of wire mesh resulted in a material with high impact resistance properties. This material differed from reinforced concrete in its flexibility and elasticity. After the Second World War, Nervi built a 165-ton motor sailer. This ship, "Irene", proved to be seaworthy. Similar ships were built in the U.K., New Zealand and Australia, and one circumnavigated the world without problems. But Nervi would not have been a structural engineer and architect if he had not also used this material for building construction. In 1947, he first built a storehouse of ferro-cement. Later he combined reinforced concrete with the ferro-cement technique and constructed the famous Turin Exhibition Hall with a roof system which spans 91 m. Nervi's work proved that ferro-cement is a high quality construction material. The question remains why ferro-cement is relatively seldom used as a building material in industrial countries. The answer lies in the process of industrialization of construction work. In order to minimize the labour cost, construction work has become more and more capital-intensive. As a result, working processes have been mechanized wherever possible. In this context the possibilities for mechanizing ferro-cement remain very limited. A high percentage of labour cost will always characterize this technology. While this is considered to be a disadvantage for* *industrialized countries, it is a positive factor in developing countries where the labour market is characterized by high unemployment and low labour costs".* [29]

[29]http://docslide.us/education/hydraulic-ram-pumps-and-sling-pumps.html

"*Antonio Gaudí (1852, Barcelona 1926) uses the ferrocement as a material in his works of architecture laden with mystical elements, in order to shape their buildings, showing the virtues of this as a material in modern architecture.*

Ferrocement as a material can be defined according to the authors differently:
"Ferrocement is a type of reinforced concrete thin-walled, usually built with cement and reinforced mesh layers of continuous wire, and occasionally small-caliber steel bars frame. The mesh may be made of metal or other suitable material. Mortar workability and its composition must be tissue compatible mesh and frame rods to allow placement. The mortar may contain staple fibers. " [30]

[30]Bedoya, 2005

Ferrocement is a type of reinforced concrete construction, with thin thicknesses, in which the hydraulic mortar is generally reinforced with continuous layers of relatively small diameter mesh. The mesh may be metal or other suitable materials.

This material takes when the "construction boom" of common reinforced concrete have very large cross sections and becomes too heavy. Although ferrocement has approximately the same density of concrete per unit volume, this provides a lower total volume because in construction thin-walled turning used lighter structure.

Components

- Mortar

"*It is a result of plastic mixture attachment of a binder, sand and water. To improve its properties, you can add additives.*

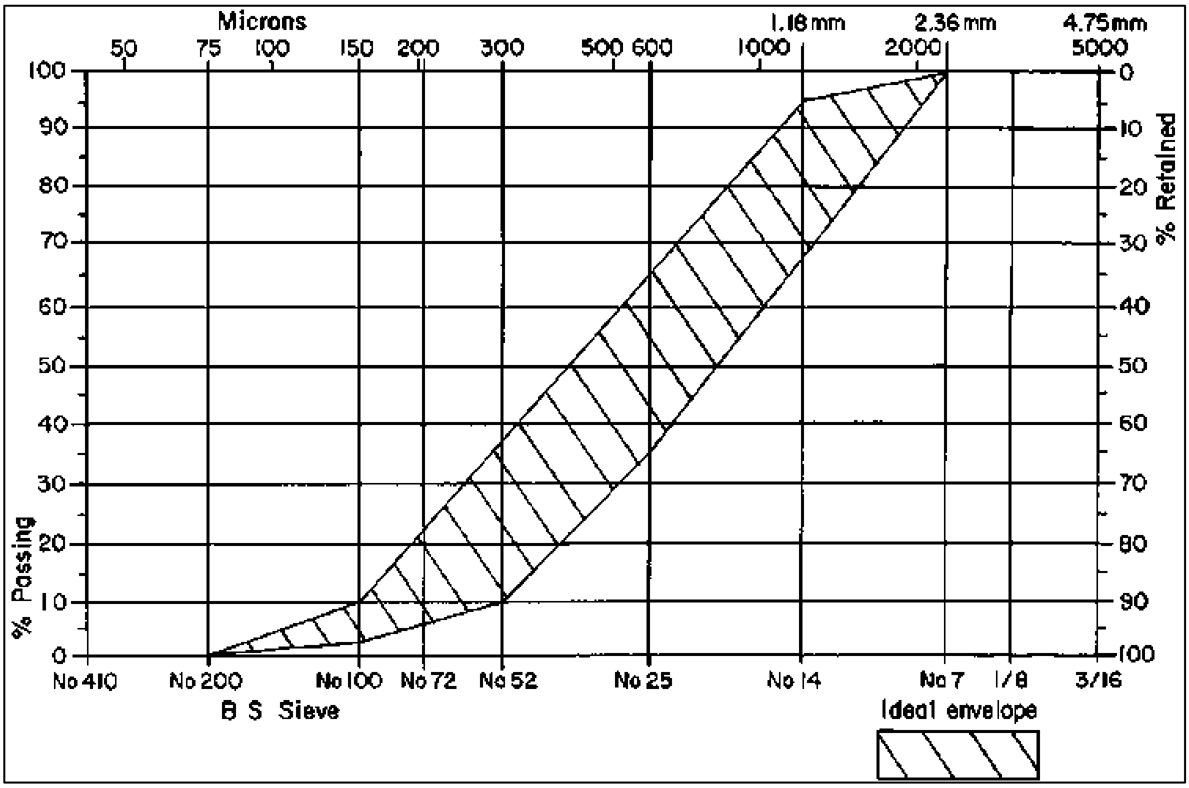
The mortar usually used to form the matrix, represents more than 95% of the volume, is a mixture of hydraulic cement and sand to which you can add additives to improve their behavior according to the proposed use ferrocement element.
It has established a density of 2200 kg / m3.

- Sand

Sand shall be obtained from reliable supplier. It should be clean, hard, strong, free of organic impurities and deleterious substances. It should be inert with respect to other materials used and of suitable type with regards to strength, density, shrinkage and durability of the mortar made with it. Grading of the sand is to be such that a mortar of specified proportions is produced with a uniform distribution of the aggregate, which will have a high density and good workability of the aggregate, which will have a high density and good workability and *which will work into position without segregation and without use of a high water content. The grading of the sand shall be as given in the next TAble.*

I.S. Sieve	Percentage passing by weight
2.36 mm	100
1.18 mm	50 – 70
600 Micron	25 – 45
300 Micron	10 – 20
150 Micron	2 – 5

The aggregate, sand, is the most important ingredient ferrocement as it occupies 60 to 70% by volume of mortar and is responsible for the strength and impermeability of it.
The sand will be of a silicious nature and conform to the grading envelope shown in Fig. Sand Gradin Chart.



- Cement

The cement to use is usually ordinary Portland. However, a rapid hardening Portland cement may be used in cold climates. Sometimes a sulphate resistant Portland cement is used, either wholly or in part mixed with ordinary Portland against sulphate attack, although as most vessels are protected by marine paints and antifouling, its use is hardly necessary. If the cement is used with admixtures, care should be exercised in compatibility. All cements are to be to BS 12 or equivalent local standard.

In some underdeveloped countries it may be necessary to obtain a certificate of the materials composition and date of manufacture, where there is the likelihood of low quality and, perhaps, adulteration between point of manufacture and delivery. This may mean that the cement has to be picked up by the yard's transport and a reliable person checks there is no problem in delivery.

Ideally the cement will be no more than three weeks old and delivery accomplished two to three days before use.

Other cements may be considered providing they offer adequate strength, density, and uniform consistency.

- Water

Water used for making and curing shall be clean and free from injurious amounts of oil, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to mortar or steel. Potable water is generally considered satisfactory for making cement : sand mortar and its curing.

- Admixtures

There is such a wide range of admixtures available today that one cannot make recommendation without first testing those chosen. If they are to be employed, care and discretion should be exercised at all times.

Three main criteria should be considered when applying admixtures:

a) Is the strength of the mortar increased or decreased?
b) The effect of the admixture on the steel reinforcement.
c) Practicality of use on site and supervision of exact mixing quantities.

- Mix proportioning

The ranges of mix proportions for common ferrocement applications shall be sand cement ratio by weight, 1.5 to 2.5, and water cement ratio by weight, 0.35 to 0.5. The higher the sand content, the higher the required water content to maintain the same workability. Fineness modulus of the sand, water cement ratio, and sand cement ratio shall be *determined from trial batches to ensure a mix that can infiltrate (encapsulate) the mesh and develop a strong and dense matrix. The moisture content of the aggregate shall be considered in the calculation of required water. Quantities of materials shall preferably be determined by weight. The mix shall be as stiff as possible, provided it does not prevent full penetration of the mesh. Normally the slump of fresh mortar shall not exceed 50 mm. For most applications, the 28 day compressive strength of 75 by 150 mm moist cured cylinders shall not be less than 35 N/mm2*." [31]

[31]http://www.fao.org/docrep/003/V9468E/v9468e07.htm

- Reinforcement rod

"Villegas" tells us that reinforcements ferrocement are classified into two groups "depending on the amount, strength and guidance that are used, so that the mortar will not disintegrate and have a direct effect on the cracking of the element." These two groups are:

Diffuse rod/armor: In which a small diameter wire meshes are formed with a very small gap, and these are distributed in several that support the mortar layer covering the element. Among the most commonly used stand Hexagonal Mesh, Square Mesh, expanded metal mesh, welded, among others.
Discreet rod/armor: You turn subdivided into skeletal armor and additional armor. The first consists of mild steel rods welded small diameter. And the second structural steel bars is formed and works together with the meshes of diffuse armor. Discrete armor fulfill the role of structural armor, but its main goal is to provide support to the meshes.

"*The reinforcement shall be clean and free from deleterious materials such as dust, loose rust, coating of paint, oil, or similar substances. Wire mesh with closely spaced wires is the most commonly used reinforcement in ferrocement. Expanded metal, welded wire fabric, wires or rods, prestressing tendons, and discontinuous fibers may also be used in special applications or for reasons of performance or economy.*

Wire Mesh: Reinforcing meses for use in ferrocement shall be evaluated for their susceptibility to take and hold shape as well as for their strength performance in the composite system.

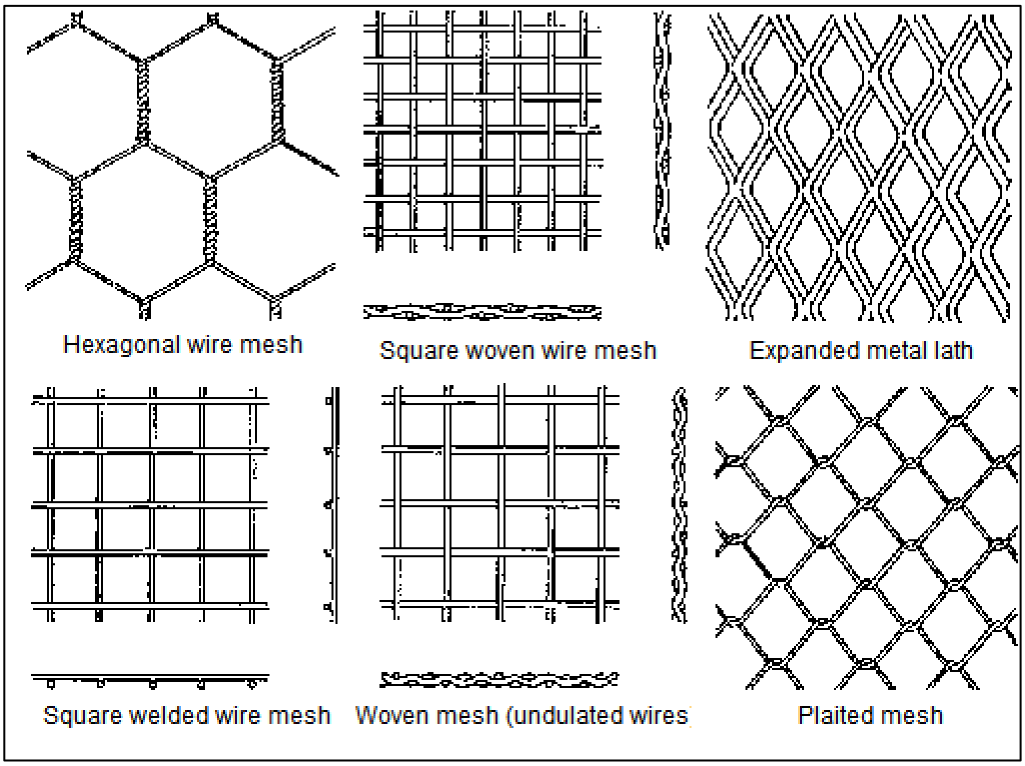
Welded Wire Fabric: Welded wire fabric may be used in combination with wire mesh to minimize the cost of reinforcement. The mínimum yield strength of the wire measured at a strain of 0.035 shall be 410 N/mm2. Welded wire fabric normally contains larger diameter wires (2mm or more) spaced at 25 mm or more.

Expanded Metal Mesh Reinforcement: Expanded mesh reinforcement (metal lath), formed by slitting thin gauge Steel sheets and expanding them in a direction perpendicular to the slits, may be used in ferrocement. Punched or otherwise perforated sheet products may also be used. Expanded mesh is suitable for tanks if proper construction procedures are adopted.

Bars, Wires and Prestressing Strands: Reinforcing bars and prestressing wires or strands may be used in combination with wire meshes in relatively thick ferrocement elements or in the *ribs of ribbed or T - shaped elements. Reinforcing bars shall be Steel with a mínimum yield strength of 410 N/mm 2 and a tensile strength of about 615 N/mm 2 .*

Discontinuous Fibres and Nonmetallic Reinforcement: Fibre reinforcement consisting of irregularly arranged continuous filaments of synthetic or natural organic fibres such as jute and bamboo may be used in ferrocement. If organic materials are used, care shall be taken to conduct appropriate investigations to ensure the strength and durability of the finished ferrocement product."[32]

[32]https://law.resource.org/pub/bd/bnbc.2012/gov.bd.bnbc.2012.06.12.pdf



"Compressive strenght

The matrix contributes directly to ferrocement strength in proportion to its cross-sectional area, so strength and amount of reinforcement are most appropriately defined in terms of stress and volume fraction of reinforcement. Obviously, matrix strength, governed primarily by its water-cement ratio, is a major factor, as for conventionally reinforced concrete. However, the type, orientation, and mode of arrangement of the reinforcement are also important. For example, solid and hollow (identified as cored in Fig. A because they are formed with the aid of a soft polystyrene core) columns peripherally reinforced with welded mesh are significantly stronger than their counterparts reinforced with expanded metal (Fig. A).
This is attributed to the lateral wires in the mesh acting in a manner similar to conventional helical reinforcement by restraining the enclosed matrix, while the expanded metal undergoes a scissors action, visually apparent in the failure mode, that prevents effective triaxial restraint and renders the ferrocement little stronger tan the unreinforced matrix. The

drastic change of slope in the upper two curves of Fig. A is attributed to general yielding of the mesh system, as observed by substantial increase in Poisson's ratio. When mesh reinforcement is arranged parallel to the applied load in one plane only (as opposed to the closed peripheral arrangement), no improvement in strength is observed.

When axial compression is associated with bending, the resulting interaction relationship is similar to that for conventional reinforced concrete as shown in Fig. B.

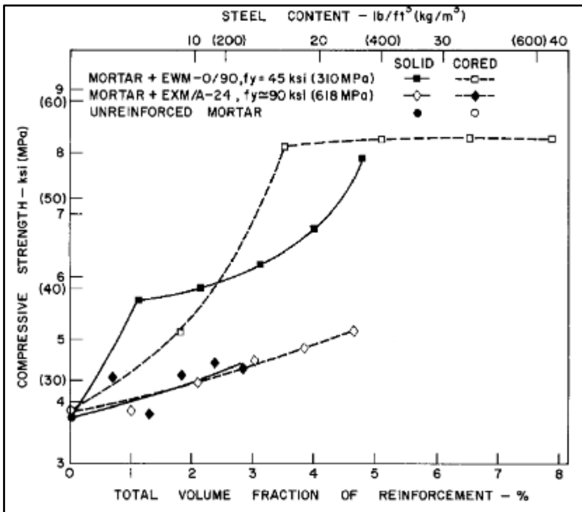


Fig A —Relationships between compressive strength and steel content or volume fraction for ferrocement columns reinforced with expanded metal or welded mesh (Ref. 35)

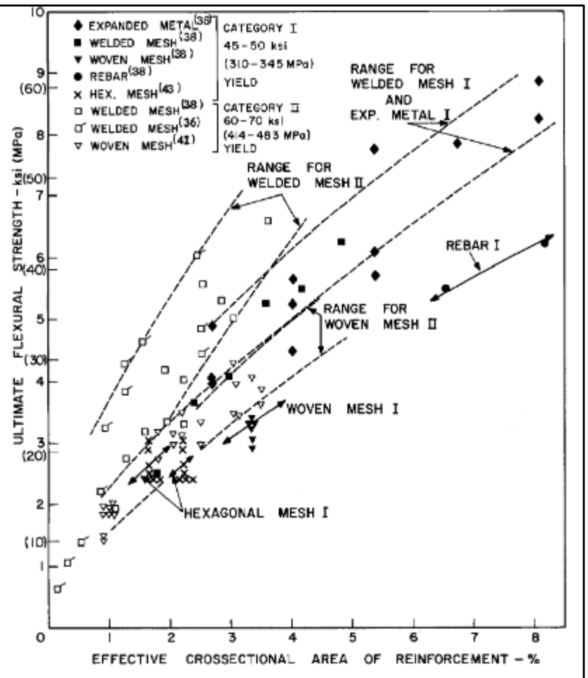


Fig. B —Relationships between ultimate flexural strength of ferrocement and effective cross-sectional area of reinforcement in the direction of applied stress (Ref. 38, 40, 44, 46)

Flexural strength

Ultimate strength in flexure naturally reflects the combined influence of factors governing tensile and compressive strength, that is, the amount, type, orientation, and intrinsic geometry of the reinforcing layers.
The orientation of the reinforcement is just as important for flexural strength as it is for tensile strength, particularly when strength under biaxial loading is considered. While square meshes offer equal strength in both directions parallel to the wires, strength in the 45 deg orientation is 67 to 80 percent of that parallel to the wires for welded mesh, with rather less difference for woven mesh.
With expanded metal and hexagonal mesh, an even greater degree of strength anisotropy is posible. The spacing of the reinforcing layers in ferrocement is normally fairly uniform throughout the available depth of cross section, except when the skeletal bar reinforcement is present. Nevertheless, the idea that concentrating the layers at the top and bottom faces of a flexure specimen increases the flexural strength because of their greater distance from the neutral axis is not unreasonable.
However, such an arrangement may sometimes reduce the absolute strength and efficiency ratio by promoting horizontal shear failure, which normally is not a problem in ferrocement units with uniformly and closely spaced reinforcement and a large span-depth ratio (Fig. C). When expanded metal mesh is used, optimal efficiency ratios and compliance with the

expectations of conventional ultimate strength analysis seem to result when the reinforcing layers are spaced uniformly through the effective depth (Fig. C).

In general, the optimal choice of reinforcement for flexural strength, as already noted for tensile strength, depends on whether the loading is essentially uniaxial or significantly biaxial. For uniaxial loading, the cost-effectiveness of different reinforcements is illustrated by the relationship between flexural strength and steel content or volume fraction (Fig. D). Clearly, expanded metal is the best choice on this basis. Also, it generally costs less per unit weight.

Alternating layers of hexagonal mesh with skeletal bars in both directions seems equally effective for the same yield strength (note the lower yield strength in Fig. D for this system). Under biaxial conditions, welded mesh is probably the best choice, although the inherent weakness on the 45 deg diagonal axial should be taken into account. When expanded metal or hexagonal mesh are employed under these conditions, the orientation of the successive layers should be alternated to counter their anisotropic characteristics.

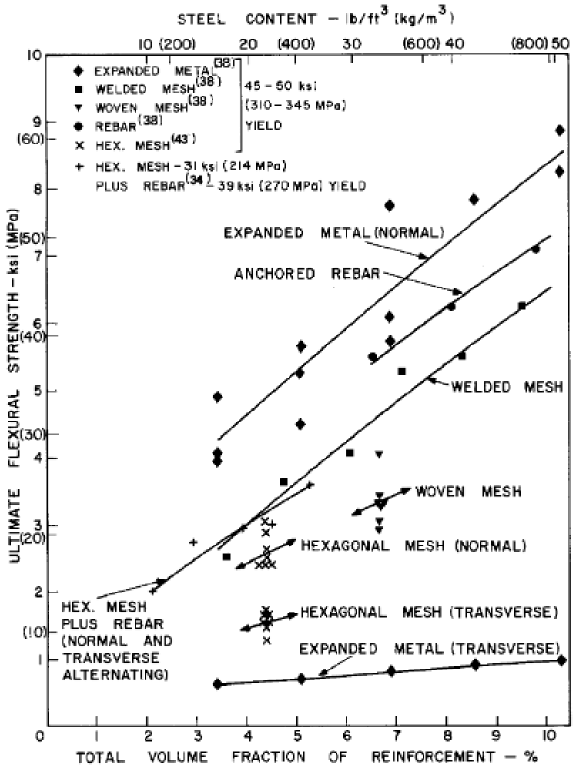


Fig. C —Relationships between ultimate flexural strength of ferrocement and total amount of reinforcement (Ref. 36, 40, 46)

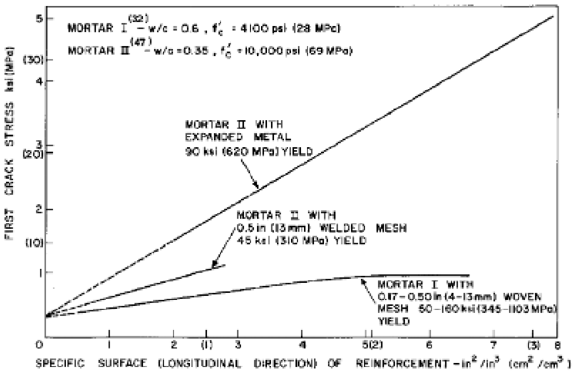


Fig. D —Relationships between fire-crack strength of ferrocment in direct tension and the specific surface of the reinforcement (Ref. 34, 50)

Shear Strenght

Remarkably few of the many studies of ferrocement have included shear strength evaluation, perhaps because ferrocement is used primarily in thin panels where the span-depth ratio in flexure is large enough that shear is not the governing failure criterion. Parallel longitudinal alignment of the reinforcing layers in ferrocement effectively precludes the inclusion of shear reinforcement equivalent to the bent-up bars or stirrups used in reinforced concrete, so ferrocement is not particularly suited to resisting shear. However, this is not required in most applications.

Shear strength has been determined for specimens reinforced with woven mesh and skeletal bars, tested in bending at a shear span/depth ratio of 0.4.
While the test values reflect the characteristics of the steel and mortar used, the shear strength remains at a constant fraction of about 32 percent of the equivalent flexural strength for a fairly wide range of steel contents 18 to 35 lb/ft (288 to 480 kg/m3). Tests conducted in bending on specimens reinforced with welded mesh at span/depth ratios ranging from 1 to 3 indicate that failure in transverse shear is possible for specimens with high volume fraction of reinforcement and low strength of mortar only at a small span-depth ratio.
However, in general, shear failure is preceded by the attainment of flexural capacity of ferrocement. In the case of in-plane shear, similar to that existing in the web of an I-beam under transverse loading, the Truss Model Theory has been found to give a good estimate of the ultimate shear strength.
Some ferrocement boat builders have demonstrated qualitatively the toughness of the material in punching shear through accidental and deliberate tests involving collisions with rocks or other boats."[33]

[33]https://www.scribd.com/document/103693829/549R-97

"Advantages

The materials required to produce ferrocement are readily available in most countries.

It can take almost any shape and is adaptable to almost any traditional design.

Where timber is scarce and expensive, ferrocement is a useful substitute.

As a roofing material, ferrocement is a climatically and environmentally more appropriate and cheaper alternative, to galvanized iron and asbestos cement sheeting.

The manufacture of ferrocement components requires no special equipment, is labour intensive and easily learnt by unskilled workers.

Compared with reinforced concrete, ferrocement is cheaper, requires no formwork, is lighter, and has a ten times greater specific surface of reinforcement, achieving much higher crack resistance.

Ferrocement is not attacked by biological agents, such as insects, vermin and fungus.

Problems

Ferrocement is still a relatively new material, therefore its long-term performance is not sufficiently known.

Although the manual work in producing ferrocement components requires no special skills, the structural design, calculation of required reinforcements and determination of the type and correct proportions of constituent materials requires considerable know-how and experience.

Galvanized meshes can cause gas formation on the wires and thus reduce bond strength.

The excessive use of ferrocement for buildings can create unhealthy living conditions, as the high percentage of reinforcement has deleterious electromagnetic effects."[34]

[34]http://collections.infocollections.org/ukedu/en/d/Jsk01ae/3.10.html

Adds and cons against sismic risk

Among the advantages we can mention:
Structures with high internal damping.
Suitable control of horizontal deformation.
Structures have a large reserve of energy that allow structural recovery after being subjected under severe actions.
Structures low periods with little influence of side effects.
Its low vibration period allows structures with good behavior.

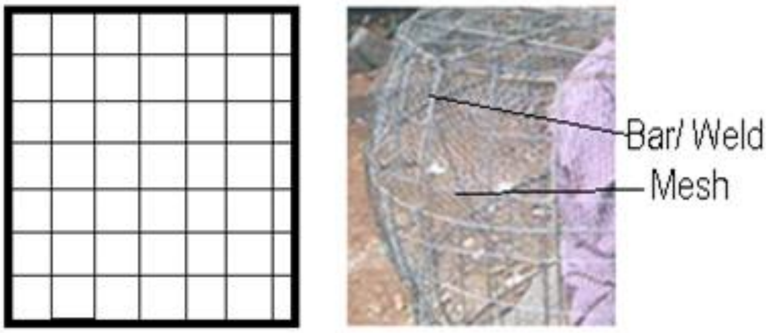
Also this material present disadvantages to seismic action:
Low tensile strength, but sometimes it is greater than that of reinforced concrete.
Concentration of armor joints with low resistance trends mortar.
Belts need for earthquake resistant level floors to provide adequate strength and rigidity to floors and roofs of buildings.
Placing bolts between panels is required to ensure a mechanically working together panels that form the vertical eardrums of buildings subjected to lateral actions of consideration, especially when the work is over two levels.

Steps involved in building ferrocement structures

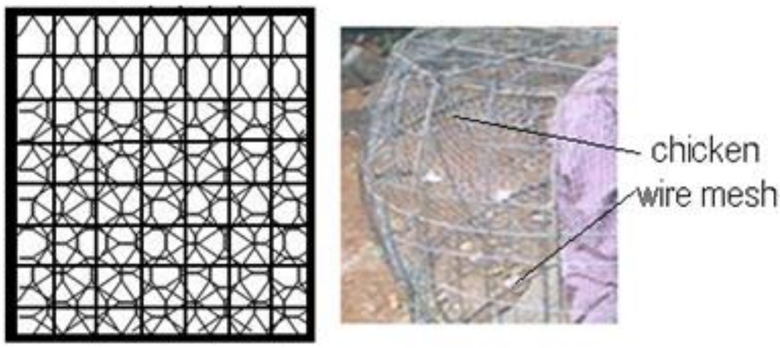
"There are five steps in making a conventional ferrocement structure.

- *An outline of the structure is made from thin mild steel / iron rods.*

- *Weld Mesh / Bar mesh attached to this out line.*

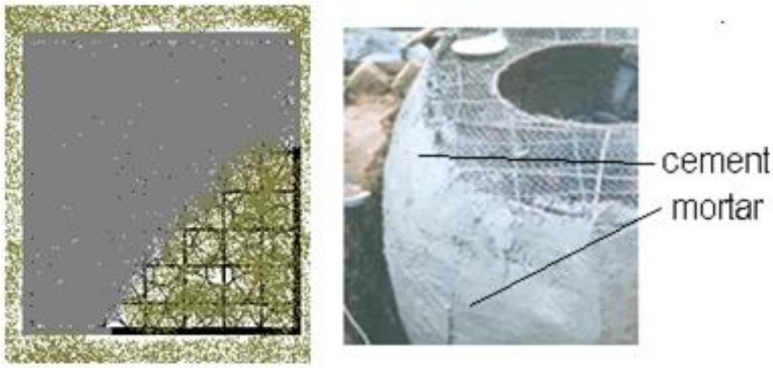


- *A chicken wire mesh layer is attached to this outline.*



- *Tie Jute cloth inside the structure with wire / trait.*

- *Together they are plastered over with a rich cement mortar (mixture of cement, sand and water).*



To prevent early cracking, improve the rate of strength gain, improved abrasion resistance and impermeability, the entire structure must be cured ferrocement".[34]

[34]http://oer.nios.ac.in/wiki/index.php/Ferrocement

Ferrocement and low cost housing

In Third World countries, where it has been used ferrocement for construction of affordable housing, it is possible to identify four building systems for manufacturing: construction site, construction with prefabricated modular elements, construction of prefabricated panels and building mobile homes.
The availability of materials, the minimum technology necessary, low final cost of the work and high quality present in the result, is the answer to successful implementation of ferrocement in low-cost housing.

Design

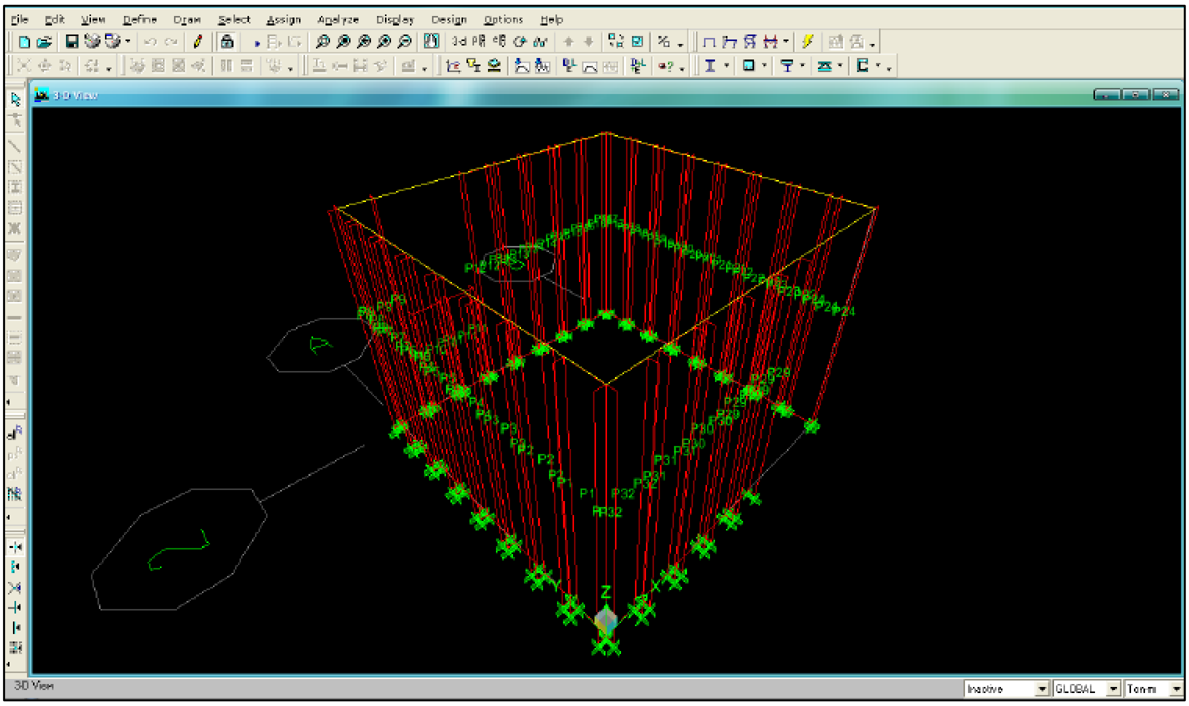
I have used as an example and guide the Project : "*Diseño de una vivienda unifamiliar utilizando elemtnos prefabricados de ferrocemento con opción de ampliación*" from Cuenca University.

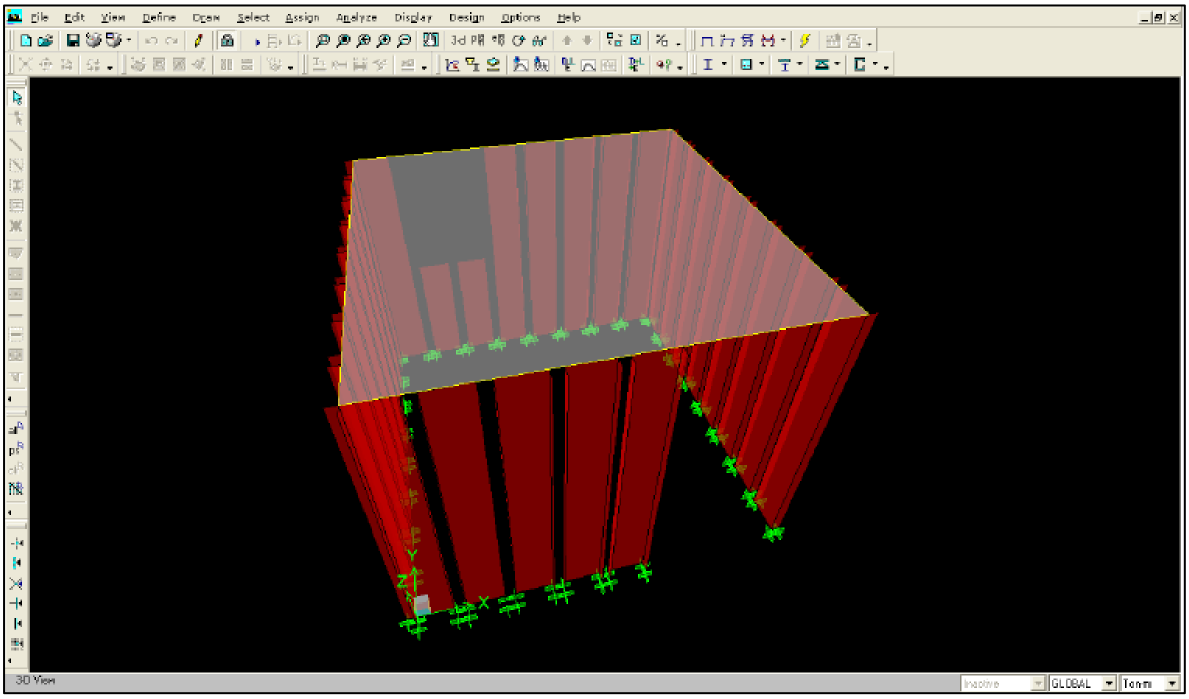
The need is the same as in the previous case. A family of two to five members with two bedrooms, living room, a bathroom and a kitchen. In this case service facilities are good and the house is oriented north facade to have more light.

The basic module will have an area of 9.00 m², it consists of 29 panels ferrocement, placed on the prefabricated beams of the same material. The panels may be constructed from 1.25 to 5.00 meters long, the panels used have a dimension of 2.50 to 3.40 meters long for the walls and 1.40 for the walls where windows were placed. The most common beam in this structures is a ferrocement wall, but for resist the thrusts produced by the earthquake such a unic component structural, the better choice is a string of armed.
This part of our research is to evaluate the capacity and seismic behavior of ferrocement panels and houses, as an alternative for building low-cost housing. To assess a structural model seismic behavior was performed on a software ETABS structures.

ETABS “Extended Three-dimensional Analysis of Building Systems” integrates every aspect of the engineering design process. Creation of models has never been easier - intuitive drawing commands allow for the rapid generation of floor and elevation framing. CAD drawings can be converted directly into ETABS models or used as templates onto which ETABS objects may be overlaid.

Using the configuration shown in the image it’s proceeded to the Etabs model of a typical low-cost housing ferrocement. This module represents the actual building in different parts of the country building.





In this part of the investigation all procedures designed in order to assess the capacity and seismic behavior of precast panels ferrocement as an alternative for building low-cost housing are described. To assess their seismic behavior in a seismic spectrum model republic Bolivia, for soil type undefined equal 1.35. For this part I try to make as real as possible and the properties of the materials that make the panels according to the tests made before and taken from a doctoral thesis in Barcelona were defined.

For the purpose of seismic analysis, standards considers that Bolivia is divided into two zones according to their levels of seismic activity, with a zone of seismicity average. According to the standard for seismic analysis and Bolivian guide building construction, our house enters the C group and type of Social Interest.
public buildings, where a normal degree of security is required, for example housing buildings (houses, apartment buildings), offices, small shopping centers, offices, shops, restaurants, hotels, stores, industries that do not have materials and toxic substances or explosive, retaining walls, perimeter walls, etc. Importance factor FI = 1.0.

CLASIFICACIÓN DE EDIFICACIONES					
TIPOLOGÍA	**SUPERFICIE**	**ALTURA**	**PROYECTOS OBLIGATORIOS**	**PROYECTOS ESPECÍFICOS**	**RESPONSABLES DE LA OBRA**
De Interés Social (Vivienda básica, dirigida a los sectores de bajos ingresos)	Igual o menor a 60 m².	Hasta 3.50 m.	Para conjuntos de Viviendas Sociales: Proyecto Arquitectónico. Diseño estructural. Hidrosanitario. Eléctrico. Para proyectos de una sola unidad, se requiere sólo Anteproyecto	Sismoresistente cuando corresponda.	Propietario, Constructor, Supervisor (Técnico Superior en Construcción Civil)
Simple (Vivienda privada, dirigida a los sectores medios)	Hasta 300 m² de superficie cubierta.	Hasta 4.50 m. Nivel y medio.	Arquitectónico Diseño estructural. Hidrosanitario. Eléctrico. Gas. Sistemas de prevención contra incendios (cuando corresponda)	Sismoresistente cuando corresponda	Propietario, Constructor Director de Obra o Residente: Arquitecto o Ingeniero (según especialidad si corresponde) Lic. Constructor Civil, Supervisor
Mediana (Vivienda uso mixto, dirigida a los sectores medios)	De 300 m² a 600 m² de superficie construida	Hasta 6.50 m. equivalente a Planta baja y Planta Alta.	Arquitectónico. Estructural. Hidrosanitario. Eléctrico. Gas. Sistemas de prevención contra Incendios.	Sismoresistente cuando corresponda.	Propietario, Constructor Director de Obra y/o Residente: Arquitecto o Ingeniero (según especialidad si corresponde), Supervisor
Medianamente Compleja (Vivienda uso mixto, multifamiliar, dirigida a los sectores medios)	De 601 a 1.000 m² de superficie cubierta.	Hasta 12.5 m. o equivalente a Planta Baja y tres niveles.	Arquitectónico. Estudio de suelo. Estructural. Hidrosanitario. Eléctrico. Gas. Sistemas de prevención	Sismoresistente cuando corresponda. Otros según complejidad del proyecto.	Propietario, Constructor Superintendente y/o Director de Obra y Residente: Arquitectos o Ingenieros (según especialidad), Supervisión

General criteria

The structures will be analyzed separately for two orthogonal or (approximately orthogonal) directions.

Three fundamental seismic analysis procedures will be established: simplified method, quasi-static method and dynamic method (modal analysis and step by step).

For the determination of the critical effects on the structure, vectorially added up the effects of gravitational loads (dead load and overload) and produced by a component of ground motion, amplified by the corresponding coefficients according to the codes provided.

We need the coefficient C which when multiplied by the weight of the structure gives you the base shear of it, as the program calculates the weight of the structure must enter the coefficient, the base shear is:

$$V = \left(\frac{Z \cdot I \cdot C}{R \cdot fiP \cdot fiE}\right) \cdot W$$

Where:

Z = factor depending on the seismic zone, 2/3 in our case.

I = coefficient importance of structure, according the NBDS, “Grupo C o tipo IV: Edificaciones comunes, donde se requiere un grado de seguridad normal, por ejemplo edificaciones de vivienda (casas, edificios de departamentos), oficinas, centros comerciales pequeños, consultorios, tiendas, restaurantes, hoteles, almacenes, industrias que no posean materiales y sustancias toxicas o explosivas, bodegas de almacenamiento, muros de contención, muros perimetrales, etc. Factor de Importancia FI=1.0”.

C = coefficient depending on the type of ground and the vibration period, being a land undefined, the value is 1.35.

R = reduction factor seismic resistance, 1.5 according to the following table.

TABLA No. IV

TIPO ESTRUCTURAL	d_i	R_d
I	–	7.0
II–A	< 0.10 ⩾ 0.10	5.0 4.5
II–B	< 0.10 ⩾ 0.10	4.0 3.5
III	–	6.5
IV	–	1.5

fiP y fiE= coefficients structural configuration in plan and elevation, respectively.

W= weight of the structure

These data are provided by the program.

The coefficient determines as the base shear is distributed on all floors, if it equals 1 the distribution is linear, if greater than 1 the distribution is parabolic. This value is generally used in American codes and unless your country establishes a distribution of parabolic forces should not use a different value of 1.
Following the program steps:

Use:	Housing
Location:	Bolivia
Number of the floors:	1,00
Height of 1st floor:	2,95
Height of other floors:	-
Total Height build:	2,95
Ground type:	No definidos

Limit verification casuistry method	
h = 3 < 45.00m	OK
Nº floors = 1 < 15 niveles	OK

Coefficient Determination Baseline shear	
Z = 2/3	Zone: Bolivia
I = 1,00	Group D
S = 1,35	undefinied
Rd = 1.50	Type IV
g = 9,81	m/s^2
Sf = 3,27	

Period determination	
Ko = 0,10	Type IV
h = 2,95	m
Ds = 3,12	m
T x-x = 0,15	seg.
Ko = 0,10	Type IV
h = 2,95	m
Ds = 3,12	m
T y-y = 0,15	seg.

Spectral Seismic coefficient	
C x-x =	0,635
C y-y =	0,635

C x S Product	
C x-x · S =	0,857 > 0,635
C y-y · S =	0,857 > 0,635

Baseline shear		
Cb x-x =	0,212 > 0,03	OK
Cb y-y =	0,212 > 0,03	OK

Permanent weight total	**5.77**	
Live load		
floors	0,15	
Roof	0,1	1,02
Totals		**0,10**
Weight total	**5.82**	

Baseline Shear				
V x-x =	1,24	to	65,00%	0,81
V y-y =	1,24	to	65,00%	0,81

DISPLACEMENTS		
Floor Height [m]	2,50	
	Cd = 5,4	
Maximum permissible (0,008xh)	0,00370	**OK**
Maximum		
TOTAL	**0,000003**	**0,000003**

DEPLAZAMIENTOS (DERIVA-drift-) MAXIMOS POR COMBINACIONES								
Story	**Item**	**Load**	**Point**	**X**	**Y**	**Z**	**Drift X**	**Drift Y**
STORY1	Max Drift Y	DEAD	957	3,3	0	2,5	0	
STORY1	Max Drift Y	DEAD	912	1,6	3,3	2,5		0
STORY1	Max Drift X	LIVE	986	3,2	3,2	2,5	0	
STORY1	Max Drift Y	LIVE	986	3,2	3,2	2,5		0
STORY1	Max Drift X	LIVET	957	3,3	0	2,5	0	
STORY1	Max Drift Y	LIVET	912	1,6	3,3	2,5		0
STORY1	Max Drift X	EX	912	1,6	3,3	2,5	0,000003	
STORY1	Max Drift Y	EX	967	3,3	1,6	2,5		0,000001
STORY1	Max Drift X	EY	913	1,6	3,3	2,5	0,000001	
STORY1	Max Drift Y	EY	967	3,3	1,6	2,5		0,000003

MODAL PERIODS AND FREQUENCIES

MODE NUMBER	PERIOD (TIME)	FREQUENCY (CYCLES/TIME)	CIRCULAR FREQ (RADIANS/TIME)
Mode 1	0.01755	56.99031	358.08070
Mode 2	0.01755	56.99157	358.08857
Mode 3	0.01380	72.47037	455.34476

STORY MAXIMUM AND AVERAGE LATERAL DISPLACEMENTS

STORY	LOAD	DIR	MAXIMUM	AVERAGE	RATIO
STORY1	EX	X	0.0008	0.0008	1.018
STORY1	EX	Y	0.0003	0.0003	1.062
STORY1	EY	X	0.0003	0.0003	1.058
STORY1	EY	Y	0.0009	0.0008	1.022

The displacements don’t arrive to the milimeters. This are really low values for the movement of a earthquake in Bolivia rate. The different about the previous structure (Papua New Guinea’s Project) is the movement of the house. With this construction system and material we have a static block complete inlaid to the fundation.

Checking the results we can admit this cube structure as valid.

Construction System

The module that we propose has a foundation slab surrounded by armed beams. This beam prefabricated ferrocement entire length of the module, and these panels were placed ferrocement. Both beams and panels are secured together with mortar. Once placed the beams and panels, we tie these with a bolt that rises from the slab.

The same process used for the upper beam, in this case we tied with screwed the panel, beam and downspouts used for the roof structure that we use.

Once placed the beams, both inferior and superior, together with the screw, proceed to fill the empty space between the panels and beams covering the screw pitch.
For the cover structure, we chose zinc sheets supported on a ferrocement beam structure (truss , downspouts and belts).

Although not base our research on how the panels are made, a brief explanation of the construction process of these is necessary.

The method chosen is precast ferrocement. It's more easy and fast then transport and build all the build.

For the manufacture of the panels it is initially needs a rectangular molds prefabricated reinforced concrete on the floor level. This reinforcing mesh is placed along with the four rods in the upper and lower ends.

We use a vibrating machine, pour the mortar on the reinforcing mesh and placed in the mold, vibrating while doing so have greater resistance.

Once they emptied the panels are left one day molds , ensuring coat well with plastic in order to minimize evaporation of water contained in the panel , and avoid deviations in the water cement ratio mortar matrix ; They are then removed and stored (where they are watered water twice a day) to spend 28 days when they get their maximum strength.

The panels can be used as beams, walls and roofs. The only difference between them is size. They may have a length of between 1.25 to 5 meters, depending on the application that you want to give.

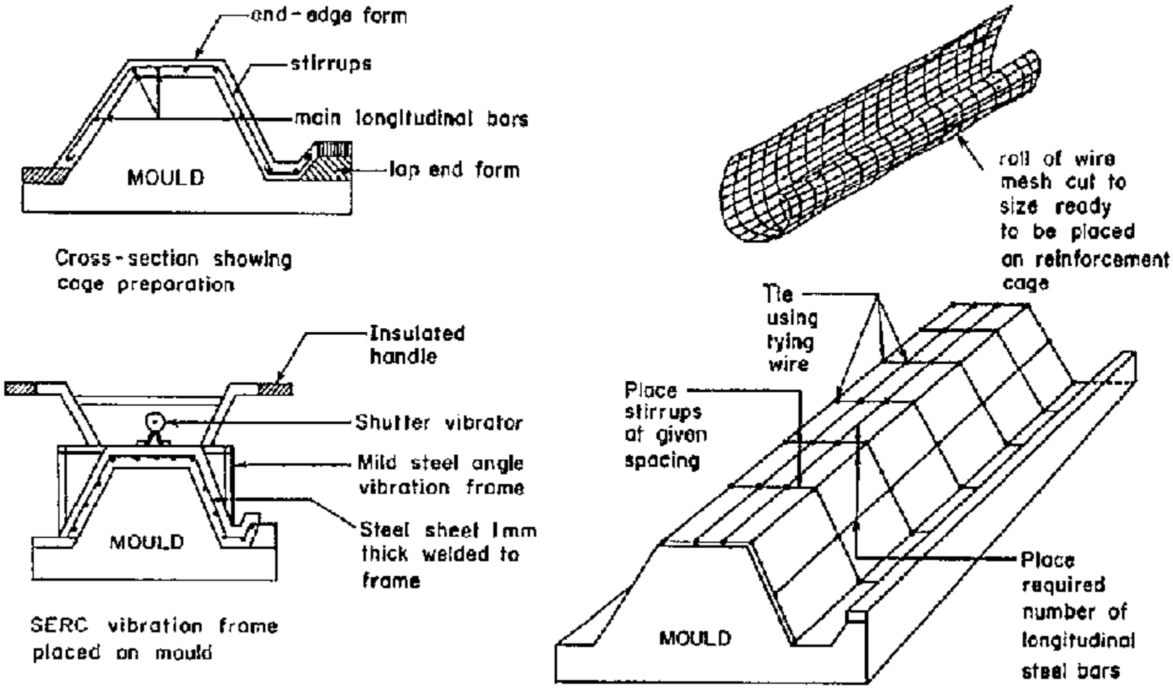


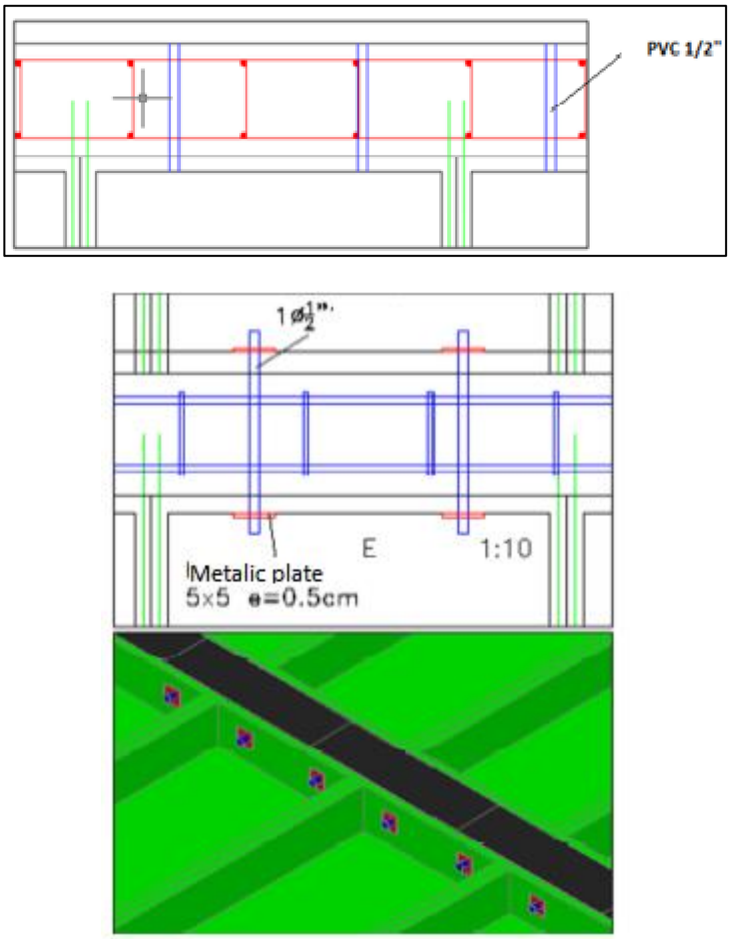
Illustration about the colocation of the moulds.

Illustration about the moulds and plastic coat.

The excavation is done in order to reach undisturbed soil or remove all organic matter of the same, ie to try to soil-structure interaction is more effective. Depending on the amount of organic matter in soil and the dimensions of this structure will vary digging depth dimensions.
For this structure to be a housing of small dimensions and small area; and also taking into account that the weight of it will not be excessive considering that the construction material is ferro and is small thick enough with a digging depth of about 40 cm below the natural ground level. Will can help with wooden struts to maintain the position of the ferrocement panels.

Then we will proceed to cast beams chain foundation level.

For the arrangement of windows smaller panels may be obtained in these prefabrication process giving the smallest dimension to the panel rail suggested for prefabricated were used. To keep the monolithic system after having placed all wall panels shall be casting the upper beam that is placed on the wall panels that serve as the basis for the cast of the beam.
This beam chain has the special feature of present PVC pipe ½ "vertical direction, these are intended for the expansion phase as well as for bonding with the cover.



Details of the unions between panels.

Prior to the placement of the cover panels cut on the central beam of housing in the north-south direction and this cover panels which will be joined by attaching the mesh of each panel and use will support were placed one insitu concreting.
These panels will be centered attached to the central beam by using connections bolted.

Between a side wall panels joint between panels it is not necessary but if desired can be given a layer of mortar or plaster changing the facade of the house. In all cases binding chain wall foundation level or higher chain should respect and maintain the union of pre-cast reinforced chains.
Both unions, deck and foundation, must take special care with the placement of reinforcement to maintain the geometric regularity of the housing preventing movement of the panels ferrocement.

The rest of details about this project such as structure, unions, etc. are in *Annexed 3. Bolivia's Project*

Conclusions

Concerning the purpose of this project, designed homes are suitable for building and house the less favored society of these countries. It is to clarify that for affordable housing is not essential the details or finishes, but essential be resistant and keeps the comfort of its owners, which normally call decent housing.
The draft new Papua Guiena is designed for a development of detached houses staggered towards the sea, to help city services not increase a cost by the government is created.
Homes in Bolivia are directed to a sector that lives from agriculture or handicrafts and can easily move to the field to collect the products and to the city to sell.
Construction is directed so that they can supply the means by which closer and labor is the community itself.
It is clear that without government aid these houses can not be created because of their low profit. The government has to supply the services, supports, and means for possible adaptation of the space of the houses and the same structures.
I wanted to incorporate the theory of earthquakes to teach the behavior of structures in order to prepare against this danger. This requires cononcer the definition and types of earthquakes.
It is also important to know what is a developing country and the reasons that may cause these effects in a country. It is obvious that history, the succession of power, political instability, wars, migration and other factors affect each country by uneven. We must find a solution to regulate and normalize these causes for these gaps between countries are not provoked.
The greatest difficulty of this project has been to unify an antiseismic house and turn it affordable, as the connections of the elements are often reinforced by expensive items such as plates, sheet metal, bolts, etc. In order to solve this problem I have concentrated into two

parts: the structure to withstand the earthquake; and the other part that the constructive and materials are low cost and fast construction.

I hope someday catch an earthquake-proof system designed for affordable houses can withstand the forces of earthquakes and not have to rebuild again. Although sometimes it is inevitable for materials or means in the area, at least ensure that the structure can not collapse without prior notice.

Acknowledgement

This section is to acknowledge the invaluable assistance of two people:
Servando Garcia Fluxa for the help with the anti-earthquake system and explanations of the program used "STAAD".
To my tutor, Antoni Cladera Bohigas, for guiding me to do this project.

Annexed 1. STAAD REPORT

STAAD.Pro Report

To:		From:			
Copy to:		Date:	01/06/2016 12:52:00	Ref:	ca/ Document1

Job Information

	Engineer	Checked	Approved
Name:	Carlos García Fluxa		
Date:	20-Apr-16		

Structure Type SPACE FRAME

Number of Nodes	30	Highest Node	32
Number of Elements	87	Highest Beam	98

Number of Basic Load Cases	1
Number of Combination Load Cases	0

Included in this printout are data for:
All The Whole Structure

Included in this printout are results for load cases:

Type	L/C	Name
Primary	2	SEISMIC LOADING

Materials

Mat	Name	E (kN/mm^2)	ν	Density (kg/m^3)	α (/°C)
3	STEEL	205.000	0.300	7.83E 3	12E -6
4	STAINLESSSTEEL	197.930	0.300	7.83E 3	18E -6
5	ALUMINUM	68.948	0.330	2.71E 3	23E -6
6	WOOD	11	0.25	5.02E 3	0.000
7	CONCRETE	21.718	0.170	2.4E 3	10E -6

Supports

Node	X (kN/mm)	Y (kN/mm)	Z (kN/mm)	rX (kN˙m/deg)	rY (kN˙m/deg)	rZ (kN˙m/deg)
1	0.600	10E 3	0.600	-	-	-
4	0.600	10E 3	0.600	-	-	-
7	0.600	10E 3	0.600	-	-	-
10	0.600	10E 3	0.600	-	-	-
13	0.600	10E 3	0.600	-	-	-
16	0.600	10E 3	0.600	-	-	-
19	0.600	10E 3	0.600	-	-	-
22	0.600	10E 3	0.600	-	-	-
25	0.600	10E 3	0.600	-	-	-

Basic Load Cases

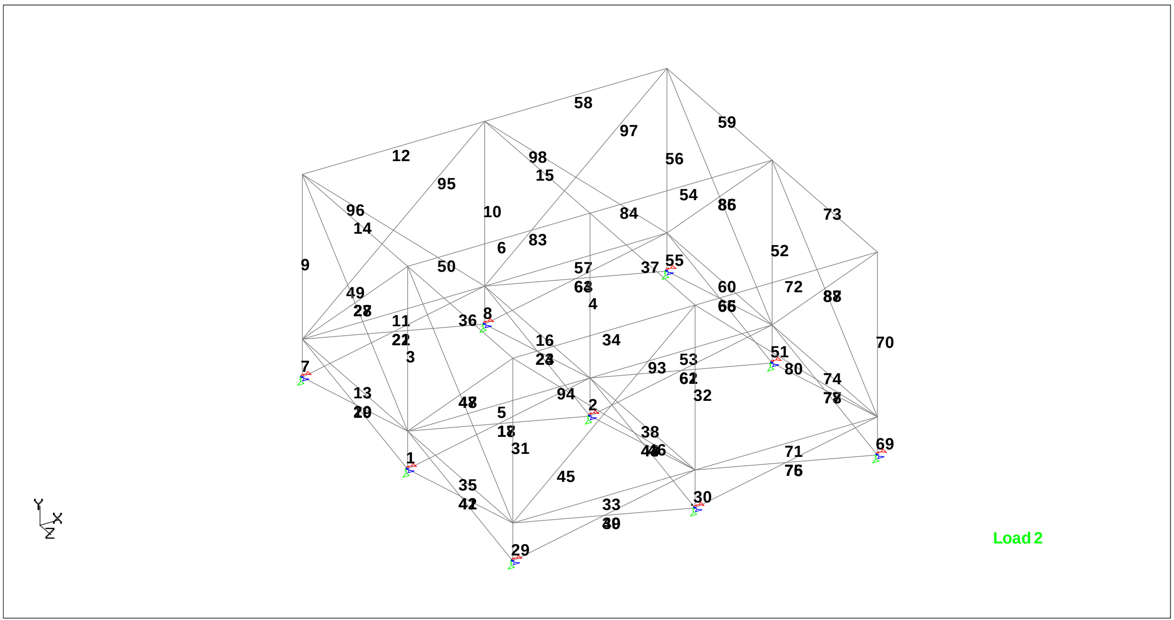
Number	Name
2	SEISMIC LOADING

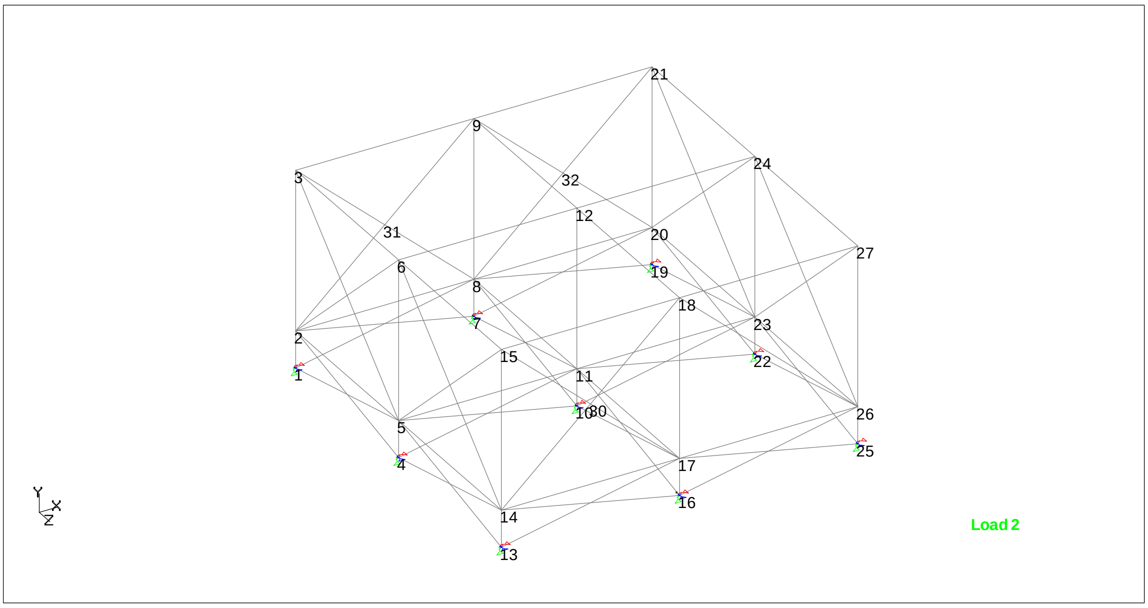
Selfweight : 2 SEISMIC LOADING

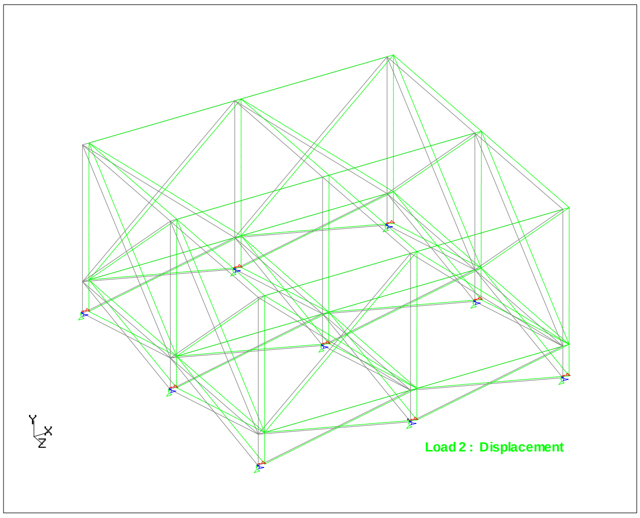
Direction	Factor
X	1.000
Y	1.000

Response Spectrum : 2 SEISMIC LOADING

Modal Combination	Factor X	Factor Y	Factor Z	Type	Scale	Damping
CQC	-	-	1.000	Displacement	-	0.000







Node Displacement Summary

	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)	rX (rad)	rY (rad)	rZ (rad)
Max X	24	2:SEISMIC	**122.842**	0.018	0.608	122.843	0.000	0.000	0.001
Min X	22	2:SEISMIC	**117.550**	0.007	0.608	117.551	0.000	0.000	0.001
Max Y	15	2:SEISMIC	121.487	**0.034**	0.612	121.488	0.000	0.000	0.000
Min Y	7	2:SEISMIC	122.011	**0.000**	0.004	122.011	0.000	0.000	0.000
Max Z	15	2:SEISMIC	121.487	0.034	**0.612**	121.488	0.000	0.000	0.000
Min Z	9	2:SEISMIC	122.658	0.000	**0.000**	122.658	0.000	0.000	0.000
Max rX	32	2:SEISMIC	122.418	0.015	0.307	122.418	**0.000**	0.000	0.000
Min rX	7	2:SEISMIC	122.011	0.000	0.004	122.011	**0.000**	0.000	0.000
Max rY	19	2:SEISMIC	121.884	0.009	0.607	121.885	0.000	**0.000**	0.001
Min rY	17	2:SEISMIC	120.820	0.008	0.004	120.820	0.000	**0.000**	0.000
Max rZ	23	2:SEISMIC	118.269	0.010	0.609	118.270	0.000	0.000	**0.001**
Min rZ	31	2:SEISMIC	122.418	0.015	0.309	122.418	0.000	0.000	**0.000**
Max Rst	24	2:SEISMIC	122.842	0.018	0.608	**122.843**	0.000	0.000	0.001

Reaction Summary

	Node	L/C	Horizontal FX (kN)	Vertical FY (kN)	Horizontal FZ (kN)	MX (kNm)	Moment MY (kNm)	MZ (kNm)
Max FX	7	2:SEISMIC	**73.206**	0.041	0.002	0.000	0.000	0.000
Min FX	22	2:SEISMIC	**70.530**	68.091	0.365	0.000	0.000	0.000
Max FY	13	2:SEISMIC	72.326	**113.554**	0.362	0.000	0.000	0.000
Min FY	7	2:SEISMIC	73.206	**0.041**	0.002	0.000	0.000	0.000
Max FZ	22	2:SEISMIC	70.530	68.091	**0.365**	0.000	0.000	0.000
Min FZ	7	2:SEISMIC	73.206	0.041	**0.002**	0.000	0.000	0.000
Max MX	1	2:SEISMIC	73.130	90.493	0.362	**0.000**	0.000	0.000
Min MX	1	2:SEISMIC	73.130	90.493	0.362	**0.000**	0.000	0.000
Max MY	1	2:SEISMIC	73.130	90.493	0.362	0.000	**0.000**	0.000
Min MY	1	2:SEISMIC	73.130	90.493	0.362	0.000	**0.000**	0.000
Max MZ	1	2:SEISMIC	73.130	90.493	0.362	0.000	0.000	**0.000**
Min MZ	1	2:SEISMIC	73.130	90.493	0.362	0.000	0.000	**0.000**

Calculated Modal Frequencies & Mass Participations

Mode	Frequency (Hz)	Period (sec)	Participation X (%)	Participation Y (%)	Participation Z (%)
1	2.391	0.418	99.985	0.000	0.000
2	3.439	0.291	0.002	0.000	0.000
3	15.342	0.065	0.005	0.000	0.000
4	23.266	0.043	0.008	0.000	0.000

Beam Maximum Moments

Distances to maxima are given from beam end A.

Beam	Node A	Length (m)	L/C		d (m)	Max My (kNm)	d (m)	Max Mz (kNm)
1	4	0.600	2:SEISMIC	Max -ve	0.600	0.012	0.600	30.408
				Max +ve				
2	10	0.600	2:SEISMIC	Max -ve	0.600	0.004	0.600	58.380
3	5	2.600	2:SEISMIC	Max -ve	2.600	0.031	2.600	48.110
				Max +ve				
4	11	2.600	2:SEISMIC	Max -ve	2.600	0.015	2.600	73.500
				Max +ve				
5	5	2.900	2:SEISMIC	Max -ve	0.000	0.030	0.000	1.592
				Max +ve				
6	6	2.900	2:SEISMIC	Max -ve	0.000	0.688	0.000	39.338
				Max +ve				
7	1	0.600	2:SEISMIC	Max -ve	0.000	0.057	0.600	9.163
				Max +ve				
8	7	0.600	2:SEISMIC	Max -ve	0.600	0.046	0.600	1.241
				Max +ve				
9	2	2.600	2:SEISMIC	Max -ve	2.600	0.057	0.000	8.451
				Max +ve				
10	8	2.600	2:SEISMIC	Max -ve	2.600	0.053	2.600	4.157
				Max +ve				
11	2	2.900	2:SEISMIC	Max -ve	0.000	0.299	0.000	0.459
				Max +ve				
12	3	2.900	2:SEISMIC	Max -ve	0.000	6.258	0.000	3.953
				Max +ve				
13	5	2.900	2:SEISMIC	Max -ve	0.000	1.342	2.900	0.006
				Max +ve				
14	6	2.900	2:SEISMIC	Max -ve	0.000	12.211	0.000	0.188
				Max +ve				
15	12	2.900	2:SEISMIC	Max -ve	0.000	13.329	0.000	0.054
				Max +ve				
16	11	2.900	2:SEISMIC	Max -ve	0.000	1.409	0.000	0.002
				Max +ve				
17	4	2.961	2:SEISMIC	Max -ve	0.000	0.030	0.000	1.235
				Max +ve				
18	10	2.961	2:SEISMIC	Max -ve	2.961	0.030	2.961	1.262
				Max +ve				
19	1	2.961	2:SEISMIC	Max -ve	2.961	1.433	0.000	0.004
				Max +ve				
20	4	2.961	2:SEISMIC	Max -ve	0.000	1.367	2.961	0.006
				Max +ve				
21	1	2.961	2:SEISMIC	Max -ve	0.000	0.312	0.000	0.504
				Max +ve				
22	2	2.961	2:SEISMIC	Max -ve	0.000	0.297	0.000	0.437
				Max +ve				
23	8	2.961	2:SEISMIC	Max -ve	2.961	1.400	2.961	0.001
				Max +ve				
24	7	2.961	2:SEISMIC	Max -ve	2.961	1.454	2.961	0.001
				Max +ve				
27	5	3.895	2:SEISMIC	Max -ve	3.895	0.648	0.000	0.003
				Max +ve				
28	2	3.895	2:SEISMIC	Max -ve	3.895	0.066	0.000	0.001
				Max +ve				
29	13	0.600	2:SEISMIC	Max -ve	0.600	0.066	0.600	9.196
				Max +ve				
30	16	0.600	2:SEISMIC	Max -ve	0.600	0.039	0.600	2.954
				Max +ve				
31	14	2.600	2:SEISMIC	Max -ve	2.600	0.037	0.000	8.321
				Max +ve				
32	17	2.600	2:SEISMIC	Max -ve	0.000	0.049	2.600	7.386
				Max +ve				
33	14	2.900	2:SEISMIC	Max -ve	0.000	0.267	0.000	0.502
				Max +ve				
34	15	2.900	2:SEISMIC	Max -ve	0.000	7.003	0.000	4.899
				Max +ve				

34	15	2.900	2:SEISMIC	Max -ve Max +ve	0.000	7.003	0.000	4.899
35	14	2.900	2:SEISMIC	Max -ve Max +ve	2.900	1.295	2.900	0.002
36	15	2.900	2:SEISMIC	Max -ve Max +ve	2.900	12.736	2.900	0.179
37	18	2.900	2:SEISMIC	Max -ve Max +ve	2.900	14.308	0.000	0.082
38	17	2.900	2:SEISMIC	Max -ve Max +ve	2.900	1.329	0.000	0.002
39	13	2.961	2:SEISMIC	Max -ve Max +ve	0.000	0.281	0.000	0.547
40	16	2.961	2:SEISMIC	Max -ve Max +ve	0.000	0.268	2.961	0.461
41	4	2.961	2:SEISMIC	Max -ve Max +ve	0.000	1.317	0.000	0.003
42	13	2.961	2:SEISMIC	Max -ve Max +ve	2.961	1.377	0.000	0.003
43	11	2.961	2:SEISMIC	Max -ve Max +ve	0.000	1.384	2.961	0.000
44	10	2.961	2:SEISMIC	Max -ve Max +ve	0.000	1.325	2.961	0.002
45	14	1.947	2:SEISMIC	Max -ve Max +ve	0.000	0.201	0.000	0.472
46	17	1.947	2:SEISMIC	Max -ve Max +ve	0.000	0.176	0.000	0.083
47	14	3.895	2:SEISMIC	Max -ve Max +ve	0.000	0.072	0.000	0.001
48	5	3.895	2:SEISMIC	Max -ve Max +ve	3.895	0.637	0.000	0.003
49	2	1.947	2:SEISMIC	Max -ve Max +ve	0.000	0.220	0.000	0.405
50	8	1.947	2:SEISMIC	Max -ve Max +ve	0.000	0.189	0.000	0.152
51	22	0.600	2:SEISMIC	Max -ve Max +ve	0.600	0.043	0.600	30.417
52	23	2.600	2:SEISMIC	Max -ve Max +ve	2.600	0.038	2.600	48.132
53	11	2.900	2:SEISMIC	Max -ve Max +ve	2.900	0.026	2.900	1.592
54	12	2.900	2:SEISMIC	Max -ve Max +ve	2.900	0.661	2.900	39.328
55	19	0.600	2:SEISMIC	Max -ve Max +ve	0.000	0.059	0.600	9.164
56	20	2.600	2:SEISMIC	Max -ve Max +ve	0.000	0.073	0.000	8.451
57	8	2.900	2:SEISMIC	Max -ve Max +ve	2.900	0.296	2.900	0.459
58	9	2.900	2:SEISMIC	Max -ve Max +ve	2.900	6.191	2.900	3.948
59	24	2.900	2:SEISMIC	Max -ve Max +ve	0.000	12.099	2.900	0.064
60	23	2.900	2:SEISMIC	Max -ve Max +ve	0.000	1.342	2.900	0.003
61	10	2.961	2:SEISMIC	Max -ve Max +ve	2.961	0.025	2.961	1.263
62	22	2.961	2:SEISMIC	Max -ve Max +ve	0.000	0.025	0.000	1.235
63	7	2.961	2:SEISMIC	Max -ve Max +ve	2.961	0.293	2.961	0.437
64	8	2.961	2:SEISMIC	Max -ve Max +ve	2.961	0.309	2.961	0.504
65	20	2.961	2:SEISMIC	Max -ve Max +ve	2.961	1.366	2.961	0.005
66	19	2.961	2:SEISMIC	Max -ve Max +ve	2.961	1.432	0.000	0.002
69	25	0.600	2:SEISMIC	Max -ve Max +ve	0.000	0.060	0.600	8.845
70	26	2.600	2:SEISMIC	Max -ve	0.000	0.042	0.000	8.166

				Max +ve				
71	17	2.900	2:SEISMIC	Max -ve	2.900	0.280	2.900	0.518
				Max +ve				
72	18	2.900	2:SEISMIC	Max -ve	2.900	6.936	2.900	5.356
				Max +ve				
73	27	2.900	2:SEISMIC	Max -ve	2.900	12.574	0.000	0.028
				Max +ve				
74	26	2.900	2:SEISMIC	Max -ve	2.900	1.292	0.000	0.002
				Max +ve				
75	16	2.961	2:SEISMIC	Max -ve	2.961	0.277	2.961	0.473
				Max +ve				
76	25	2.961	2:SEISMIC	Max -ve	0.000	0.292	0.000	0.558
				Max +ve				
77	23	2.961	2:SEISMIC	Max -ve	0.000	1.374	2.961	0.003
				Max +ve				
78	22	2.961	2:SEISMIC	Max -ve	0.000	1.314	2.961	0.001
				Max +ve				
80	26	3.895	2:SEISMIC	Max -ve	0.000	0.091	0.000	0.244
				Max +ve				
83	8	1.947	2:SEISMIC	Max -ve	0.000	0.186	0.000	0.152
				Max +ve				
84	20	1.947	2:SEISMIC	Max -ve	0.000	0.219	0.000	0.405
				Max +ve				
85	23	3.895	2:SEISMIC	Max -ve	3.895	0.648	0.000	0.003
				Max +ve				
86	20	3.895	2:SEISMIC	Max -ve	3.895	0.067	3.895	0.001
				Max +ve				
87	26	3.895	2:SEISMIC	Max -ve	0.000	0.073	0.000	0.002
				Max +ve				
88	23	3.895	2:SEISMIC	Max -ve	3.895	0.642	3.895	0.001
				Max +ve				
93	30	1.947	2:SEISMIC	Max -ve	1.947	0.090	0.000	0.098
				Max +ve				
94	30	1.947	2:SEISMIC	Max -ve	1.947	0.130	0.000	0.073
				Max +ve				
95	31	1.947	2:SEISMIC	Max -ve	1.947	0.082	0.000	0.090
				Max +ve				
96	31	1.947	2:SEISMIC	Max -ve	1.947	0.121	0.000	0.077
				Max +ve				
97	32	1.947	2:SEISMIC	Max -ve	1.947	0.119	0.000	0.077
				Max +ve				
98	32	1.947	2:SEISMIC	Max -ve	1.947	0.080	0.000	0.090
				Max +ve				

Beam Maximum Shear Forces

Distances to maxima are given from beam end A.

Beam	Node A	Length (m)	L/C		d (m)	Max Fz (kN)	d (m)	Max Fy (kN)
1	4	0.600	2:SEISMIC	Max -ve	0.000	0.023	0.000	49.184
				Max +ve	0.300	0.000	0.300	0.000
2	10	0.600	2:SEISMIC	Max -ve	0.000	0.008	0.000	95.529
				Max +ve	0.300	0.000	0.300	0.000
3	5	2.600	2:SEISMIC	Max -ve	0.000	0.022	0.000	31.623
				Max +ve	1.300	0.000	1.300	0.000
4	11	2.600	2:SEISMIC	Max -ve	0.000	0.008	0.000	53.063
				Max +ve	1.300	0.000	1.300	0.000
5	5	2.900	2:SEISMIC	Max -ve	0.000	0.020	0.000	1.025
				Max +ve	1.450	0.000	1.450	0.000
6	6	2.900	2:SEISMIC	Max -ve	0.000	0.440	0.000	25.300
				Max +ve	1.450	0.000	1.450	0.000
7	1	0.600	2:SEISMIC	Max -ve	0.000	0.096	0.000	16.320
				Max +ve	0.300	0.000	0.300	0.000
8	7	0.600	2:SEISMIC	Max -ve	0.000	0.076	0.000	3.562
				Max +ve	0.300	0.000	0.300	0.000
9	2	2.600	2:SEISMIC	Max -ve	0.000	0.005	0.000	3.635
				Max +ve	1.300	0.000	1.300	0.000
10	8	2.600	2:SEISMIC	Max -ve	0.000	0.039	0.000	1.682
				Max +ve	1.300	0.000	1.300	0.000
11	2	2.900	2:SEISMIC	Max -ve	0.000	0.201	0.000	0.290
				Max +ve	1.450	0.000	1.450	0.000
12	3	2.900	2:SEISMIC	Max -ve	0.000	3.872	0.000	2.588
				Max +ve	1.450	0.000	1.450	0.000
13	5	2.900	2:SEISMIC	Max -ve	0.000	0.893	0.000	0.004
				Max +ve	1.450	0.000	1.450	0.000
14	6	2.900	2:SEISMIC	Max -ve	0.000	7.460	0.000	0.109
				Max +ve	1.450	0.000	1.450	0.000
15	12	2.900	2:SEISMIC	Max -ve	0.000	8.707	0.000	0.034
				Max +ve	1.450	0.000	1.450	0.000
16	11	2.900	2:SEISMIC	Max -ve	0.000	0.944	0.000	0.001
				Max +ve	1.450	0.000	1.450	0.000
17	4	2.961	2:SEISMIC	Max -ve	0.000	0.020	0.000	0.810
				Max +ve	1.481	0.000	1.481	0.000
18	10	2.961	2:SEISMIC	Max -ve	0.000	0.020	0.000	0.694
				Max +ve	1.481	0.000	1.481	0.000
19	1	2.961	2:SEISMIC	Max -ve	0.000	0.907	0.000	0.002
				Max +ve	1.481	0.000	1.481	0.000
20	4	2.961	2:SEISMIC	Max -ve	0.000	0.911	0.000	0.004
				Max +ve	1.481	0.000	1.481	0.000
21	1	2.961	2:SEISMIC	Max -ve	0.000	0.201	0.000	0.302
				Max +ve	1.481	0.000	1.481	0.000
22	2	2.961	2:SEISMIC	Max -ve	0.000	0.199	0.000	0.270
				Max +ve	1.481	0.000	1.481	0.000
23	8	2.961	2:SEISMIC	Max -ve	0.000	0.921	0.000	0.001
				Max +ve	1.481	0.000	1.481	0.000
24	7	2.961	2:SEISMIC	Max -ve	0.000	0.934	0.000	0.001
				Max +ve	1.481	0.000	1.481	0.000
27	5	3.895	2:SEISMIC	Max -ve	0.000	0.251	0.000	0.001
				Max +ve	1.947	0.000	1.947	0.000
28	2	3.895	2:SEISMIC	Max -ve	0.000	0.002	0.000	0.001
				Max +ve	1.947	0.000	1.947	0.000
29	13	0.600	2:SEISMIC	Max -ve	0.000	0.204	0.000	16.442
				Max +ve	0.300	0.000	0.300	0.000
30	16	0.600	2:SEISMIC	Max -ve	0.000	0.062	0.000	3.535
				Max +ve	0.300	0.000	0.300	0.000
31	14	2.600	2:SEISMIC	Max -ve	0.000	0.018	0.000	3.175
				Max +ve	1.300	0.000	1.300	0.000
32	17	2.600	2:SEISMIC	Max -ve	0.000	0.035	0.000	4.487
				Max +ve	1.300	0.000	1.300	0.000
33	14	2.900	2:SEISMIC	Max -ve	0.000	0.182	0.000	0.309
				Max +ve	1.450	0.000	1.450	0.000
34	15	2.900	2:SEISMIC	Max -ve	0.000	4.319	0.000	3.308

35	14	2.900	2:SEISMIC	Max -ve	0.000	0.858	0.000	0.001
				Max +ve	1.450	0.000	1.450	0.000
36	15	2.900	2:SEISMIC	Max -ve	0.000	7.875	0.000	0.109
				Max +ve	1.450	0.000	1.450	0.000
37	18	2.900	2:SEISMIC	Max -ve	0.000	9.438	0.000	0.055
				Max +ve	1.450	0.000	1.450	0.000
38	17	2.900	2:SEISMIC	Max -ve	0.000	0.884	0.000	0.001
				Max +ve	1.450	0.000	1.450	0.000
39	13	2.961	2:SEISMIC	Max -ve	0.000	0.183	0.000	0.321
				Max +ve	1.481	0.000	1.481	0.000
40	16	2.961	2:SEISMIC	Max -ve	0.000	0.180	0.000	0.270
				Max +ve	1.481	0.000	1.481	0.000
41	4	2.961	2:SEISMIC	Max -ve	0.000	0.873	0.000	0.002
				Max +ve	1.481	0.000	1.481	0.000
42	13	2.961	2:SEISMIC	Max -ve	0.000	0.869	0.000	0.002
				Max +ve	1.481	0.000	1.481	0.000
43	11	2.961	2:SEISMIC	Max -ve	0.000	0.881	0.000	0.000
				Max +ve	1.481	0.000	1.481	0.000
44	10	2.961	2:SEISMIC	Max -ve	0.000	0.866	0.000	0.001
				Max +ve	1.481	0.000	1.481	0.000
45	14	1.947	2:SEISMIC	Max -ve	0.000	0.147	0.000	0.345
				Max +ve	0.974	0.000	0.974	0.000
46	17	1.947	2:SEISMIC	Max -ve	0.000	0.131	0.000	0.028
				Max +ve	0.974	0.000	0.974	0.000
47	14	3.895	2:SEISMIC	Max -ve	0.000	0.008	0.000	0.001
				Max +ve	1.947	0.000	1.947	0.000
48	5	3.895	2:SEISMIC	Max -ve	0.000	0.248	0.000	0.001
				Max +ve	1.947	0.000	1.947	0.000
49	2	1.947	2:SEISMIC	Max -ve	0.000	0.159	0.000	0.287
				Max +ve	0.974	0.000	0.974	0.000
50	8	1.947	2:SEISMIC	Max -ve	0.000	0.143	0.000	0.085
				Max +ve	0.974	0.000	0.974	0.000
51	22	0.600	2:SEISMIC	Max -ve	0.000	0.071	0.000	49.200
				Max +ve	0.300	0.000	0.300	0.000
52	23	2.600	2:SEISMIC	Max -ve	0.000	0.008	0.000	31.633
				Max +ve	1.300	0.000	1.300	0.000
53	11	2.900	2:SEISMIC	Max -ve	0.000	0.017	0.000	1.025
				Max +ve	1.450	0.000	1.450	0.000
54	12	2.900	2:SEISMIC	Max -ve	0.000	0.438	0.000	25.297
				Max +ve	1.450	0.000	1.450	0.000
55	19	0.600	2:SEISMIC	Max -ve	0.000	0.070	0.000	16.320
				Max +ve	0.300	0.000	0.300	0.000
56	20	2.600	2:SEISMIC	Max -ve	0.000	0.034	0.000	3.635
				Max +ve	1.300	0.000	1.300	0.000
57	8	2.900	2:SEISMIC	Max -ve	0.000	0.198	0.000	0.290
				Max +ve	1.450	0.000	1.450	0.000
58	9	2.900	2:SEISMIC	Max -ve	0.000	3.824	0.000	2.584
				Max +ve	1.450	0.000	1.450	0.000
59	24	2.900	2:SEISMIC	Max -ve	0.000	7.401	0.000	0.041
				Max +ve	1.450	0.000	1.450	0.000
60	23	2.900	2:SEISMIC	Max -ve	0.000	0.893	0.000	0.002
				Max +ve	1.450	0.000	1.450	0.000
61	10	2.961	2:SEISMIC	Max -ve	0.000	0.016	0.000	0.694
				Max +ve	1.481	0.000	1.481	0.000
62	22	2.961	2:SEISMIC	Max -ve	0.000	0.016	0.000	0.811
				Max +ve	1.481	0.000	1.481	0.000
63	7	2.961	2:SEISMIC	Max -ve	0.000	0.196	0.000	0.270
				Max +ve	1.481	0.000	1.481	0.000
64	8	2.961	2:SEISMIC	Max -ve	0.000	0.199	0.000	0.302
				Max +ve	1.481	0.000	1.481	0.000
65	20	2.961	2:SEISMIC	Max -ve	0.000	0.911	0.000	0.003
				Max +ve	1.481	0.000	1.481	0.000
66	19	2.961	2:SEISMIC	Max -ve	0.000	0.906	0.000	0.001
				Max +ve	1.481	0.000	1.481	0.000
69	25	0.600	2:SEISMIC	Max -ve	0.000	0.151	0.000	15.876
				Max +ve	0.300	0.000	0.300	0.000
70	26	2.600	2:SEISMIC	Max -ve	0.000	0.010	0.000	2.939
				Max +ve	1.300	0.000	1.300	0.000
71	17	2.900	2:SEISMIC	Max -ve	0.000	0.189	0.000	0.319

72	18	2.900	2:SEISMIC	Max -ve	0.000	4.300	0.000	3.667
				Max +ve	1.450	0.000	1.450	0.000
73	27	2.900	2:SEISMIC	Max -ve	0.000	7.771	0.000	0.012
				Max +ve	1.450	0.000	1.450	0.000
74	26	2.900	2:SEISMIC	Max -ve	0.000	0.855	0.000	0.001
				Max +ve	1.450	0.000	1.450	0.000
75	16	2.961	2:SEISMIC	Max -ve	0.000	0.187	0.000	0.277
				Max +ve	1.481	0.000	1.481	0.000
76	25	2.961	2:SEISMIC	Max -ve	0.000	0.190	0.000	0.328
				Max +ve	1.481	0.000	1.481	0.000
77	23	2.961	2:SEISMIC	Max -ve	0.000	0.866	0.000	0.002
				Max +ve	1.481	0.000	1.481	0.000
78	22	2.961	2:SEISMIC	Max -ve	0.000	0.870	0.000	0.001
				Max +ve	1.481	0.000	1.481	0.000
80	26	3.895	2:SEISMIC	Max -ve	0.000	0.028	0.000	0.093
				Max +ve	1.947	0.000	1.947	0.000
83	8	1.947	2:SEISMIC	Max -ve	0.000	0.140	0.000	0.085
				Max +ve	0.974	0.000	0.974	0.000
84	20	1.947	2:SEISMIC	Max -ve	0.000	0.157	0.000	0.287
				Max +ve	0.974	0.000	0.974	0.000
85	23	3.895	2:SEISMIC	Max -ve	0.000	0.251	0.000	0.002
				Max +ve	1.947	0.000	1.947	0.000
86	20	3.895	2:SEISMIC	Max -ve	0.000	0.002	0.000	0.001
				Max +ve	1.947	0.000	1.947	0.000
87	26	3.895	2:SEISMIC	Max -ve	0.000	0.008	0.000	0.001
				Max +ve	1.947	0.000	1.947	0.000
88	23	3.895	2:SEISMIC	Max -ve	0.000	0.250	0.000	0.000
				Max +ve	1.947	0.000	1.947	0.000
93	30	1.947	2:SEISMIC	Max -ve	0.000	0.082	0.000	0.090
				Max +ve	0.974	0.000	0.974	0.000
94	30	1.947	2:SEISMIC	Max -ve	0.000	0.097	0.000	0.060
				Max +ve	0.974	0.000	0.974	0.000
95	31	1.947	2:SEISMIC	Max -ve	0.000	0.077	0.000	0.081
				Max +ve	0.974	0.000	0.974	0.000
96	31	1.947	2:SEISMIC	Max -ve	0.000	0.094	0.000	0.061
				Max +ve	0.974	0.000	0.974	0.000
97	32	1.947	2:SEISMIC	Max -ve	0.000	0.092	0.000	0.061
				Max +ve	0.974	0.000	0.974	0.000
98	32	1.947	2:SEISMIC	Max -ve	0.000	0.075	0.000	0.081
				Max +ve	0.974	0.000	0.974	0.000

Annexed 2. Papua New Guinea's Project

Annexed 2. Bolivia's Project

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Norma Boliviana de Diseño Sísmico

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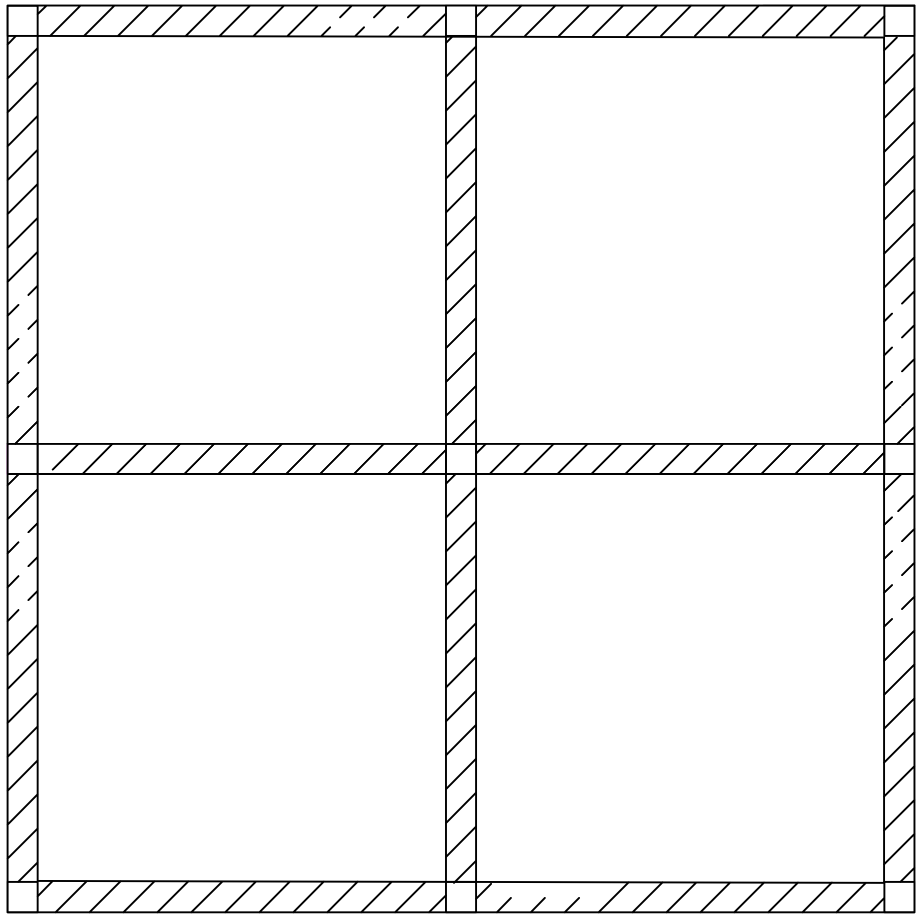
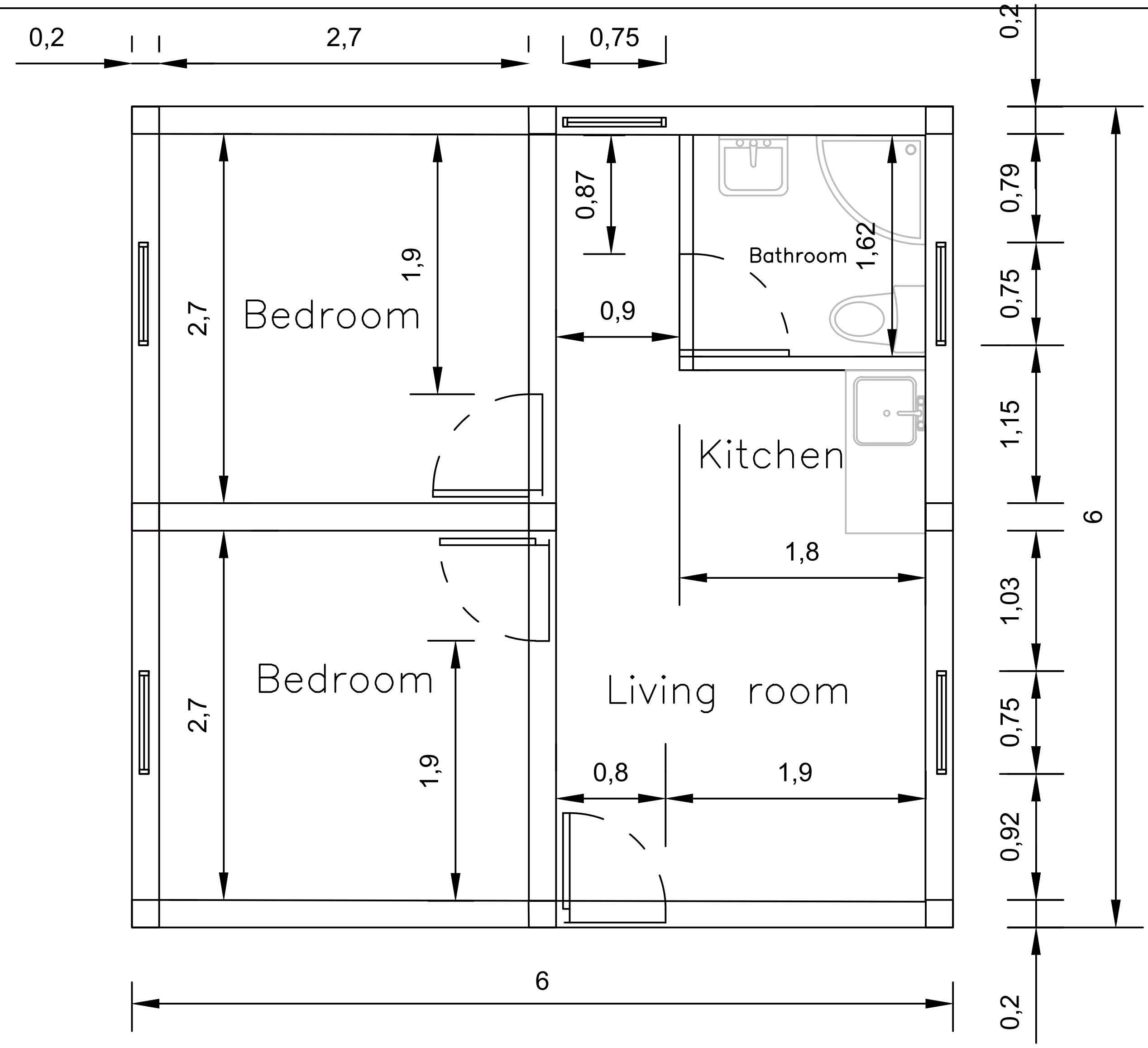
LONDON ASSEMBLY

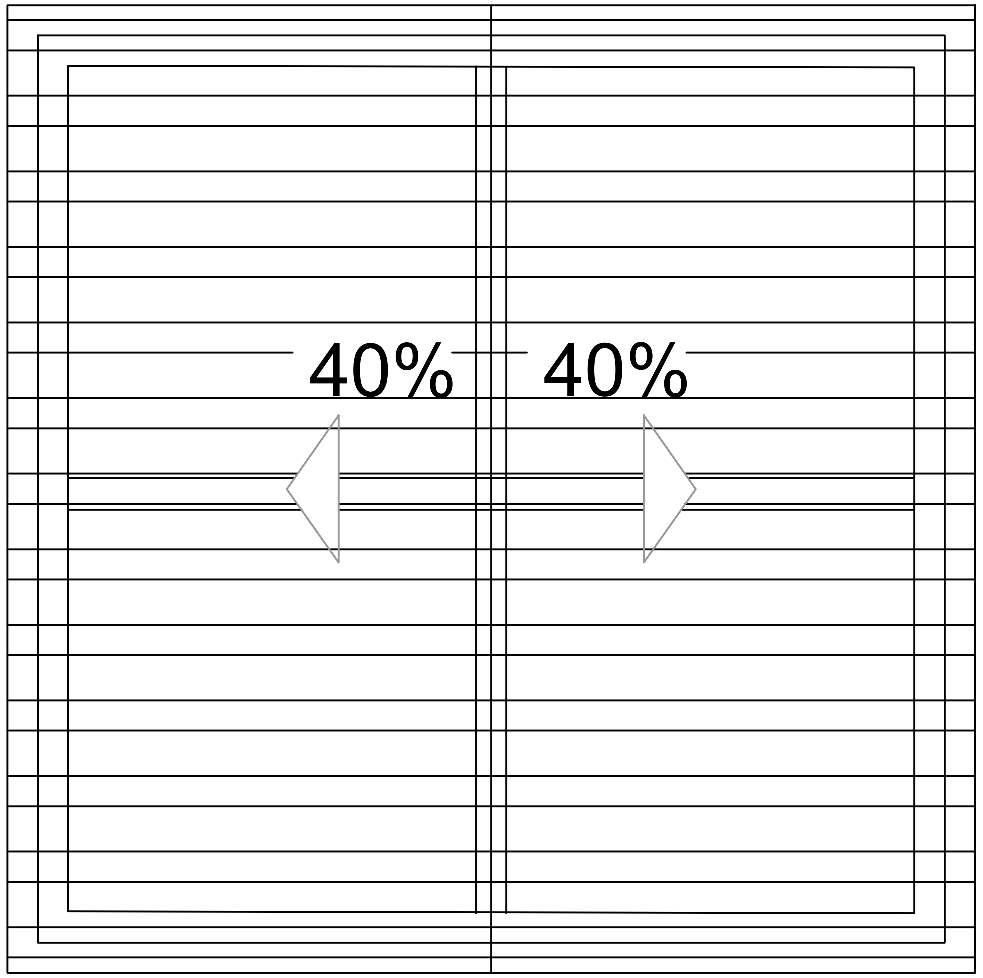
Foundation



Dwelling



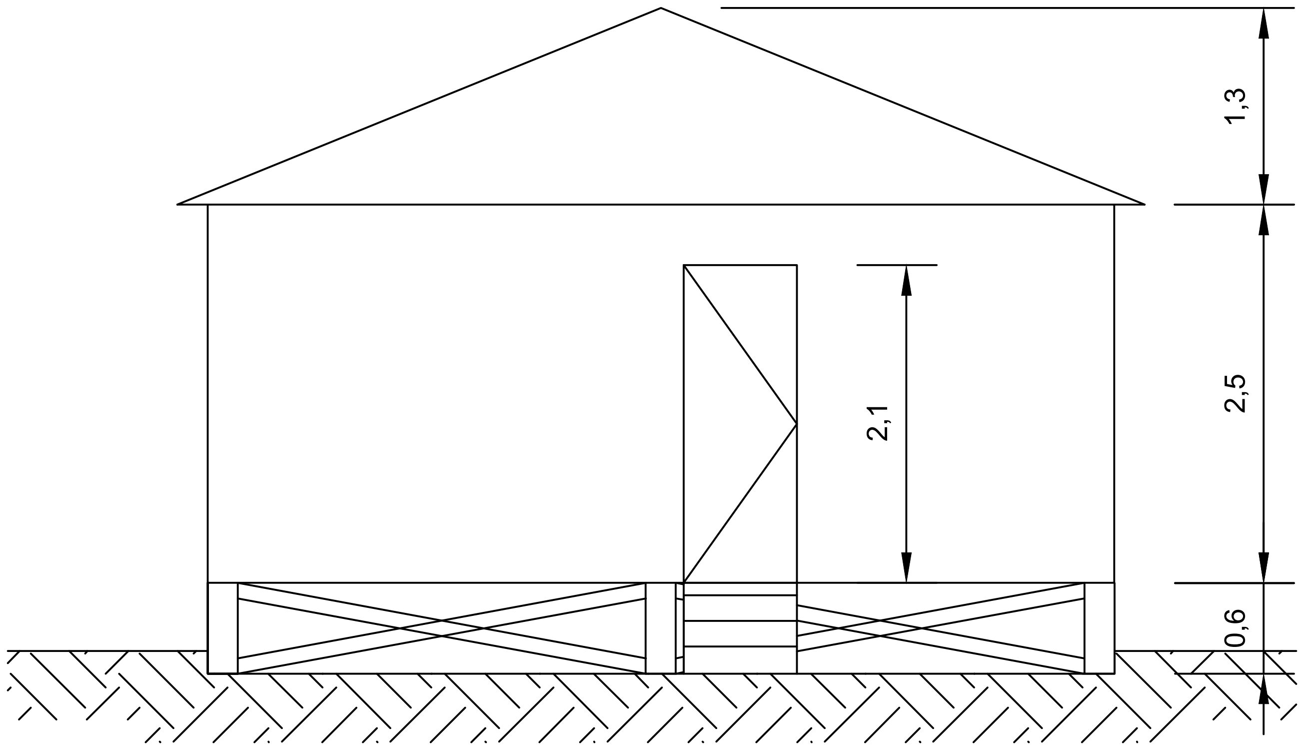
Roof



Name	Carlos García Fluxa		*ESCOLA POLITÈCNICA SUPERIOR DE LA UIB*
Date	02/09/16		
Scale: 1:50		*Plan* 01	Floor plan Papua New Guinea
		Grau en Edificació	

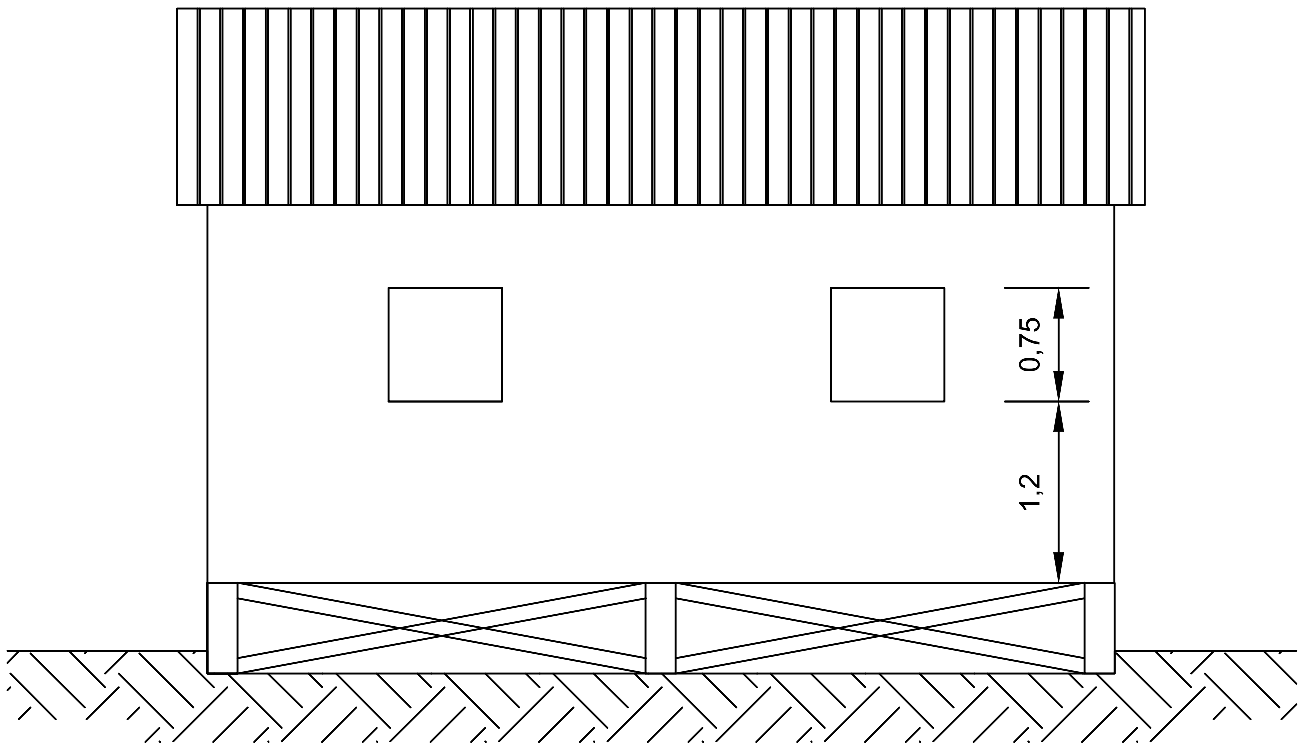
Main Façade

Outline A–A



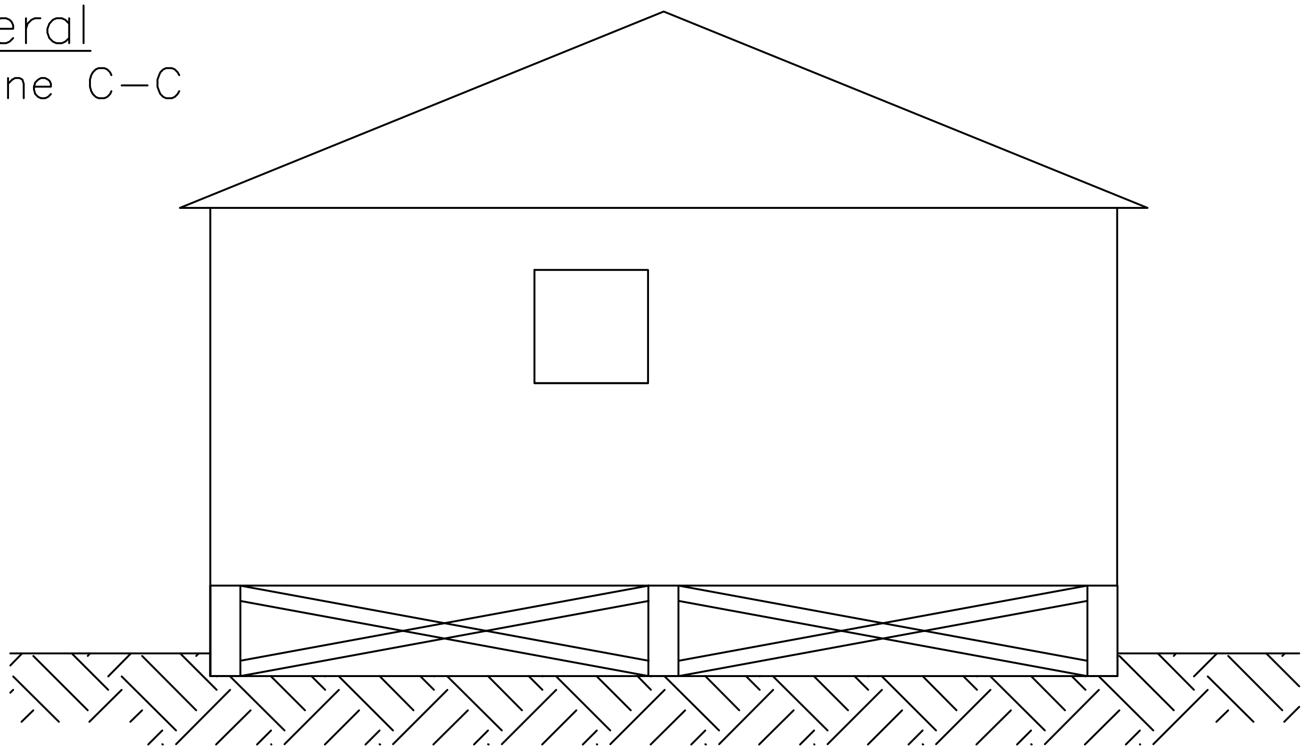
Back Façade

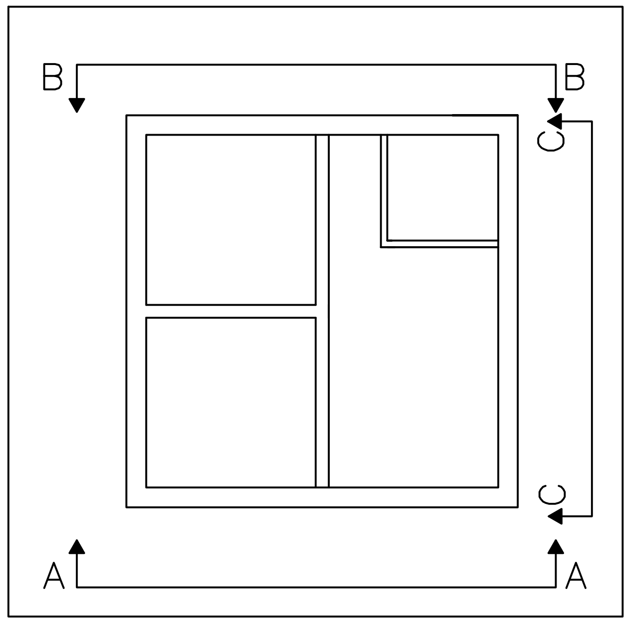
Outline B–B



Lateral

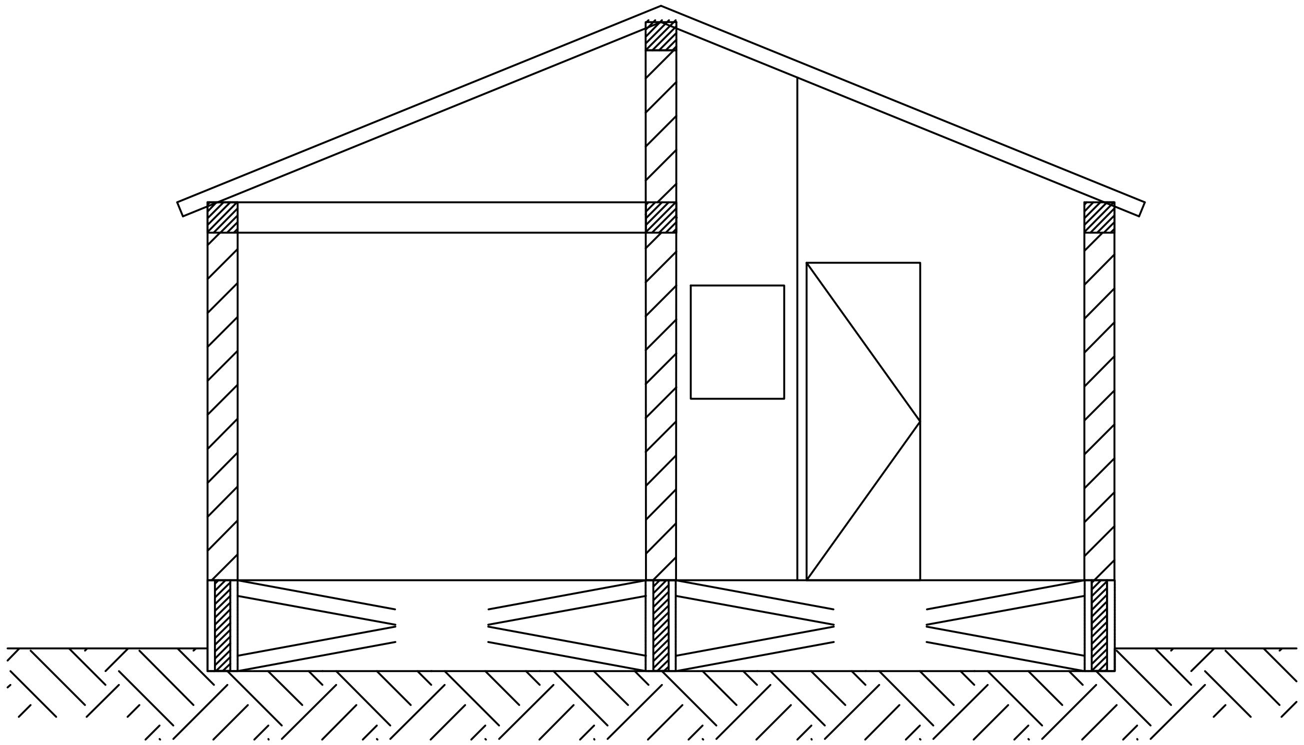
Outline C–C



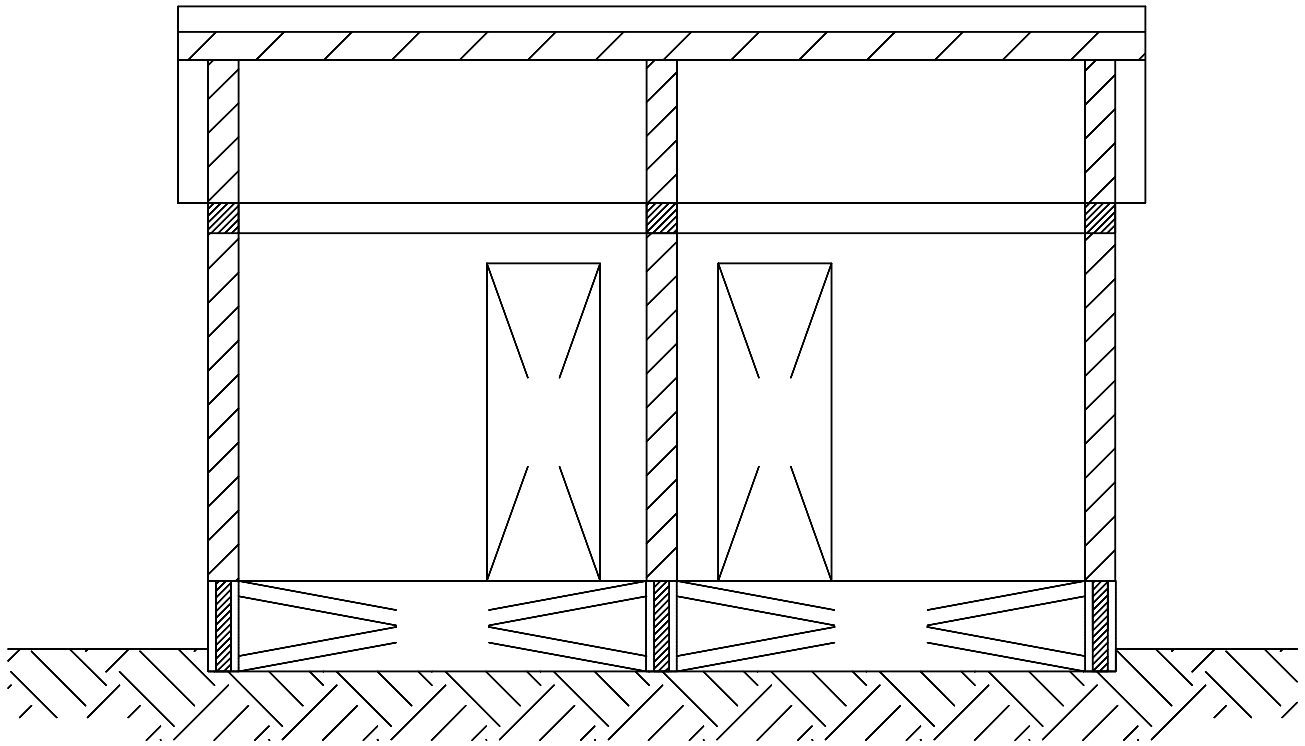


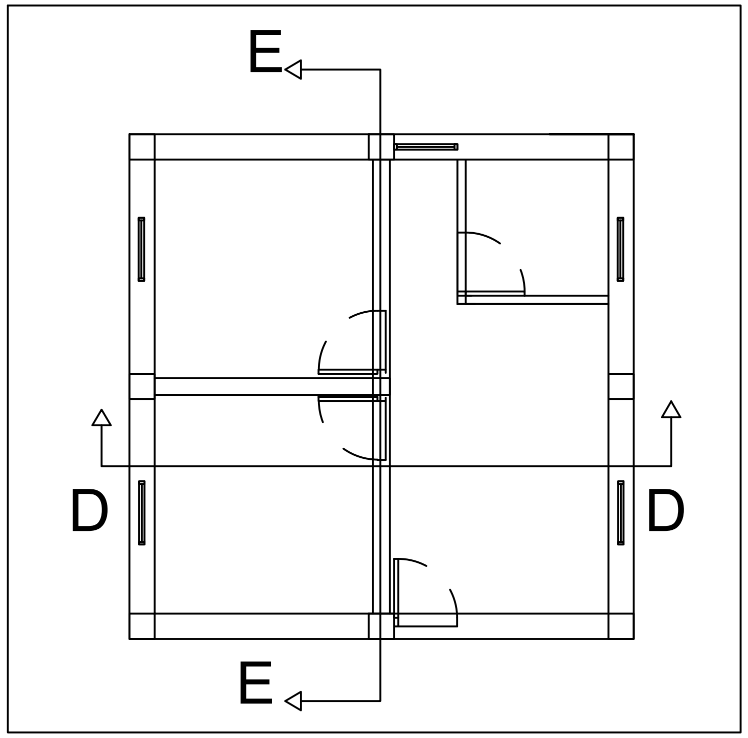
Name	Carlos García Fluxa		*ESCOLA POLITÈCNICA SUPERIOR DE LA UIB*
Date	02/09/16		
Scale: 1:50		*Plan* 02	Raised Plan Papua New Guinea
		Grau en Edificació	

Section D–D



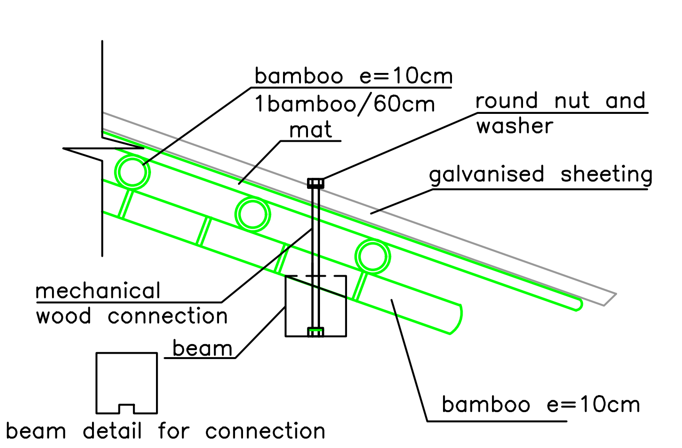
Section E–E



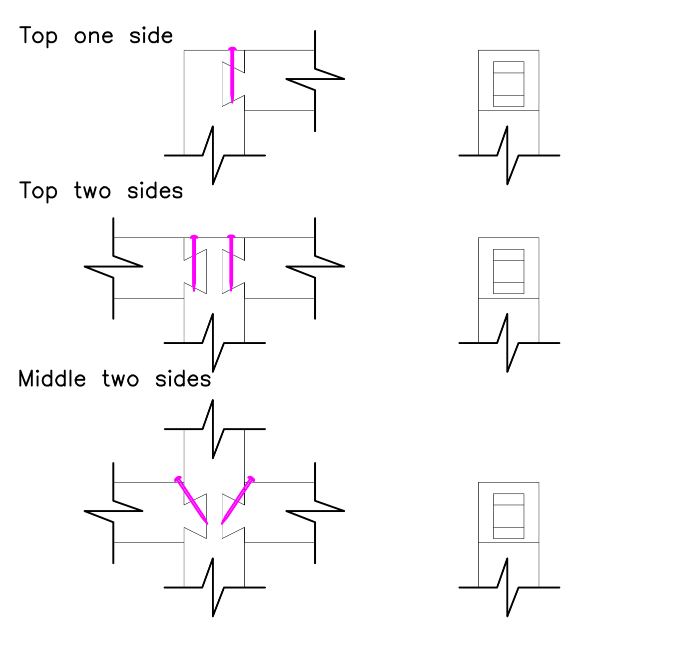


Name	Carlos García Fluxa		*ESCOLA POLITÈCNICA SUPERIOR DE LA UIB*
Date	02/09/16		
Scale: 1:50		*Plan* 03	Section plan Papua New Guinea
		Grau en Edificació	

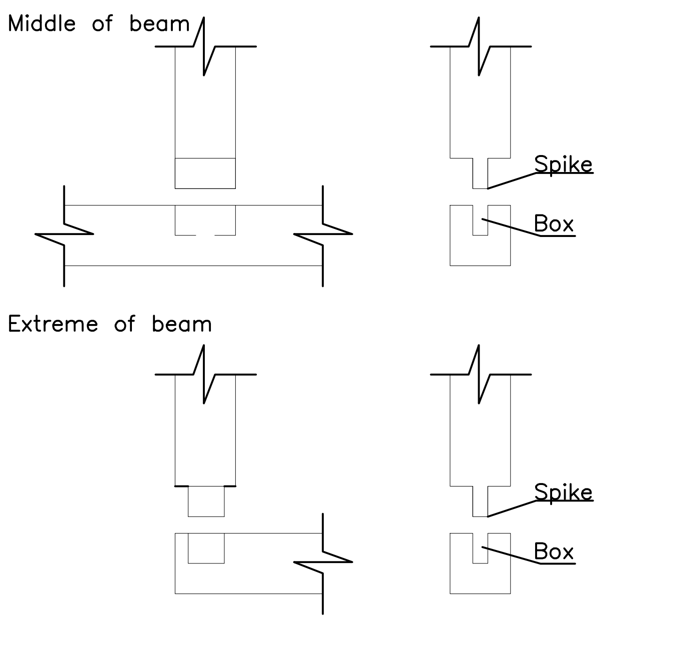
Connection between roof and beam



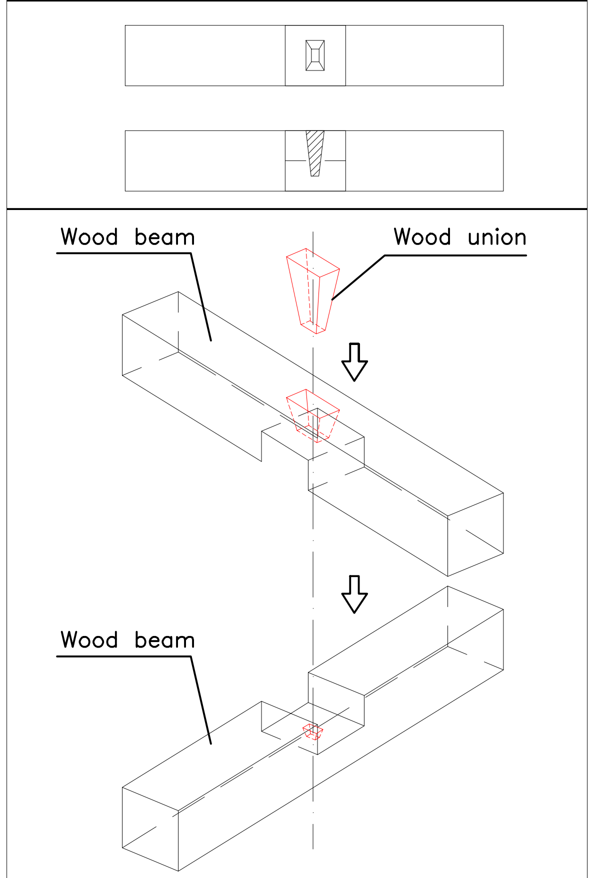
Connection between column and beam



Connection between column and beam



System of connectión between beams

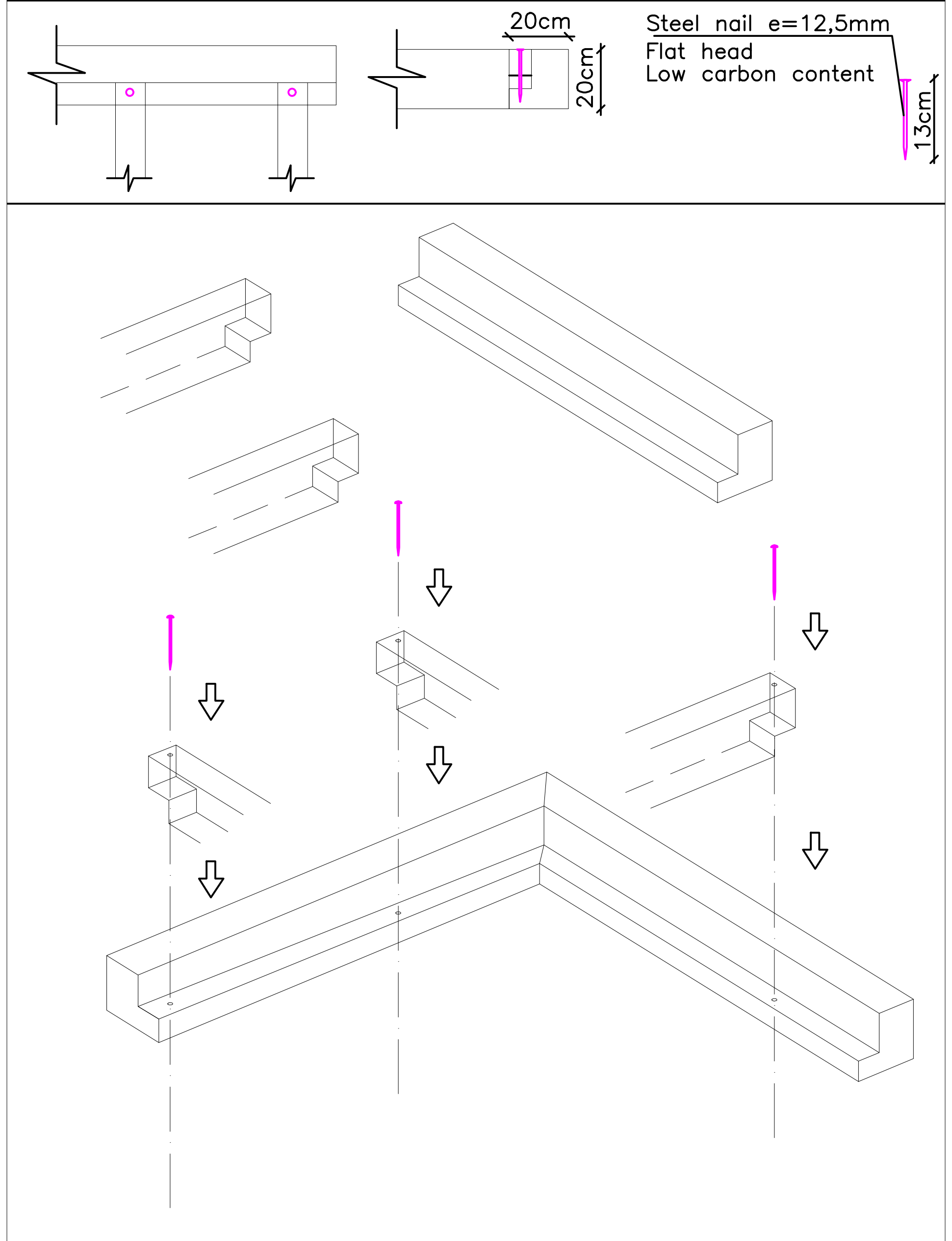


Material

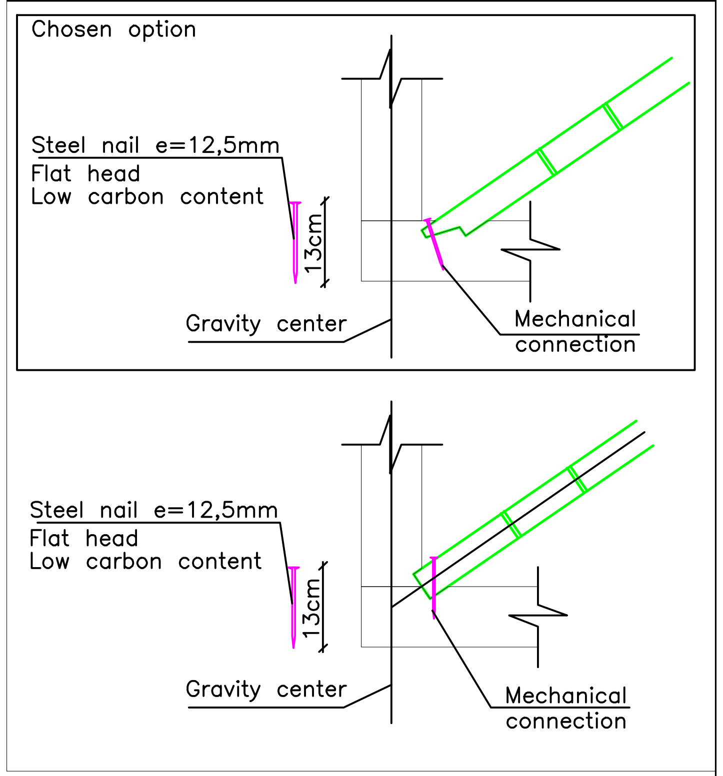
RESISTANCE CLASS OF SAWN WOOD. CONIFER.	
PROPERTIES OF RESISTANCE N/mm2	
Flexión	24
Tracción paralela	14
Tracción perpendicular	0.4
Compresión paralela	21
Compresión perpendicular	5.3
Cortante	2.5
PROPERTIES OF STIFFNESS KN/mm2	
Módulo elasticidad paralelo medio	11
Módulo elasticidad paralelo 5ª percentil	6.7
Módulo de elasticidad perpendicular medio	0.4
Módulo de cortante medio	0.7
DENSITY Kg/m3	
Densidad característica	350
Densidad media	420

CLASE RESISTENTE DE BAMBUSA BLUMEANA.	
PROPIEDADES RESISTENTES EN N/mm2	
Flexión	18
Tensión	4.18
Compresión	18
Cortante	1.1
PROPIEDADES DE RIGIDEZ EN KN/mm2	
Módulo elasticidad paralelo a la fibra	18.4
Módulo elasticidad flexión	17.8
Módulo de elasticidad tracción a la fibra	20.7
DENSIDAD EN Kg/m3	
Densidad característica	300–400
Peso específico	790

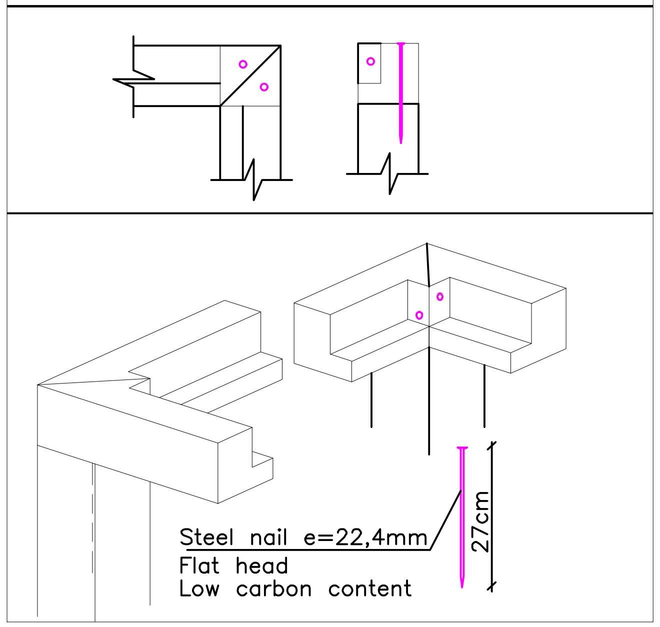
Timber framework for the beams foundation



St. Andrew's cros detail

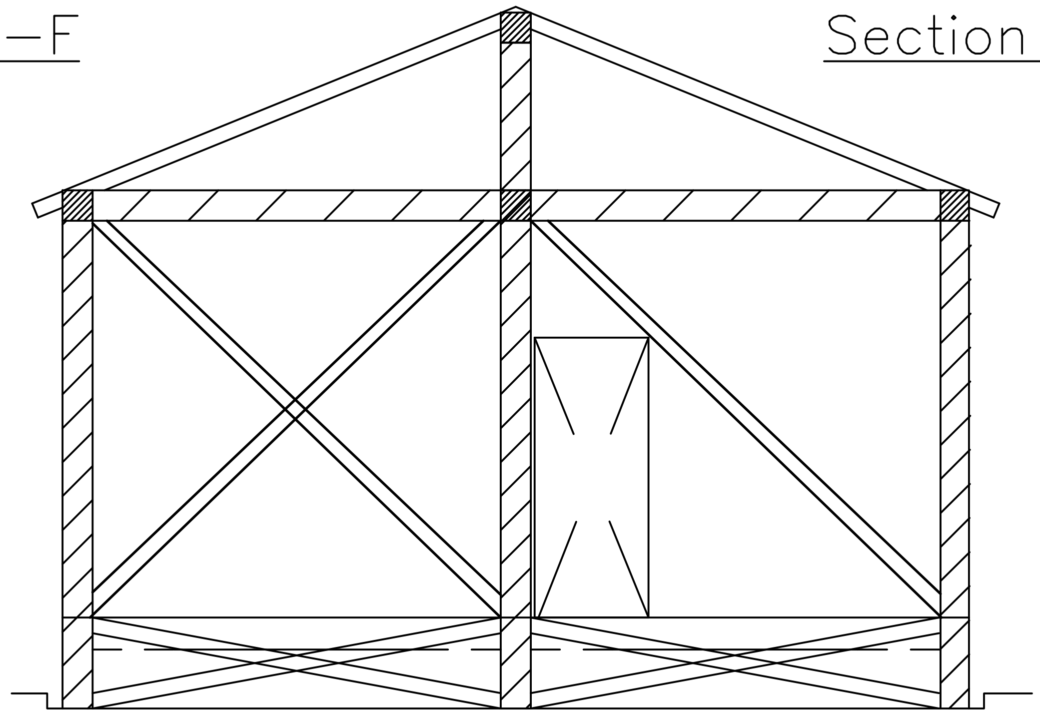


Timber framework for the columns foundation

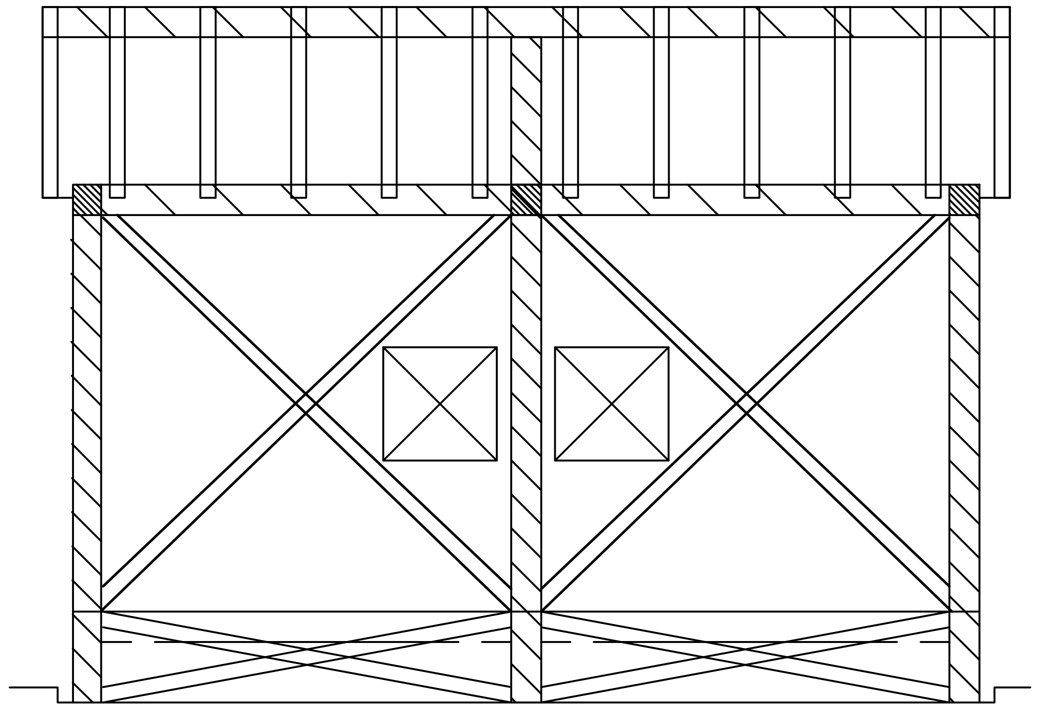


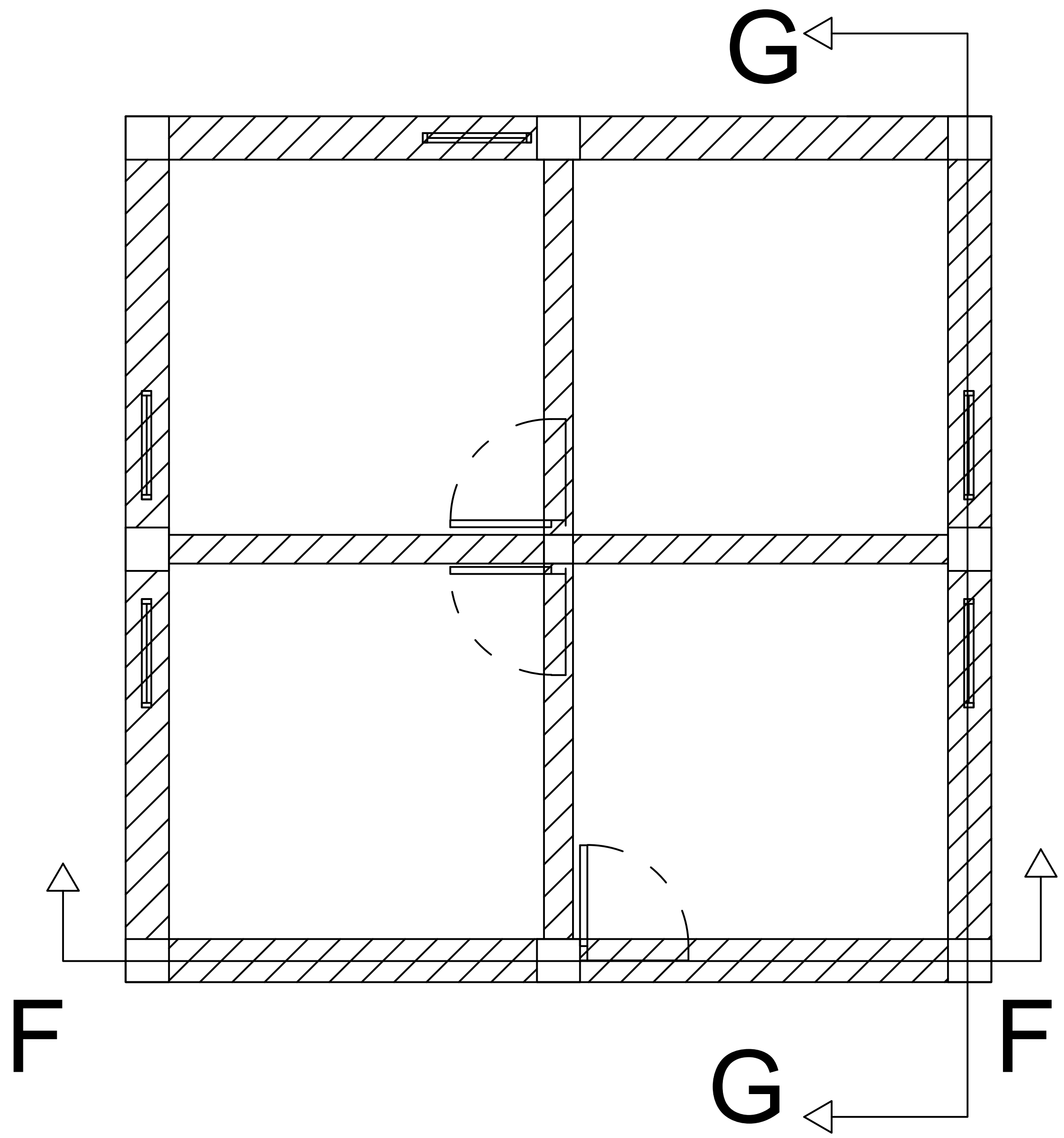
Name	Carlos García Fluxa	*ESCOLA POLITÈCNICA SUPERIOR DE LA UIB*	
Date	02/09/16		
Scale: 1:50		*Plan* 04	Details plan Papua New Guinea
		Grau en Edificació	

Section F–F



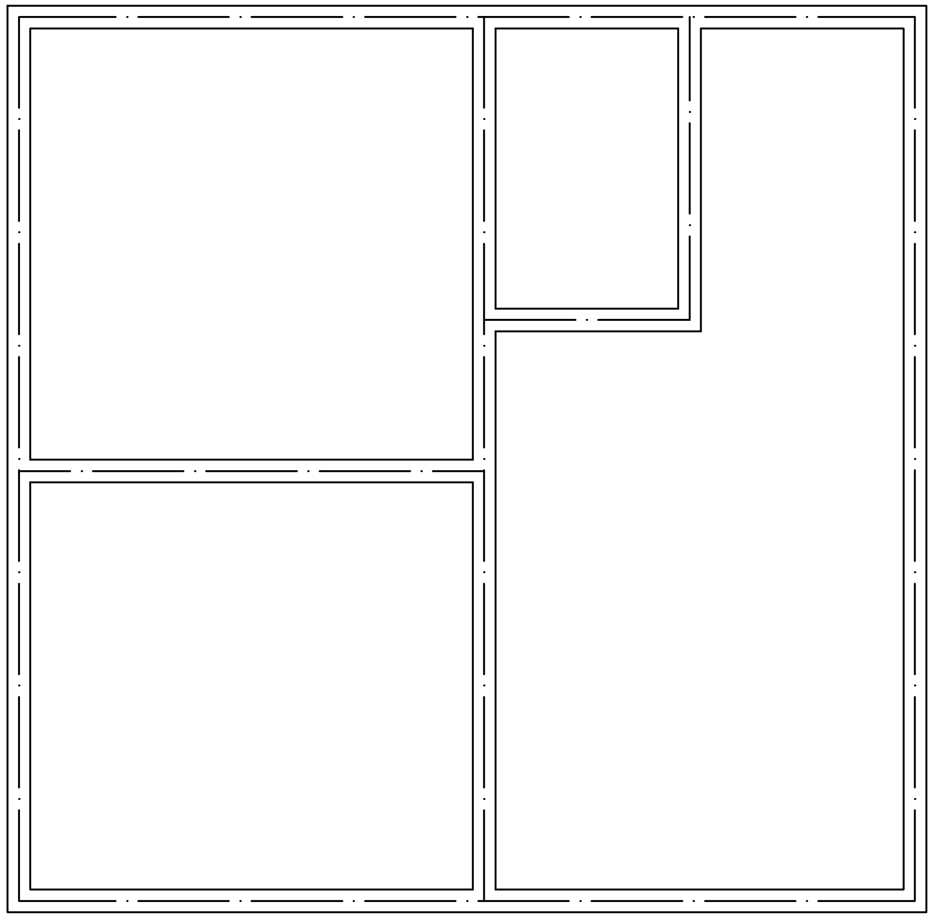
Section G–G



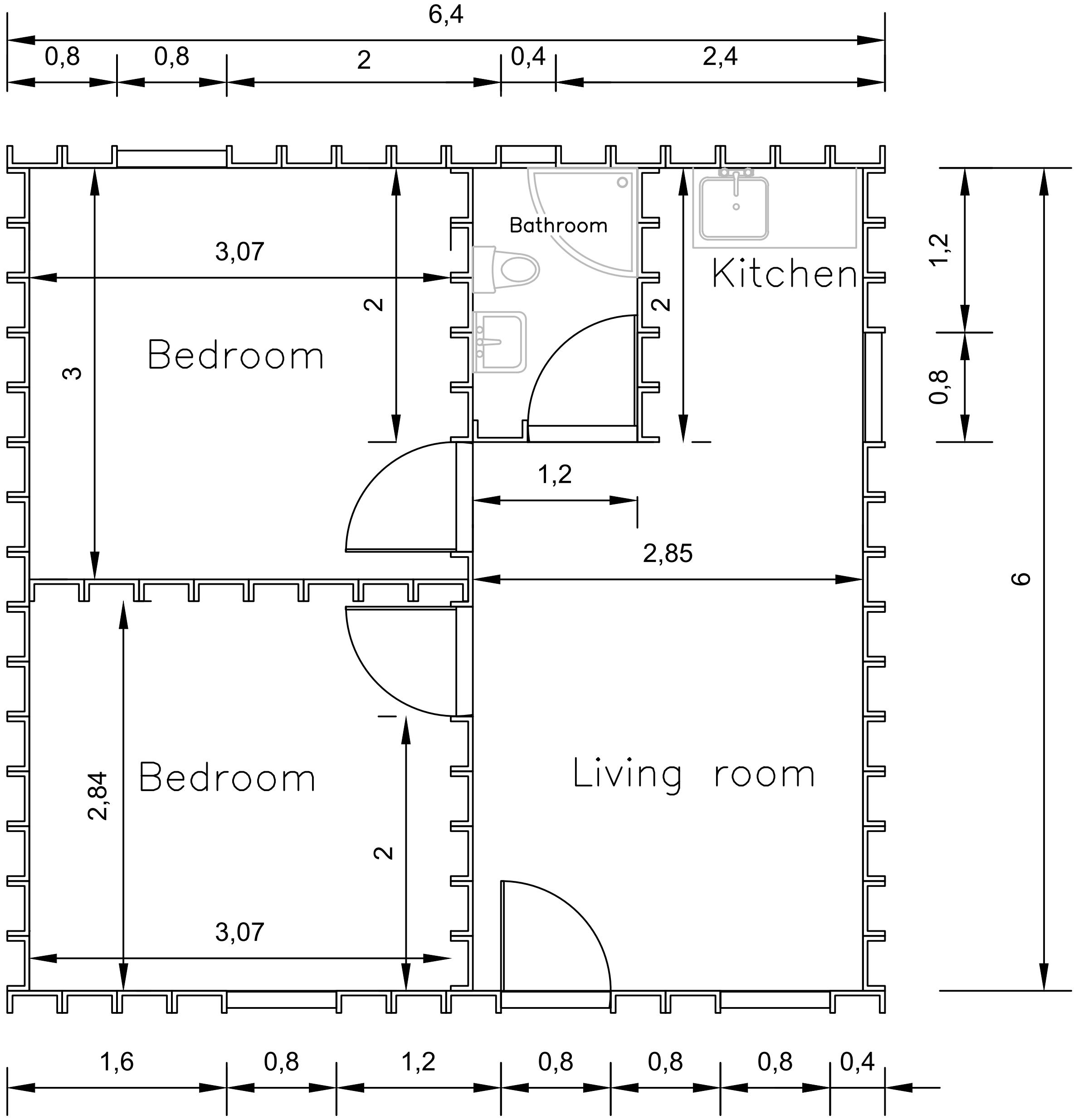


Name	Carlos García Fluxa		*ESCOLA POLITÈCNICA SUPERIOR DE LA UIB*
Date	02/09/16		
Scale: 1:50		*Plan* 05	Structure plan Papua New Guinea
		Grau en Edificació	

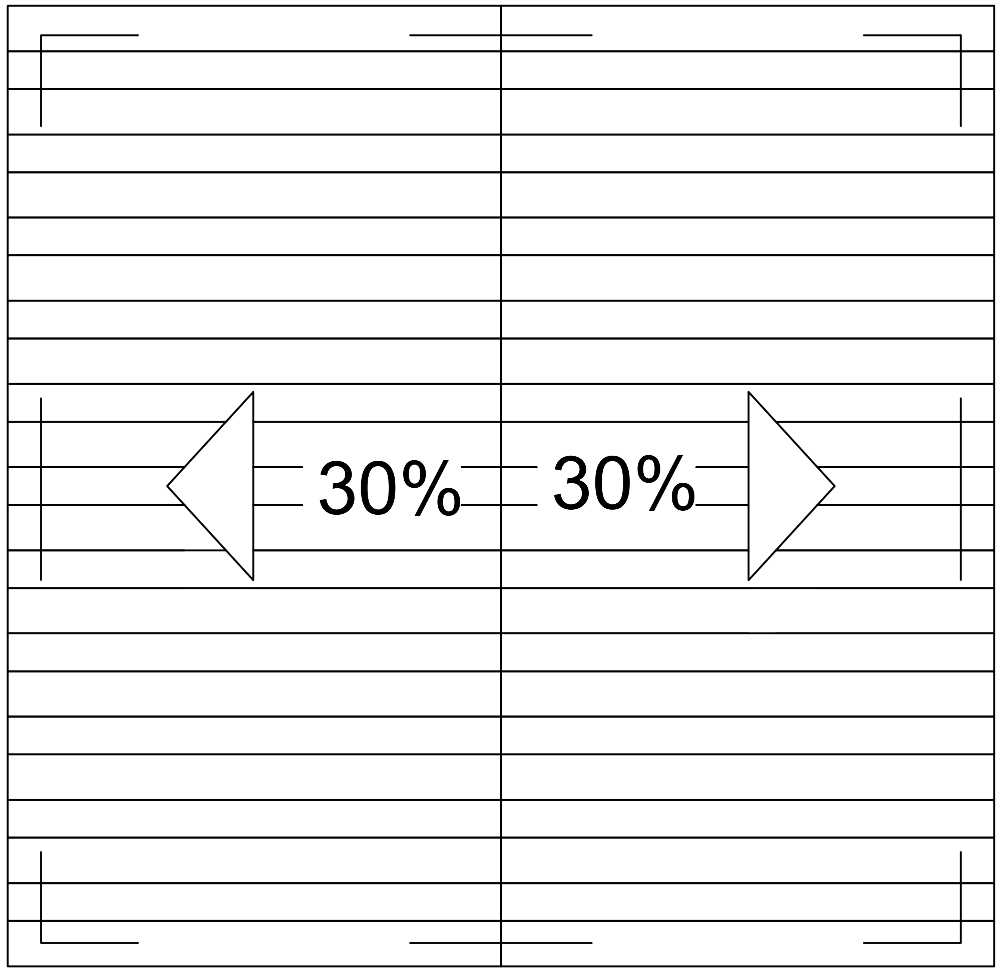
Foundation



Dwelling

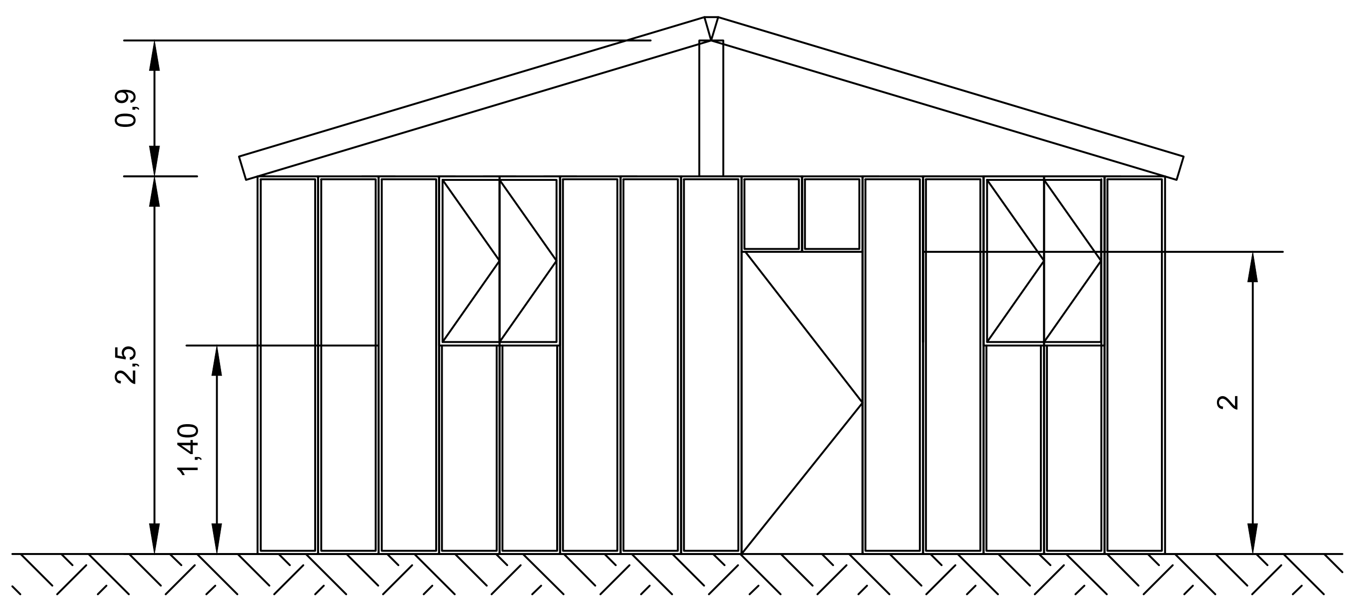


Roof

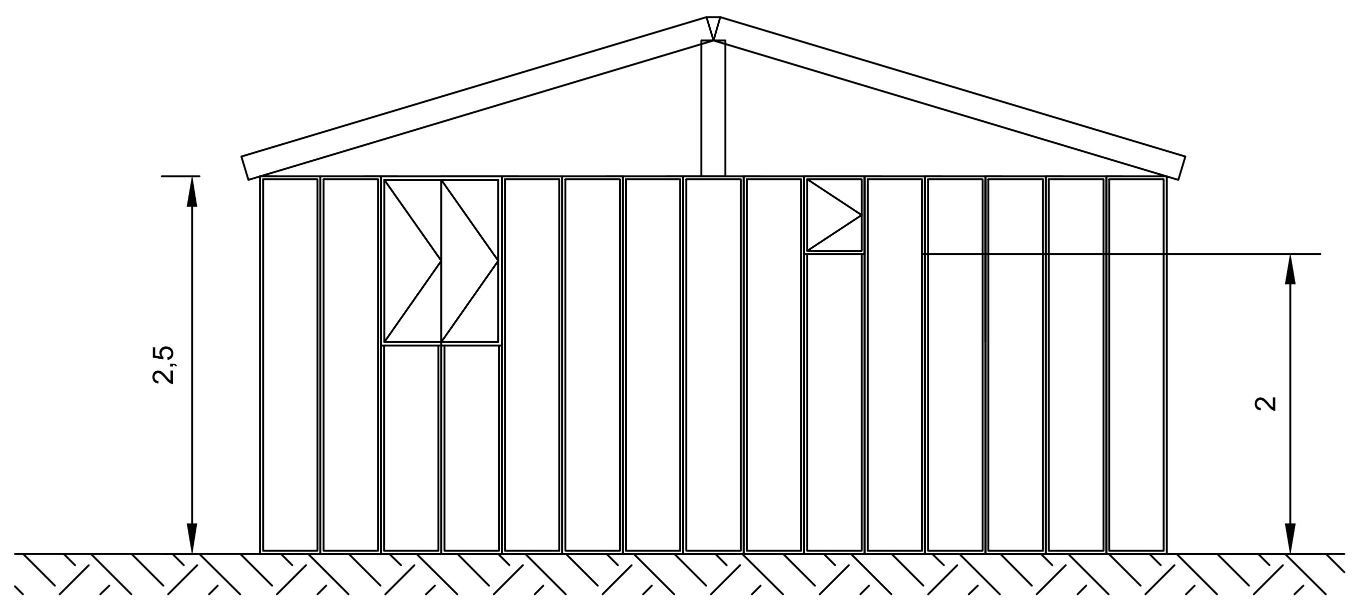


Name	Carlos García Fluxa	*ESCOLA POLITÈCNICA SUPERIOR DE LA UIB*	
Date	02/09/16		
Scale: 1:50		*Plan* 06	Floor plan Bolivia
		Grau en Edificació	

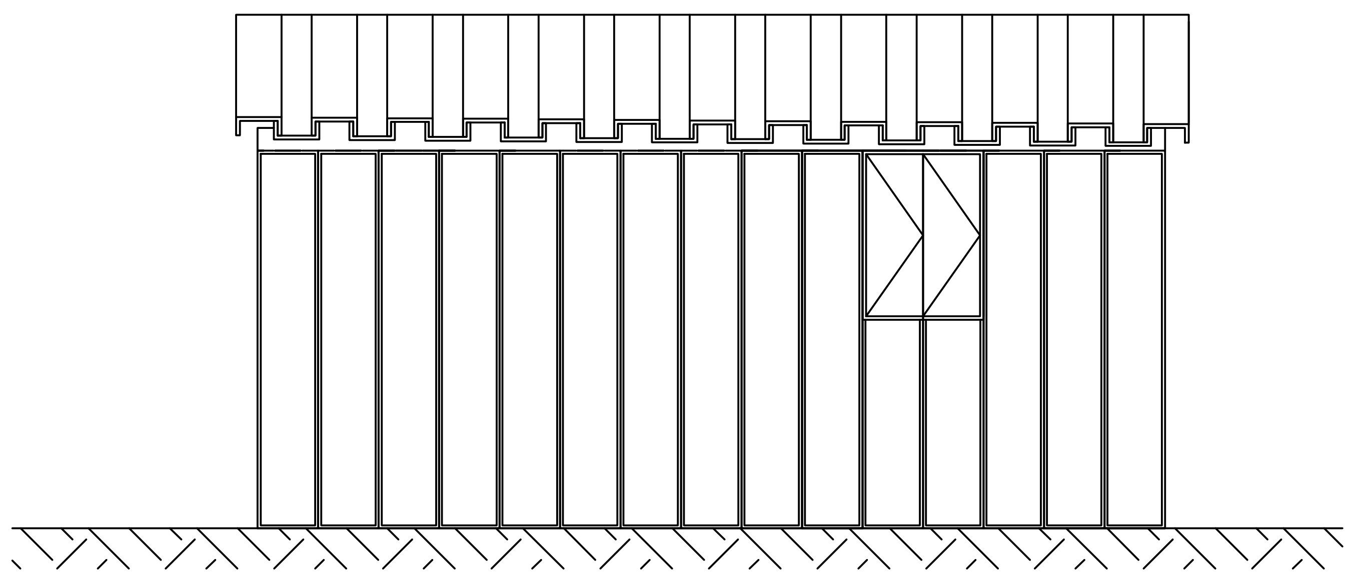
Main Façade
Outline A–A

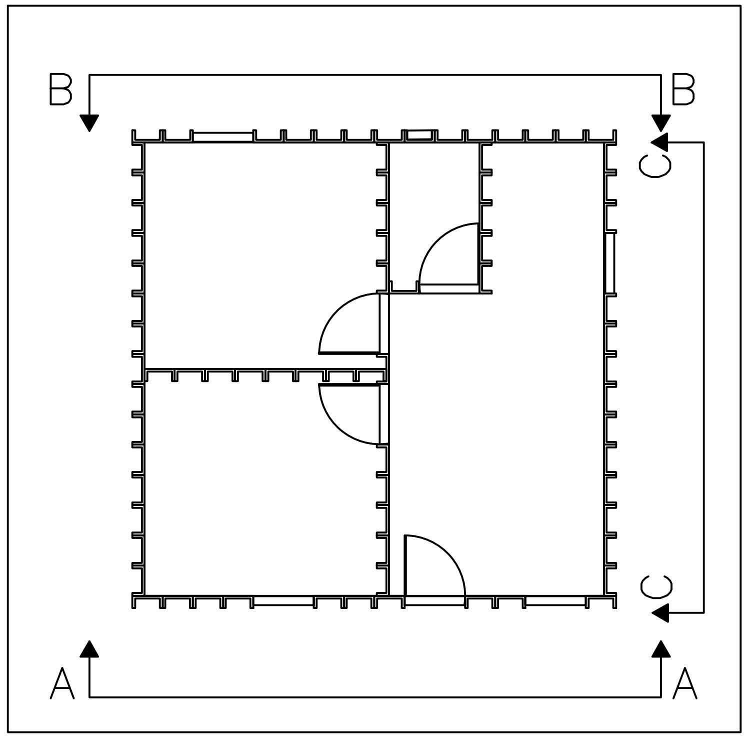


Back Façade
Outline B–B



Lateral
Outline C–C





Name	Carlos García Fluxa	*ESCOLA POLITÈCNICA SUPERIOR DE LA UIB*	
Date	02/09/16		
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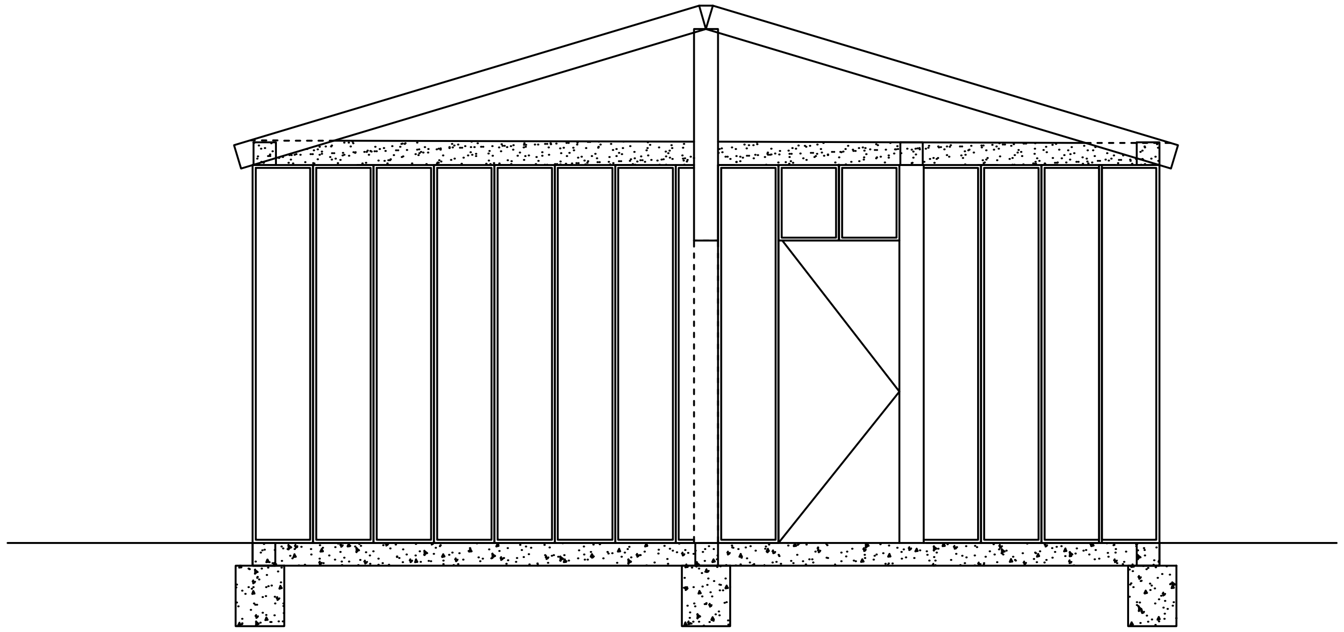
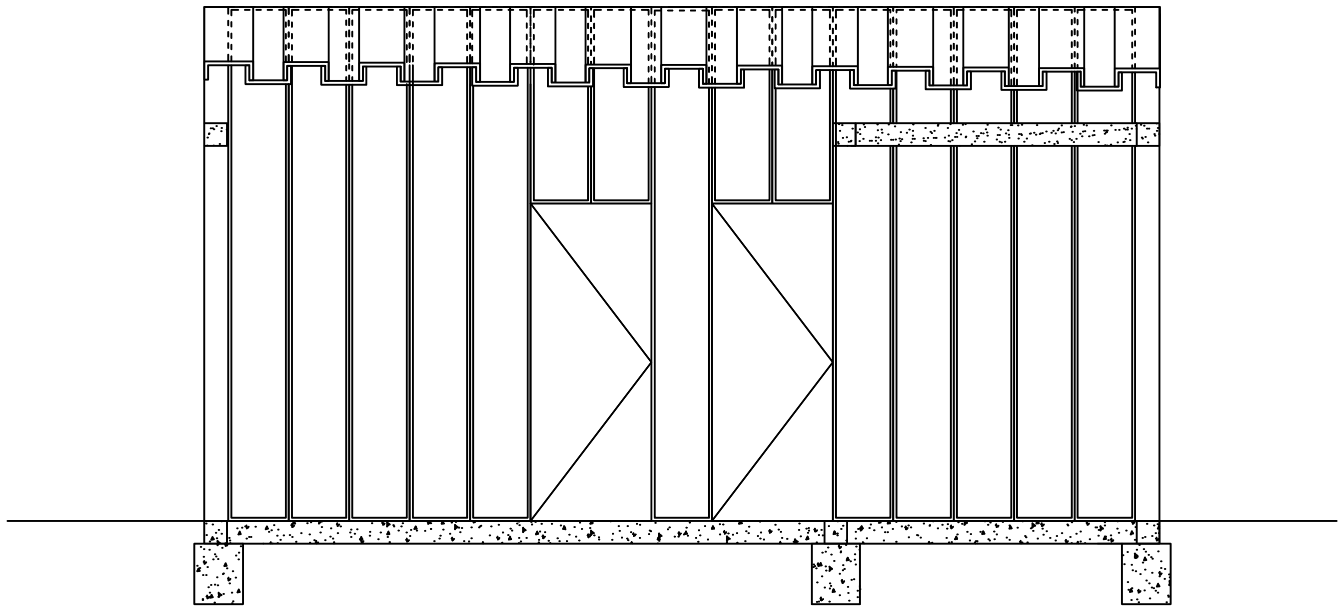
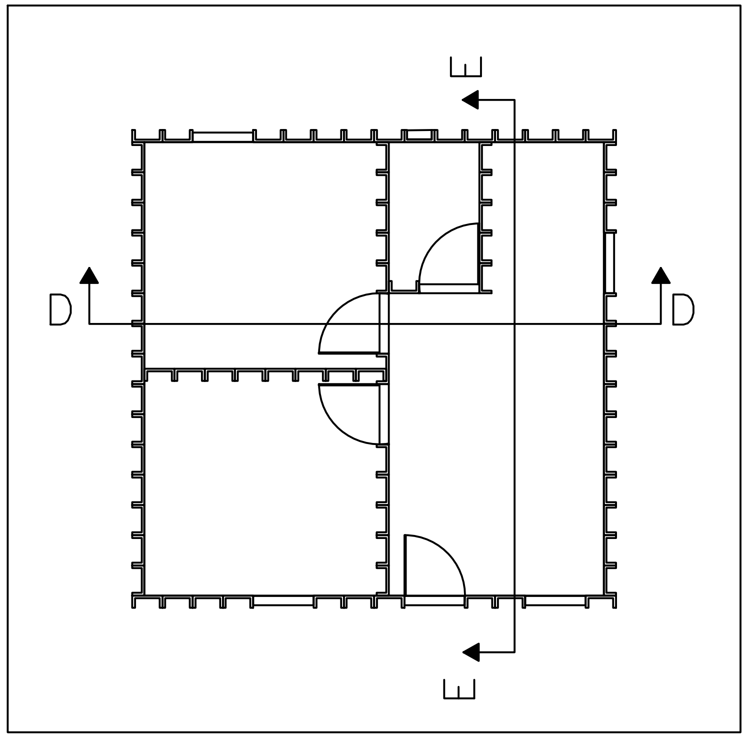
		Grau en Edificació	

Section D–D



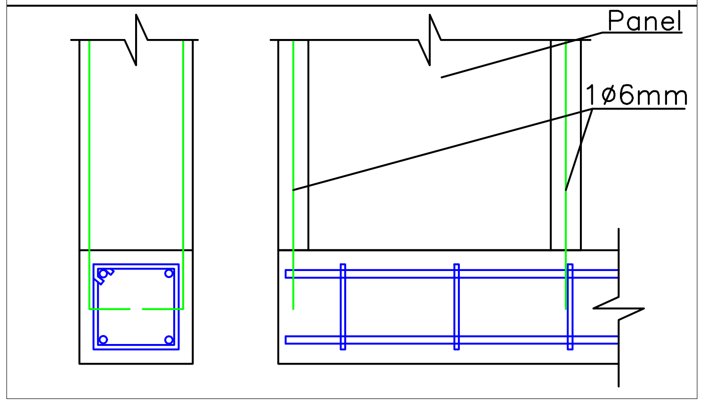
Section E–E



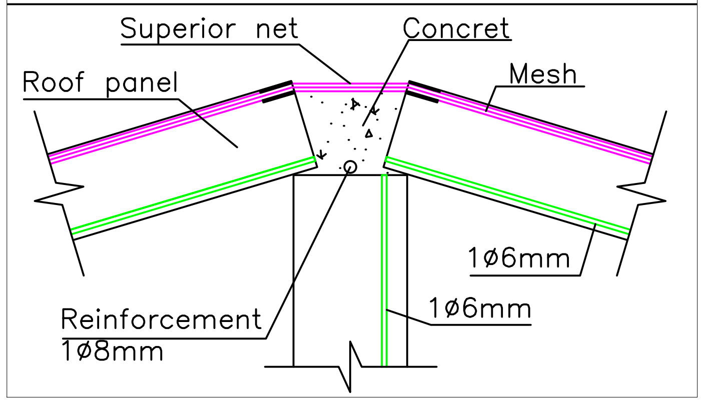


Name	Carlos García Fluxa	*ESCOLA POLITÈCNICA SUPERIOR DE LA UIB*
Date	02/09/16	
Scale: 1:50	*Plan* 08	Sections plan Bolivia
		Grau en Edificació

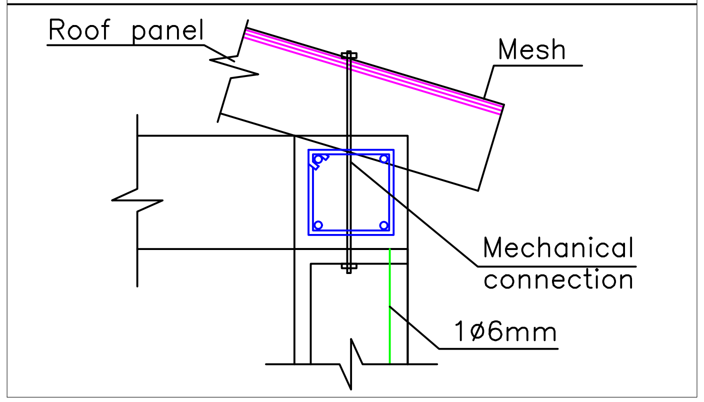
Connection between panels and beam



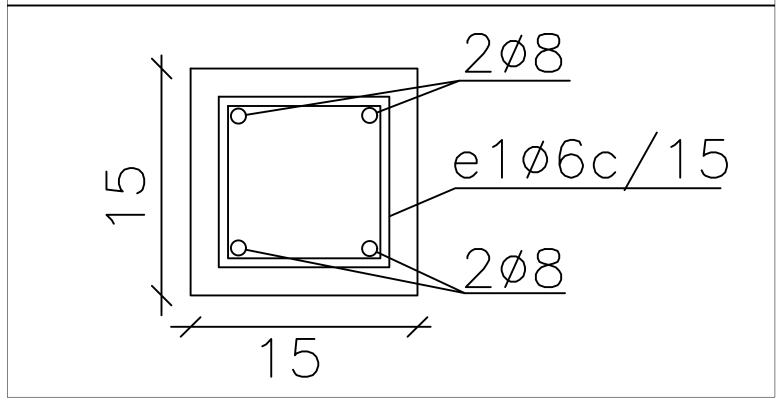
Roofs and top panel connections



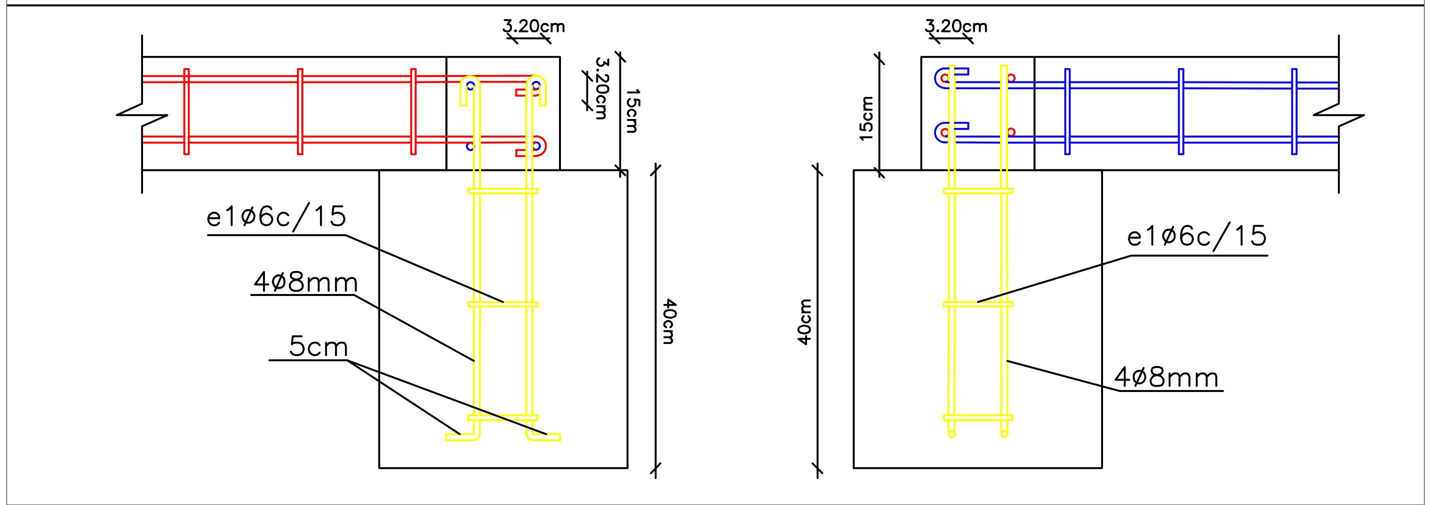
Roofs and side panel connections



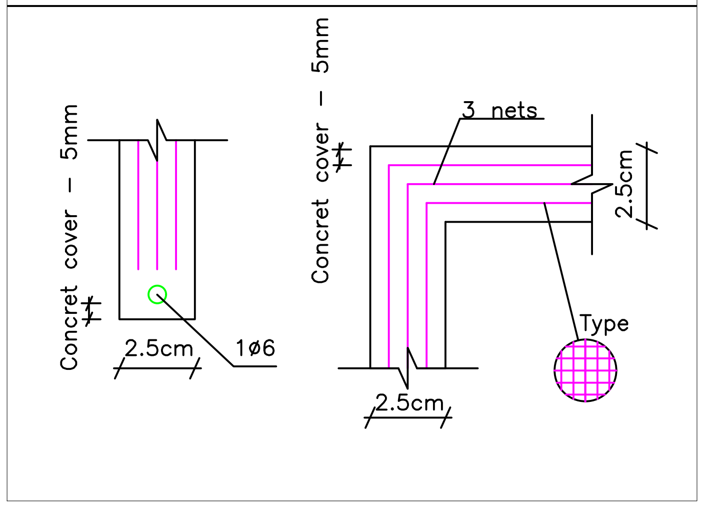
Beam section



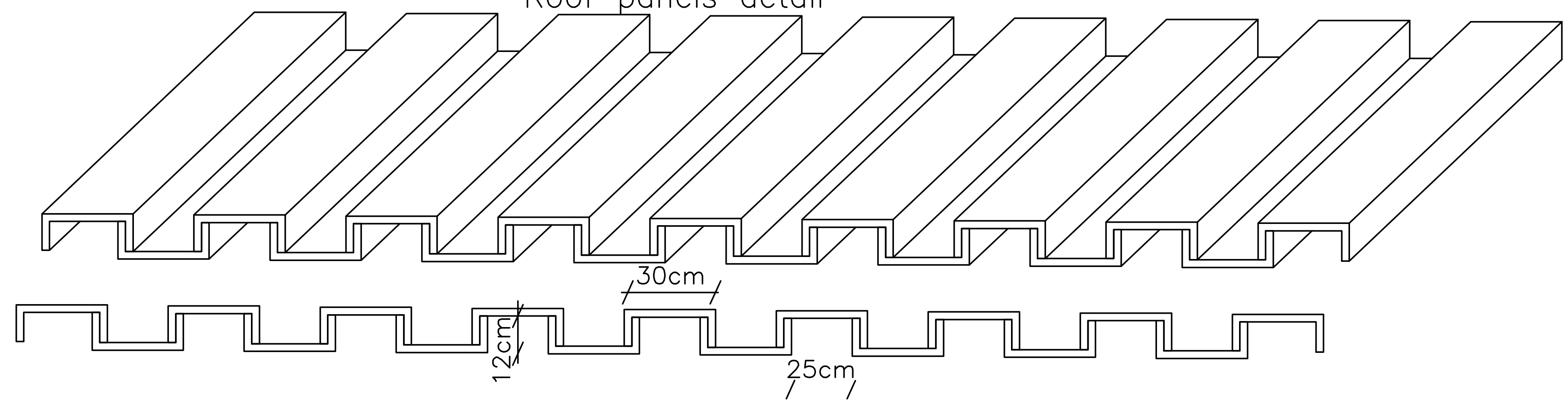
Fundation details



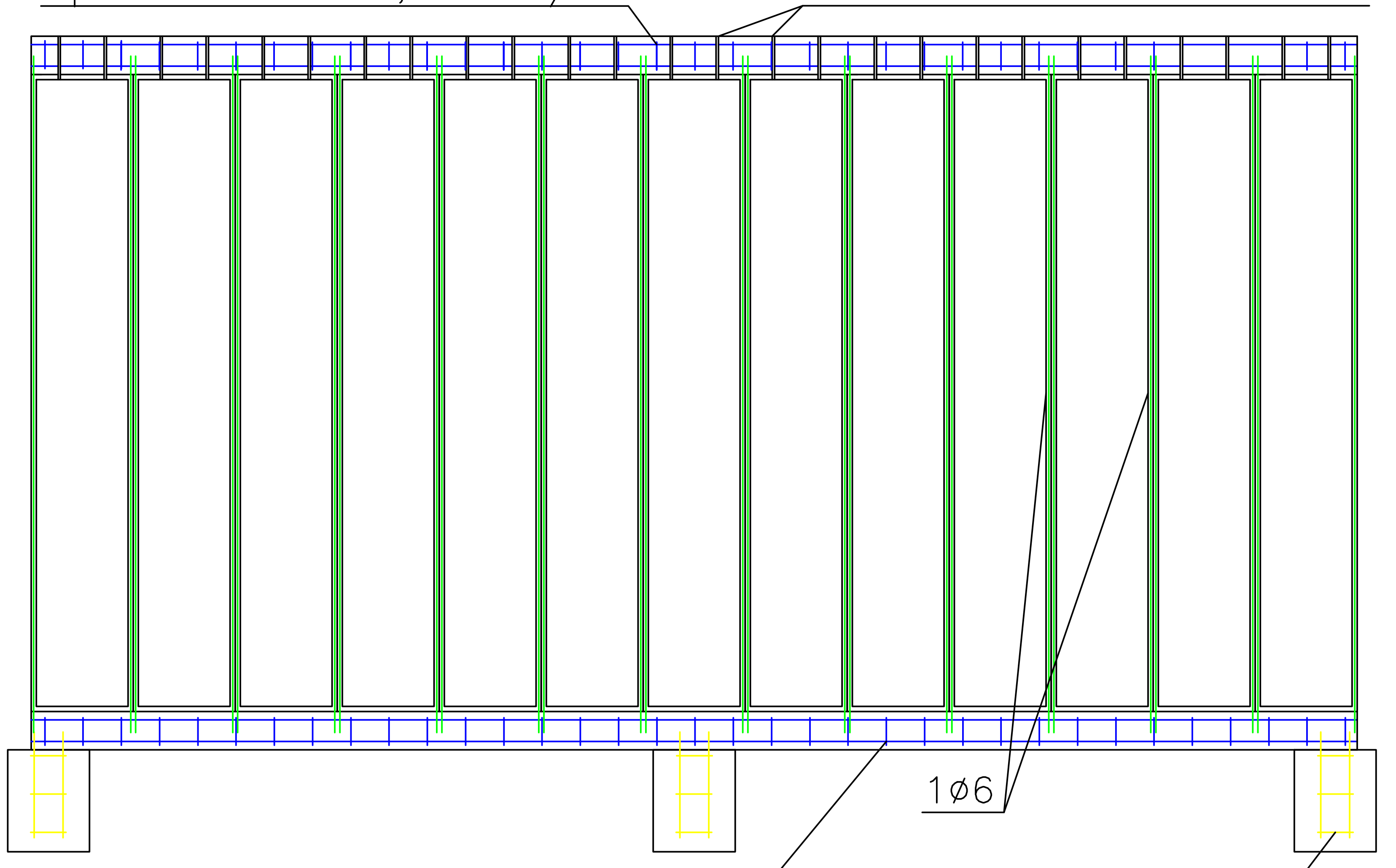
Mesh details

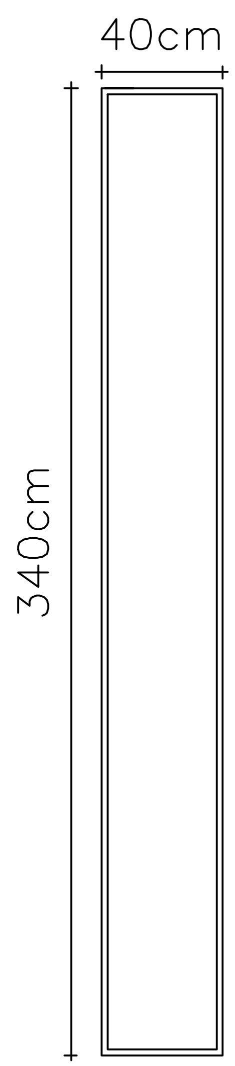


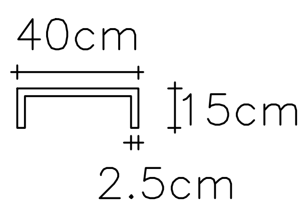
Roof panels detail



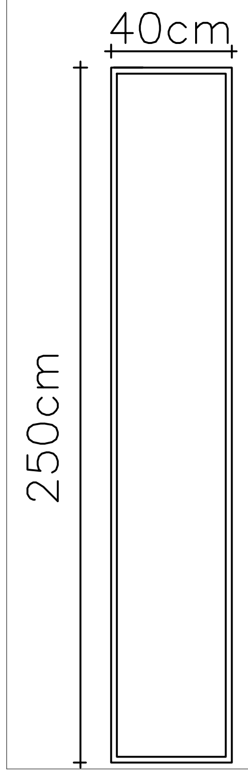
Name	Carlos García Fluxa		*ESCOLA POLITÈCNICA SUPERIOR DE LA UIB*
Date	02/09/16		
Scale: 1:50		*Plan* 09	Details plan Bolivia
		Grau en Edificació	

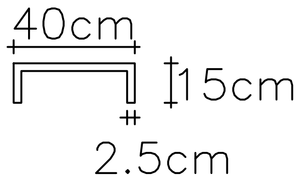




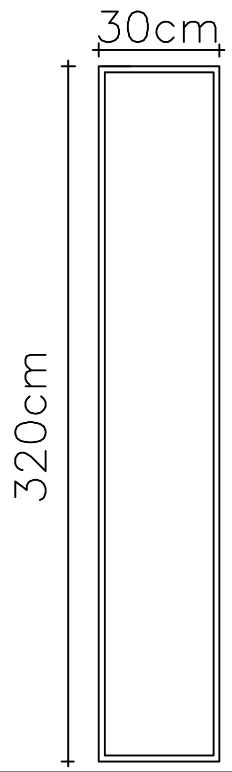


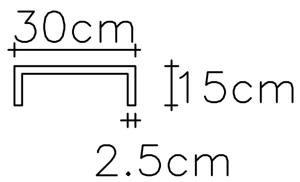
Weight : 139kg
Number : 11
Reinforcement : Square electrowelded wire mesh
fy = 4200kg/cm2
Mortar : f'c = 300kg/cm2
Steel reinforcement : 2ø6mm





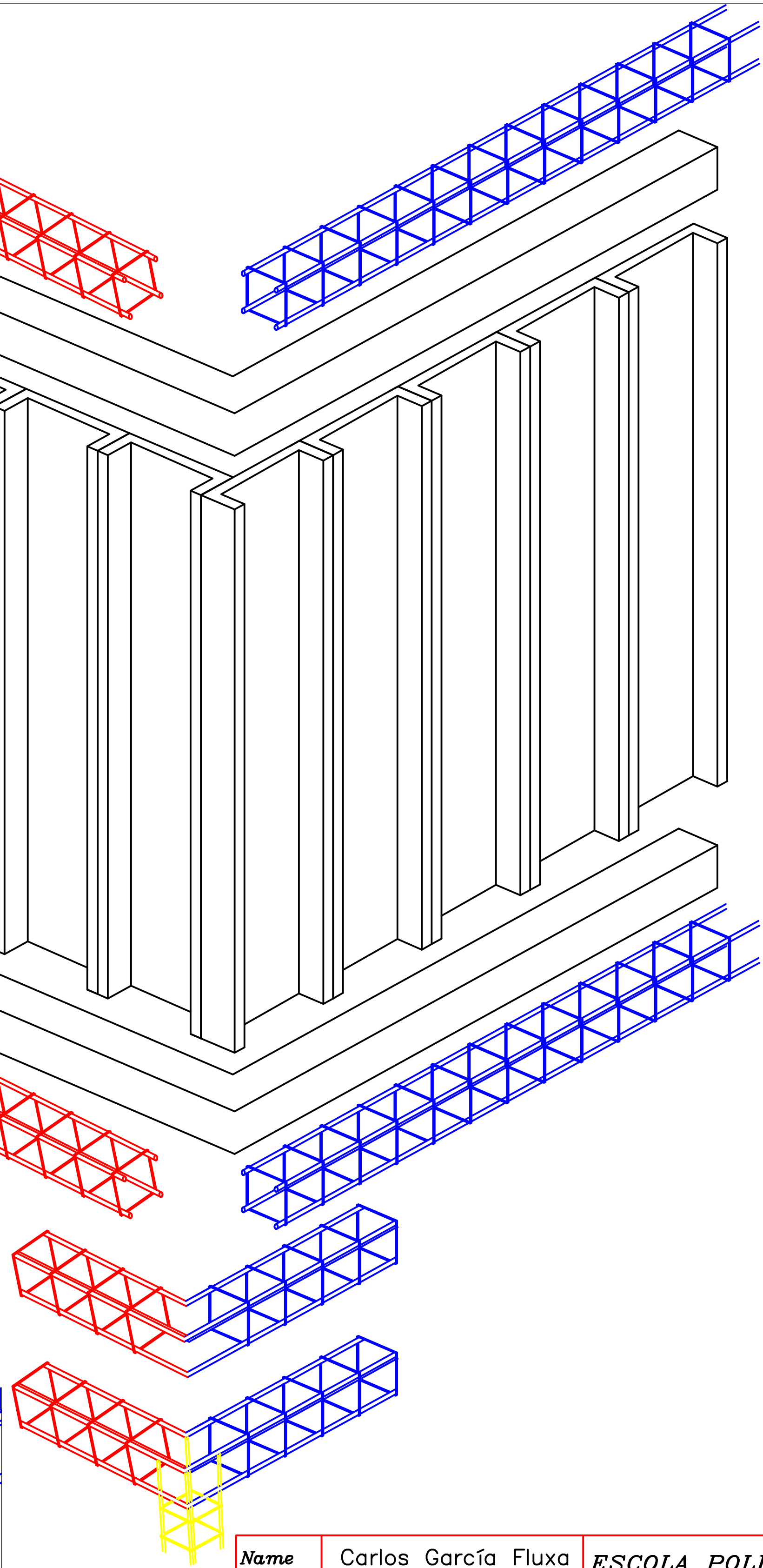
Weight : 102kg
Number : 51
Reinforcement : Square electrowelded wire mesh
fy = 4200kg/cm2
Mortar : f'c = 300kg/cm2
Steel reinforcement : 2ø6mm

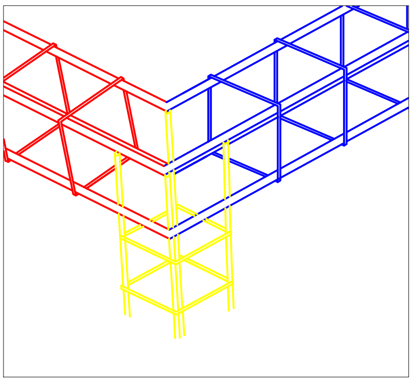




Weight : 132kg
Number : 50
Reinforcement : Square electrowelded wire mesh
fy = 4200kg/cm2
Mortar : f'c = 300kg/cm2
Steel reinforcement : 2ø6mm

Name	Carlos García Fluxa	*ESCOLA POLITÈCNICA SUPERIOR DE LA UIB*
Date	02/09/16	
Scale: 1:50	*Plan* 10	Details plan Bolivia
		Grau en Edificació





Name	Carlos García Fluxa	***ESCOLA POLITÈCNICA SUPERIOR DE LA UIB***
Date	02/09/16	
Scale: 1:50	*Plan* 11	Rods detail plan Bolivia
		Grau en Edificació