POLITECNICO DI MILANO

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Scuola di Architettura Urbanistica Ingegneria delle Costruzioni

RENAISSANCE OF TOKYO-NESS

Prefabricated wooden system to be installed in the suburbs of Tokyo

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Abstract

What does the future hold for Tokyo? The continuous development of the planet's busiest metropolis is incredibly fascinating from the urban point of view. Tokyo's demographic and economic expansion was triggered by the end of World War Two, which led to a fast urbanisation process that was characterised by a never before seen spike in the number of housing needs and complexes.

The major Japanese housing companies responded to this by turning towards prefabricated buildings mirroring Western styles of architecture, which quickly took over the housing market and in the process drastically impacted the capital's traditional traits. The most evident change can be found in Tokyo's fragmentation into several independent centres and commuters' towns, some of which lack any instance of mundane life and therefore serve almost uniquely as dormitories, therefore being labelled as "bed towns".

This new Western trend spread quickly within Japanese architecture and housing market and, lacking a middle ground with Japanese traditions and lifestyle, consequently led to the emergence of several societal issues. The most significant are represented by the frenetic rhythm of daily life in the metropolis, and by the presence of areas and quarters that are aesthetically drastically at odds with the Japanese tradition, therefore creating a sense of discontinuity and estrangement.

Therefore, this thesis aims at filling the gap between modern and new beginning with the *home* itself, without the ambition to propose a definite solution to a contemporary social problem. This is in fact not a scientific question, where a solution can be found starting from Question A and arriving to Solution B. Rather, this being a social concern, a given Question A could be answered by a myriad of different solutions, each part of an evolutionary process that reflects several societal issues.

Beginning with the concept of *housing* itself, this thesis aims at initiating a socio-cultural debate that focuses on the rebirth of Tokyo's "dead areas", achieved through the return to an architectural identity that is currently missing. The thesis's main proposal is that of moving towards a prefabricated model built in wood that, in opposition to the current ones, is much closer to the Japanese traditions and architectural customs. Following from this, the thesis also develops a system that brings together modern building techniques and ancient cultural trends, suiting both contemporary housing needs and the search for identity within traditions.

Abstract

Quale sarà il futuro di Tokyo? Lo sviluppo della metropoli più abitata del pianeta è qualcosa di estremamente interessante dal punto di vista urbanistico. Infatti a partire dagli anni successivi alla seconda guerra mondiale, Tokyo ha vissuto un periodo di grande espansione demografica ed economica, che ha portato ad una rapida ed incontrollata crescita del numero di abitazionioni.

Le principali *housing companies* giapponesi proposero edifici prefabbricati, con stili però più occidentali che popolarono in gran numero il mercato edilizio nipponico e che lentamente mutarono alcuni tratti identificativi della capitale. Il più drastico di questi cambiamenti è evidente nella frammentazione di Tokyo in diversi centri indipendenti, alcuni di questi vere e proprie "bed towns", ovvero aree residenziali nate principalmente come dormitori, dove la presenza di vita giornaliera è assente.

Il nuovo stile occidentale si diffuse rapidamente e, avendo origini molto lontane a quelle tradizionali giapponesi, portò Tokyo a soffrire problematiche sociali importanti, alcune di queste sono rappresentate dai ritmi di vita frenetici imposti dalla città stessa e aree con tratti diversi da quelli originali giapponesi.

Questa tesi vuole colmare il *gap* nato fra moderno ed antico partendo dalla dimora stessa, senza però avere la pretesa di essere la soluzione definitiva ad un problema sociale contemporaneo.

Infatti non si tratta di un quesito matematico, dove la logica porta da una domanda A, ad una soluzione B, ma piuttosto di un problema sociale, dove una domanda A può avere diverse soluzioni, interpretazioni di un processo evolutivo, che possono a loro volta dare vita a nuove questioni sociali. Partendo dal concetto di *housing* si vuole iniziare un dibattito socio-culturale sulla rinascita delle aree morte di Tokyo, restituendo una identità architettonica ormai assente.

La proposta è quindi un sistema prefabbricato in legno, per la realizzazione di unità abitative singole, a differenza dei sistemi esistenti proposti dal mercato nipponico, questo citato ha caratteristiche legate più ai costumi architettonici giapponesi. È giusto però rispondere anche alle esigenze odierne dettate dalla società oltre che preoccuparsi solo delle tradizioni, quindi su questa logica nasce un sistema che lega la tecnica del costruire moderno allo spirito culturale del passato.

1 Introduction

“What incredible pains the fancier of traditional architecture must take when he sets out to build a house in pure Japanese style, striving somehow to make electric wires, gas pipes, and water lines harmonize with the austerity of Japanese rooms; even someone who has never built a house for himself must sense this when he visits a teahouse, a restaurant, or an inn.
For the solitary eccentric it is another matter, he can ignore the blessings of scientific civilization and retreat to some forsaken corner of the countryside; but a man who has a familiy and lives the city cannot turn his back on the necessities of modern life—heating, electric lights, sanitary facilities— merely for the sake of doing things the Japanese way.
The purist may rack his brain over the placement of a single telephone, hiding it behind the staircase or in a corner of the hallway, wherever he thinks it will least offend the eye. He may bury the wires rather than hang them in the garden, hide the switches in a closet or cupboard, run the cords behind a folding screen. Yet for all his ingenuity, his efforts often impress us as nervous, fussy, excessively contrived. For so accustomed are we to electric lights that the sight of a naked bulb beneath an ordinary mild glass shade seems simpler and more natural than any gratuitous attempt to hide it. Seen at dusk as one gazes out upon the countryside from the window of a train, the lonely light of a bulb under an old-fashioned shade, shining dimly from behind the white paper shoji of a thatch-roofed farmhouse, can seem positively elegant.” [1]

This thesis begins as Junichiro Tanizaki did in his "In Praise of Shadows", an essay exploring the link between modernity and Japanese traditional architecture. The author wrote the book in 1933, when Japanese lifestyle underwent a real radical change, and similar questions began to arise. This was a trend that originated in 1853 when Japan, which had existed essentially in isolation from the rest of the world since then, was forced to open its borders to the American *black ships*, which brought of trends of Western thought to the country for the very first time. The clash with Western culture and philosophy marked the Eastern world in an irreversible manner, affecting language, food, clothing, and especially the way of living. In modern day Japan, the emotional bond between the past and the present is still very strong, with ancient uses and costumes sharing the daily reality of Japanese cities with modern styles, creating a paradox that has become the true strength of Japan.

The contrast created by these two elements is very evident, but it also acquires a logic of its own in cities like Tokyo, Osaka and Nagoya. These urban centres in particular were at the core of socio-cultural evolution during the second half of the 20th century, when the pace of progress became so fast that it bypassed what would be the middle stages of every evolutionary process.

This unprecedented speed of change was embodied by the *baby boomers* generation, who moved from one shore to the other without going through the normal evolution phases that would normally act as interface. Let us imagine that one wants to pass from one side of a river to the other; a bridge able to connect two extremes would normally be built in order to do this. However, in Japan this process has occurred in a different way, with generations being almost teleported from one bank to the other without realising, and being left with the need to find a connection to fill that gap. In particular, when it comes to living and *experiencing* the house, the gap between the past and modern times is something that has not been possible to bridge in Japan yet, as there is missing link in the evolutionary process that will have to be filled eventually.

Tanizaki's tragicomic opera can therefore be understood as a real tribute to the traditional features of the Japanese House. One of the focal points underlined by the author, which it is often hard for Western people to understand, is the desire of the ancient masters to create spaces of shadow:

In temple architecture the main room stands at a considerable distance from the garden; so dilute is the light there that no matter what the season, on fair days or cloudy, morning, midday, or evening, the pale, white glow scarcely varies. And the shadows at the interstices of the ribs seem strangely immobile, as if dust collected in the corners had become a part of the paper it self. I blink in uncertainty at this dreamlike luminescence, feeling as though some misty film were blunting my vision. The light from the pale white paper, powerless to dispel the heavy darkness of the alcove, is instead repelled by the darkness, creating a world of confusion where dark and light are indistinguishable. Have not you yourselves sensed a difference in the light that suffuses such a room, a rare tranquility not found in ordinary light? Have you never felt a sort of fear in the face of the ageless, a fear that in that room you might lose all consciousness of the passage of time, that untold years might pass and upon emerging you should find you had grown old and gray? [1]

Here can be seen how Japanese architecture is much closer to philosophy than its Western counterpart, as its environments and spaces are designed to purposely stimulate an introspective analysis. The aim is to please the depth of the soul through simple elements: as the shadow represents the absence of light, Japanese architecture mirrors the absence of something, with space being defined by the absence of a perimeter. The concepts of space, environment and dwelling are then very different from the Western ones, and often an eye poorly trained cannot grasp what is hidden behind the absence of an architectural element.

On the one hand there is the issue of the Japanese dwelling destined to disappear, on the other there is Tokyo and its 37 million inhabitants. The Japanese territory is fragmented in 6852 islands, leading this concept of separation and remoteness to clash with the highest rate of population that makes the inhabited centres the most densely populated in the world. Japan's population is therefore grouped in locations that are currently filled to the rim, with only 31% of the soil being liveable, a little more than 5% of the soil is inhabited. [2]

Mirroring the Japanese territory, even Tokyo sees its urban fabric fragmenting in a multitude of satellite centres, packed with architectural structures. Because of this, living in Tokyo also means living in different cities, which comes with being part of this spatial fragmentation. Therefore, subscribing to Tokyo's identity means having a multitude of identities. This is precisely what is meant by Tokyo-ness, Tokyo's architectural identity. Arata Isozaki had coined the term *Japan-ness* to define the most characteristic features of Japanese architectural dimension. Tokyo is a reality so evolved that, when compared to the rest of Japan, today we can speak of a kind of Tokyo "true style", where Japan-ness has become a Tokyo-ness.

But what happens when an area is not able to acquire a characteristic trait to distinguish itself within Tokyo's broad and varied wealth? It simply dies. This begs the questions, is it possible to revitalize the various dead centres– areas of the capital? This thesis proposes a system that does not have the pretence to be the solution to the problem, but rather the beginning of a socio-cultural debate, a pattern of evolution. Going back to this ever changing concept of identity, starting from the house is the key to change as, besides changing the aesthetics of a district, it affects the way to live a place.

Tanizaki's work, after praising the uniqueness of the Japanese way of living the house, comes to an abrupt conclusion: it is impossible to live the spaces of the traditional Japanese house in a modern, more Western way. This thesis aims to address this final statement and try to re-propose it in a modern key. 84 years, almost a century, of changes have gone by from 1933 to 2017, with technologies evolving and styles consequently changing, Japan has learned how to live this mixture of styles in a balanced way. Therefore, is it possible to give life to spaces showcasing a Japanese soul realized by means of technologies more linked to a Western world?

2 Tokyo historical and geographical analysis

2.1 From the past to the modern age

There is no memory of the birth of Tokyo; some historical documents indicate that in 2000 B.C. these lands were already inhabited by fishing populations. To understand the arise of Tokyo, first, it is necessary to know the political-military history that radically changed Japan.

In 794 B.C., the capital of the Kingdom was moved from Nara (Heijō-kyō) to Kyoto (Heian-Kyō) and there it remained until 1868. This period is considered the golden age of Japanese culture, especially because in this historical period Shintoism welcomed and integrated both Buddhist doctrine and Zen philosophies, giving rise to new artistic movements, unique in the world. Towering pagodas were erected near the wooden Shinto temples, the artisans began sculpting wooden statues representing the Buddhist masters of the past and the classical Japanese painting turned to brighter, more colorful representations of nature, inspired by the mandala tradition.

However, in the artistic and cultural explosion this time was principally marked by the fragmentation of the Emperor dominion: the imperial dynasty primarily focused on issues concerning the power and family prestige, without giving due importance to the people's problems and demands. Wanting to increase their military power, the Emperor increased taxes on nationalized lands, that is, those owned by the State; this act, anyway, led to the opposite effect, i.e. the rural villages, far from the capital, oppressed by the tax increase, gave rise to revolutionary movements to demand independence.

There was, however, a need to manage this revolutionary movement and above all to defend the lands from a sudden attack by the Emperor, so the villages decided to entrust the management and control of the land to the local feudal lords. This occurred sporadically throughout the whole country until, in the year 1000, the noble families had to manage more lands than the imperial power itself and the lost taxes could no longer ensure the management of a large national army. Although, on the one hand, the military power lying with the emperor was decreasing, on the other the military power in the hands of feudal lords was growing, in fact with the earnings coming from the management of lands, the noble families managed, over time, to create their own small army, mainly made up of samurai warriors.

In an always changing context power struggles unfolded for more than 500 years, some families allied with the Emperor, others went on struggling for independence. Japan was completely divided and fragmented in different lands, and the city of Tokyo was born from this general chaos.

Fig. 2.1.1 Old map showing the division of Japan

Fig. 2.1.2 Gyoukizu map, the division of Japan

The first intervention in Edo took place during the Kamakura period (1185-1333) by the military governor Edo Shigenaga, who decided to build an important military outpost and, in 1457, the famous Edojuku Castle [3].

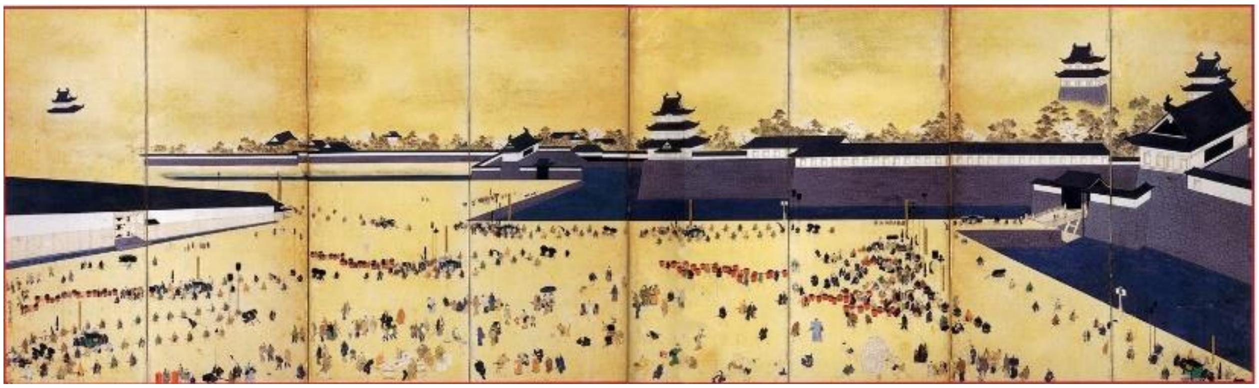


Fig. 2.1.3 Painting of Edojuku

Subsequently, in 1590, the military General Tokugawa Ieyasu chose Edo as military base and Edojuku Castle as their headquarters. Tokyo became a major player in the history of Japan since 1603 when Tokugawa I., after winning the battle of Sekigahara, became shogun, and started the Edo period. The situation was more stable than before, but still critical: Theoretically, the power rested in the Emperor's hands, and Kyoto was the capital city, but, in practice, the real decisions were taken by the Shogun and Tokyo was the most booming city in those years. A period of expansion and growth began, but strictly linked to the city, in fact the Tokugawa shogunate imposed a total ban on trade between Tokyo and the rest of the world, closing the borders of the country, until the arrival of the Americans in 1853. In 1721, Edo became the most populous city all over the world, with an estimated population of 1.1 million people. [3]

The only adversities that halted the city's progress were surprisingly the natural ones, such as Mount Fuji's eruption in 1707, which covered Tokyo with ash, the Great fire of 1657, which caused 100'000 deaths and destroyed two thirds of Edo and the great Edo earthquake in 1855. [4]

Fig. 2.1.4 Ancient rappresentation of Tokyo great fire

The shogunate's power ended in 1868, when imperial troops entered Edo, defeating Tokugawa forces. Emperor Meiji, then only sixteen, was transferred, together with the imperial family, from Kyoto to Edo, renaming Edo as Tokyo, which means Eastern capital. It is interesting to note that the famous Edojuku Castle, which gave fame to the small village of Edo, became the imperial palace, and has continued to be so until today.

Fig. 2.1.5 Painting of Edojuku

What happened next is still hardly explainable: large numbers of people left the city of Tokyo, from 1.3 million people living there at the beginning of 1800, the population dropped down to 500'000 people in 1869. After this period of population decline, anyway, once the Emperor's power was put in place, there was an impressive increase in population that brought the city of Tokyo to have 2 million residents in 1905. [5]

These numbers help to explain the possible difficulties in managing the plan of a city that changes so quickly over time. A solution to the population management, still used nowadays, was to divide the bureaucratic power of Tokyo in different city wards, namely self-sufficient satellite towns; The capital was divided in the first 15 wards in 1889.

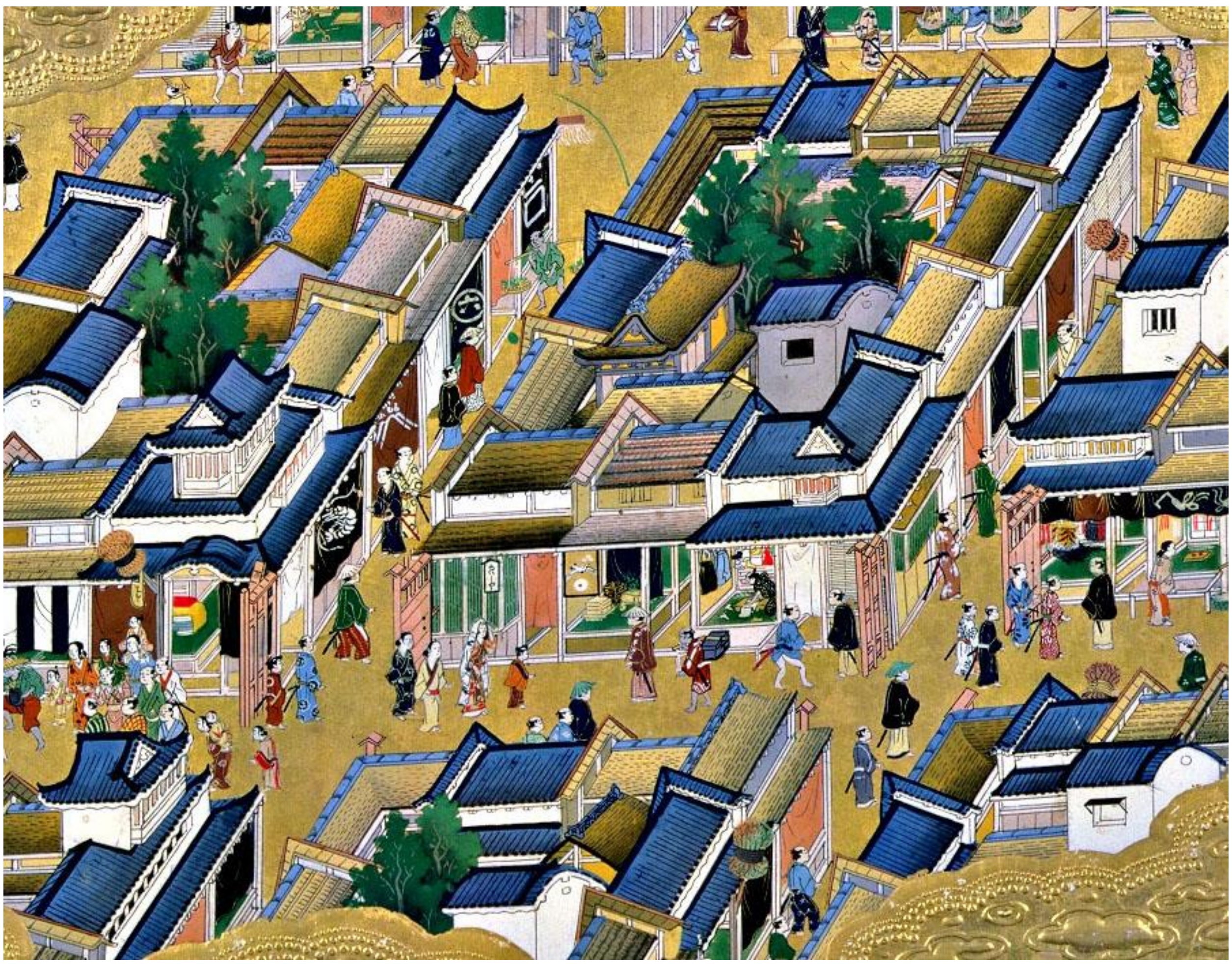


Fig. 2.1.6 Life in Edo

2.2 XX century

Japan opened to the Western world in the Meiji period, and this led to an important economic growth. From 1870 to the 1980s, Japan grew economically, going through a hard stop only because of World War II, which brought the whole country to its knees.

During the 20th century, two historic events most impacted the city, the first occurred in 1923, the great Kanto earthquake. At noon on Sunday, 1st September, the Earth began to shake, the epicenter was about 80 km south of Tokyo, the magnitude 8.3 on the Richter scale: the city fell into complete chaos. First, the earthquake caused a tsunami, with waves up to 12 meters, sweeping through the city of Yokohama and destroying all the buildings along the coast. [6]

Fig. 2.2.1 Yokohma the day after the earthquake

Moreover, the earthquake struck at lunchtime, when many families were cooking their meals and when most of the city burners were lit; this caused several fires that were able to spread across the city that had a high concentration of wooden buildings. In those days, in addition to the earthquake, a large typhoon hit the city, blowing on the flames that were burning the different parts of the city, and contributing to the fire extension. The nightmare of the flames ended just two days later, when most of the buildings were carbonized and there was nothing left to burn.

The streets were burning and the asphalt melted, people were unable to escape and were trapped in the area, before being burnt alive, a tornado of flames carbonized 38’000 people in a single blaze, the city had fallen into complete chaos. It provoked 142’000 dead and 37’000 missing people, 75% of the buildings suffered irreparable structural damage: Tokyo City was literally razed to the ground by an earthquake. [7]

Fig. 2.2.2 Tokyo after the earthquake

The consequences were different, it was suggested to move the capital to Kyoto or to Seoul, then under Japanese rule, but it was decided to rebuild again from scratch, as in the past, around Edojuku Castle, built 500 years before. Gotō Shinpei, Home Affair Minister at the time, organized Tokyo reconstruction plan with modern networks of roads, railways and public transport services. The parks were rethought throughout Tokyo as places of refuge and the public buildings were designed with security constraints greater than private ones, to host refugees. Two-storey wooden buildings were replaced by concrete and steel buildings of five and six floors, the first subway was opened in 1927 and the new airport in 1931. In 1935 Tokyo reached 6.36 million inhabitants and the city was wider than before the earthquake. [8] Even today, in all the parks in Tokyo, a melody is played at 6.00 o'clock p.m. to test the alarm system in the whole city.

Therefore, once again, the city of Tokyo saw a radical change of its urban fabric and it was especially fast, considering the time frame of 10 years. All this was turned upside down once again when Japan decided to enter the war. Firstly, Tokyo geared up for fight: factories were built for the production of armaments and ammunition, scattered along the entire urban area. After the attack on Pearl Harbour in 1941 and the beginning of the war between Japan and America, Tokyo was bombed. On April 18, 1942 the capital was the first city to be attacked from the air, and the bombing lasted for some 3 years. The population suffered from hunger, artificial rice fields were raised across the city; nowadays it is still possible to admire a little lake in Ueno Park, formerly used to feed the entire East Tokyo area.

Fig. 2.2.3 Tokyo after the bombing

The military Government equipped to defend against the attacks by realizing several anti-aircraft stations but they could do nothing against the great bombing on the night of March 9th, 1945. In fact America sent 325 fighter bombers that, flying at very low altitude, managed to circumvent Japanese anti-aicraft fire. 1665 tons of incendiary bombs were dropped, killing 100'000 people, burning 45 square kilometres of land. The strategic bases were no longer attacked, carpet bombing were carried out to frighten the civilian population and compel the workers who worked in armament factories to escape. About 7.4 million inhabitants fled from Tokyo during World War II, It was back to square zero, once again. [9]

Fig. 2.2.4 Tokyo after the earthquake

But during the war, in 1943, Tokyo underwent a transformation as regards the administration of the city, in fact, both Tokyo city and Tokyo prefecture were aggregated to merge into a single Tokyo metropolis. The 35 urban areas of the city and the previous urban wards were regrouped resulting in 23 special wards. The war ended and the Tokyo City Government was entrusted to the Americans for 6 years, Tokyo, as before, began to rebuild and to repopulate.

The date that marked the end of the crisis was October 10th, 1964. In that year Tokyo hosted the summer Olympic Games, this event served mainly to prove to themselves and to the whole world that Japan had raised again, that the dark period of the war had now ended and that a rich and prosperous future was expected to come. 10.0 million people lived in Tokyo in 1962, it was the most populous city in the world, the infrastructures grew and perfected, new buildings, highways, train stations and airports stepped up.

Fig. 2.2.5 Higways built for Tokyo Olympics games

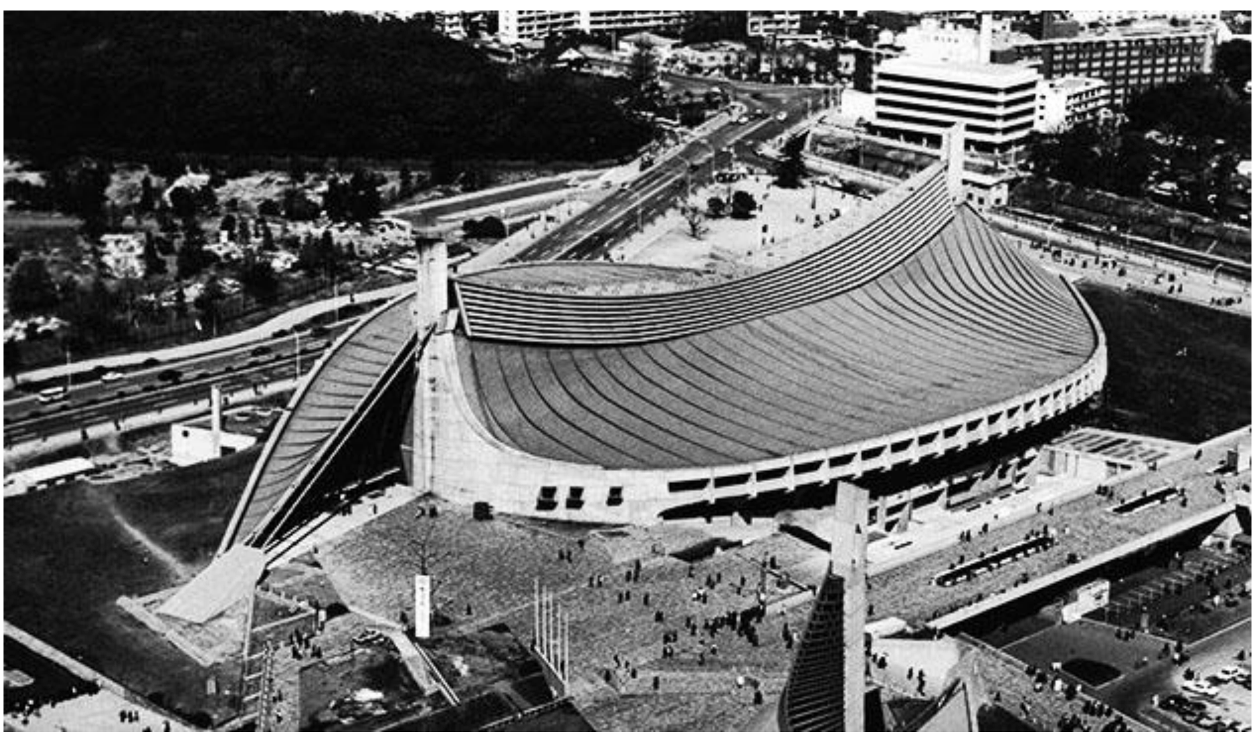


Fig. 2.2.6 Kenzo Tange - Yoyogi National Gymnasium

Fig. 2.2.7 Inauguration of Shinkansen

A real migration to suburban areas of the city began in Tokyo, but also in Osaka and Nagoya during these years: the increasingly expensive prices prevented the poorest families to continue living in the center of the capital, and then a great movement towards peripheral areas of cities started. Even young job-seekers rushed to Tokyo from all corners of Japan, this led to an economic development but also to the tremendous demographic development of areas very remote from the city centre.

2.3 Contemporary times

From 1964 to the present Tokyo has been able to expand without limits: The greater Tokyo area is the most populous metropolitan area in the planet, with 37’832’892 people, set to rise in the coming years up to 50 million people. Tokyo City is home to 15’185’502 people, this means that 22’647’390 people live in the suburb areas; this is particularly relevant as regards the urban management of areas that are developing around Tokyo. It covers an area of some 13500 km^2, with a density of 2.642 people/km^2. [10]

On the world stage:

1) Tokyo 37’832’892 million people

2) Shanghai 34 million people

3) Jakarta 30 million people

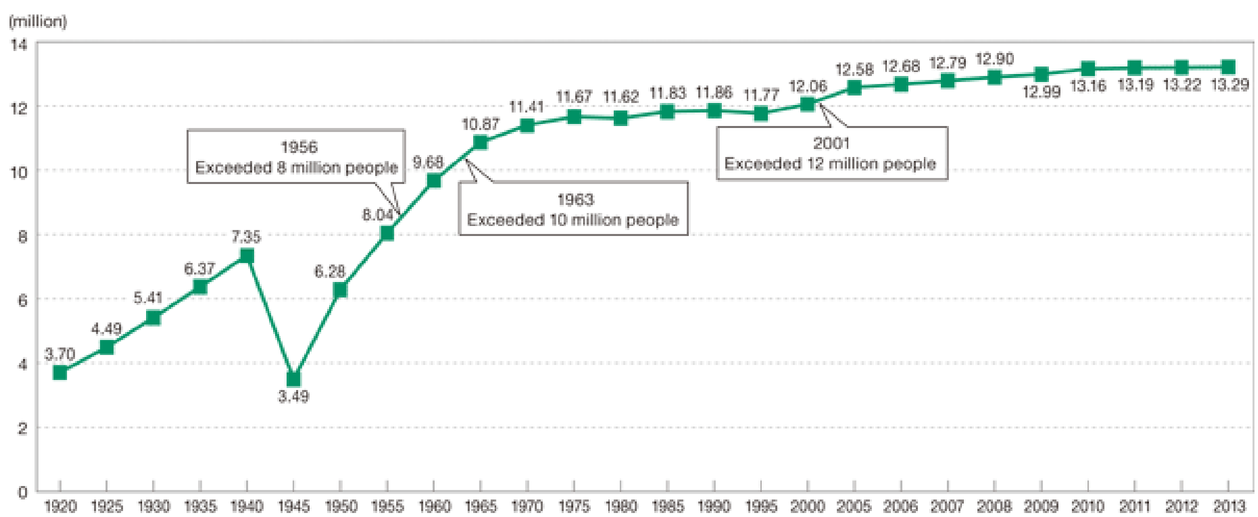


Chart 2.1 Tokyo population over the years [2]

It is the world's richest and most productive area, capable of producing 837 billion USD. Japan, also thanks to Tokyo, is the third largest economy, albeit in a paradoxical manner. In fact, despite having a debt-to-GDP ratio by 236%,it continues to increase the government spending by primarily investing on its population which boasts an unemployment rate of 4.5% versus 11% of the European one. Japan also manages to finance American and European government debt. How is this possible? The Japanese economy manages to control the public debt because of the fact that they can print money autonomously through the Bank of Japan, and thanks to the debtors who fund the State who are mainly living within the Country, these being both Japanese citizens and investors. The main risk relates to potential inflation, but following the line of paradox, a period of deflation began after the Bank of Japan had adopted quantitative easing policies. The Government debt is held within itself, this means that it is technically unassailable by speculation from foreign investors and that allows the citizens to live in a strange but potentially harmonious balance where they themselves, through their invested savings are those who finance public spending.

Of course, there are not only pros. On the negative side of Japan's enormous "public debt", there is demography, in fact much of the richness of Japanese savers invested in domestic debt is in the hands of those who were born between the 1940s and 1960s, many of whom are close to retirement: the moment when those subjects will stop saving and start spending. At that point, the Japanese debt might open to international investors, who, despite a public debt equal to 236% of GDP, could ask for an interest greater than the current one. [9]

As previously explained, in the central part of Tokyo there are 23 special wards, formerly considered single cities and economic realities, in fact every special ward has its own political leader and its Administrative Council. Examples include Shinjuku, Ikebukuro and Ginza districts, where, every day important decisions with a global impact are taken.

The 23 wards are:

Adachi	Chūō	Kita	Nakano	Shibuya
Arakawa	Edogawa	Kōtō	Nerima	Shinagawa
Bunkyo	Itabashi	Meguro	Ōta	Shinjuku
Chiyoda	Katsushika	Minato	Setagaya	Suginami

The economic triangle that feeds the metropolis is defined by the areas of Chiyoda, Chuo and Minato, which during the day are home to 7 times as much their inhabitants. Chiyoda is also the city that hosts the Imperial Palace and then the nucleus of all Japan administrative power. The central area of Tokyo, Japan's real heart is represented by Edo Castle, and the Imperial Park. The oddity is that while in a European country like Italy the town Centre is the square, that is the people's place, in Tokyo, the downtown area is completely closed to the public. It is a closed Park, no plane can fly over it and no subway can pass under, it is an area where access is impossible, it is an attempt to safeguard the rights of a Tokyo now changed, as it can be testified by the great contrast between the Park and the skyline of the buildings erected 30 meters from the private area.

Fig. 2.3.1 Contrast between the gate of the Castle the high buildings district

Fig. 2.3.2 Private Emperor area

Outside these 23 central special wards there is a multitude of settlements that have gradually enlarged and melted into more compact urban conglomerates, forming some sort of large loop 40 Km away from central Tokyo. The major cities along this ring are Yokohama, Chiba, Saitama, Hachioji and Omiya.

Beyond this ring, the territory becomes more rural, the countryside wins out and the landscape starts to be filled with rice paddies. Many rivers descend to the ocean, crossing these areas, the main ones being Arakawa and Tama.

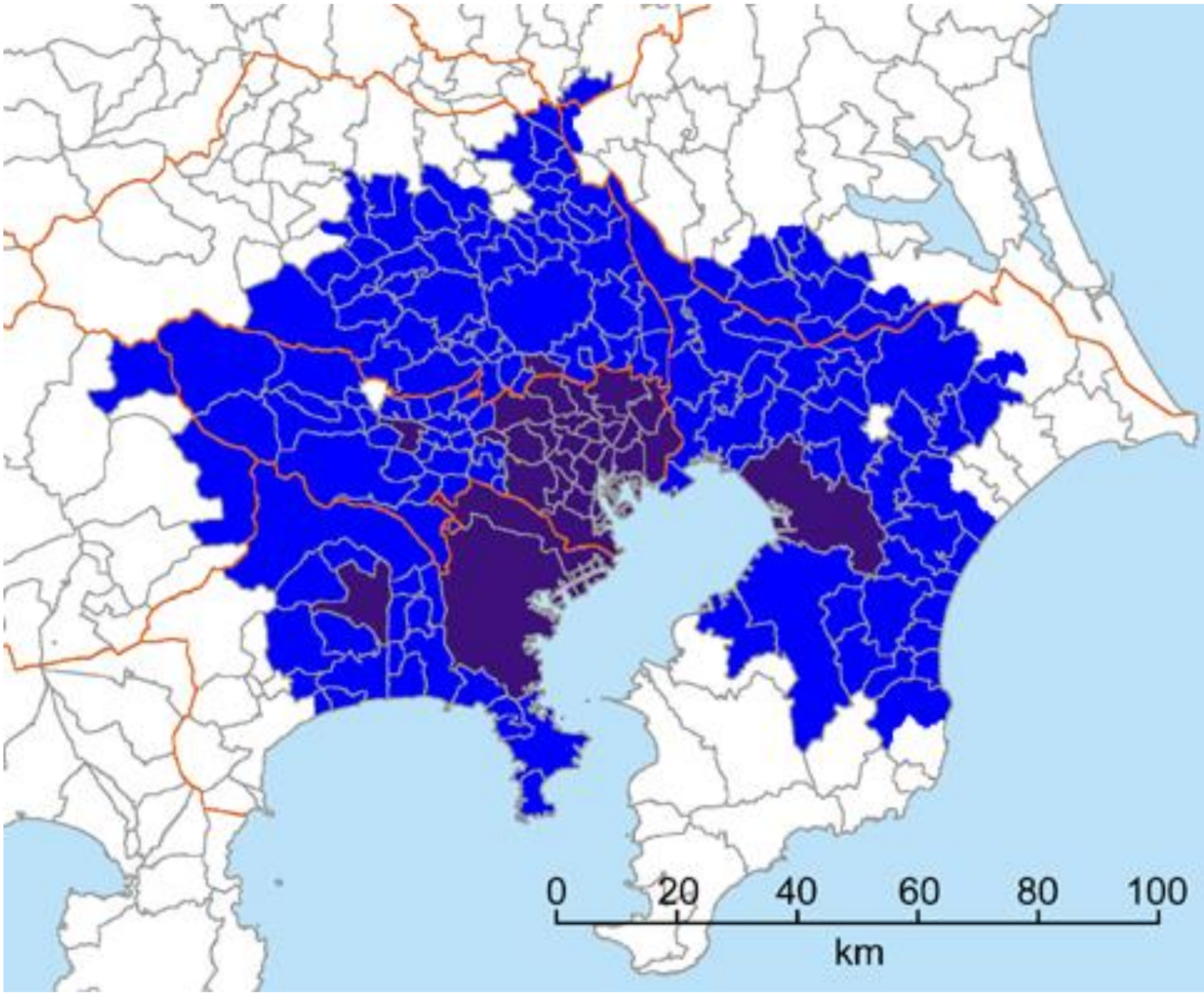


Fig. 2.3.3 Greater Tokyo area

In addition to the 23 special wards there are other 26 cities, 5 towns and 8 villages, the main difference lies in the administrative relations between the special wards and Tokyo Prefecture. The 23 special wards are the central area of Tokyo, to the west there is the Tama Area. This area includes towns and villages, not wards because these areas are created as bed towns, meaning that the people live in these areas only to sleep, passing the full working day in Tokyo. These are places that have little to offer, built in function of the capital, they are the main reality where this project would like to intervene.

The 26 cities are:

Akiruno	Hachiōji	Hino	Kokubunji	Musashimurayama
Akishima	Hamura	Inagi	Komae	Musashino
Chōfu	Higashikurume	Kiyose	Kunitachi	Nishitōkyō
Fuchū	Higashimurayama	Kodaira	Machida	Ōme
Fussa	Higashiyamato	Koganei	Mitaka	Tachikawa
				Tama

Besides the Tama area, further west, there is the Nishi-Tama district, this area is mountainous and poorly suited to the urban settlement. In this area you will find Tokyo's highest mountain, Kumotori, reaching 2017 m. above sea level.

The district is made up of three towns and a village:

Hinode	Mizuho	Okutama	Hinohara

In addition to the Mainland, under Government control, in Tokyo there are also several distant islands, even 1850 Km far from the capital. [10]

The island groups are divided into:

Izu Islands	Ogasawara Islands

This disproportionate size, however, also leads to several environmental responsibilities: in the last 100 years, the average temperature in Tokyo has risen 3° C. [11] It was difficult to predict that one single built-up area could have such a strong impact on the environment, but since 2000, numerous measures have been taken with regard to the decrease of greenhouse gases. The goal is to reduce greenhouse gases by 75% by 2020, and this has led to a huge impact on the city itself: more than 1 million trees were planted along the roadsides and 1'000 hectares of new green spaces throughout the city have been created. Changes in the way of living are also expected, therefore, in the future.

Tokyo's history is quite poetic , it is a city that, on many occasions, has reached the total decline, a reality that has seen its destiny reaching its end more times than it should have to , but also the city that has always been able respond, rise again and continue to grow, without any mental or physical limitation. The castle which meant the beginning of everything still symbolizes the centrality of Japan.

3 Urbanism of Tokyo

3.1 Living Tokyo

"al·ien·a·tion":

1. The act of alienating, or of causing someone to become indifferent or hostile,
2. The state of being alienated, withdrawn, or isolated from the objective world, as through indifference or disaffection,
3. The act of turning away, transferring, or diverting.

The adjective most commonly used by a foreigner to describe Tokyo is "alienating". Reading the definitions we can understand that the term often carries a negative connotation: the being is brought to another dimension, detached from the real one. But if Tokyo's reality is already pure alienation, can it still be defined as an alienating dimension? Tokyo city has a dimension of its own, an end in itself, that dictates the rhythms on human life: the city is not fit for man, then the man who lives there must learn how to live according to its rules. Shops open 24/7, factories never switched off and streets crowded at all hours of the day are synonyms not with human rhythms of life, but with rather robotic ones.

Fig. 3.1.1 Business men sleeping one their way to work

All this may look like the most total disorder, but in reality it is not so. It is a balanced and sublime chaos, everything works and has its own rationale reason to exist. Each logic has acquired its own meaning for the continuation of life in Tokyo, each gear has its own purpose in the machine, and the Tokyoites are the lifeblood of the whole system.

While Tokyo was expanding, there were also numerous proposal to change this rhythm of life, trying to make it more human, for example, the last metro ride is set around 1 at night, to prevent office employees who work during the day to stay until late. The prompt response of the employees was to start sleeping in their offices without returning home, working until late at night. These measures appear not to have had any effect on the jerky rhythms of this city.

In the 1920s and especially after the catastrophic earthquake of 1923, the government tried to control the natural tendency for a radiocentric urban development by means of a planning policy imported from Europe, which implemented a partial decentralization of the settlements. The Monumental Centre is represented by the Imperial Palace, around which there are the Embassy and the university district, then, to the Southeast, the Office District; and then the shopping malls, and, to follow, the industries (on the North side, on the waterfront) and the residential areas.

During the reconstruction after World War II, Tokyo has become the Executive Center of all Japan, trying to to climb the ladder of the world economic power: this objective is pursued not only by the strengthening of its industry, but also by a profound transformation of it. The administration focused on light industry, structured on large manufacturing sectors and a network depending on small-sized semi-craft enterprises producing consumer goods, competitive on the world market in terms of quality and costs.

Quantitative and practical problems counteracted this development, in particular in 1964 the 200,000 immigrants that since World War II had arrived in Tokyo and an insufficient housing policy led to a building deficit of 470,000 units, to a lack of services and an inadequate and outdated transport network (it covered, approximately, 10 % of the urban area and was established between 1920 and 1940). These conditions had a huge impact on the urban fabric, in fact today Tokyo presents itself as an anti-town, not for lack of urban structures, but because the most vital characteristic of the urban phenomenon, i.e. the ability to relate, seems bound by its infrastructures, whatever the weight-importance and the timeliness of its realization. The infrastructural arterial roads of the city mark the urban organization of Tokyo and are of vital importance for the city itself. The main project of the administration consisted in the regional decentralization and the creation of satellite centers, in doing so infrastructures gains huge importance since it was the only way to guarantee interaction between the individual and the city. [12]

A whole generation of architects has been thus stimulated to design solutions capable of making Tokyo a more controllable city. This is where Kenzo Tange's pattern of plans comes from, in 1960, together with the projects of metabolism city. On the first January 1961 Kenzo Tange explained his new plan for Tokyo-bay on a television program. In 1958, Tokyo regional plan proposed a series of satellite cities and a general decentralization so as not to increase the density of the city in the special wards. Tange used this proposal to advance his own: he understood that the automobile could give new conceptions of space, and instead of continuing the expansion of some satellite areas, he focused on creating infrastructures able to connect the city at its best, so making them even more necessary. He proposed an open network around which the inhabited areas had to be developed. Instead of thinking first and foremost of satellite cities and then how to connect them by means of infrastructure networks, he thought in the opposite direction, i.e. strengthening the infrastructure networks, leaving free the population to settle along the areas which they believed to be potentially more interesting. The project designed a linear city, which used modules 9 km long, stretching 80 km around Tokyo-Bay, from Ikebukuro to Kisarazu, i.e. cutting Tokyo from north-west to south-east. The perimeter of each module was divided into three levels of looping highways, the modules themselves were organized by areas with office buildings and transport centers, to connect each module with the rest of Tokyo. The residential areas were meant to be arranged parallel to the roads in order to facilitate the city traffic. Tange incorporated urban concepts such as mobility, urban structure and the city centre as a process inserted in a powerful architectural language, trying to elevate them to a new conception of the relationship between the whole and the part, and between the permanent and the transient. However, Tange's way to approach these concepts was symbolic, rather than practical, an orientation which was also present in his later works. His vision for the creation of a new spatial order for a metropolis in continuous expansion and transformation was, in a final analysis, unfortunately, a utopian ideal. [13]

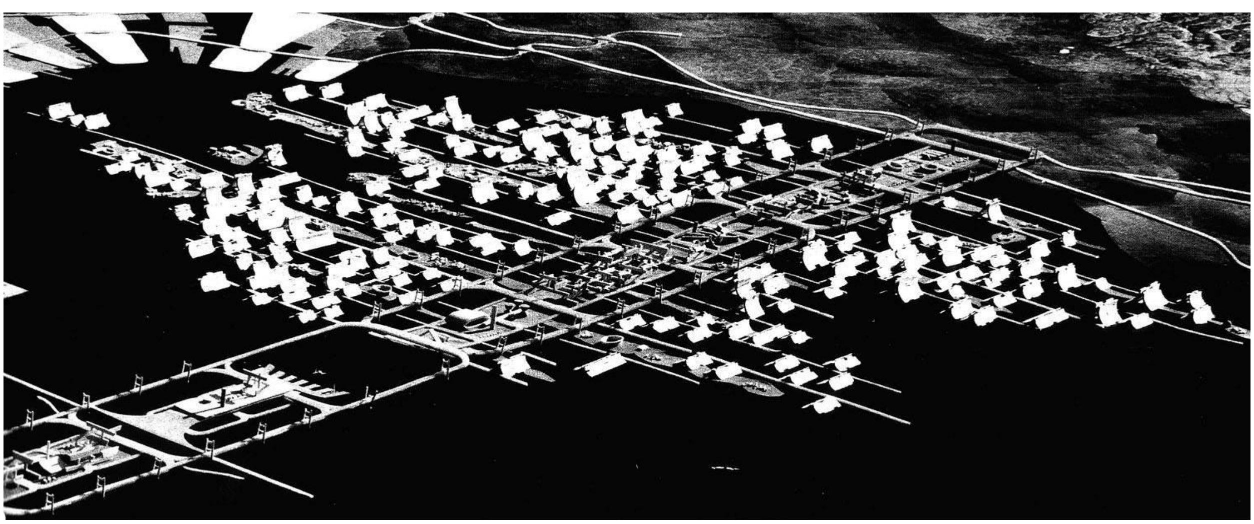


Fig. 3.1.2 Kenzo Tange plan for Tokyo Bay

Fig. 3.1.3 Kenzo Tange plan for Tokyo Bay

In addition to the proposals of individual architects, Tokyo has been able to inspire real philosophical trends, such as the metabolist movement: a Vanguard born in Tokyo in the sixties, of architectural and urban planning inspiration. The guiding principle that supports it all was the idea that the city was a machine in complete transformation and therefore it was impossible to think of urban solutions linked to the traditional models, people should give life to types of ductile and changing structures able to satisfy the needs of the city, this is how they referred to themselves:

Metabolism is the name of the group, in which each member proposes further designs of our coming world through his concrete designs and illustrations. We regard human society as a vital process - a continuous development from atom to nebula. The reason why we use such a biological word, metabolism, is that we believe design and technology should be a denotation of human society. We are not going to accept metabolism as a natural process, but try to encourage active metabolic development of our society through our proposals. [14]

The foundation of their projects lies in the ineluctability of the city growth and the consciousness that this growth must be carried out by means of using technology. The 1970 Expo in Osaka Expo gave way to experiment and broaden their horizons. In particular, the group became especially known for the theme of the capsule, as housing unit.

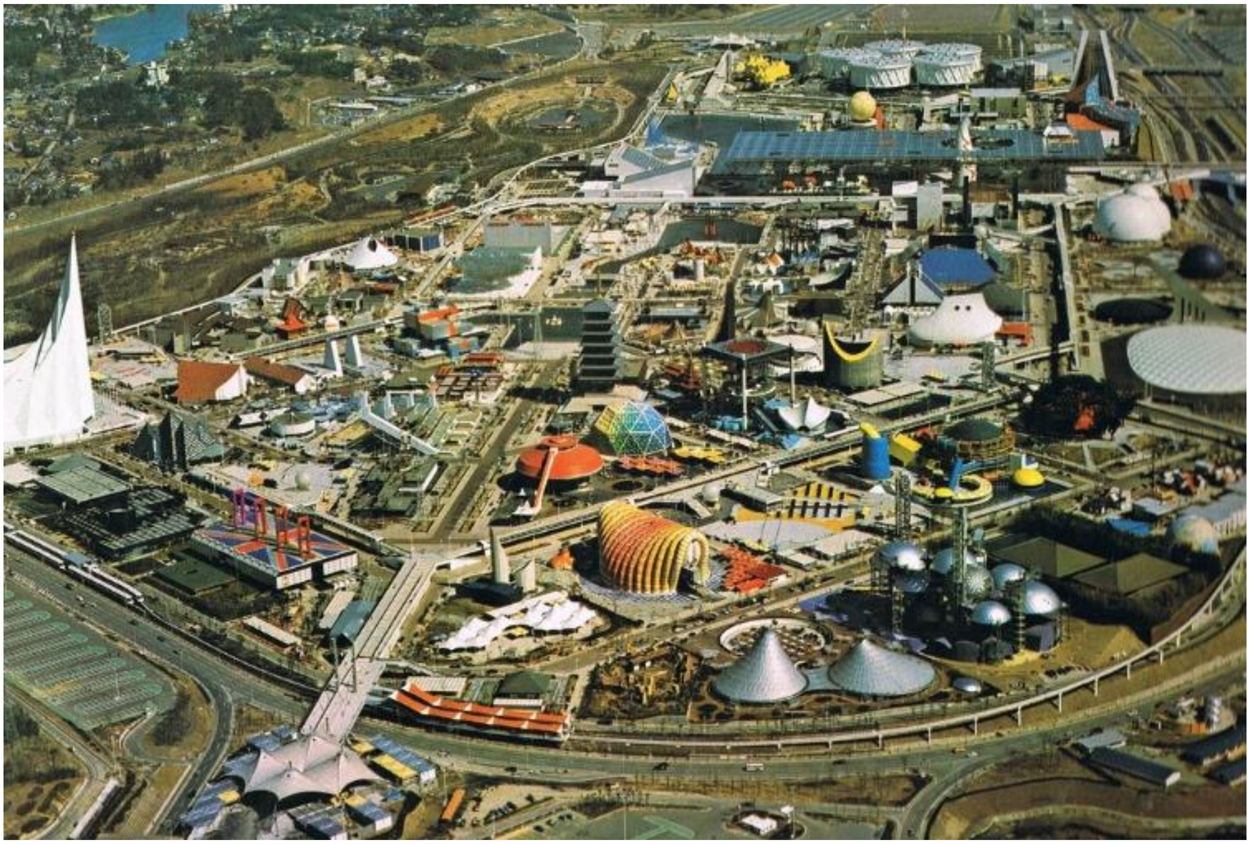


Fig. 3.1.4 EXPO Osaka '70

In their urban planning they often adopted the case of the tower to which, habitable cells, precisely capsules, are hooked. This idea reflects the ideals and goals of the group that is an open and indefinite architecture, governed by the laws of mutation. The capsule is not intended, in the metabolist formulation, but as an instrument of social diversification, a refuge which protects the individual sphere.

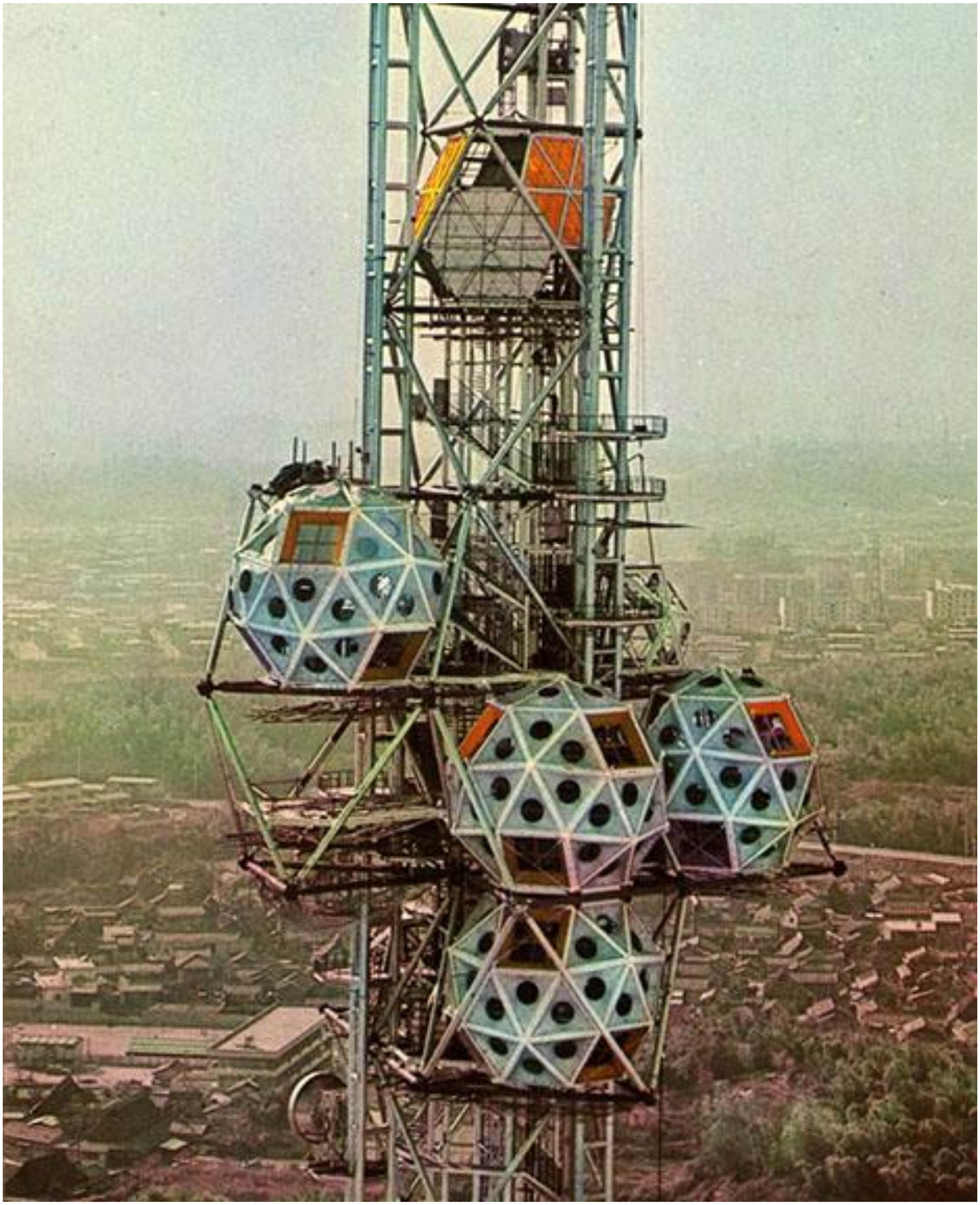


Fig. 3.1.5 EXPO Osaka tower '70

The Nakagin Capsule Tower is the highest result achieved by the metabolist architectural research, and is located in the southern part of Tokyo. The building, designed by Kisho Kurokawa, is made of 144 units, i.e. capsules of 2.5 m x 4 m x 2.5 m and hooked on two service towers of 11 and 13 floors. Designed for the man of the future, with a very committed life and little time to cook, the capsule has neither kitchen nor household appliances. This architecture became greatly known in those years when people breathed air of innovation, but it is totally abandoned nowadays. Some units have been 'sealed'' with plastic sheeting, others are often in an advanced state of decay: walls to pieces, broken shelves, mildew and moisture. Living here is also dangerous because, as in many buildings of the 1960s, they used asbestos as insulating material. [15]

In the past there were several attempts to contain the chaos, with plans and projects conceived and reasoned, often completely innovative, but Tokyo often takes over and the urban structure takes shape in a spontaneous way, as if it had its own life.

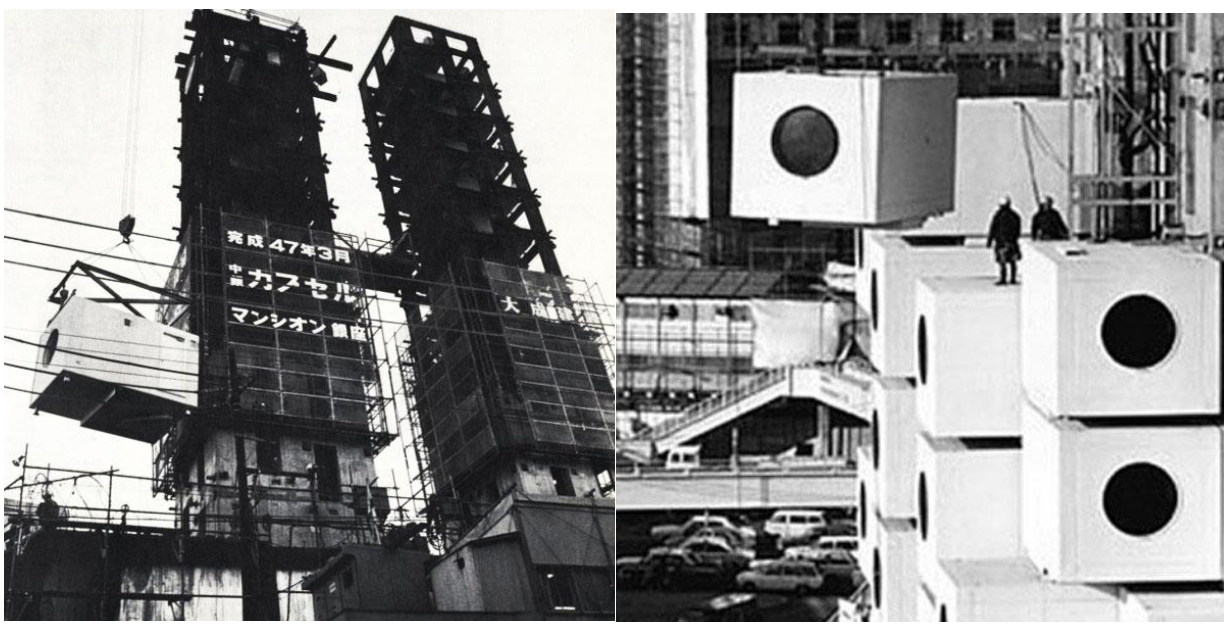


Fig. 3.1.6 Nagakin capsule tower under construction

Fig. 3.1.7 Nagakin capsule tower

Tokyo scale varies dramatically: from tens of thousands of square kilometers of its total area, to the few square metres of the capsule hotel. In 1500 the Japanese architecture changed in connection with the human element and each product was made in scale with the human body. The tatami mat is a key example; the capsules of the capsule hotels can be considered the great-grandchildren of tatami dating 500 years ago.

The scale is so varied, mainly because there are no real limitations, either mental or physical. Arata Isozaki, called to propose a design concept at Venice Biennale in 2002, applied a very interesting reasoning, he relates Japanese architecture to the Japanese language. The Japanese language leaves a certain degree of flexibility, a space for understanding the speech meaning, it is not direct, such as the English but leaves room for some interpretation. It Is ambiguous and has multiple meanings, one sentence is rich in images, and, compared to a European language, it leaves more insight to the listener. Similarly Japanese spaces seem to have no bounds, no set limits. Instead of having a simple distinction between inside and outside, Japanese people have a series of spatial tools and configurations, gate (もん) wall (へい) fence (いけがき) eaves (ひさし). [16] They create a multitude of boundaries between the public and the private sphere without having a clear sharp and uniform limit. This leads to a decentralization and to an increase in the fragmentation of space, which is similar to the grammatical structure of the Japanese language: a sentence consists of small parts that is the kanji, connected by a weak syntax and a poor grammar.

The irrepressible expansion can be explained by the fact that there are no real limits, the capital has a chance to grow horizontally and vertically without any special physical difficulty. On the contrary, looking at a European city, there is a clear distinction between what is inside and what is outside the city, for example in Italy, in cities with Roman imprint it's possible to speak about areas inside or outside the city walls, because they are separated by a physical architectural element. In the Western oldest cities, such as Milan, Paris or Belgrade, it's possible to see a clear distinction between what is central and what is not.

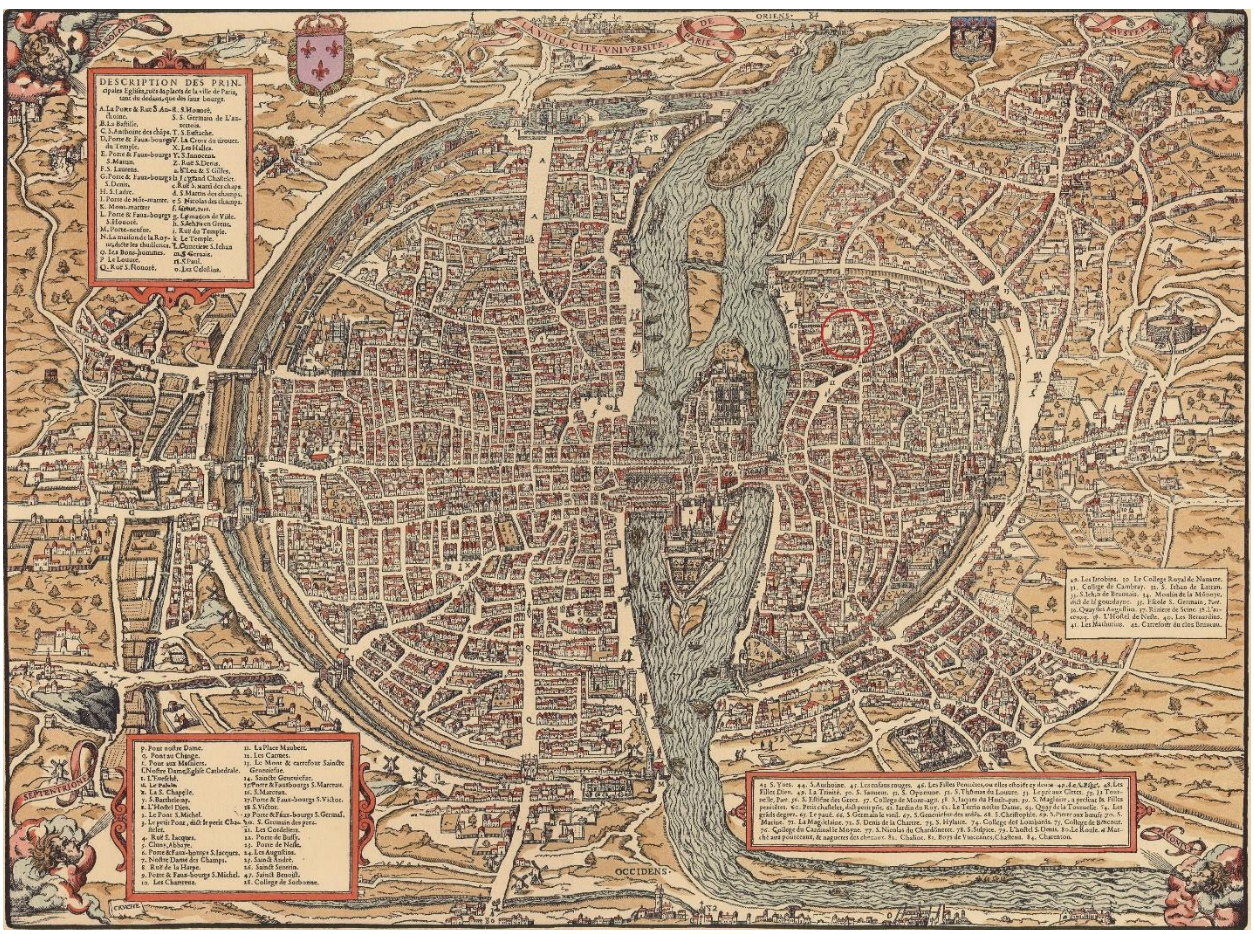


Fig. 3.1.8 Old map of Paris

In Tokyo, the measuring unit to describe the potential of an area in comparison with another is represented by the time necessary for everyday journeys; an area gains or loses interest depending on how it is served by transport infrastructures.

It has been explained that Edo Castle is situated at the centre of Tokyo but its centrality is – represents as mentioned above a kind of no one's land, a grey area in Tokyo's everyday social life. The economic and trade centers are much more central and influential than the real center, closed to political power. The birth of the 23 special wards brought, consequently, the creation of 23 new central areas. Each ward has managed to create a sort of identity, starting from a physical symbolic center, the great wealth of Tokyo lies in the fact that every ward has its own characterization and sometimes you have the feeling of living in a multitude of cities completely different, one from the other. Tokyo has 23 faces, but in reality there are many, different masks. Eating fresh shushi at the Tsukiji fish market at Chuo, praying inside the Senso-ji temple in Taito, admiring the skyline from the 53th-floor of the metropolitan government building in Shinjuku and walking along the streets of the Electrictown in Akihabara, Chiyoda. It is like watching a Kabuki show with various characters, very characteristic and different, but all grown up under a single great theater, which is Tokyo.

Fig. 3.1.9 Four different areas of Tokyo

Enlarging the scale, it can be said that the center of Tokyo is represented by all the 23 special wards, imagining a historical and cultural center with a radius of 30 km. It is possible to compare this vision of centrality of Tokyo to the Japanese mountains: multiple peaks give life to the mountain itself, the panorama is fragmented into a sea of small peaks, each center gives strength and centrality to the whole metropolis.

Fig. 3.1.10 Mountains of Japan

The theme previously mentioned, that is, the relationship between the public and the private, deserves further insight explanation. In Japan the distinction between public and private sectors is a relatively new concept, led and developed by the arrival of the Americans in the mid-nineteenth century. Shintoism envisages a world shared between human beings and natural divinities, this ideal of sharing has led to a feeling of openness to the world outside the private sphere. This is visible in the Shintoist temple, where it is possible to enter from different entrances gates without finding a unique main entrance, it is open to everybody. Instead the church, even if it is open to the people, has a single main entrance, which clearly distinguishes the public world outside from the house of the Lord. You can guess that the church was conceived as an architecture easy to close while the Shinto temple is not conceived like that, and this happened for the residential area as well. In the Western world there is a strong distinction between the way people live publicly in the *Forum* market and the way they live within the private sphere once you have closed the entrance door to strangers. This distinction did not exist in Japan, or better said it was not as strong as in the West, the residences were designed as structures open to the life of the village, then considered as public domain. Nowadays this topic is often tackled in the architectural field, especially as regards the residences. Japanese houses have begun to close in themselves, and many Japanese architects have instead tried to fight this tendency, further increasing the dialogue between the building and the urban fabric.

Among these professionals you can find Go Hasegawa and the house he built in Gotanda. The young architect’s proposal is literally to open the building to the realities of the road by providing an entrance that splits the whole building, dividing it into two blocks. The two sides communicate by means of a staircase and especially through skillful opening plays that allow the view from one in-house room to the other, as far as the road. From the outside you can see, through the structure, what is inside and even beyond. The private and the public merge, both losing significance.

Fig. 3.1.11 House in Gotanda

If the odiern Roman cities rest on different layers coming from the past, then Tokyo is standing on as many futuristic ones. It’s like living in a multy-level city: going down to the second basement to reach the underground line and then going to the fifth floor to wait for the bus. This results comes from the need to improve and increase the transport network without modifying the existing urban pattern, and obviously, when you cannot pass below existing buildings, you pass above them.

Fig. 3.1.12 Yokohama roads

This greatly increases the feeling of chaos and, at urbanistic level, the growth was so rapid that it often led to the disorder of the infrastructure fabric. Moreover there are no real urban axes, in fact the building usually follow the physical context of nature, as the Sumida river route, without following easier perimeters. Architettonically, it is the image of caos.

Fig. 3.1.13 Architecture disorder in a residential area

Fig. 3.1.14 Higashi residential area

How can the future be imagined for the city of Tokyo? At the urbanistic level the city is expected to stop growing in numbers but it is supposed to starts developing in quality. Not because of a decrease in its productivity or its population, but because the aim is optimizie the areas already constructed: Tokyo must stop widening out horizontally. The concept that it wanted to be followed is the one of the fiber city, a city with a thousand interlinked fibers, there is a plan that follows this idea, designed by Hidetoshi Ohno, to be developed by 2050. The aim is to avoid wasting spaces, revitalize the city's dead zones, a capital for agglomerations, more than for neighborhoods, around which, one by one, there is a maze of green areas, and where each home cannot be farther than 800 meters from a metro station.

The present is already the future of the New Tokyo; this thesis would like to join the philosophy of requalification.

3.2 The birth of a social problem

The will of the local authorities was to decentralize the residential areas, in order to conceive the development of the least flourishing areas in the city, this has led to the opposite effect, their paralysis, with the growth of bed towns. The National Land agency promoted the project *Sekaimachi Tokyo*, where many changes were imposed. The most ambitious of all was to free up to 50 million square meters of land to construct the central business district; the consequences were the displacement of 1 million residents in the existing suburbs or in new cities toward Tama, and the increase of rental prices in the new created Center. [16]

This attempt to control the expansion has led to the creation of dormitory areas, i.e. strictly residential areas, with a dense flow of people, that during the daytime hours migrates toward Tokyo leaving them completely empty, to re-inhabit them at night time. In fact if the working life takes place during the day in the streets of Tokyo, the night life is lived far from the centers, many of the 40 million people who crowd the streets during the day must go back home: it is a real daily migratory phenomenon. Some of these residential centers are in full bloom, giving life to lively and very characteristic districts which attract also foreign tourists and leave a strong impression on the panorama of Tokyo.

Fig. 3.2.1 Yanaka district in Tokyo

Other centers have remained dead: bedtowns during the night and ghost towns during the day, entire neighborhoods completely residential, zones without commercial activities but satellite areas that live in function of Tokyo, without any degree of independence.

This is an important social problem also because, as previously said, the areas outside the urban center of Tokyo are populated by more than 22 million people. Tokyo exceeds New York by population density for the contribution given by its peripheral areas.

The difficulty also lies in figuring out beforehand which area will become a bed town or which area will be able to flourish; it is difficult to predict a bedtown, usually many individuals invest in the realization of their residence in an area that could become a dead appendix of Tokyo in a few years. In fact, it must be understood that the peripheral residential areas are inhabited both by those who really want to live there, preferring a place quieter than chaotic Tokyo, and also by people who mainly settle there for economic reasons, and then forced. This forced decentralization acted mainly in two ways: by providing residential areas from nothing, or increasing the settlement in residential areas already existing. If the birth of a bed town takes place in the second case, the consequences could be even worse, since an area that was previously alive is destined to die and than, the commercial areas are bound to close for lack of customers. According to this theme, the house is of significant importance throughout the urban fabric, because it is often a single element within the urban context.

During the 1950s, the most peripheral areas of the city were populated by a large number of farms, which played an important role in the economy of Tokyo. With the economic boom of the secondary and tertiary sector the farm landowners started to sell the land to housing societies, new on the Japanese market. In fact, as already explained, there was a need for houses in a relatively short time span and the companies of prefabricated houses managed to meet these needs in the best way for the local administrations of the urban area. This phenomenon grew like wildfire , to encompass all peripheral centers; prefabricated house companies bought the lands of the old farmsteads and made then available to their customers, building and then selling the houses or leaving the customers more freedom in design them.

Fig. 3.2.2 Residential area in Aoba-ku, Yokohama – Google Earth

Choosing the speed of implementation of a prefabricated system, usually the time to the design phase is decreased. The houses are sold in sizes, for example the living room can be purchased as S, M, L or even XL, this seems to meet the customer's need but actually it constrains a lot to the very concept of prefabricated structure. Then the housing companies have been able to dictate law in matters of the building architectural style and consequently of the urban fabric. Here lies another problem linked to the characterization of a place: The housing companies often associate real architectural styles to prefabrication systems, many are inspired by existing systems, from the United States, New Zealand and Australia, countries that have nothing in common with the thousands years of Japanese architecture.

Fig. 3.2.3 Tokyo prefab district

These buildings, and consequently also these places, miss what Isozaki Arata defines as *Japanness* [17], that is the historical architecture consciousness of Japan itself. The theme of the identity linked to a place is something extremely difficult to tackle, each case should be analyzed in and for itself; this thesis is not meant to be the solution of the problem, but only a speculation on solution proposals. Giving an identity to the bed towns could mean restoring life to the area. If the house is the architectural element that most influences the public identity, then it's important to begin from its peculiarity.

Examples of this can be found in several villages scattered throughout Japan; these inhabited centers have efficiently reacted against the decadence caused by the migrant motion of the inhabitants, and investing everything on a strong architectural characterization. For instance the village of Shirakawago, UNESCO heritage, has been able to enrich and expand thanks to the more traditional identity of its streets, born from its particular houses that attract many tourists every year.

Fig. 3.2.4 Shirakawago typical home

The process is a rather complicated one: an area can only be enriched if people inhabit and live it, while these people are only keen to do so if a given place offers something worth doing to start with. Thereofre, it is incredibly hard for a residential area to result attractive to the external individual. The only way to go around it would be showcasing the possibility of experiening another identity, something characteristics and unique, like in the village of Shirakawago.

4 Mutation of Japanese housing

4.1 Japanese houses in the past

When people think of Japanese architecture, they unknowingly expect the use of wood. In the past, in the rest of the world, as in Europe and China, the raw materials offered by the soil, that is stones and clay, favoured the development of the brick as the main structural component. In Japan and in other Pacific Islands, the raw materials offered by the volcanic soil were not suited for that, but on the other hand there was an infinite variety of trees that could be used for different types of structures. The typologies of autochthonous wood were mainly conifers, such as pine, cedar and Japanese cypress, but in the past, there was also a considerable import from all over Asia, and builders began to use new types of wood such as teak, red sandalwood, ebony, Indian ironwood and lauan as well.

Then the first and real reason why Japanese forefathers began to build in wood timber structure was because of its abundant presence. While China and Europe were refining their brick structure techniques, Japanese people began working on iron, a material offered in abundance by the volcanic soil, to make working tools to shape wood. This phenomenon is particularly important, since the development of work tools different from those used in the rest of the world has consequently given life to arts and crafts different from those used in Western countries.

A second reason that promoted the use of wood concerns the reaction that a wooden structure was able to give under seismic events. Earthquakes have always existed in Japan; we can say that Japan itself was born from a series of earthquakes. In the past, they were known and feared, and the ancient builders knew that wood, for the types they used was the best structural material they could think of. In the first place, wood, with respect to stone buildings, is lighter, as the mass of a wooden building was about one third the mass of a stone building. This meant there was the possibility to activate the building with a lesser force. Wood has also a particularly favorable mechanical behavior when compared with its mass. For a given mass the mechanical resistance of wood is among the best. This means that wooden structures are able to absorb even important forces and stresses without damage. For its mechanical characteristics, then, wood is naturally elastic and therefore can easily support a slight deformation: this is expressed in a positive way during the earthquake action, in so far as the lesser rigidity, i.e. the greater deformability, of the building allows a better absorption of the seismic wave. A third and last reason in favor of wood is that Japan native woods are naturally resistant to bacteria, fungi and insects. With the passing of the years they have been able to develop a certain self-defense from the attacks by these organisms. Especially the Japanese termite, a particular insect that has destroyed most of the temples of the South Pacific, has caused only little damage in Japan. [18]

Kodama (こだま) is the name of the Spirit who dwells inside the tree, meaning that the Japanese venerate and take care of their trees and of their forests. Many Japanese leaders of the past imposed a rigid reforestation plan: for so many trees that were cut as many had to be planted, as a form of respect toward kodama. Many of the woods used in today's buildings come from remote times, for example the renowned Cedar of Akita prefecture, was planted during the Edo period, 400 years ago. [18] Japanese were the pioneers of reforestation, not for economic reasons, but to a great and profound sense of respect toward nature. The Japanese building was born as the highest example of inspiration that man can draw from nature, and it represents its strength. During the years this concept has evolved, but the respect of both places and materials has marked the architectural culture of these people.

4.1.1 Jomon period 8000 BC – 300 BC

At the dawn of the Japanese society, the main settlements were composed of villages located along the banks of the main rivers, since fishing was the main source of livelihood. The houses had a circular or square floor, however symmetrical, with a hearth inside, at the center of the hut. They were dug into the ground for 30/50 cm and the curve coverage stretched until the ground, to better protect the hut from the wind, but also to collect the rainwater more easily. It was also open at the top to let the smoke go out. The wood was used in the cover roof structure, which had to withstand typhoons and very strong rains.

Fig. 4.1.1 Jomon house

4.1.2 Yayoi period 300 BC – 250 AC and Kofun period 250 AC – 600 AC

The house, besides being dug into the soil, was also raised from the ground. The villages started to evolve, also thanks to the stimulus of agricultural production. They began to grow rice and other legumes, and, in order to store them, they constructed the first buildings raised from the ground. Additonally, to protect the harvest from animals and possible floods, the houses were raised by means of a wooden structure of beams and pillars. This principle of protection and conservation was also adopted for the dwellings of the shamans, who enjoyed a socially higher position when compared to the rest of the village. The plant of simple buildings was kept symmetrical. Later they started to use the dwellings depending on the season and the climate, the huts dug into the ground were used in winter, while the huts at ground level with the roof in bamboo were used in summer.

Fig. 4.1.2 Yayoi period

4.1.3 Nara period 700 AC – 800 AC

Builders mainly develop religious buildings, real masterpieces of architecture, admired all over the world. However, the techniques and technologies related to the use of wood were improved, as they had the possibility to experiment. The house starts to expand, it is possible to build residences larger, but often composed of a single large room. The residences' style derives some features from the pagoda, imported in those years, always providing the symmetry of the plant.

Fig. 4.1.3 Shōsōin, Emperor's treasure house

4.1.4 Heian Period 794 AC – 1185 AC

The town-planning scheme of the city of Heian-kyo, today known as Kyoto, is important: the grid layout (120 square meters and multiples of it) is recreated in a reduced scale, even in the plant of the residential building, giving more irregularities and dynamism. They also began to divide the space of the living room from the private rooms', starting to acquire greater awareness on how to live the house. The increase in the size of the buildings of the capital Kyoto led to the development of an architecture neatly arranged in columns, with distances adjusted according to the Ken, a traditional Japanese measure for dimensions and proportions, explained below.

Heavier materials for the construction of walls are abandoned, and they begin to mainly use wood materials. You can distinguish two styles: the *shinden* style and the *shuden* style. The *shinden* building had the roof with an exposed roof structure and thus with a ceiling; there were walls inside, but were simply made of mobile partitions and very large areas could be created. The *shuden* was instead the style of the samurai's dwelling. The characteristic traits were the use of *tatami* mats and the creation of a studying space, an area called *tsuke-shoin*, which consisted in a desk located beneath a glazed opening. The study of the manuscripts of the time was indeed very important for the samurai's families, the realization of such a space was important because it introduced the concept of privacy, more linked to personal introspection. In this period, they began to insert the famous rock garden in the buildings of the aristocratic families, inside their own spaces.

Fig. 4.1.4 Heian Jingu

4.1.5 Kamakura period 1185 AC – 1333 and Muromachi period 1336 – 1573

The architecture of the Kamakura Period was characterised by a style that is simpler than the previous period's, perhaps due to the influence of the military attitude of the time. People withdrew, defense became a priority, and as a consequence the structures were grouped into a single agglomeration, rather than being articulated around a garden.

This changed during the Muromachi period, as the rivalry between the higher social classes in Kyoto caused a real rush after consumer goods and more luxurious life styles. The samurai's families, previously accustomed to a simple life in the countryside, began a richer and nobler life with the new shogunate. An example of this architecture is the Kinkaku-ji Temple in Kyoto, a lacquered, gold plated building. As social answer, the Zen masters introduced the tea ceremony and the respective tea house, the key example of the so much craved Japanese minimalism: simple layout, simple materials realized for one simple purpose.

This style then influenced the residential architecture, giving life to the Sukiya style. In particular, it is characterized by the realization of lighter, more intimate buildings, consisting of leaner beams and pillars, with internal sliding dividers (ふすま) and external sliding walls (しょうじ) and in particular it is possible to distinguish this style from the others because the pillars were left with the bark of the cut tree. The main changes from the previous styles, which characterise the *shoin* style are:

- from round pillars to square pillars
- the distance between the centers of the pillars changes from 3 meters to 2 meters
- from a single large room to small and several other halls
- from wooden floors to tatami floors
- from wooden doors and shutters to sliding panels, including shoji
- from the empty room to a room equipped with significant furniture
- the different characteristics of the various styles were brought together under a unique style. [19]

Fig. 4.1.5 Muromachi period building

4.1.6 Edo period 1603 AC – 1867 AC

In this period, the classic style of Tokyo started to arise, one of the best rappresentation of this is the *machiya* (まちや), a particular form of building with traditional terraced houses in wood, marked by the presence of small rooms with the front door adjacent to the road and the ground floor set aside as a shop or a workhouse. The house became more functional because of the double tasks it had to embody.

An entire district in Tokyo is called Machiya precisely for the vast amount of buildings that have these characteristics; ceramic tiles are used instead of straw, while the exposed structure, the great feature of Japanese architecture, is here plastered in the attempt to protect the building from fire. The walls were realized from intertwined bamboo canes filled with straw and mud (さかん) and architects focused more on the outside layer of the building. Several wooden details were added to the facade as a decoration, to give more character and make them unique. These geometric patterns were made by wood artisans in Tokyo, which implemented a real style exported in all over Japan. The concept of a moltitude of details repeated in a ossessive way goes against the pure minimal style of the more ancient times, but it became so popular that even the big villas started to be decorated with them.

Fig. 4.1.6 Machiya style building

The Japanese house has evolved over the centuries, adapting to the lifestyles of the time, but it has remained a characteristic trait of the entire Japanese culture.

4.2 XX century and radical turn

The old Japanese culture was rooted in daily social life, the reason for this depth is that it was able to develop in a period during which the country was not disturbed by external wars for more than a thousand years, always having the same type of government. The old, handmade Japanese house had already all the essential characteristics required today for a modern prefabricated house. In the past they had already found the answer to many of our modern requirements of simplicity, such as the relationship between internal and external parts and modular coordination, in addition, everything was based on a sort of industrialized handicrafts.

Fig. 4.2.1 Street in Kanazawa

The traditional Japanese House, as it gets to the 20th century, had independent features:

- The plant is not symmtrical; symmetry belonged to the temple.
- It has no main strong axes, but rather it prefers the "surprise effect”
- The plants are open and flexible, movable
- human proportions are taken as the base module

It is impressive to note how Japanese culture, which for centuries has had the possibility to develop and move through different phases, without any intervention and influence from foreign domination, culminated in a cult of maximum simplicity and austerity. This can be explained by the influence of the Zen culture: not so much a religion, but rather a human ideal of self-education. It is a very direct attitude to life aiming at the heart of the subject, manifesting itself in the practical action, meaning to reach the perfection of the soul through a sequence of simple gestures. This concept has led to the key minimalism of this architecture.

The tea ceremony has given dignity to poverty: a climate of noble, serene poverty in the use or cult of simple, well-molded tools, for a practical purpose. The simple gesture of drinking tea becomes a real ceremony and in the same manner, the spaces assume importance and dignity: the Japanese house, even if devoid of many possessions and assets, acquires quality and wealth directly from the practical ways to live it. Living Japanese spaces means to carry out a single great Zen ceremony, rich of rituals and simple gestures. In this climate, the house is not only a building, it is a temple of daily living. The Japanese have been educated to the concept that it is more important to develop the spirit than to indulge to the body for so long, that they are unable to adapt the modern comforts of life to the abode of the past.

The house of the common man and that of a monk, of a prince, or even of the Emperor, reveal the same spirit. Walter Gropious wrote: "It will be an unspeakable loss for all if the Japanese introspective way of living gave way to our indulgence in the search – quest - for material goods and to our futile adding up of changes only for the sake of it."

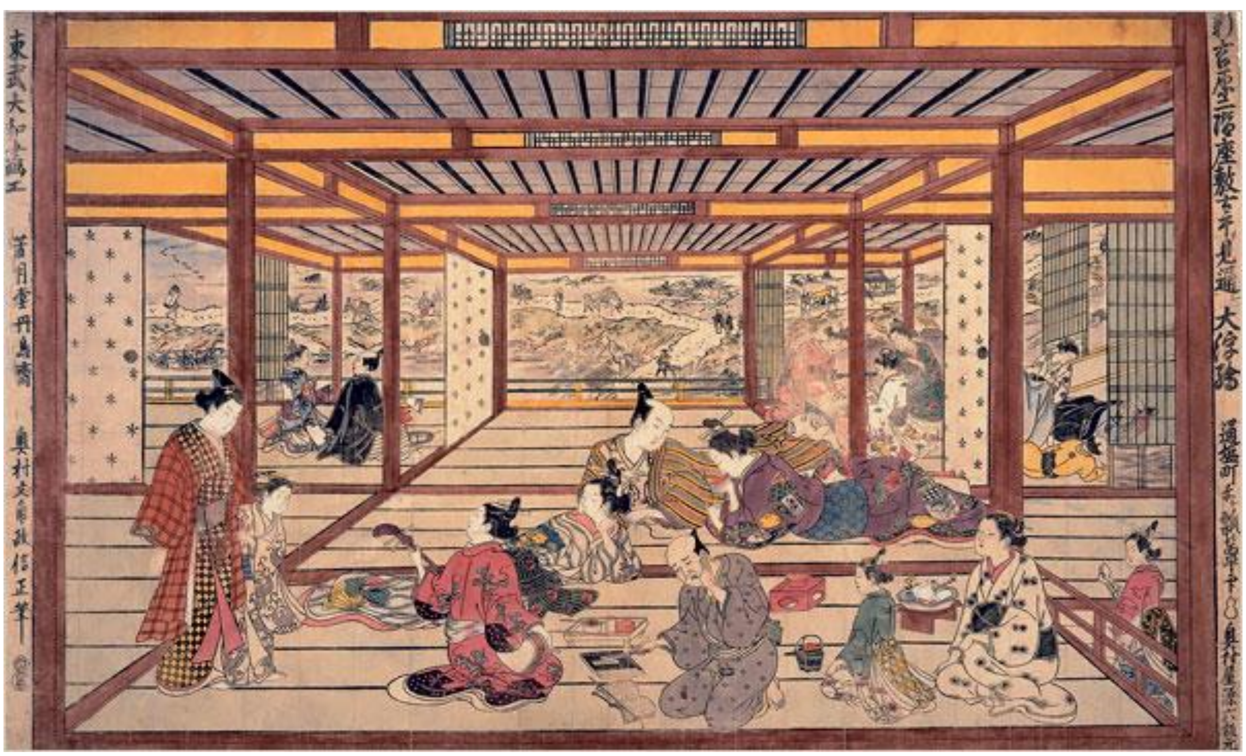


Fig. 4.2.2 Living the Japanese house

However, a radical change in the Japanese society, that consequently also influenced the way of living the residential building, took place during the 19th and 20th centuries. When the Emperor Meiji ascended the throne, Japan was invaded by new forms of foreign culture. Japan, in fact, started a rapid process of westernization that brought the need for them to adopt new types of buildings such as schools, banks and hotels. The Ryounkaku for example (りょんかく), was the first skyscraper in western style in Japan, built in 1890 in Asakusa, and then destroyed by an earthquake.

Fig. 4.2.3 Postcard showing the Ryonkaku

The urban fabric was slowly getting to know western architecture and mainly the comfort linked to it. Even the famous American architect Frank Lloyd Wright was called to express himself in the city of Tokyo, with the realisation of the Imperial Hotel (1913-1923), but his work was not well accepted by the public, the architect Arata Isozaki writes:

"In 1922, he was finally commissioned to design the Imperial Hotel in Tokyo. Ironically, the work of Wright, the architect so much in love with Japanese things, seems not to have been referred to even once in prewar discourses on Japan-ness, such as in Japan he became particularly hated around 1930. To a Western, the Imperial Hotel may have appeared Asian or Japanese, but not to the Japanese eye" [17]

Fig. 4.2.4 Tokyo Imperial hotel

Many architects of the time began to defend a certain Japanese architectural identity, understanding the absolute wealth that derives from it, but the society was not opposed to this change of style and subsequently to public buildings, even private houses began to lose their characteristic traits. The main reason was that the traditional Japanese House, even if built on solid concepts, was unable to meet the needs arising from the new way of living. The new generations were tired of this imposed economy, the simplicity of their living the house was more a requirement than a choice, imposed by the circumstances.

There was a general climate of rebellion towards the concept of noble poverty, the dignity of living in a humble way had been exceeded by the concept of home living typical of western countries. The traditional house, as already said, acquired strength from the daily rituals of its dwellers, the man lived in function of the rituals imposed by the tabernacle. According to a more Western vision, the house is realized in function of the man, the house does not dictate any ritual, but favors those imposed by the man. The real question is right here: the rituals of the past no longer coincided with the modern rituals, and it was impossible to adapt the new styles and the new requirements to the house of the past.

Changing the way to live it, the very Japanese House loses its meaning. It was built on a human scale, in fact the organization of the spaces was ideal for the life of man, but the modern conveniences and comfort features were lacking. Practically, when it comes to comfort, it meant, for example houses heated in winter, sleeping in a bed and not on the floor and above all more privacy and intimacy in life, basic things normally taken for granted in the western world, but absolutely new to the Japanese reality. The t*atami* is a key cocept of all this. The whole vital process of man was marked on the tatami, from birth to death: there people rested, made love, fed themselves; it was conceived as the essential space of a single person, the microcosm inside the macrocosm. There is a lot of poetry linked to the tatami and its use, but for the practical purposes of our contemporary times, it is almost unthinkable for Japanese people to live their lives on a tatami. What is surprising is that it is very difficult if not impossible to adapt the old to the new, as they have culturally made a real leap from one extreme to another. There is no continuity and no cohesion between East and West, the new style precisely comes from another dimension, with other styles and other cultural backgrounds that little have to do with the Japanese (social) dimension. This gap has continued to grow up until now, strongly dividing the urban fabrics with faces tied to the past, as the district of Yanaka in Tokyo, or others more Westernized as the district of Meguro.

The main fact is that an architecture that has never undergone a true radical change, but only an evolution, that has managed to remain alive for over a thousand years, has completely revolutionized its connotations, and this may seem very strange. It took thousands of years to achieve an identity, something unique all over the world, and only a generation to forget about it.

Fig. 4.2.5 House in Hakodate, Hokkaido

4.3 Present and future of Japanese houses

The new typologies of the house have had a strong impact on the change of Tokyo. The cultural gap has given life to a sort of limbo for what concerns the willingness of the future generations: there is a sort of problem precisely linked to the identity of the house, but everything is left to chance, very few attempts have been made to solve the problem, the home becomes something extremely private in a general stylistic selfishness. However, as history shows Tokyo's strength also lies in its regeneration, in its evolving and in its constant redefinition. To get out of this non-action phase, they should take a step back, the damage is relatively recent and therefore there is a large possible margin of intervention. The following are some data concerning the whole of Japan on the analyzed residential typologies.

In 1968 the total number of housing units stock was greater than the total number of households. This fact has continued to persist until today. The maximum number of new buildings erected in one year was reached in 1972, when it reached 1.8 million units. The values then began to decrease after the 1970s with the oil crisis, to climb again during the eighties and nineties, with the production of 1.6 million and 1.7 million units. In 2013, the total number of housing units stock was 60'630'000, 1.16 times greater than the total number of households, 52'450'000 people. In 2014, 880'000 units were built with 278'000 units occupied by the owners themselves, 358'000 units in rent and 236'000 units for sale. The main problem is that the relationship between supply and demand has grown up to 13.5%, leaving many houses vacant. This is because they often rely more on quantity than on quality. [2]

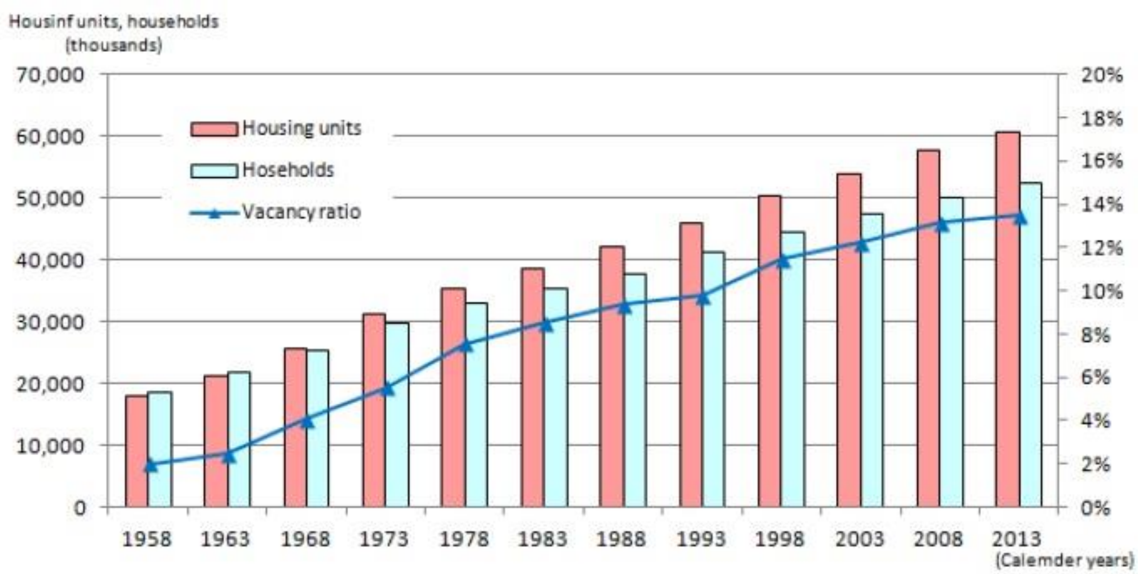


Chart 4.1 Vacant ratio [2]

In the past, the average size of a residential unit was relatively lower than those of today, the growth in the number of housing units in fact has also led to an average growth of floor area per unit of housing. In 2013 the average floor area for each unit was 94.4 m^2, so high, similar to the values of many European countries. However, there is a very great difference between owned units, i.e. those inhabited by the owner himself, and units rented to other individuals. The leased units have an average size of 46.0 m^2, a figure markedly lower than European standards. Speaking instead of residential buildings built in 2013, the percentage for detached houses was 54.1%, while it was 2.5% for terraced houses, and it was 43.3% of the housing stock for apartments. It may be noted that the detached houses, those that are most relevant to this thesis, cover a large slice of the market. [2]

After the reconstruction of the 1950s the idea of the family that had lived under the same roof and inside the same walls for 3 generations changed. The economic sprint brought each new family to desire a personal realization of their own house, every new generation was destined to construct their own house, idealized as a detached house, a single family house. The main problem was that the land and the available lots began to be hard to find, also when Japan became a true economic world power, the price of buildable soil skyrocketed. The dream continued, but in a more limited way, instead of sumptuous villas they chose simple and economic prefabricated systems to reduce total costs. Nowadays they have taken a step backwards, the desire to realize a 'personal' single family dwelling is still strong, but they must wait: what they hand down from generation to generation is no longer the house, but the soil where it will be possible to build the dream home.

In 1963, the wooden houses, i.e. the residential buildings made of a wooden frame, covered approximately the whole Japanese building construction panorama, as the percentage was 94.0%. In 2013 this data fell declined dramatically, as the percentage of wooden buildings is now 57.4%, and among these 25.2% of the total is non-fire prevention.

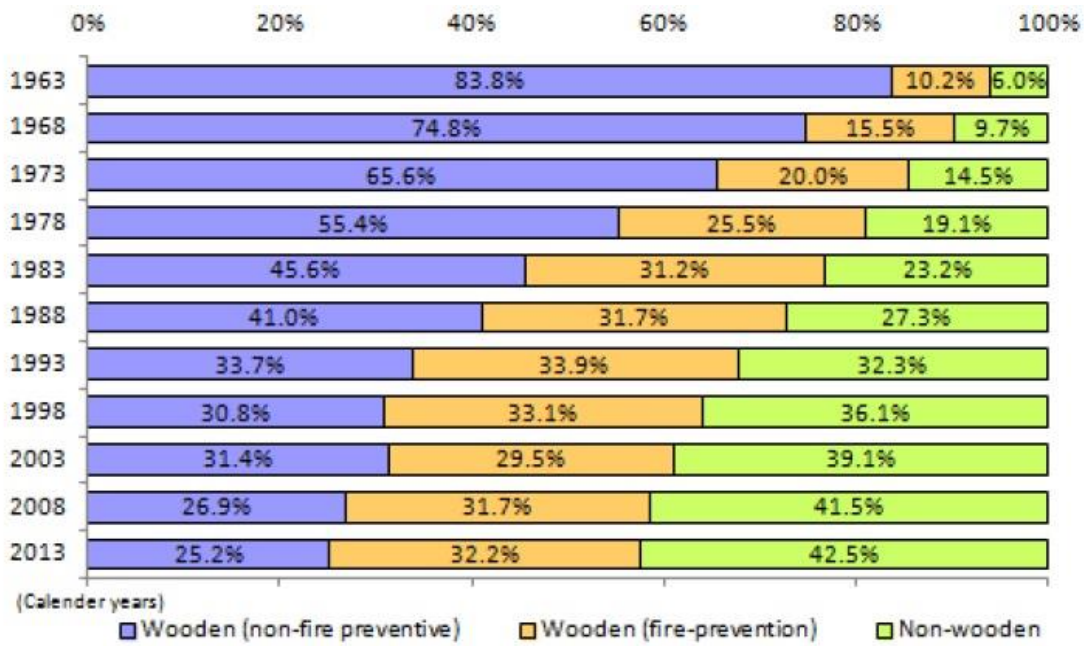


Chart 4.2 Wooden building decrease

In recent years, however, an investigation on the rate of satisfaction of the buildings in wood induced by the Cabinet Office has been proposed. The result has emphasized the great desire of the population to construct buildings in wood, as about 80% of respondents would like a wooden building when they dream of how to realize their own house. An analysis carried out by the producers of wooden houses shows that about 50% of residential buildings in wood with a pillar and beam structure is produced by small enterprises, which are able to produce only 50 units per year. There are other statistics which relate to the number of people that are satisfied with their living space: 24.9% of the population is not satisfied. The main reasons of the dissatisfaction are:

1. security in the event of an earthquake,
2. Energy consumption and costs arising from it,
3. old buildings requiring renovation. [2]

Omitting the security in the event of an earthquake, which can derive from subjective reasons linked to past events and not from real issues, it can be noted that the second reason for dissatisfaction concerns energy consumption.

As it will be explained in the chapter linked to energy analysis, the proposed system wants to intervene in this regard, reducing consumption in an environmentally sustainable way. Japanese legislation has recenteeely promoted the use of wood in construction, considering it as one of the basic principles on which to base a planning committed to the environment. Actions in favor of this promote the teaching of technical skills related to the know how necessary in the construction of wooden buildings, which is slowly weakening, and an economic support given to the companies of medium-small size. They point to the creation of buildings in wood, lasting longer than the existing ones, thus lengthening the average life of Japanese buildings, and able to reduce the energy consumption related to air-conditioning.

The wood industry, however, is more focused on mass production as they prefer a global market, and the concept of prefabrication blends perfectly with the ideology of the industry: mass production of buildings to be sold to a global panorama. The development of these mechanisms in favor of the big industry, as compared to those provided by the public administration in favor of medium-small industries, is therefore logical.

In the rest of the world a prefabricated building is considered less durable and less desirable than one realized in *loco* in longer times, as the quality is poor. The opposite occurs in Japan: Japanese prefabricated houses nowadays are the top range of the houses that people can find on the Japanese building market, and can be easily updated in a very short time. They have reached this stage, however, only because of the experimentation carried out in the reconstruction period between the post-war years and today. In the past the quality of the houses was very poor but over time the buildings have been improved, becoming the best that you can buy on the Japanese building market. The only real problem is that there are no prefabricated models that reflect Japanese architecture style.









Fig. 4.3.1 Example of prefabricate system by Sekisuiheim

In the past, as already explained, it was impossible to integrate modern facilities with the traditional way of living the Japanese house. But after 50 years of evolutionary processes related to studies and experiments, is it still so?

We must ask ourselves if the needs of new life styles can now integrate with the architectural styles of the past, if it is possible to bridge the gap that has emerged with the passing of time, if it is possible to give an identity to the dead zones of the city. Alternatively, if it's possible to go ahead and find new rituals to live the Japanese house, more related to the needs of contemporary society. It is said that the real strength of the Japanese people is their ability to capture something that comes from the outside world and make it an internal element, giving it a Japanese identity. Take a foreign body and give it a Japanese soul. With the Western systems, this has not been done yet.

5 Description of the system:

5.1 Introduction

The proposed system is a prefabricated one itself. When compared to other ones, this system does not propose the final solution for a prefabricated building, rather, a way to realise it. The system is composed by a kit containing structural elements, and by another one containing closing elements. This freedom leaves great room to intervene to both the client and the designer, allowing for the project's adaptability to both the construction area and the urban landscape.

The first kit is the structural one. This relies on laminated wood, made of Cryptomeria Japonica, more well known as Japanese red-cedar, (すぎ). This system plays a fundamental role during the designing stage, reason why its elements are regulated by technological and dimensional limits that set up the building rules. Of course the freedom left to the customer can lead to changes, often substantial, in terms of light and measurements of the elements.

Obviously in the common practice for a right design, the sections of individual structural elements would be gradually changed, depending on the reduction of the span length. It has been decided however to keep these sizes fixed, in order to speed up the building process and the practical function of the assembling system itself, which is not meant to accommodate different sections. What could be saved by designing each section according to the true area of influence is gained in terms of speed and strength of the whole system.

Until ten years ago, building a wooden structure would have meant a very high realisation cost, especially when taking into account traditional Japanese structures, which would have made it a craft in itself. Therefore there were very few wooden structures that were factory produced, as the realisation cost was extremely high for such a specialised project. However, nowadays it is possible to combine an accurate digital design and digital building techniques (such as CNC machines, automated systems), therefore achieving a very precise result at a reasonable cost. This aspect in particular has been decisive when making the choice to adopt a structural system based on wooden joints. However, since this is not a normalised system, its scientific reading is still very limited, reason why a digital model has been realised in order to be able to conduct a structural analysis of the finished product, which will be unpacked below.

Once the structure has been chosen, it is possible to proceed with the designing of the casing. The system here proposes pre-assembled elements and, in particular for the closure and partition systems it is possible to distinguish between vertical elements and horizontal elements. The perimetral walls and internal partitions are assembled in the factory so that when the semi-finished product arrives in the yard, the floor and the roof are built on site. To speed up the timing of the latter, dry technologies have been chosen. An innovative proposal is that of combining the industrialized system with traditional techniques, as in a world where the handmade crafts are slowly vanishing, it is important to make these desirable once again. Therefore, the proposal is to incorporate wooden details realized by local artisan in the facade of each building, with the aim to make them unique.

When it comes to the service system, it is almost impossible to rely on a standardised implant that would be suitable for each project, however, it has been possible to agree on a a series of elements and implants to chose from. An heating pump system with radiant floor panels has been chosen for the heating, cooling, and production of sanitary waters. This has been joined with a mechanical ventilation control for the hygrometric monitoring of the air. When assembling this system, it is possible to tailor it to diverse spaces and dimensions, these being open when it comes to more traditional architectural elements, or closed in their most contemporary conception.

5.2 Element-Kit for structure

Here all the structural elements at the disposal of the kit, in particular the maximum eligible spans are reported.

5.2.1 Interfloor level

Central joint

Below the wooden elements, in order:

Summer beam, 597cm x 30 cm x 40 cm

Secondary beam, 417 cm x 30 cm x 40 cm

Joist, 380 cm x 20 cm x 12 cm

Pillar, 310 cm x 30 cm x 30 cm

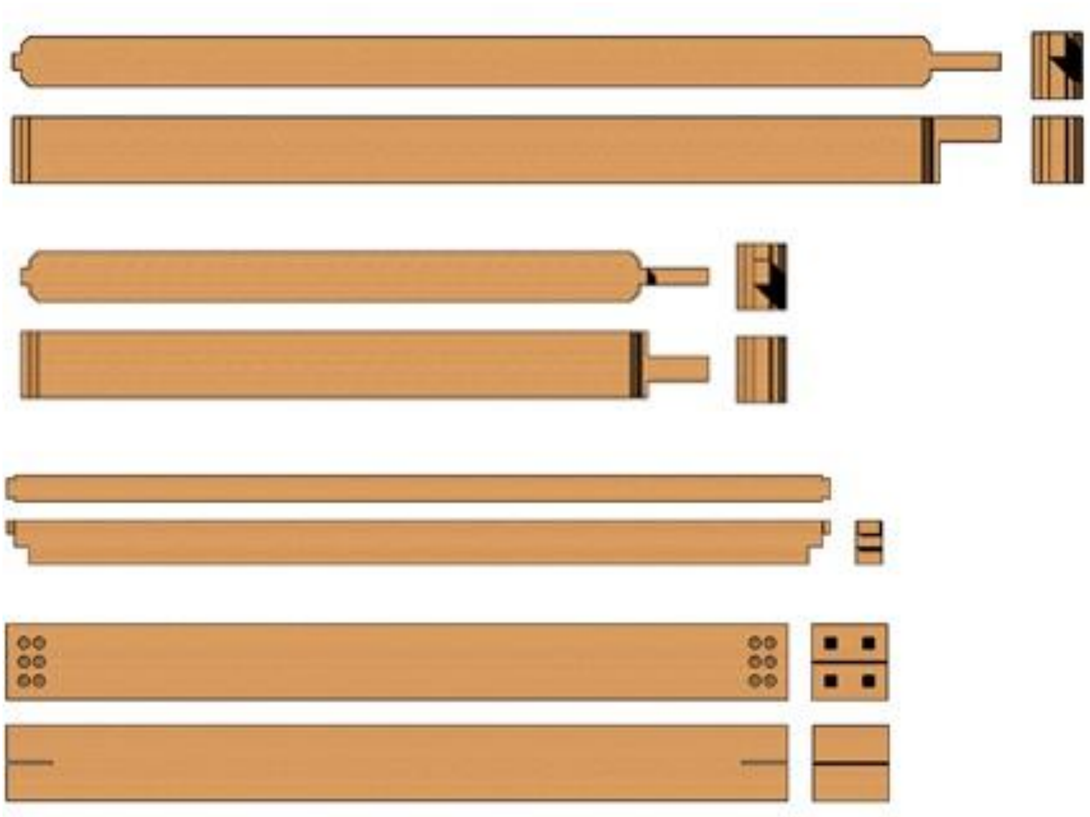


Fig. 5.2.1 Wooden elements

Below the steel elements:

Cross, 60 cm x 60 cm x 10 cm

Lower frame 59 cm x 30 cm x 30 cm

Upper frame 780 cm x 30 cm x 30 cm

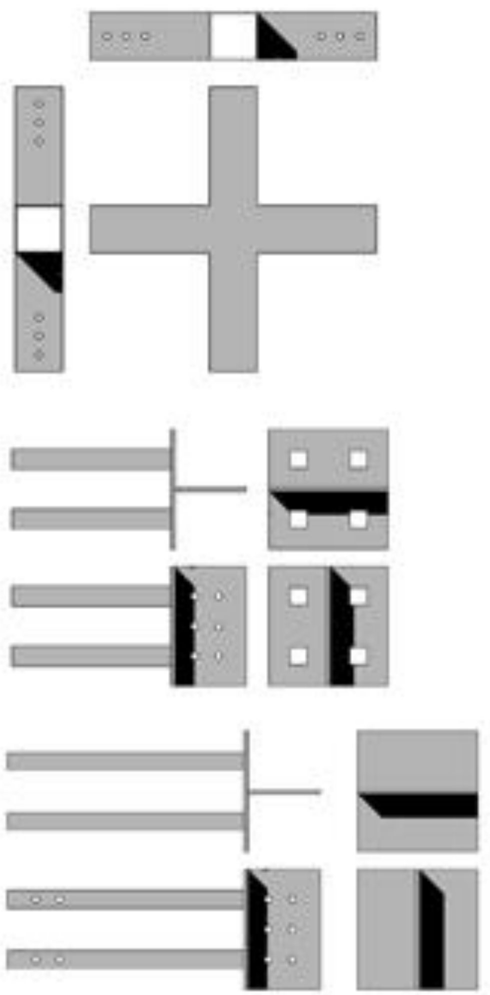


Fig. 5.2.2 Steel elements

Here the construction steps:

1) The pillar rises from the ground floor ready to accommodate the beams and the steel cross is inserted.

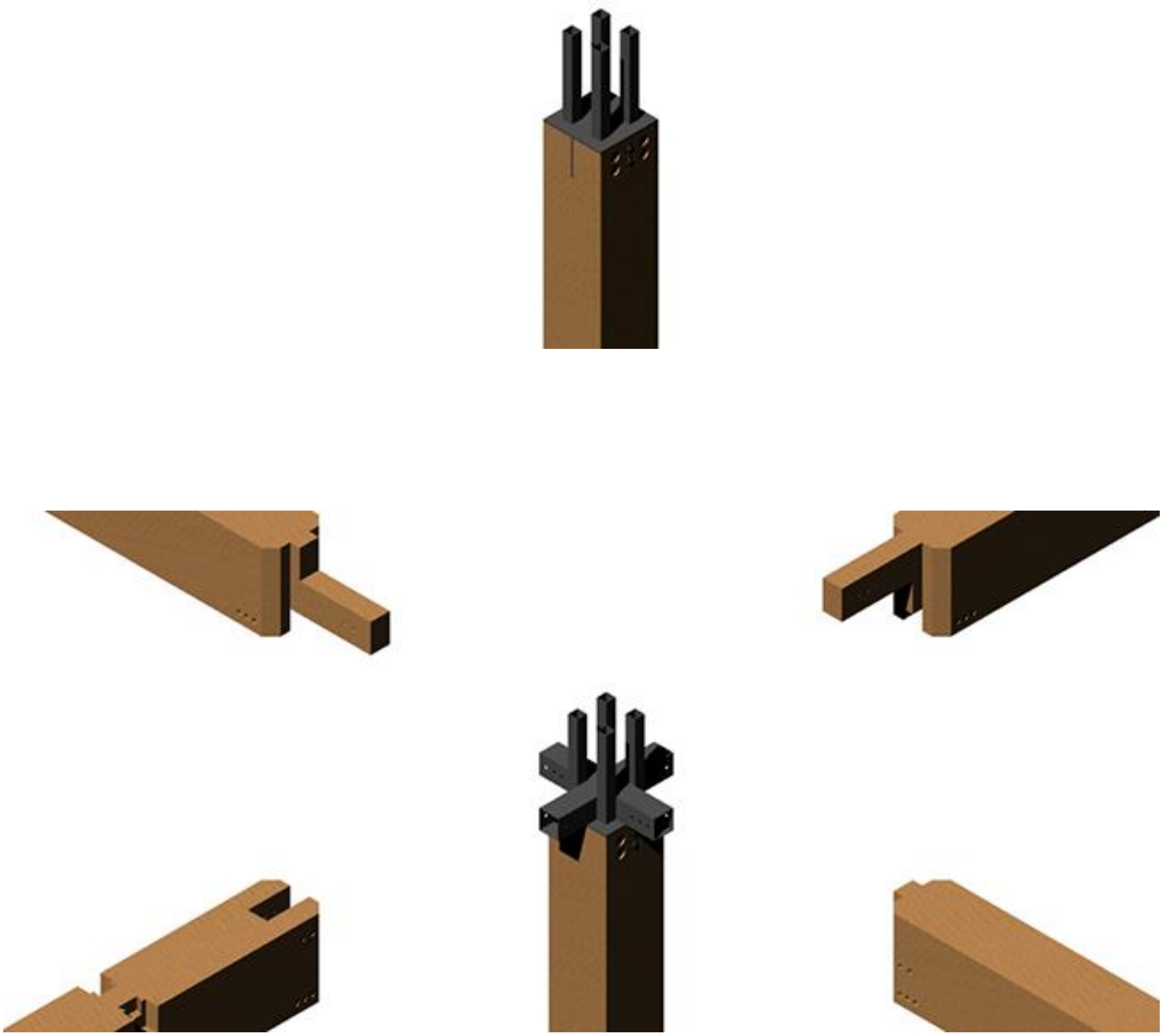


Fig. 5.2.3 Phase 1

2) The beams are connected.

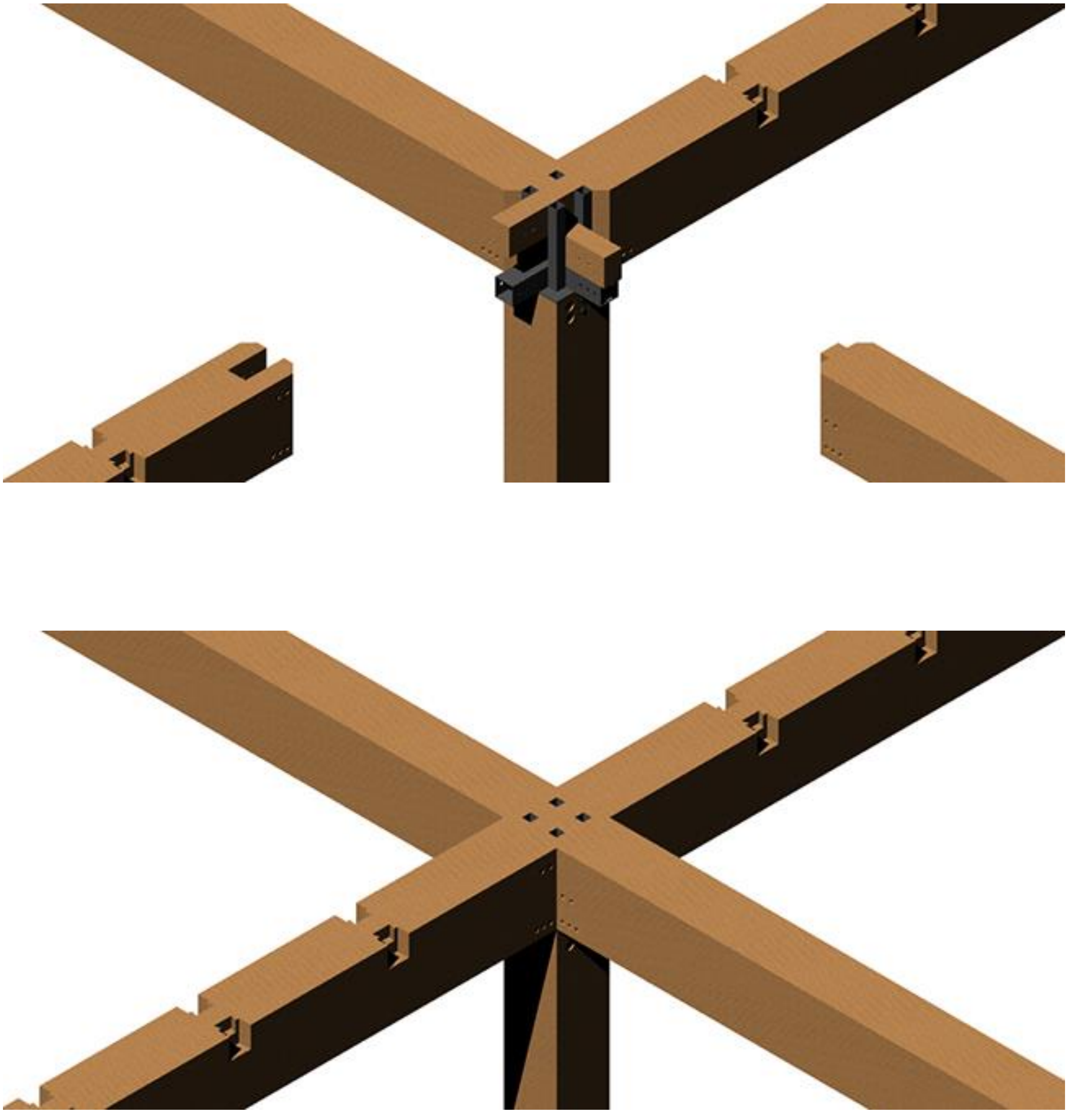


Fig. 5.2.4 Phase 2

3) The beams are fixed,connected through the bolting system.

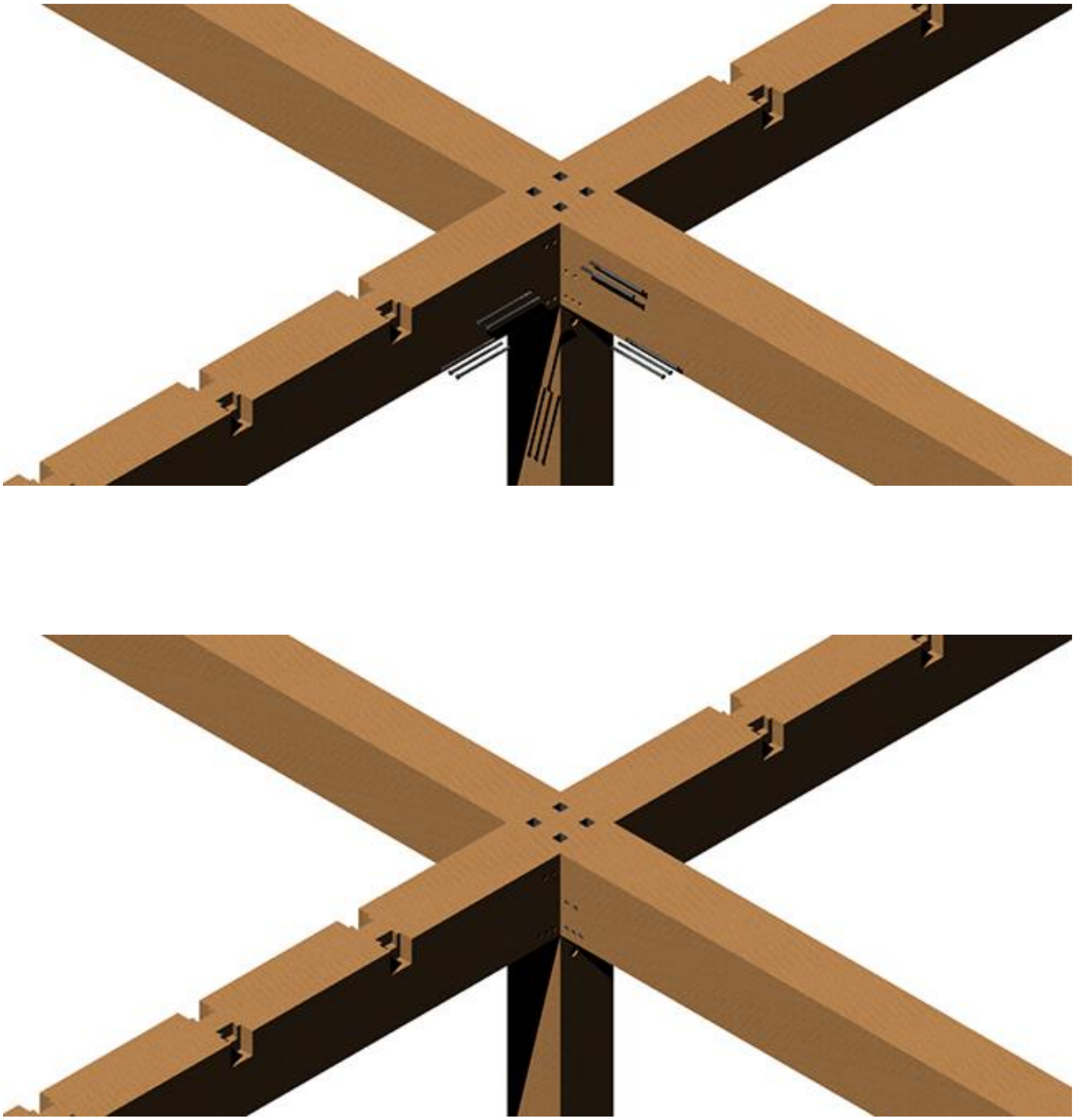


Fig. 5.2.5 Phase 3

4) The upper pillar is lowered.

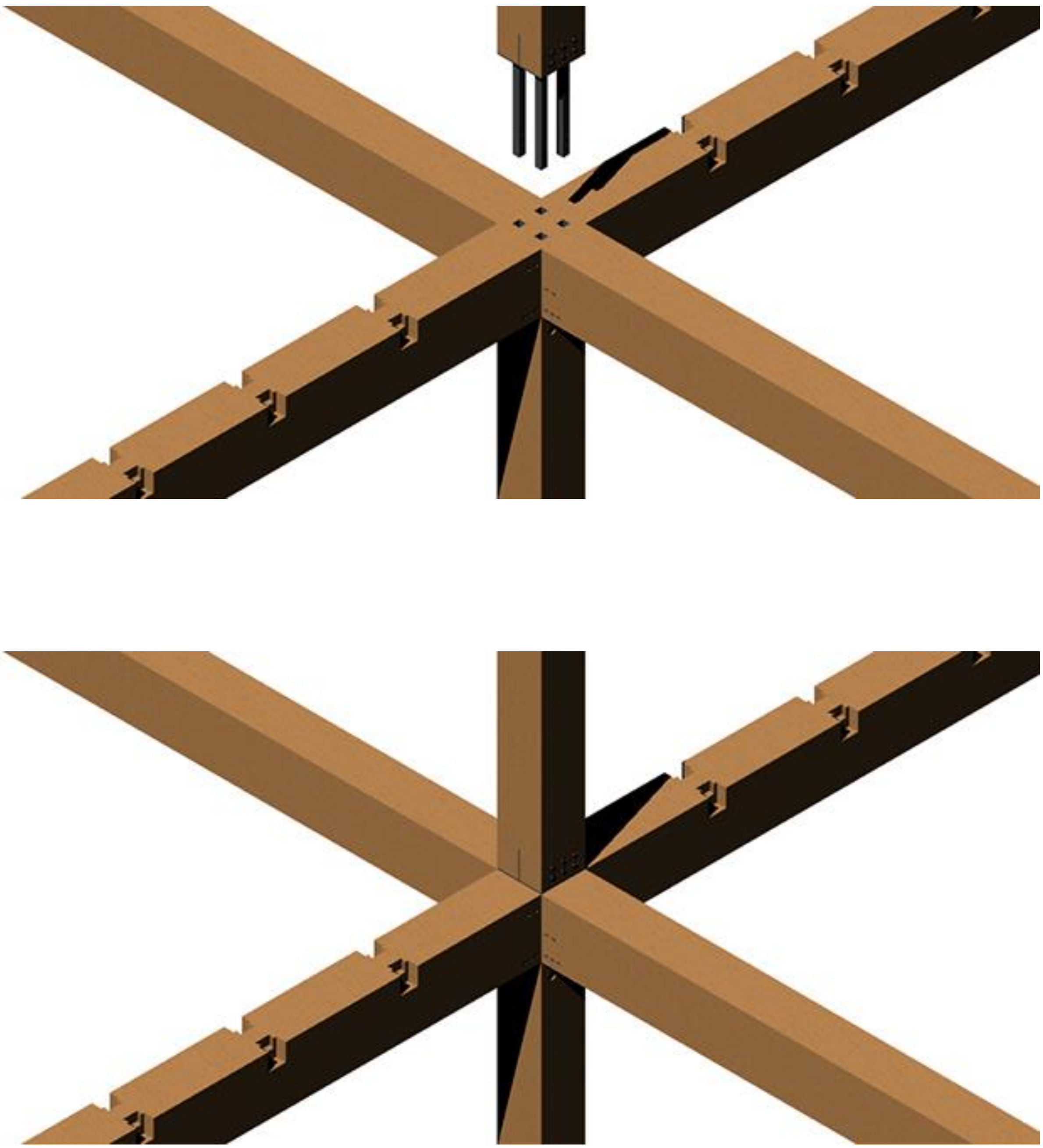


Fig. 5.2.6 Phase 4

5) The superior steel frame of the pillar is fixed to the inferior steel frame.

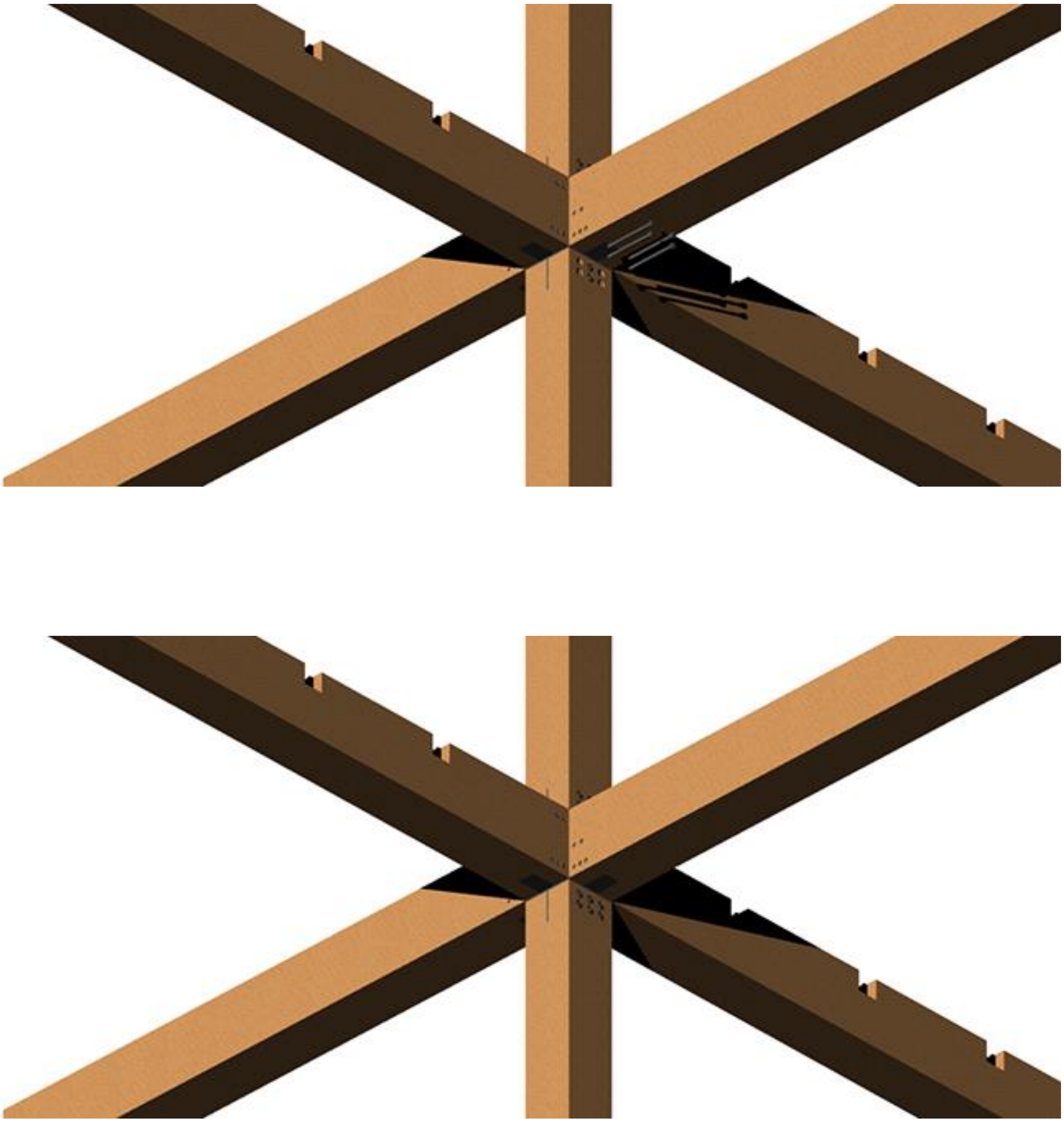


Fig. 5.2.7 Phase 5

6) The joists are positioned once the joint is fixed.

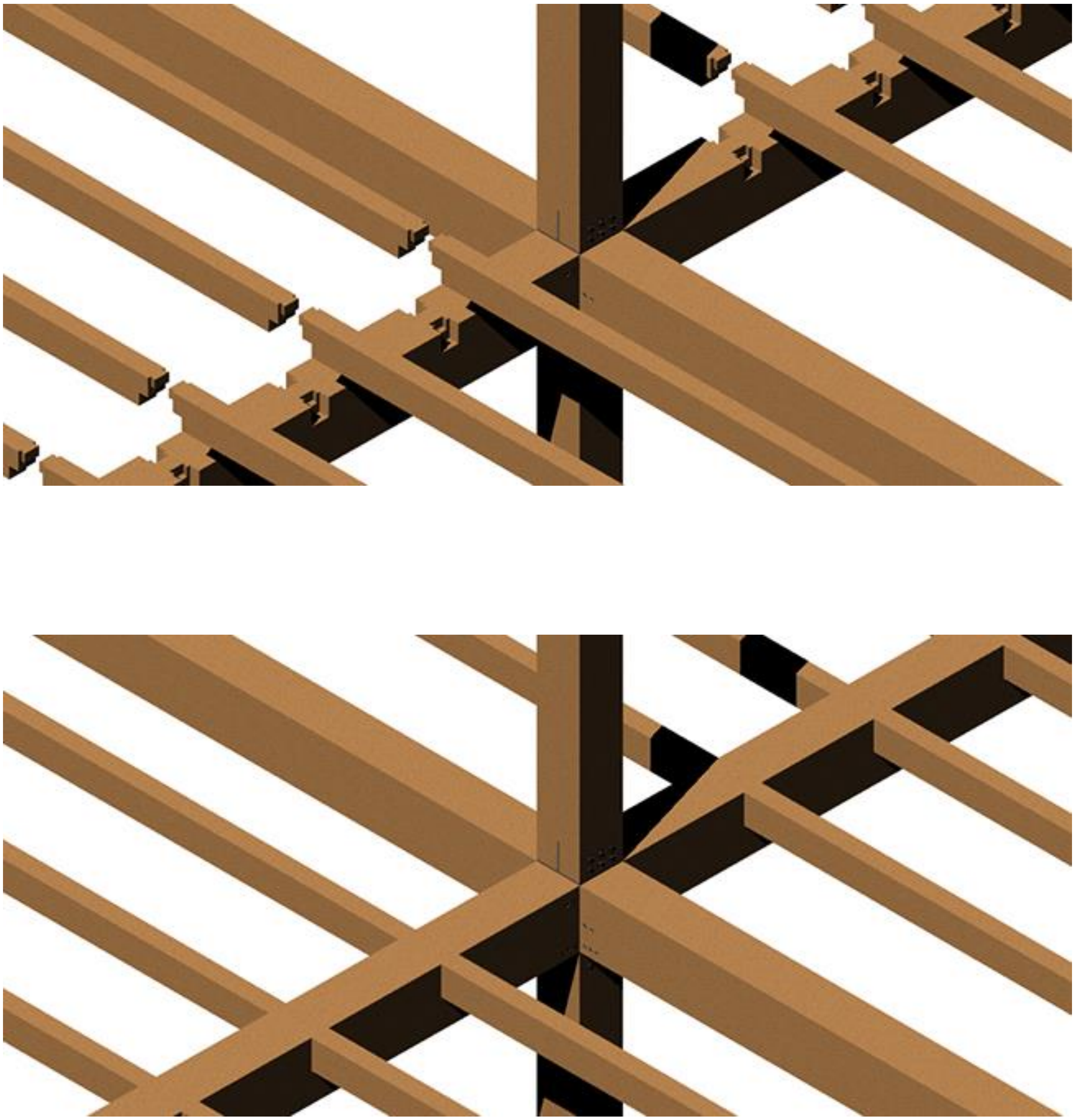


Fig. 5.2.8 Phase 6

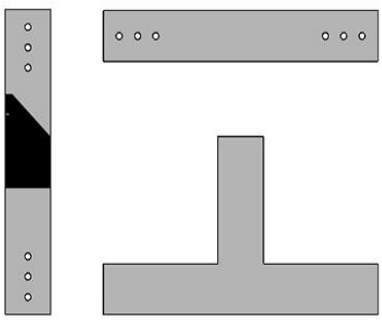
7) The structural planking, the perimetral walls and the floor are subsequently added.

The assembling steps are similar for the side and the corner interfloor joints, in particular a mask will be used as closure of the junction.

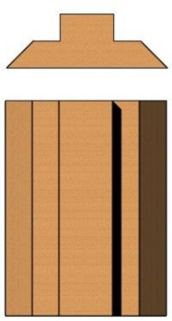
Lateral joint.

The elements of the kit that change are:

Steel cross, 35 cm x 59 cm x 10 cm



Wooden mask, 40 cm x 30 cm x 10 cm



For the assembly, it's similar with the previous one; A change is for the steel cross: when it is inserted, the closure mask is connected to this. The beams that stop at the perimetral bound don't have the extension.

Fig. 5.2.9 Phase 1

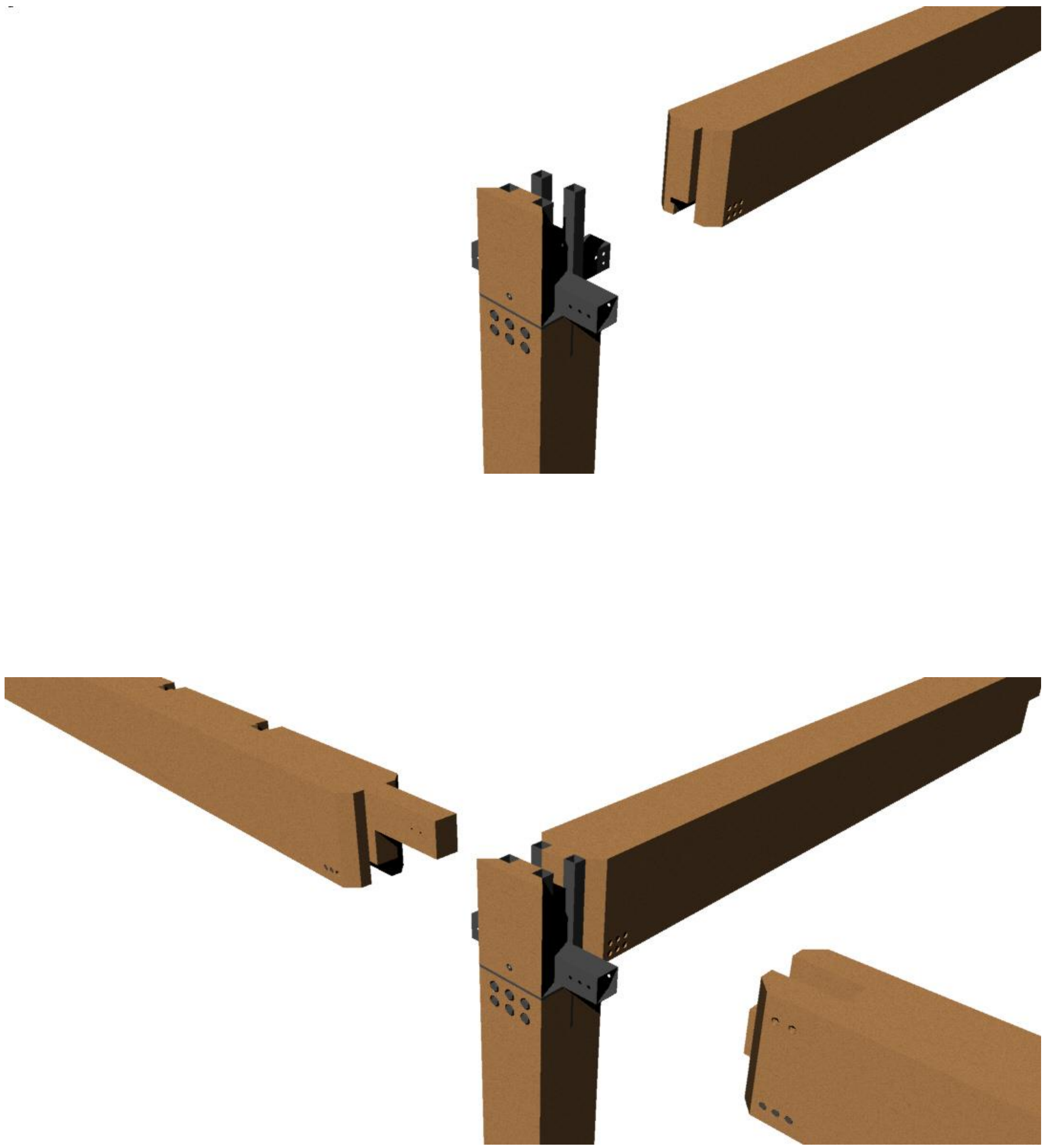
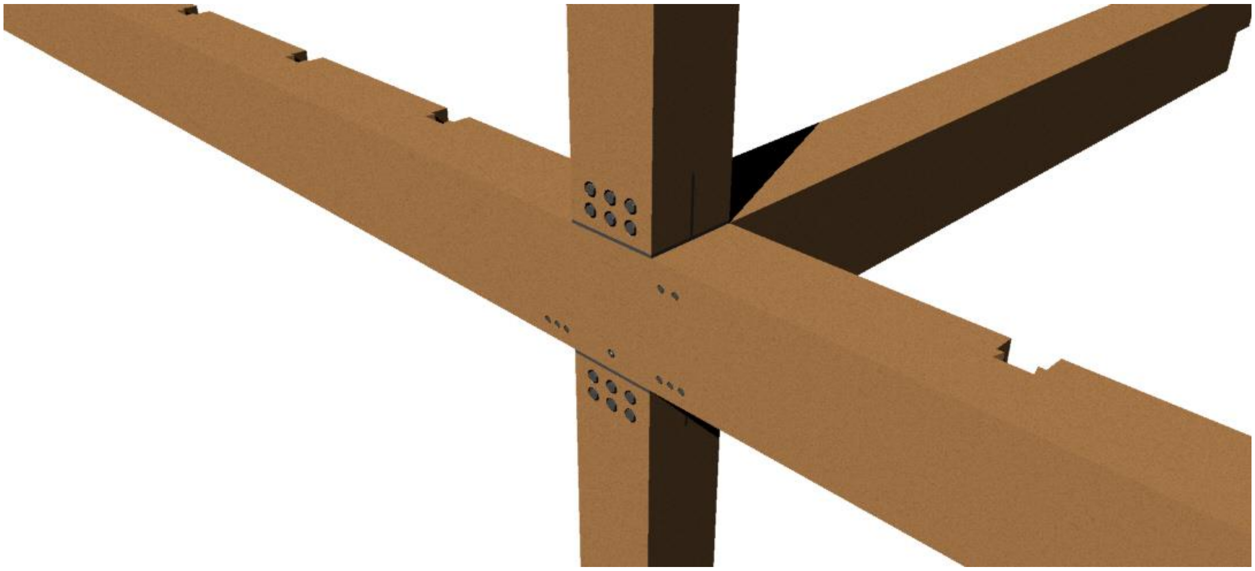


Fig. 5.2.10 Phase 2



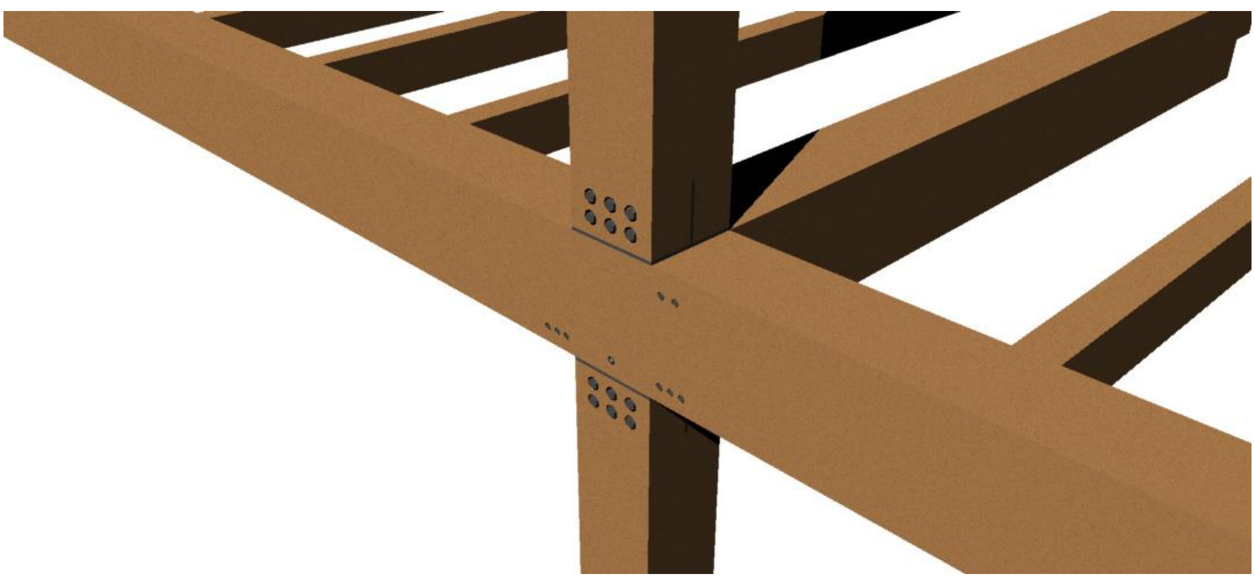


Fig. 5.2.11 Phase 3

Note the detail of connection.

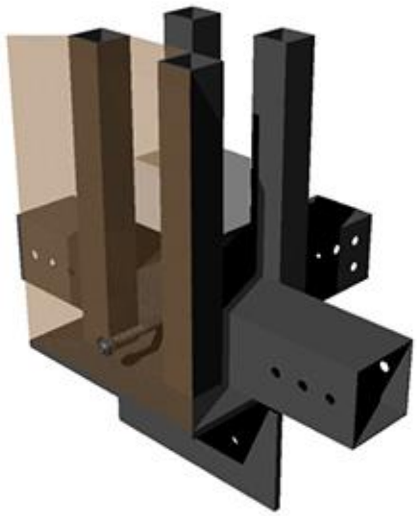
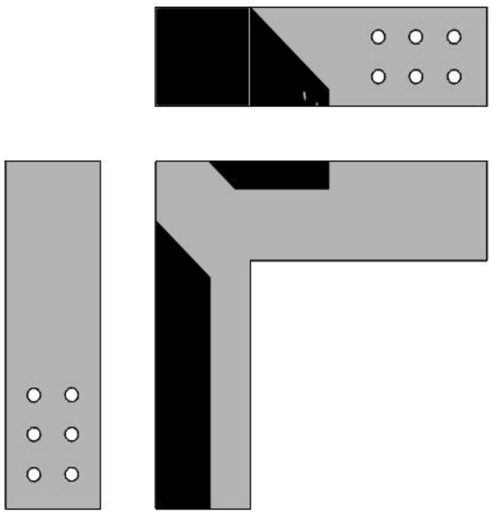


Fig. 5.2.12 Connection detail

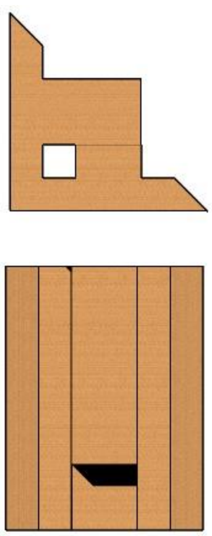
Once everything is connected, the bolt connection of the mask is recalibrated and two wood screws are inserted at the top.

<u>Corner joint.</u>

Cross, 35 cm x 35 cm x 10 cm



Mask, 40 cm x 30 cm x 30 cm



The assembly steps are identical to those of the lateral joints:

Fig. 5.2.13 Phase 1

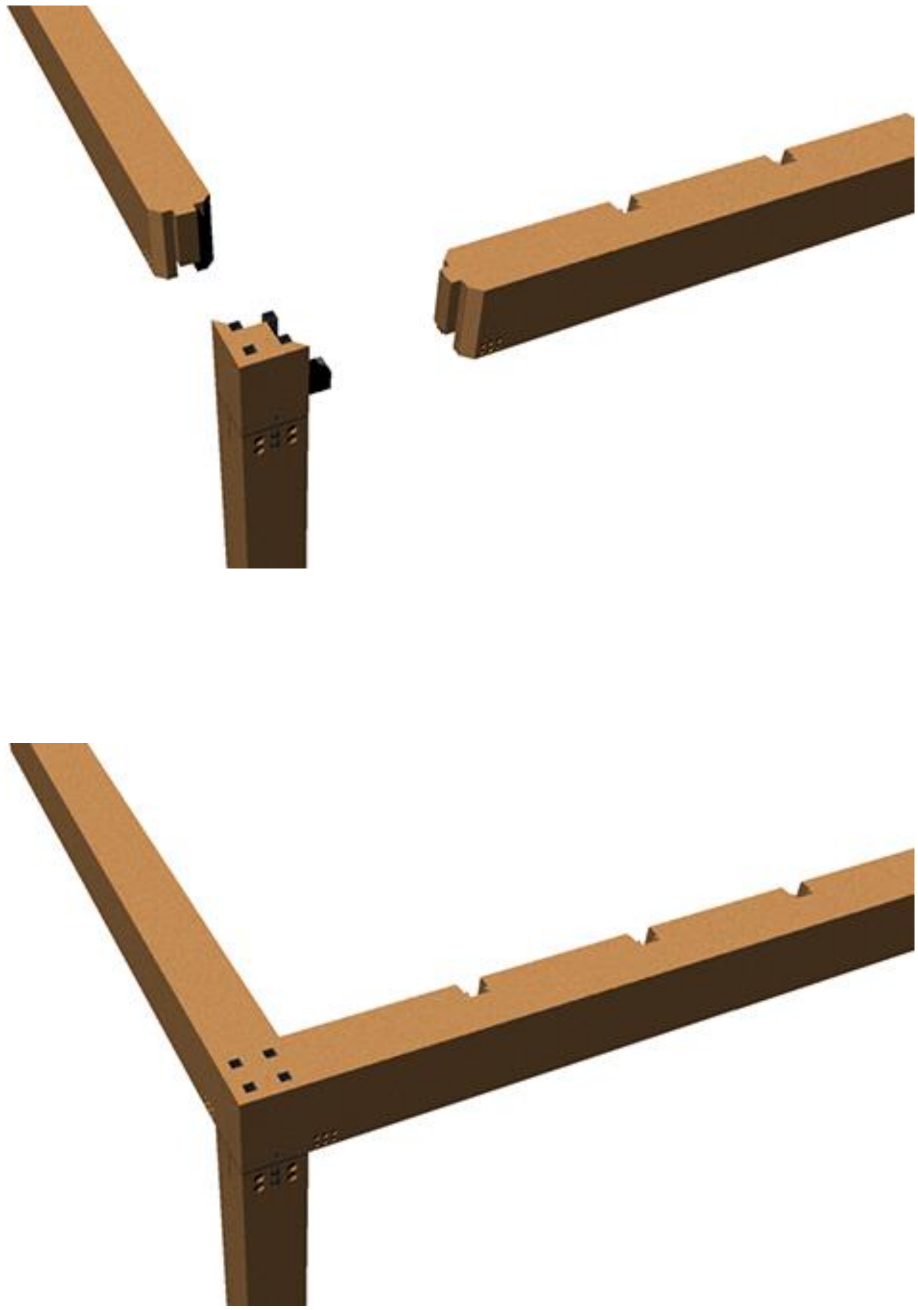


Fig. 5.2.14 Phase 2

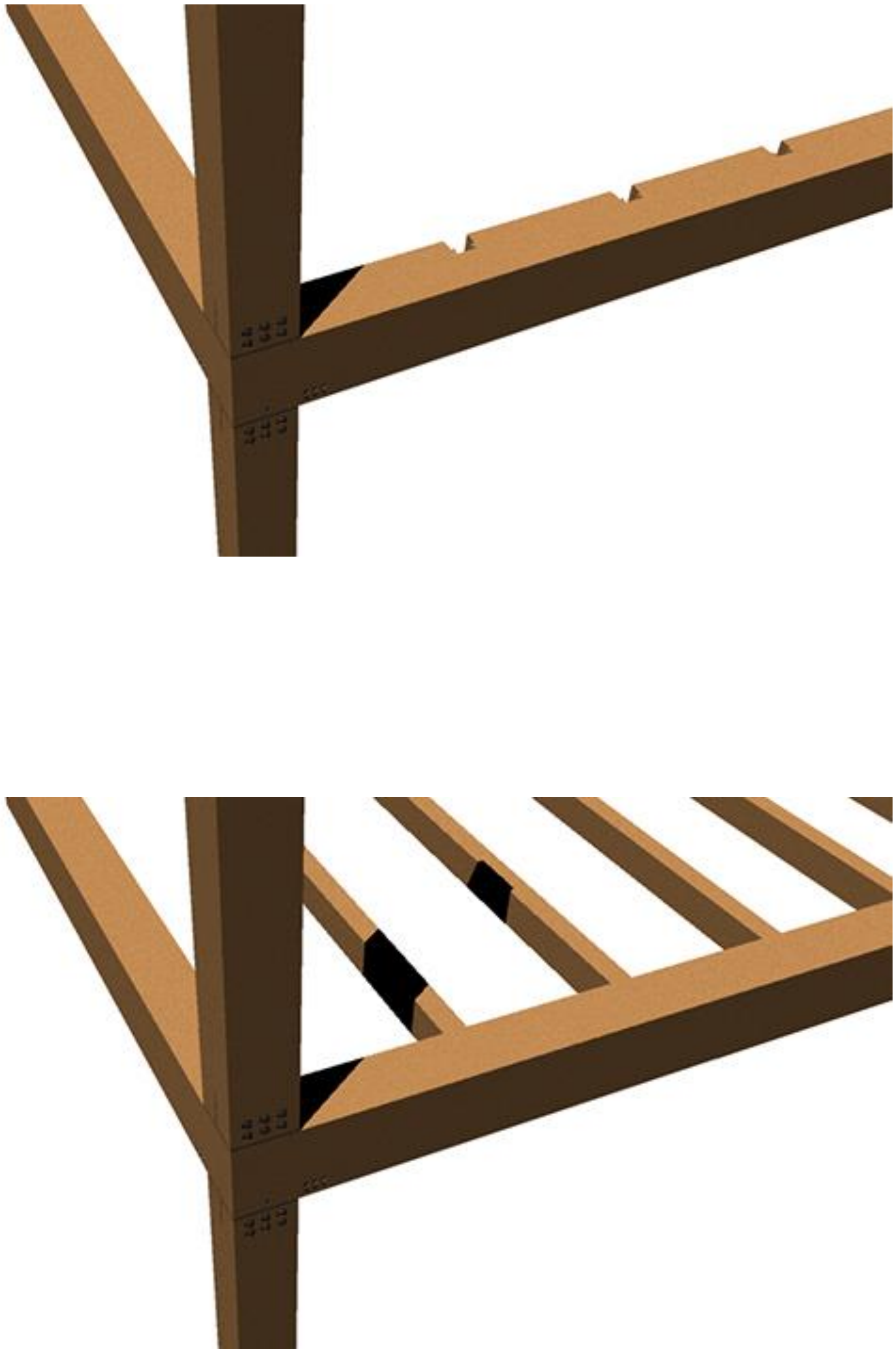


Fig. 5.2.15 Phase 3

For further detail refer to Annex A and D

5.2.2 Foundation level

Central joint.

The real foundations are formed by a system of beams and plinths in reinforced concrete directly cast in situ. A neoprene mat is then placed on upper side of the concrete to standardize the supporting surface and the wooden beam above this.

The wooden elements of the kit are, in order:

Summer beam, 540 cm x 30 cm x 30 cm

Secondary beam, 360 cm x 30 cm x 30 cm

Joist, 380 cm x 20 cm x 12 cm

Pillar, 350 cm x 30 cm x 30 cm

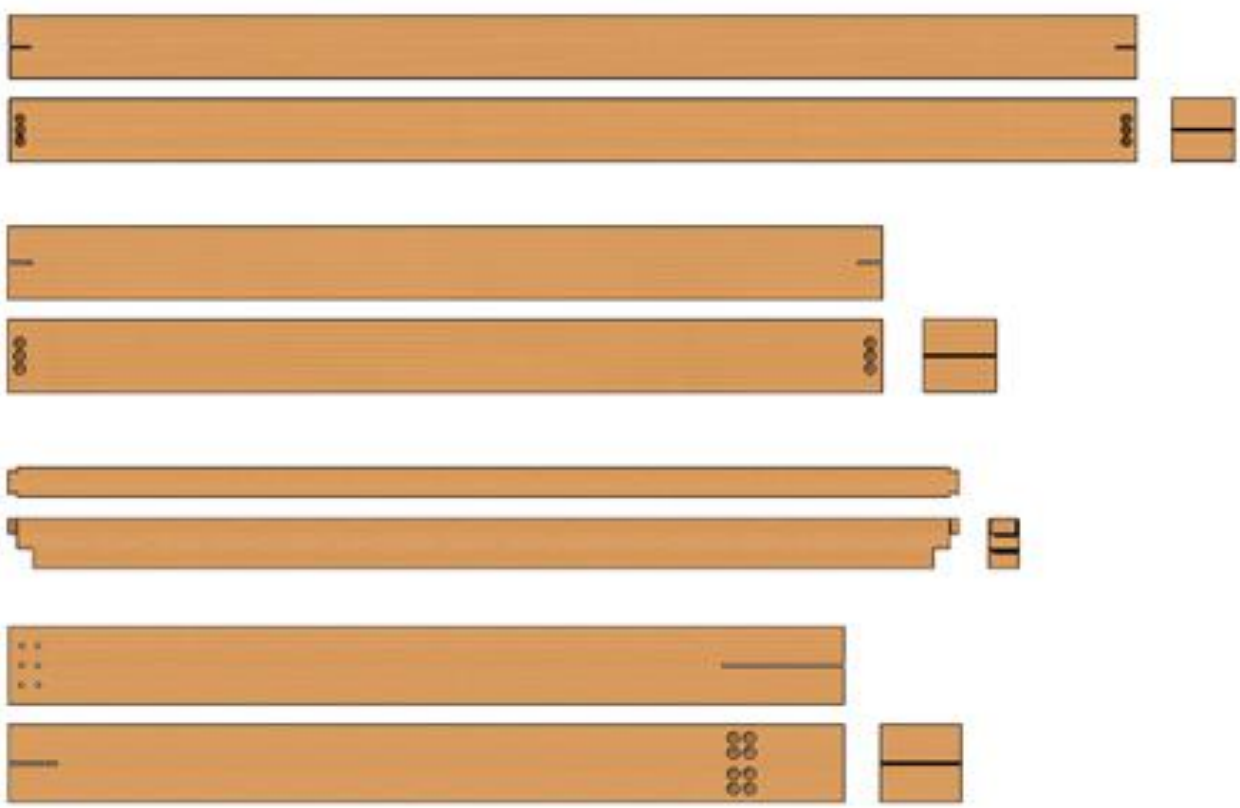


Fig. 5.2.16 Wooden elements

A steel bracket is also arranged to connect the pillar to the system of the foundation.

Plate, 50 cm x 50 cm x 47 cm

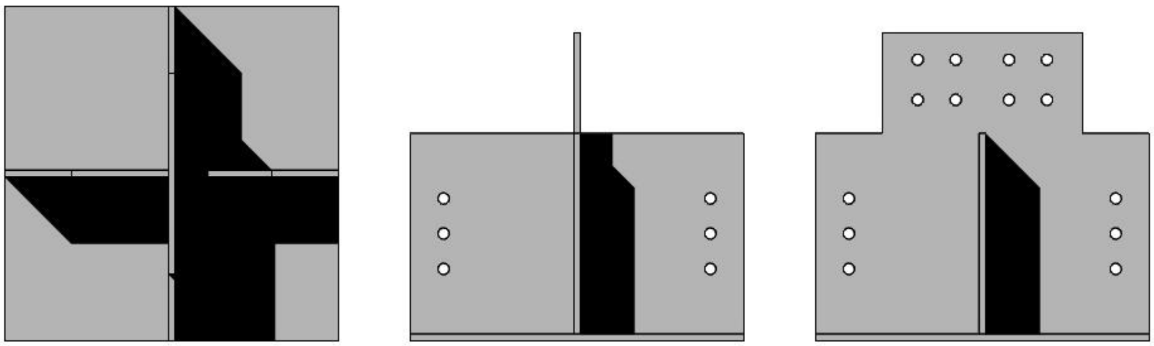


Fig. 5.2.17 Steel plate

The central joint is then assembled according to the following steps:

1) The foundation cast in situ with annexd steel frame embedded in concrete is ready to accommodate the wooden system, a mat of neoprene is put between the concrete and the wood.

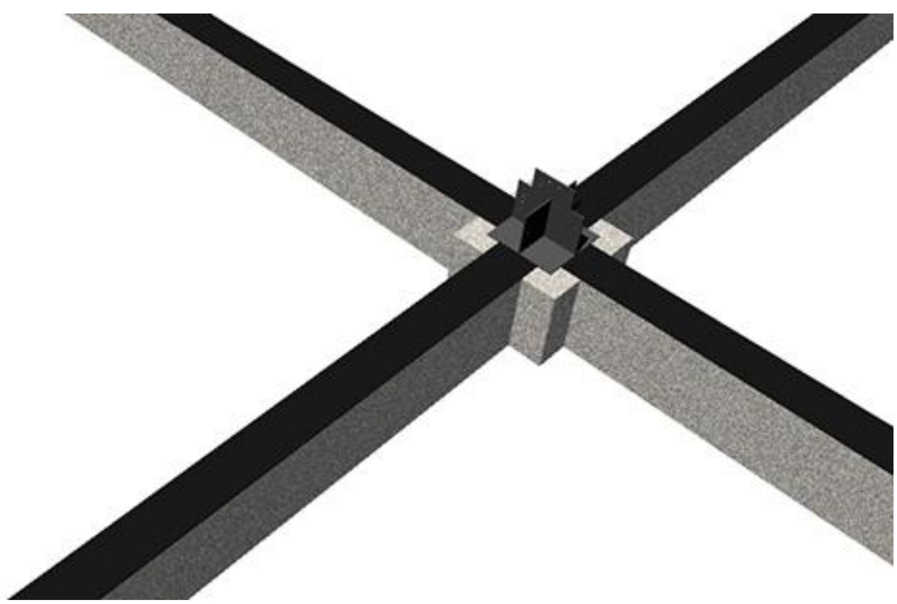


Fig. 5.2.18 Phase 1

2) The pillar is inserted and fixed.

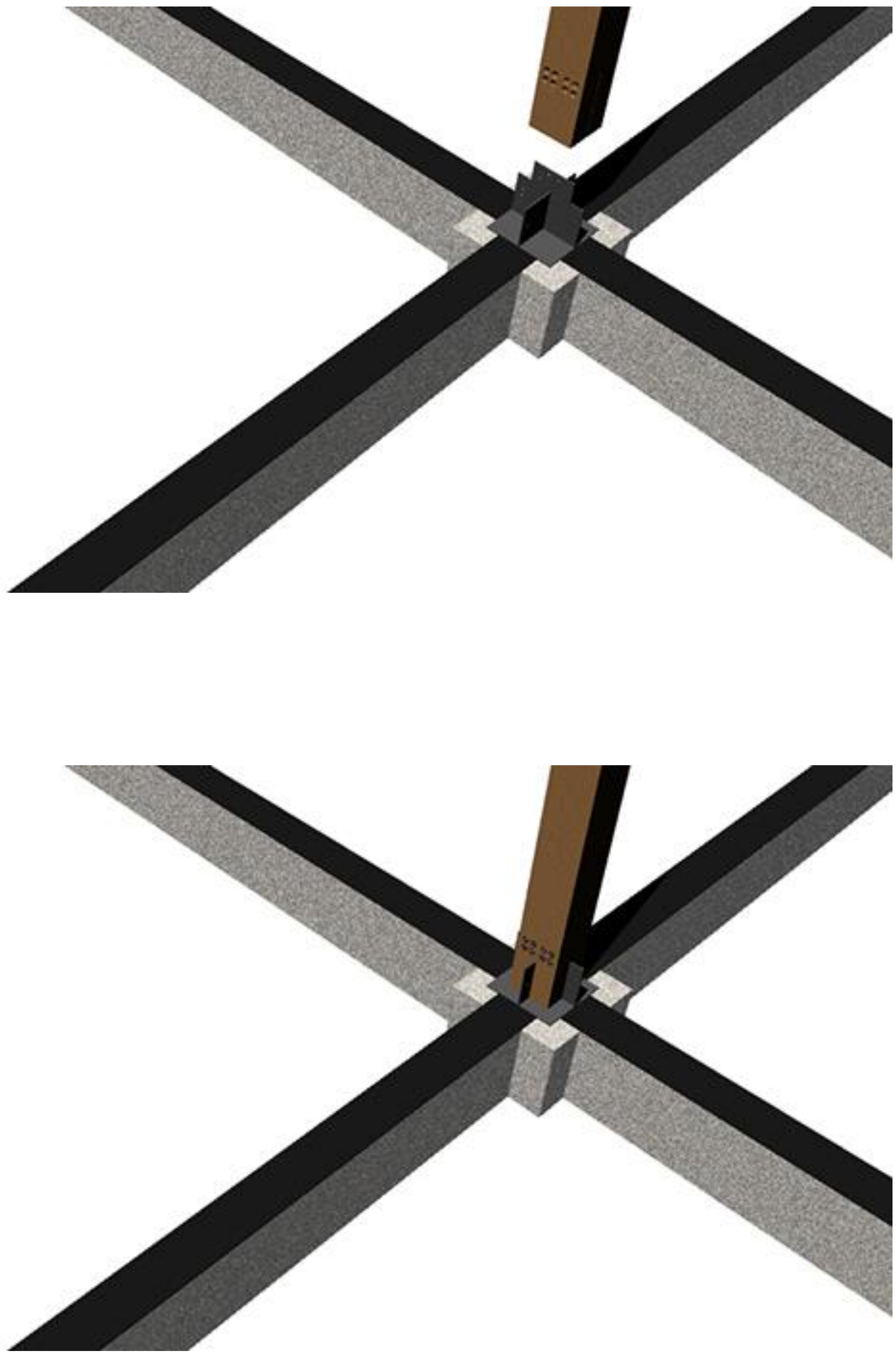


Fig. 5.2.19 Phase 2

3) The beams are connected to the joint and fixed.

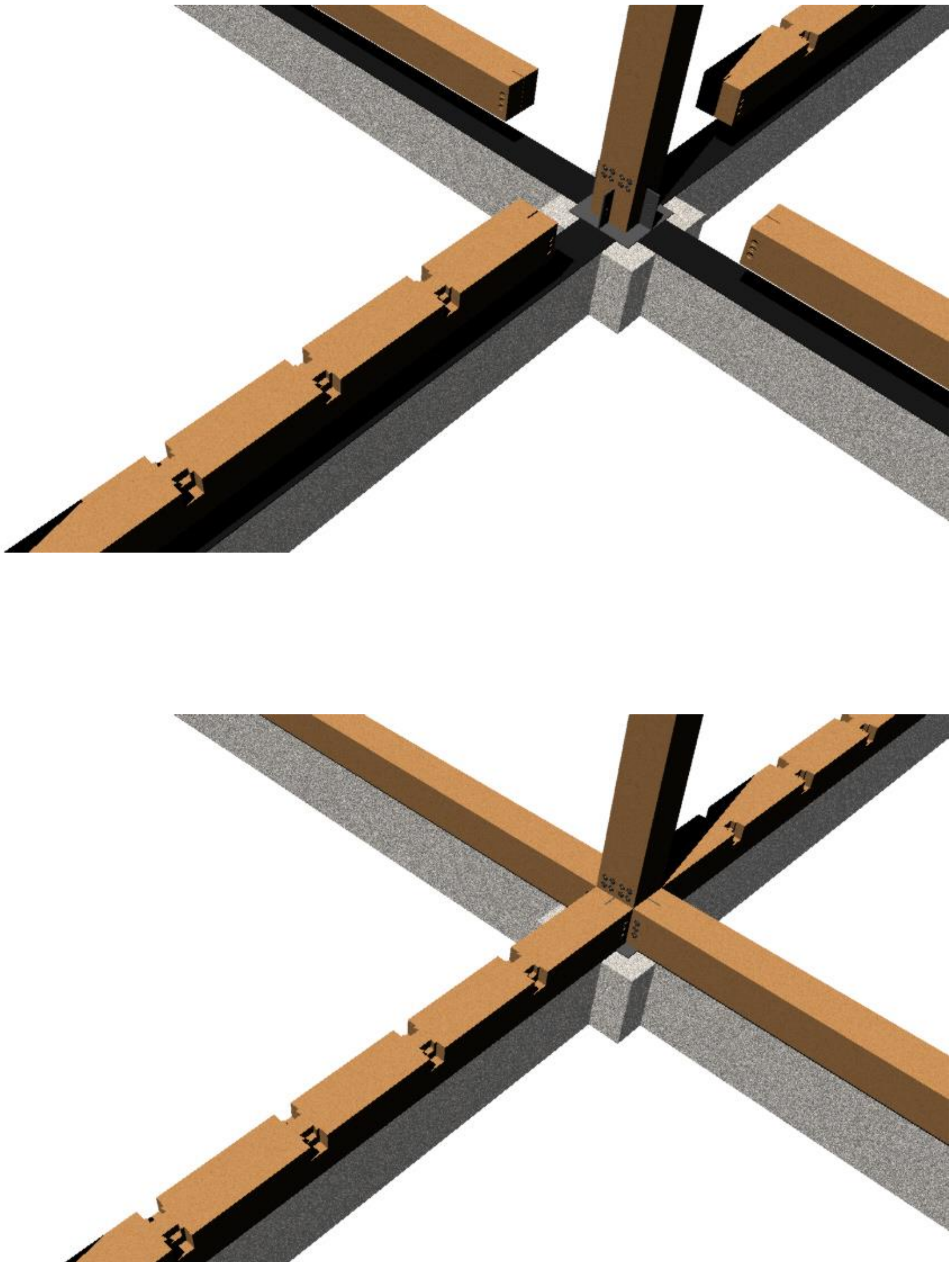


Fig. 5.2.20 Phase 3

4) then the joists are inserted.

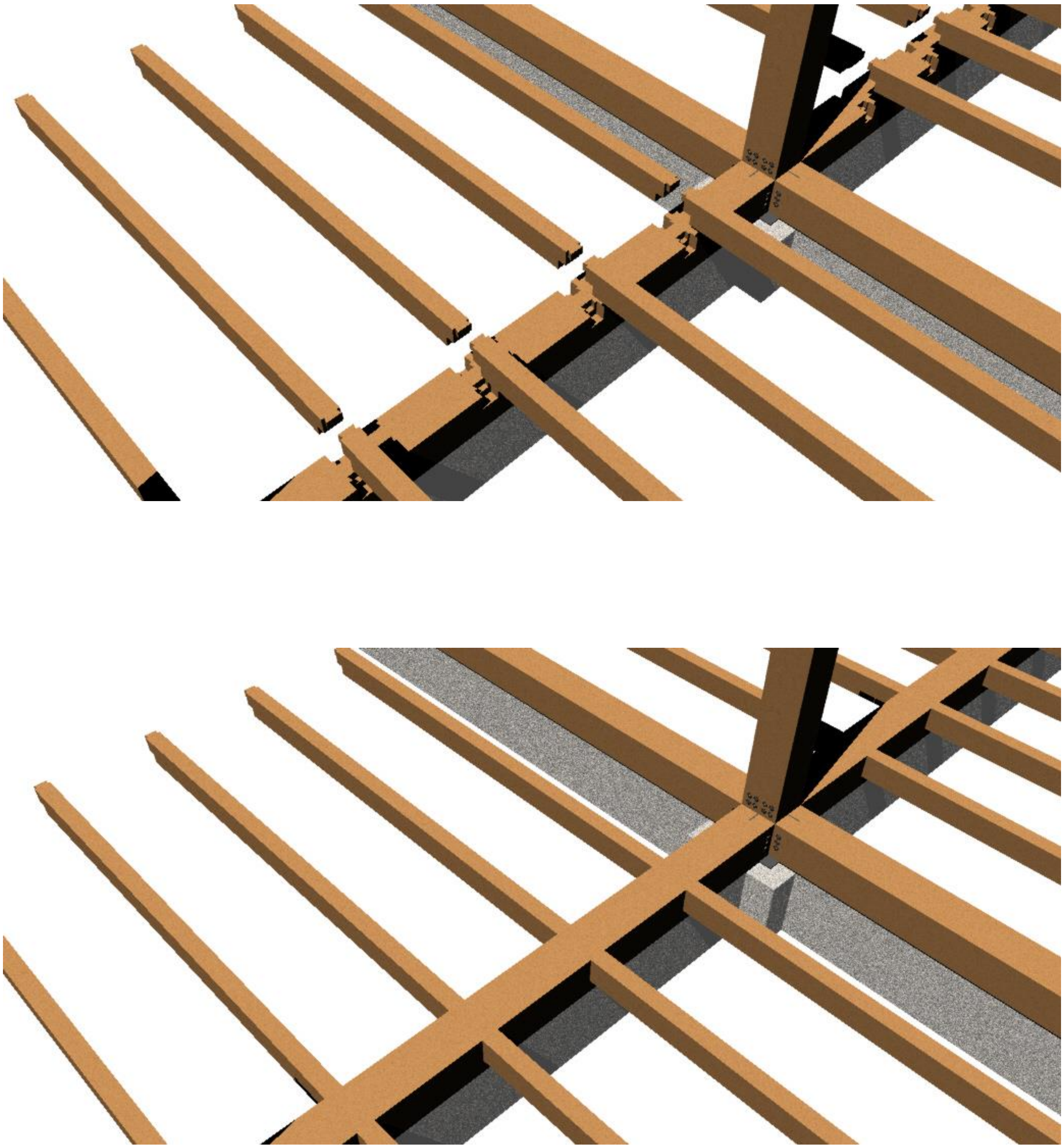


Fig. 5.2.21 Phase 4

Lateral joint.

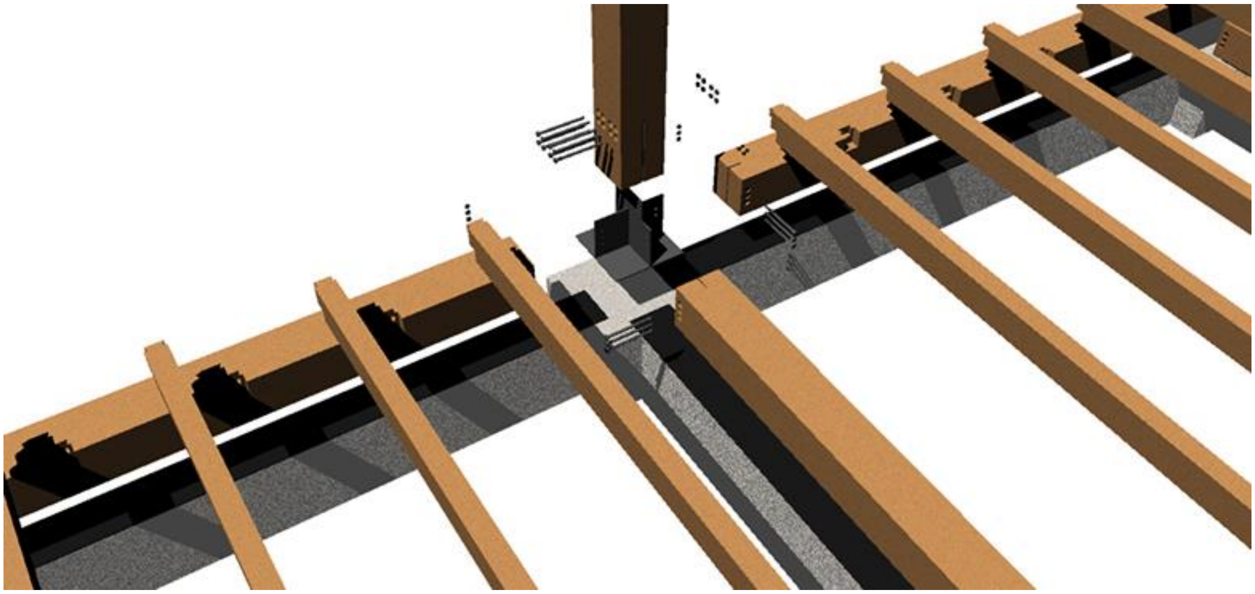


Fig. 5.2.22 Lateral joint

Corner joint.

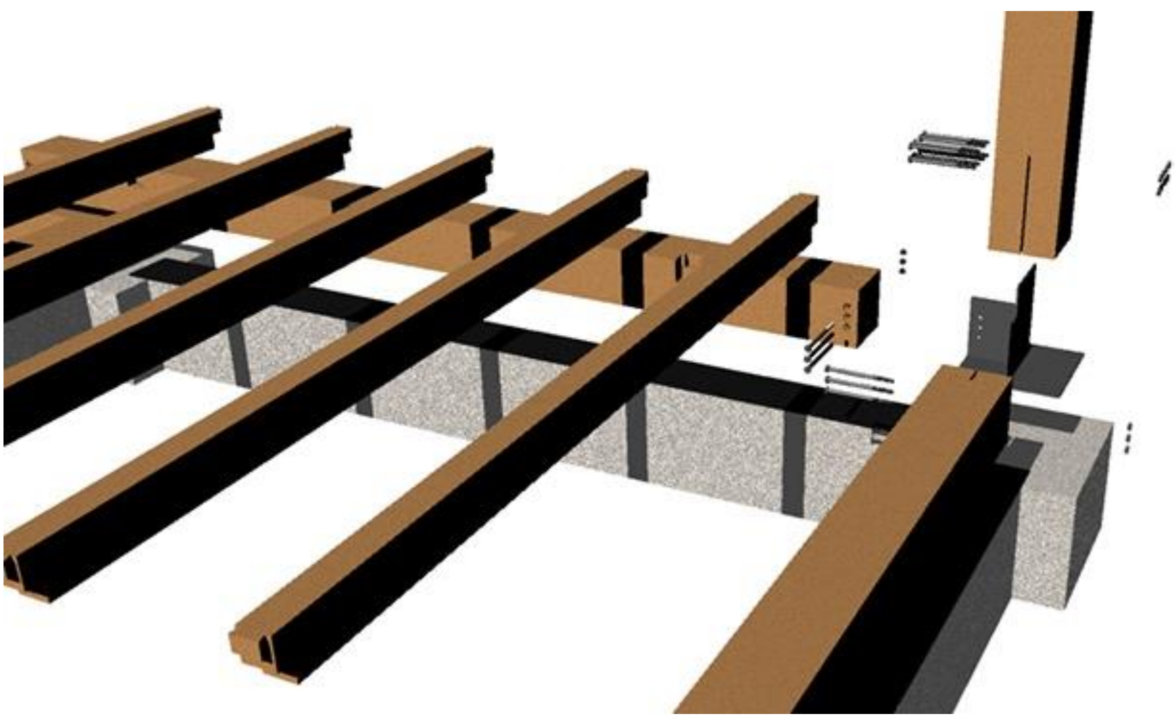


Fig. 5.2.23 Angle joint

For further detail refer to Annex B.

5.2.3 Roof level

Central joint

The coverage presents a primary wood system associated to a secondary one.

The wooden elements of the kit are in order:

Roof beam, 830 cm x 30 cm x 30 cm

Roof joist, 380 cm x 20 cm x 12 cm

Pillar, 408 cm x 30 cm x 30 cm

Secondary pillar, Max 278 cm x 20 cm x 20 cm

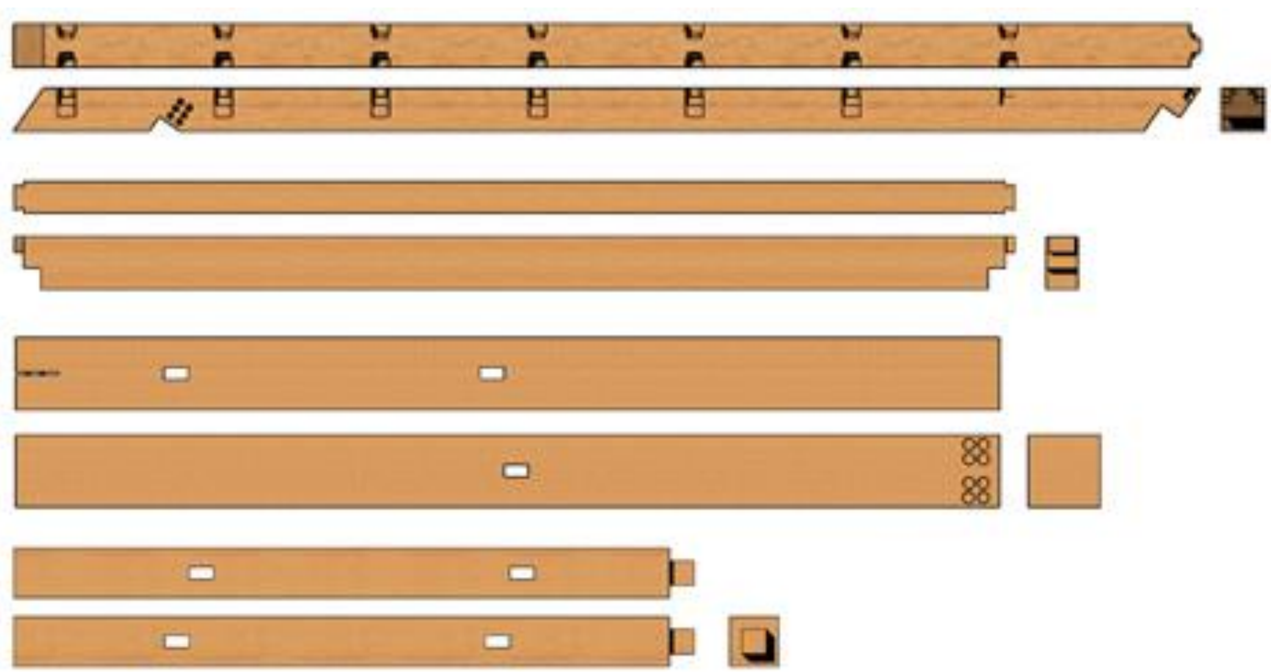


Fig. 5.2.24 Wooden elements

Steel connections:

Lower frame, 780 cm x 30 cm x 30 cm

Ridge level frame, 46 cm x 30 cm x 30 cm

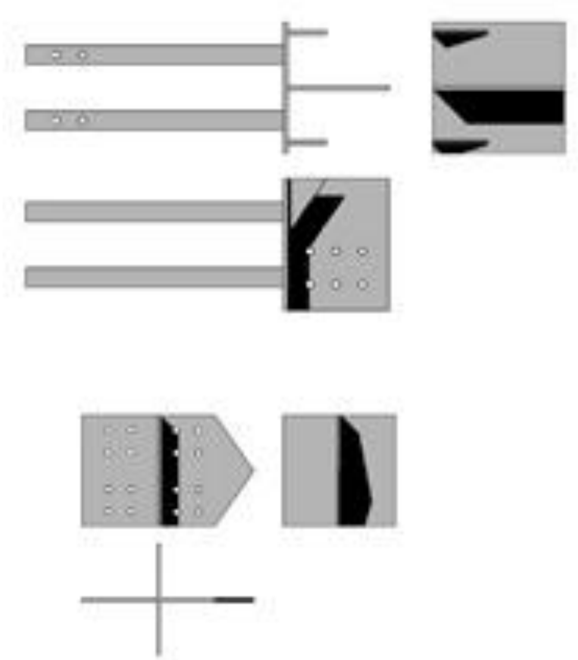


Fig. 5.2.25 Steel plates

The central joint is then assembled according to the following steps:

1) The last plan of beams is ready, it's possible to see that the supporting beam is already fitted to accommodate the secondary pillars. The joists are not present on this level.

Fig. 5.2.26 Phase 1

2) the secondary pillars are inserted on the supporting beam.

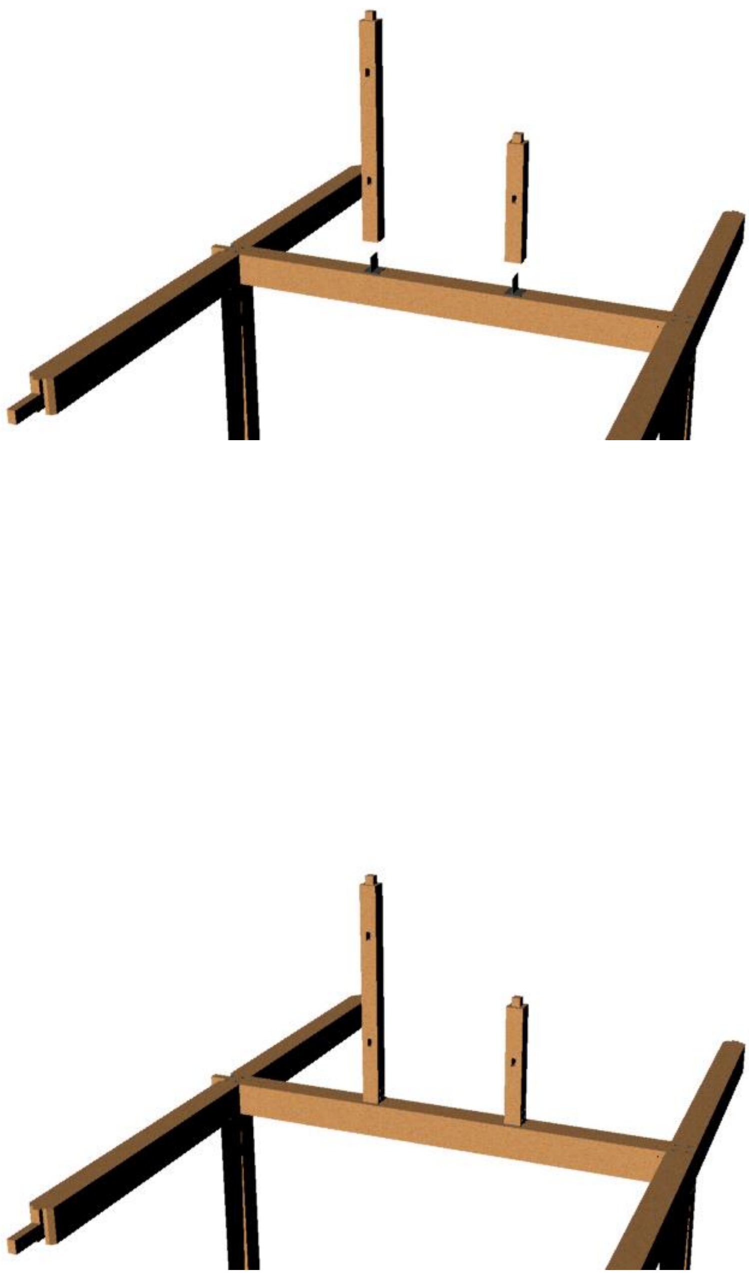


Fig. 5.2.27 Phase 2

3) The pillar of the ridgeline is inserted and fixed with the system of steel connection already preassembled.

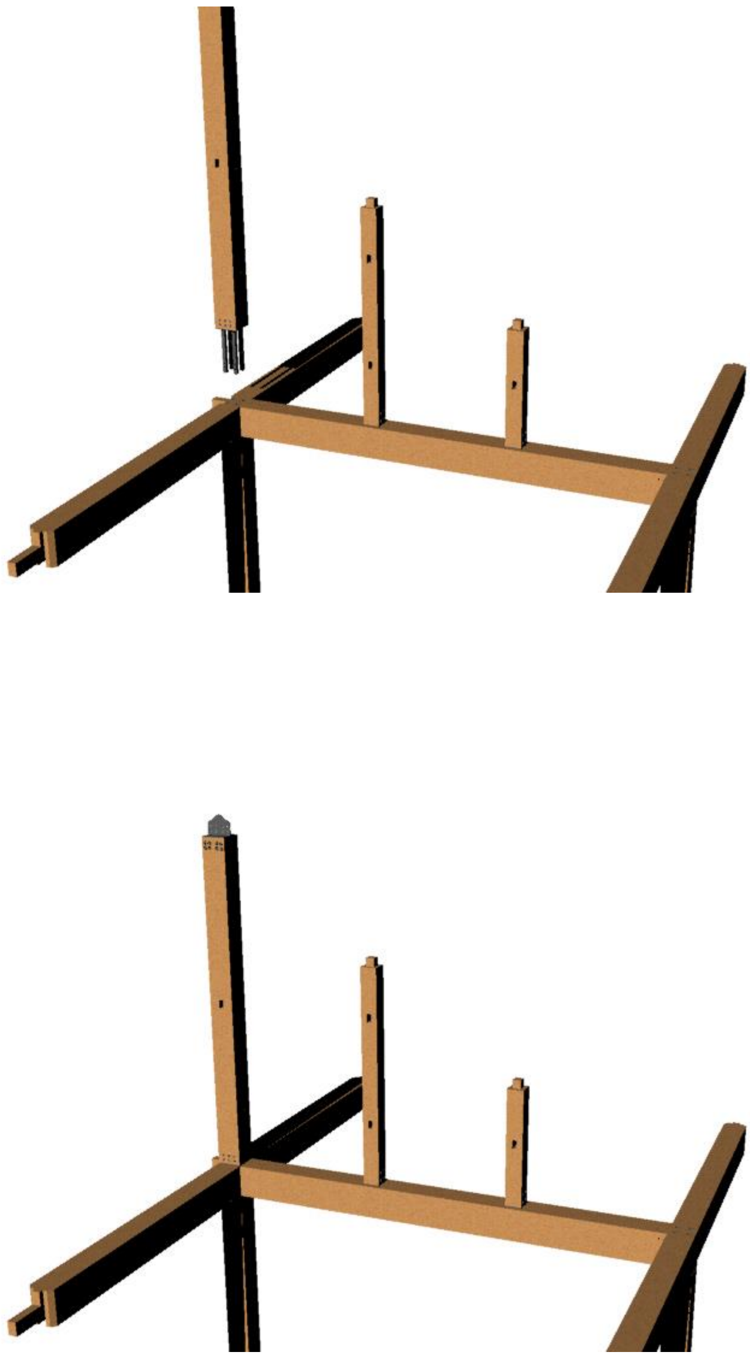


Fig. 5.2.28 Phase 3

4) the beam is lowered and fixed to the joint.

Fig. 5.2.29 Phase 4

5) the roof joists are arranged.

Fig. 5.2.30 Phase 5

6) the system of secondary connection is inserted.

Fig. 5.2.31 Phase 6

When the plan of the building does not have a rectangular shape, but has the addition of other lateral blocks, giving life for example to L, U or H plants, the system remains almost indifferent, but special steel connection will be used.

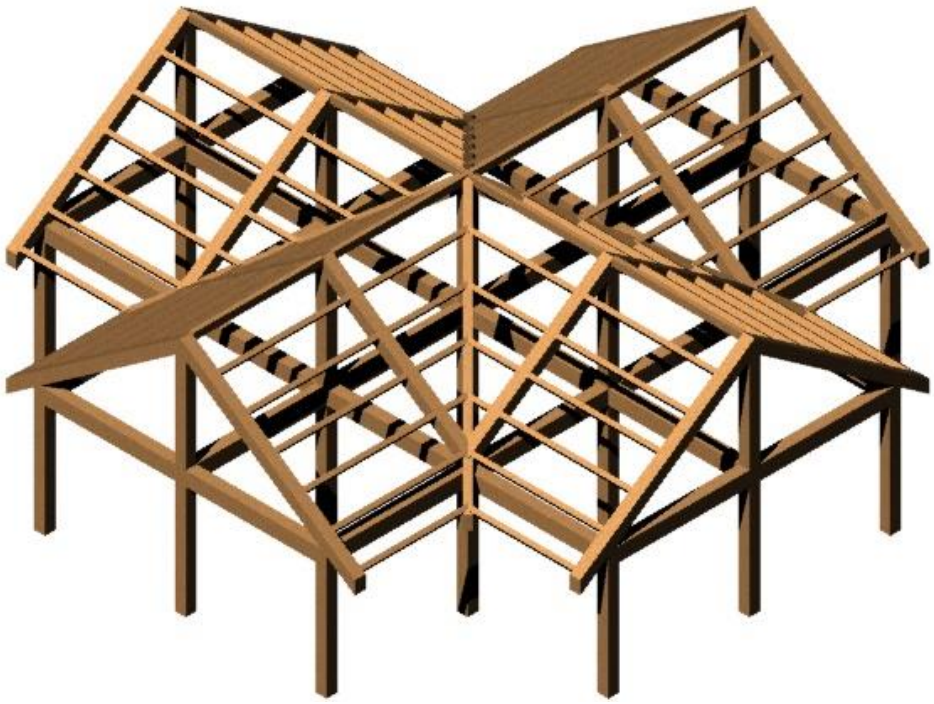


Fig. 5.2.32 Examples of structures

For the corner junction system, it is necessary to distinguish between the joint on the lower level and the joint on the ridgeline. For the lower level, it is necessary to make another distinction between the closing internal angle, with 3 beams and the opening external one, with only one diagonal beam.

Corner joint, internal angle

Fig. 5.2.33 Corner joint

Corner joint, external angle

Fig. 5.2.34 Corner joint

The joint on the ridge line varies too, for the simple case, that is, an L plant, 3 roof beams connect to the joint, for the most difficult , that is a cross plant, 4 beams are joined. Here an example to show how the system works, expecially the steel bracket system.

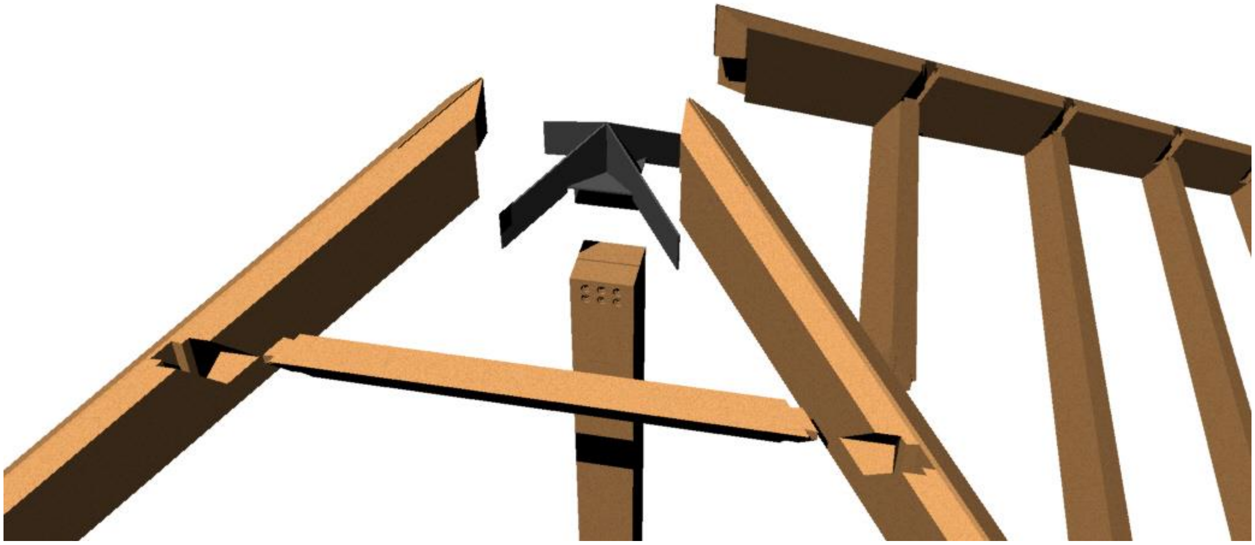


Fig. 5.2.35 Upper corner

On the outside of the building there is a cantilever joist. This will be modelled as a wooden joint and then subsequently fixed with metal screws. This system was used in the past and it is still used today.

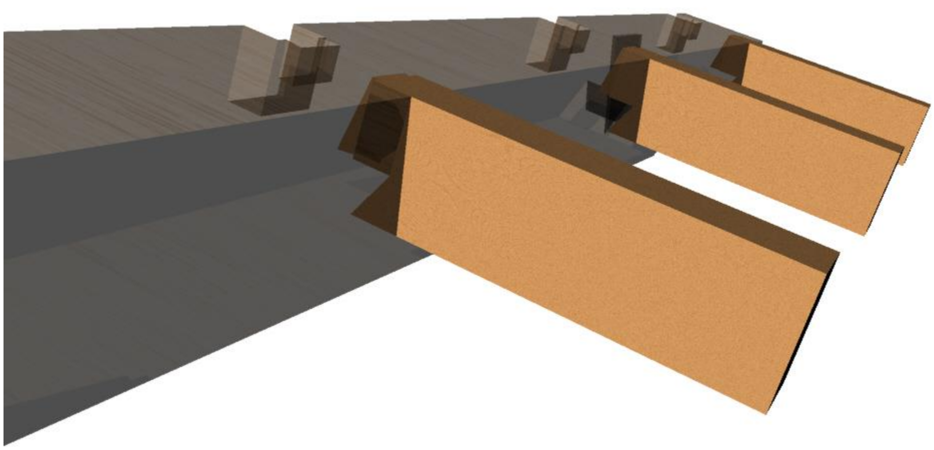


Fig. 5.2.36 External joist

For further details refer to Annex C

5.3 Element-kit for walls and floors

For the closure and partition systems, it’s possible to distinguish between vertical elements and horizontal elements. The perimetral walls and internal partitions are assembled in the factory and the semi-finished product arrives in the yard, the floor and the cover are built on site. To speed up the timing of assemblying on site, dry technologies have been chosen.

For more details refer to Annex D

5.3.1 External walls

The opaque solution perimeter is composed as follows:

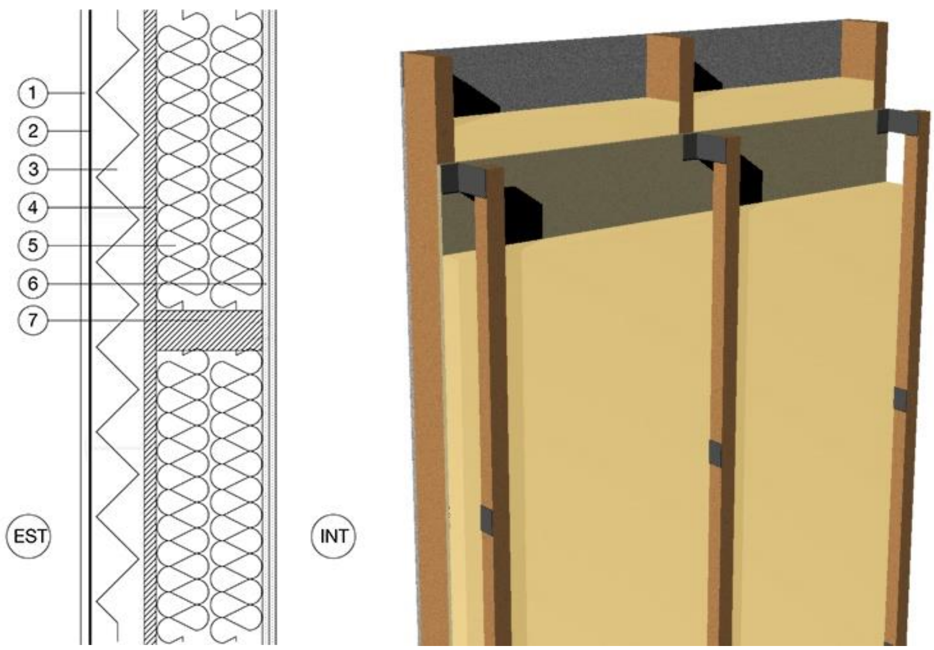


Fig. 5.3.1 External wall

1. External coating layer
2. Non-woven layer sp. 0.24 cm
3. Thermal insulation coating in wood wool 160 kg/m^3 sp. 8.0 cm
4. OSB panel sp. 1.8 cm
5. Double insulating layer in wood wool 160 kg/m^3 sp. 8.0 + 8.0 cm
6. Double gypsum fiber panel sp. 1.00 + 1.00 cm
7. Wooden mullions and traverse

The one presented is the basic assembly unit, then the external layer can be set up according to the customer's choice..

For the external coating, three different solutions are offered:

Simple solution.

The simple solution sees a coating in panels composed of aggregates and Portland cement, reinforced with a glass fiber network. These panels are fixed to the L steel profiles and then plastered and painted.

Fig. 5.3.2 Wall panels

Solution shou sugi ban.

This technique was used as a cladding of buildings, in particular in seaside areas, where the sea salt harms the facades in wood. The literal translation means "charred cedar planks", in origin, Japanese carpenters were looking for a method that would allow them to preserve the wood in time and could give wood a unique, artistic finish. In Shou Sugi Ban, the fire does not damage but it preserves, giving the wood, at the same time, the finish that both housebuilders and Japanese artisans were looking for. The practice of sugi carbonization has become common in Japan since at least 1700, and probably even before, but the technique is time consuming and therefore has been gradually abandoned. Nowadays this technique may be resumed and industrialized to speed up operation times and reduce costs.

The processes are:

1. Burn the wood, in particular way it must be charred
2. Brush with a spatula in iron wire and remove the dust given by combustion
3. Wash the wood from the residues
4. Pass a layer of oil, in the past they used sunflower oil, today it's possible to use penofin oil.

Fig. 5.3.3 Different level of burnt

Fig. 5.3.4 House in Naoshima

Shitamikabe solution.

This coating solution is very typical of Tokyo, the wooden tiles are inexpensive and easy to replace, but give the buildings true traits of Japan-ness.

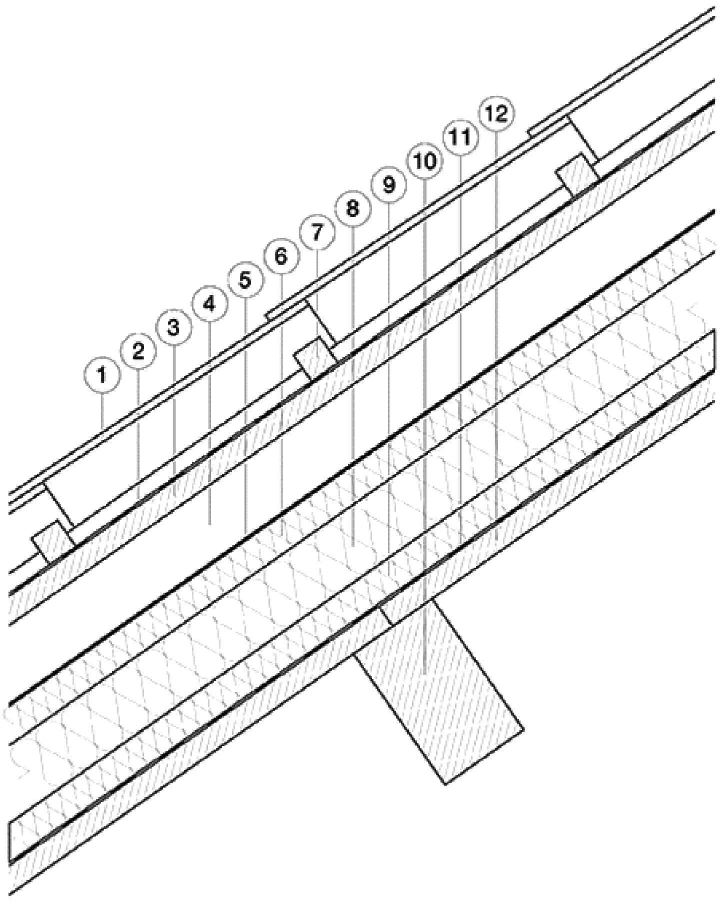
Fig. 5.3.5 Examples of shitamikabe

For what concerns windows, it's possible to choose different types and models, the customers are left quite free but they are essentially expected to prefer sliding to casement window. In fact, the concept of openable wing is something Western. Everything was sliding in Japan, doors, windows and walls too, and it is chosen to continue this way. For the detail of the window, note that a counterframe is not necessary because everything is made in the factory and then the possible mistakes, related to tolerances, are reduced.

What has been explained refers to industrial processes, where the construction steps are performed by machines and the finished product is more an industrial one. It is right then to link this process to a more handcrafedt one, more related to an individual experience, to give new life to these realities that are slowly disappearing. Threfore the facade of the traditional house combines simplicity of proportions to more elaborate details.

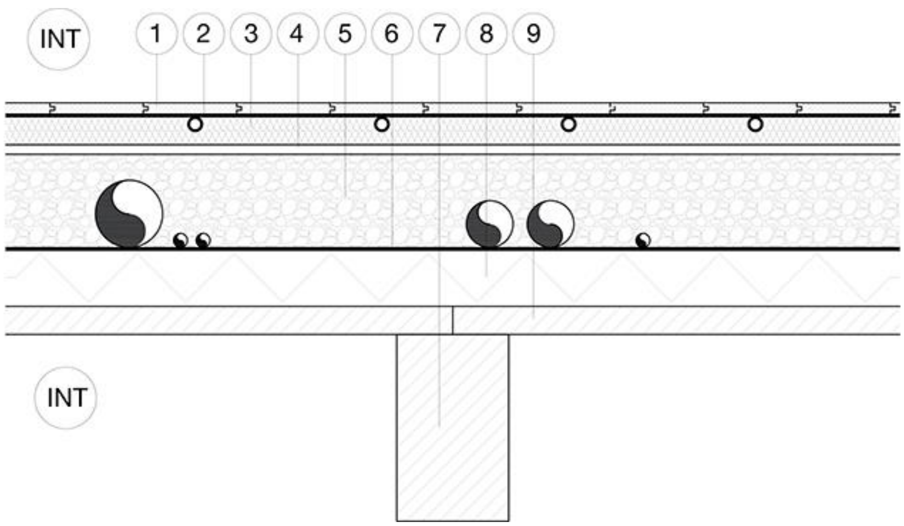
Fig. 5.3.6 Facade wooden details

5.3.2 Roof



1. Roof tiles
2. Waterproof self-adhesive membrane sp. 0.2 cm
3. OSB panel sp. 3.0 cm
4. Ventilation layer sp. 8.0 cm
5. Waterproof and breathable membrane sp. 0.1 cm
6. Insulating layer in wood wool 250 kg/m³, sp. 4.0 cm
7. Wooden lath 4.0 cm x 4.0 cm
8. Insulating layer in wood wool 160 kg/m³, sp. 8.0 cm
9. Insulating layer in wood wool 160 kg/m³, sp. 4.0 cm
10. Wooden structure 20.0 cm x 12.0 cm
11. Vapor control membrane sp. 0.106 cm
12. Structural wooden planking sp. 3.0 cm

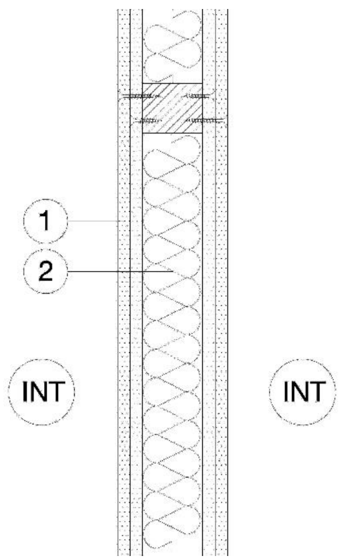
5.3.3 Floor



1. Wooden floor sp. 1.2 cm
2. Anti-impact layer in aluminum and quartz sp. 0.1 cm
3. Insulating panel with radiating multilayers tube Φ 16, 0.2 cm sp. tot. 3.0 cm
4. Gypsum fiber panel sp. 1.0 cm
5. Filling substrate of perlite sp. 10.0 cm
6. Anti-dust layer sp. 0.015 cm
7. Wood structure 20.0 cm x 12.0 cm
8. Wood fiber for thermal-acoustic insulation sp. 6.0 cm
9. Wooden planking sp. 3.0 cm

5.3.4 Internal walls

A good compromise between the tradition and the modern request of increased comfort is the key of this design, in fact in the past, the internal areas were not well defined, as it happened in relation to indoor and outdoor spaces. The house was used as a single large open space, the concept of privacy was reduced to a minimum. The shoji or dividing sliding panels, albeit capable of great poetry, were very poor elements, when it came to privacy. Then the system proposes the overcoming of these elements, being anyway always capable of accepting the traditional dividing panels.



1. Double gypsum fiber panel sp. 1.25 + 1.25 cm
2. Thermal insulation coating in wood wool 160 kg/m³ sp. 8.0 cm

5.4 Proposals

Here some possible results using the system proposed

Fig. 5.4.1 Final result of the proposal

6 Space analysis

6.1 The importance of MA

This chapter will provide the necessary background knowledge needed to fully understand the choices proposed in the dimensional analysis, which will be introduced later. Spaces of 5,4 x 3,6 metres which find their reasoning and justifications when understood within the Japanese historical and ever-evolving relationship with *space*.

The way in which the concept and units of space are understood and theorised in Japan are very much liked to the country's history. After the establishment of the nation and the growth of hierarchies of power, the the state established a system of measurement using the pillar as the starting point to control and standardise building practices. This system and others allowed the state to exert strict control over the form and structure of the Japanese house, and they reflected the belief that standardization was important in maintaining the structure of the society. The initial system of measurement was based on the *ken,* meaning a distance or interval, and its development was primarily based on an economic rather than a philosophical model.

Similarly, tied to the centrality of stability and permanence in social structures, is the complementary force of impermanence within the physical and political sphere. For much of Japan's history, cities were either destroyed by fire or earthquakes or moved for political reasons. Therefore, the ability to quickly move and relocate entire cities was crucial for ancient Japan's internal stability, consequently calling for the development of an effective system of measurement and the sophistication of a prefabricated frame to make this process smoother. The attention for such details is further explained by the fact that central governmental and religious buildings were prefabricated using standardized designs as early as the Nara Period (A.D. 710–794), with prefabrication becoming even more standardised and sophisticated later on with the rise of industrialisation. Later, prefabrication became even more sophisticated through the adaptation of industrialized methods. Although the ability to easily relocate buildings is no longer important, the potential for natural disasters and subsequent reconstruction still exists. Here, philosophy and construction methods come together in a rather unique fashion. To move a building or change its form in the West suggests a loss in the original meaning of the building, resulting in an air of impermanence. However, in a Japanese context, Buddhism allows disastrous occurrences to be placed within a larger context of natural cycles. Therefore, since according to Buddhism the "*spirit of the place is rooted in the forms which compose it*", if follows that the spirit of the place is rooted in the structure of the building, meaning that there is no philosophical conflict with off-site prefabrication of a structure. [20]

6.1.1 The Kiwari as link between architecture and the mundane

The units and measurements analysed above are so unique as, within the Japanese tradition, construction proportions are historically based on a modular coordination that is intimately related to everyday life, as simplified by the use of *tatami* mats for the measurement of floors and square metres. Construction proportions are encapsulated in the concept of *Kiwari*, and by the belief that the beauty of not only architecture but of all things, both man-made and natural, derives from their proportions. Just like in ancient Greece, Japan has also witnessed several waves of architectural experimentation aimed at achieving an order, an ideal standard of proportions, known as *Kiwari*. Subsequently, *Kiwari Jutsu* arose as the art of determining construction proportions, according to a formalised system of prescribed design techniques, which can even be used nowadays to determine the particular age and era in which traditional buildings were erected.

As mentioned when talking about the *Ma* beforehand, despite embodying the ideal standard of proportions the *Kiwari* developed following different systems across the eras. Different *Kiwari* systems have therefore been passed down from generation to generation and recorded in detailed Manuals, the most famous of which is the *Shomei* dating back to 1608, which was compiled by the Heinouchi family of government's master builders and carpenters. These *Kiwari* manuals not only set forth precise standards for the modular composition of space, but did so while taking into account several structural elements, such as the ideal spacing between rafters, or the relationships among the size of structural posts.

6.1.2 Space and dimensions

The concept of *space*, and the different ways to shape and regulate it, have been central to Japanese modern history and development. The country's *in flux* relationship with the concept goes back to the 8th century, when the state began exerting control over building practices in an attempt to standardise them, therefore leading to the establishment of precise and fixed systems and units of measurement. These include:

Ma: translated as *gap, space,* or *pause*, the Ma is better understood as meaning *interval*, suggesting more than just a mere spatial understanding. The emphasis on the interval is a core component of Japanese art and culture, finding its roots in traditional music and Kabuki theatre and in the notion that, even when there is a pause, something vital still remains. Therefore, when looking at the role that the Ma plays in architecture, it is necessary to understand that in this context *interval* suggests more than just progressive intervals of spatial designation, or the three-dimensional understanding of space. Rather, Ma refers to the consciousness of a place, meaning the "*simultaneous awareness of form and non-form deriving from an intensification of vision*." [21] Therefore, while the Ma has come to be a unit of measurement referring to the space between structural posts, Ma does not just refer to any empty space where nothing exists. Instead, Ma specifically encapsulates the notion of the interval necessary to give shape to the whole. To conclude, rather than just being created by compositional elements, the Ma is best understood as an experiential place understood with emphasis on the *interval*, which therefore takes place in the imagination of whoever gets to experience these elements.

Ken: the traditional Japanese unit for length, its exact value has consistently changed over time, but its direct relations to the Ma has remained unvaried. In its original form, the Ken derives to the same ideogram which is pronounced Ma, but here it takes a much more terrestrial dimension, as the Ken is the Ma used to indicate the actual and fixed distance between posts. Therefore, the Ken is the fundamental unit of modular construction and architecture in Japan, where it has come to being used as a proportion for the intervals placed in between the pillars of traditional buildings. However, this unit has been far from being fixed throughout its history, as its exact value has varied depending on time and location, while always being measured in terms of the *skaku* (see below), with their proportional relationship changing depending on the era. Quite recently the Ken has been defined as referring to six *shaku*, or Japanese feet, therefore standardising its length at approximately 1.8 metres. [22] To conclude, while the value of the unit is far from being fixed, something that has remained constant is the Ken and the Ma mutual dependence. In modular construction a Ma is inevitably a Ken long, referring to both width and height, therefore defining a square space.

Additionally, the Ken also has a direct connection to the *tatami* used to measure square metres, with one *tatami* being equivalent to half of a square Ken. Therefore, the Ken becomes fundamental for carpenters to define space when planning and erecting a house. Initially used specifically to indicate the space between columns, the Ken eventually evolved together with the need to standardise the *tatami* mat in order for it to fit houses of different sizes and width. As a consequence, the *tatami* mat eventually came to embody the spacing between columns (roughly 3x6 feet, depending on the region), to be more universal in its application. It follows that today the Ken is used more as a design tool than a precise measurement, in combination with the concept of *Kiwari* analysed above, here meaning “proportion of wood allotment”.

Kiwari here is intended as the proportion according to which wood members are arranged in sections. The section is based on the diameter of a column of one Ken. The Ken is therefore used as a way to determine the grid according to which the carpenter would plan the house, a practice that alongside the development of the *tatami,* led to the increasing standardisation and systematisation of building practices.

6.2 Dimensions of the proposed system

The dimensions of a prefabricated system often set up regular spaces dictated by the modularity of the system itself, these concepts were those on which the Japanese architecture of the past was based. Described here below are the dimensions of the modules, minimum and maximum. It is right to say that it is cost effective to create spaces that exploit the maximum structural size as much as possible. Even nowadays, the Japanese building market uses the tatami as measuring unit instead of square meters, this fact helps us to understand how much the modularity dictated by human proportions is present in daily life. Considering the standardized sizes of the tatami, as 90 cm x 180 cm, the system can give life to maximum modules of 12 tatami, i.e. 20 m^2.

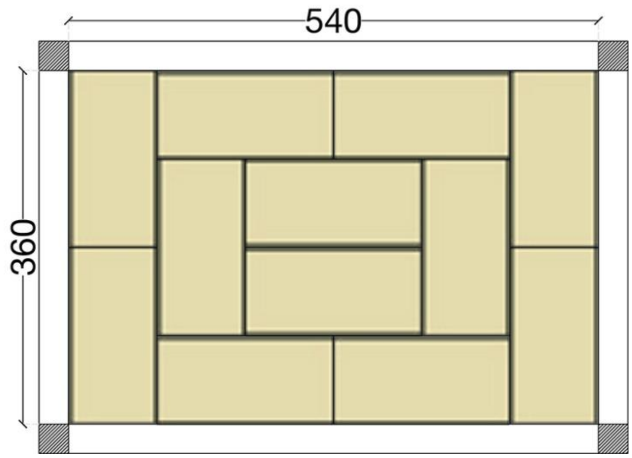


Fig. 6.2.1 Max rectangle module

The use of rectangular modules is preferred since they can give dynamism to the plant. If the wish is to use square plans it is possible to obtain spaces of 8 tatami, i.e. 13 m^2.

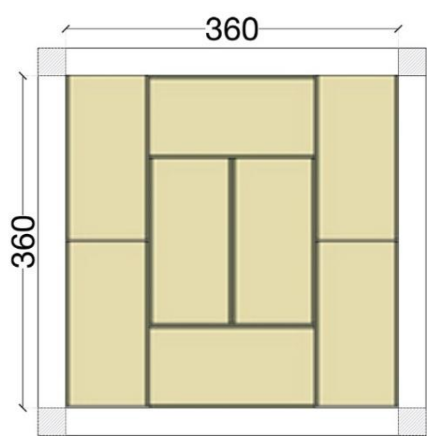


Fig. 6.2.2 Max square module

Once the modules are defined, it is possible to configure the spaces, in particular it must be pointed out that the maximum number of modules to be used in the shorter side is two, as it is linked to the strenght of the roof elements:

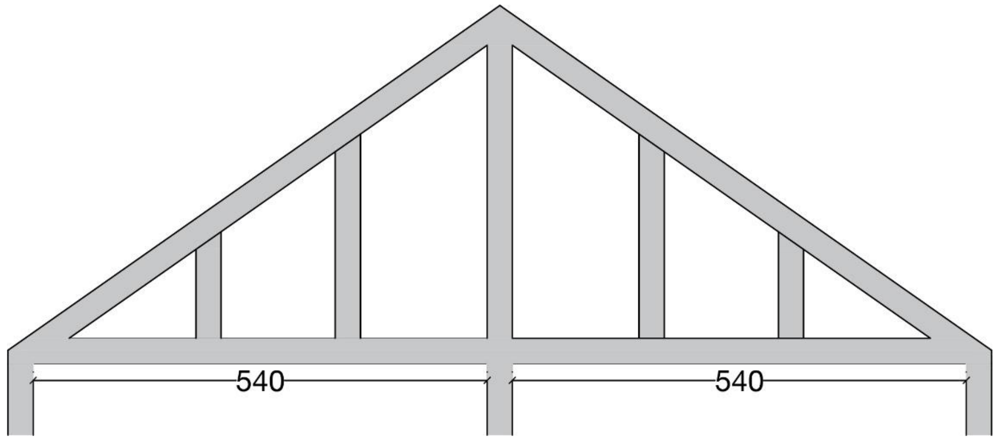


Fig. 6.2.3 Max dimension on this axis

In doing so, the shorter side of the building can measure up to 11.7 m, a widely acceptable data, considering the measures of the medium plot of land that you can find in a hypothetical suburban area of Tokyo.

In the past, the Japanese house was formed by disassembled units, i.e. the house was composed of independent pavilions, connected to each other by narrow corridors. Minimum spaces also tried to address these project goals, but within the limits imposed by the cover., for sizes smaller than 3.6 m the coverage will be a single inclined pitch. For outdoor areas, designed as narrow passages, it is convenient to realize a secondary simpler structure independent of the proposed system.

For the secondary roof pillar system, when each module does not exceed 3.6 m, the configuration should be:

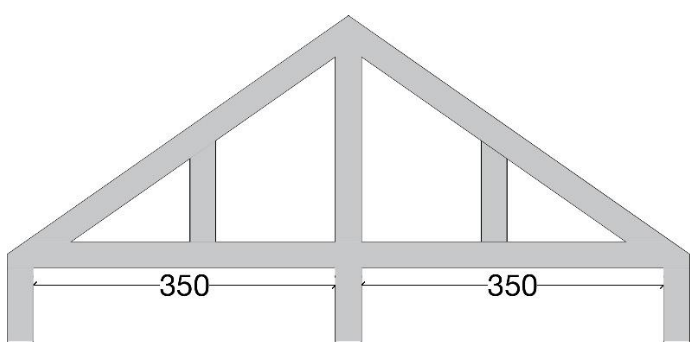


Fig. 6.2.4 Secondary pillars

When instead there is a single side with size < 5.4 m and > 3.6 m the system should becomes:

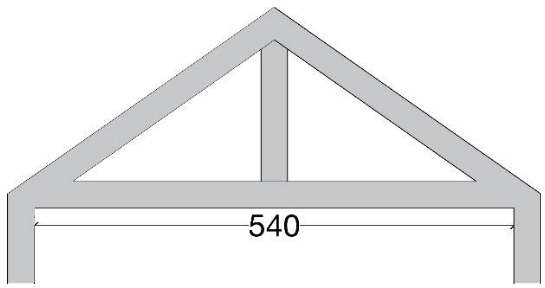


Fig. 6.2.5 Dimension rules

or with a single a pitch:

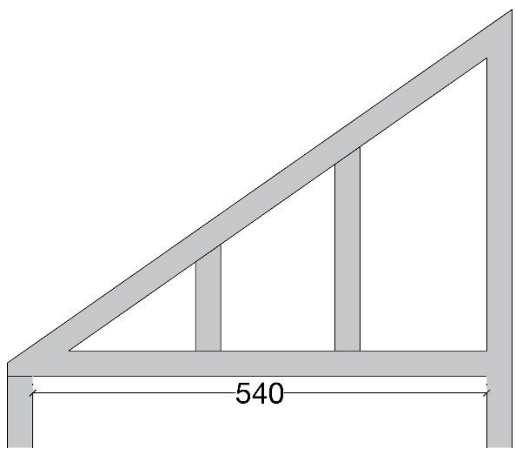


Fig. 6.2.6 Dimension rules

7 Structure analysis

7.1 Wooden structure in Japan

It is impossible to speak of wooden structures without thinking about the millennial building culture of the Japanese people who have imagined and created, in that island, wooden works unique all over the world. Starting from very ancient times it's possible to take into consideration Nara's Buddhist complex, dating 728 A.D. and still looked upon as a national treasure. The initial work included a complex of imposing wooden buildings: two pagodas higher than 100 meters and the Todaiji temple, which, hosting one of the biggest Buddha bronze statues in the world, exceeded 85 meters. After two wars (in 1181 and 1567), the complex was destroyed and only the temple was rebuilt in 1709 because the pagodas, being damaged, could no longer withstand frequent earthquakes. Observing the temple it's possible to immediately admire the size of the wooden pillars, in fact they had been made using real logs. In the past the biggest logs were chosen from all over Japan and, once carried to Nara, they were cut into cylindrical chunks 2 meters long, and then polished to give each a homogeneous diameter of 80 cm. Then they were stacked one on top of another and closed by means of wooden planks and iron meshes to avoid discontinuity between the blocks to create a kind of seamless block. They used a very special technique: the pillars were dug and a grid of beams were grounded inside to link all the pillars and limit horizontal oscillation. The most stressed beams were not directly placed against the pillar, but on a system of shelves located within the dug log. These widened the support area and made the distribution of vertical loads more homogeneous. Imagining these techniques realized 1300 years ago can help to understand the technological progress in wooden structures that has taken place in Japan; in fact, the temple kept its record as the world's biggest wooden building until 1998.

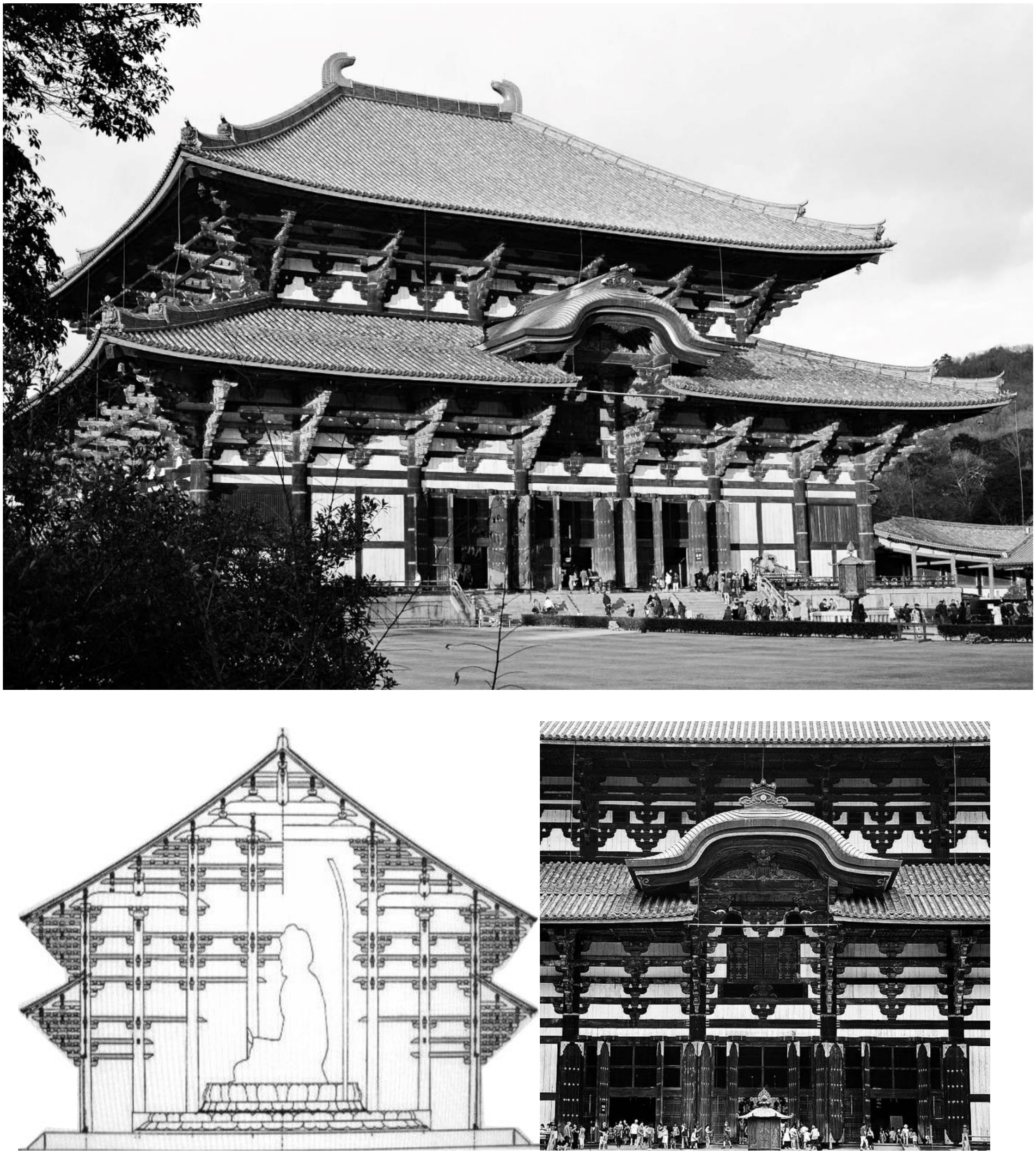


Fig. 7.1.1 Todaiji temple

Always talking about ancient building, we must consider the complex interlocking structure that sustains the temple Kiyomizu-dera, a technical goal, which earned it the finalist role as one of the new Seven Wonders of the World. The temple was born in 778 A.D., but the structure was not completed until 1633. The builders used the same techniques used in the Todaiji Temple, that is: the beams are hosted within the dug pillars, but the real peculiarity lies in the fact that *"not a single nail was used for the structure"*, then the whole connecting system only exploits the properties of the wood. To stiffen the structure, once the beams have been inserted inside the pillars, they are stoppered with wooden elements. The builders exploited the wood compression ability; the growing section elements are placed by the shorter side between beam and pillar and then wedged in by hammer blows, and the different parts of the system, beam, pillar and closing element, as they are warped, push each other, and succeed into counteracting the horizontal earthquake efforts.

Fig. 7.1.2 kiyomizu dera

Looking even to modern times, it's possible to analyse the special roof of the new library of Gifu, year 2015, designed by Mitsuhiro Kanada and made up of a particular system of supporting beams capable of giving life to new volumes and new forms. The beam element is actually formed by filled and empty spaces, the filled ones are always small wooden beams, but placed along the weaker axis of inertia. It's possible to combine the beams in the empty ones. This arrangement allows you to warp the beam more easily and to create solid and curved surfaces.

Fig. 7.1.3 Minna no mori, Gifu

It is important, anyway, to understand how the use of wood as a structural material has become a basic element of Japanese architecture. In the past, the most important families of carpenters were entrusted with the construction of several important buildings; often a family of builders was called to work in more villages, and then the building knowhow, was a handicraft skills intended for few people. Over time, working and experimenting with real works, these important families of artisans began to adopt and refine specific construction techniques, which began to pass down from generation to generation. The technique, as anywhere in the world, has been initially passed down verbally, then later, once refined, it was handed down from family to family by means of a technical manual, called Kiwari Jatsu, literally translated as "splitting the wood". The spreading of these handbooks were not only meant to pass useful information about how to create solid structures, but also to spread a common style, which by means of the right proportion of interconnected elements, could reflect the social dynamics of the age. As an example, you can find the analysis of a ceiling shown below. When a ceiling is too low, you get a feeling of closure, when it is too high it seems not related to the other elements of the room, and you should ask yourself if a single height could adapt to all types of rooms. For a 6 tatami room, about 9,7 m^2, the ideal height of the ceiling is about 60 cm from the lintel, while for a room of 8 tatami it is better to have a ceiling of 80 cm. Considering a lintel height of 180 cm from the floor, you can figure out that the ideal height of a ceiling for a 6 tatami room is 240 cm and one of 8, 260 cm.

Fig. 7.1.4 Proportion of Japanese architecture

Then the kiwari jutsu was not simply a technical handbook, explaining how to accomplish a particular structural element, but it also contained the rules for the correct proportions of the whole structure: it dictated technical requirements on the individual item but it aimed at the total homogenization of all the buildings. Getting back to the historical excursus, because of the population growth and the increasing requests for the construction of new buildings, the most important families of carpenters decided to make public the manuals and make the rules previously only handed down available to all builders. With the large-scale use of these manuals, the meaning of the kiwari jutsu changed, from rules of good housing regulations on how to make buildings, that is, they became real procedures to be followed to set up architectures. So within a short span of time, even cities with a large number of buildings, began to see their urban settings becoming compact and uniform, adapting to the new imposed styles. The modular structure firstly determined the modularity of the building, then it laid down the law on the urban network, actually getting to the schematization of a whole country.

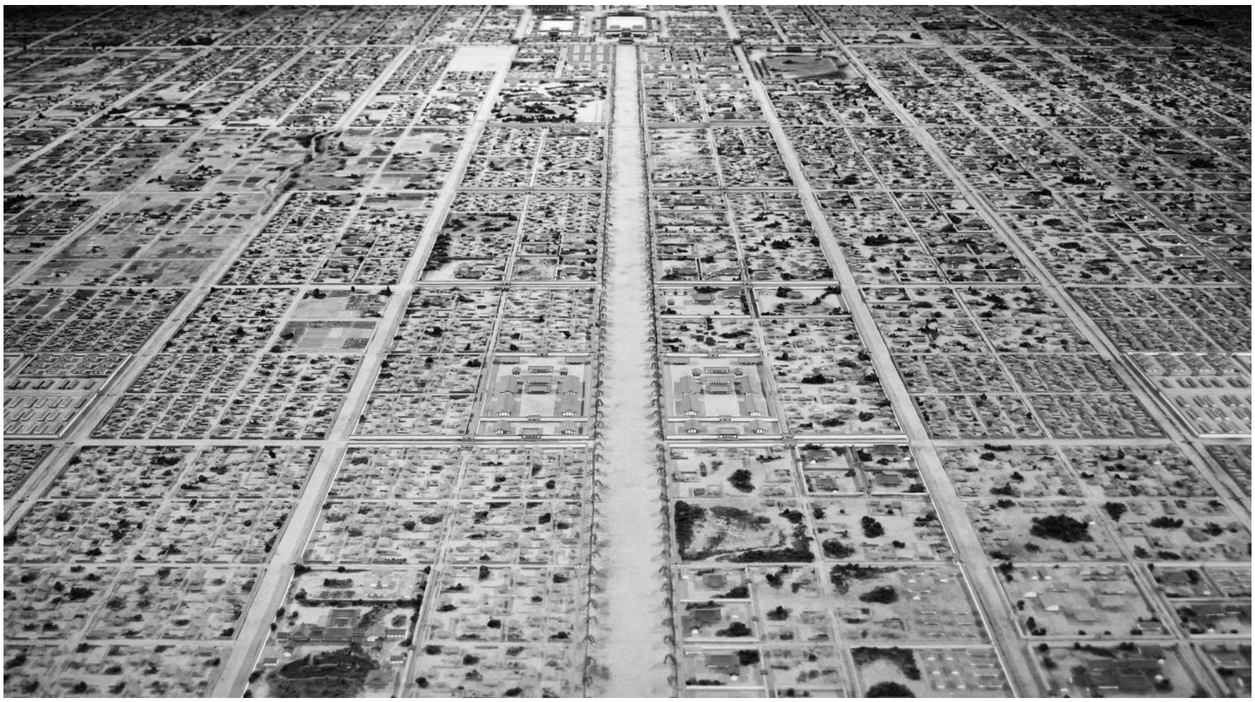


Fig. 7.1.5 Kyoto plan

The wooden structure that supported the impressive imperial villa was following the same principles upon which was designed the structure that supported the humblest abodes. In the proposed system some techniques proposed by kiwari jutsu have been studied, especially the proportions of the structural elements, adapted to the needs of a more modernized society. First we must consider that the loads acting on the buildings of the past differ a lot from those acting on modern buildings, for example, the vertical partitions of 100 years ago were represented by famous Japanese shoji — the walls of rice paper, very light when compared to today's solutions. They were used to spread more light in, but nowadays this technology has been completely changed according to new requirements of thermal comfort and, especially, privacy. While on the one hand the loads increase, on the other, the materials become stronger, especially wood.

The structure of the whole system originates from the use of a particular wood-steel joint; old joints have been analyzed: strengths and weaknesses have been studied and the latter have been improved by today's technologies. The joint beam-pillar is considered below.

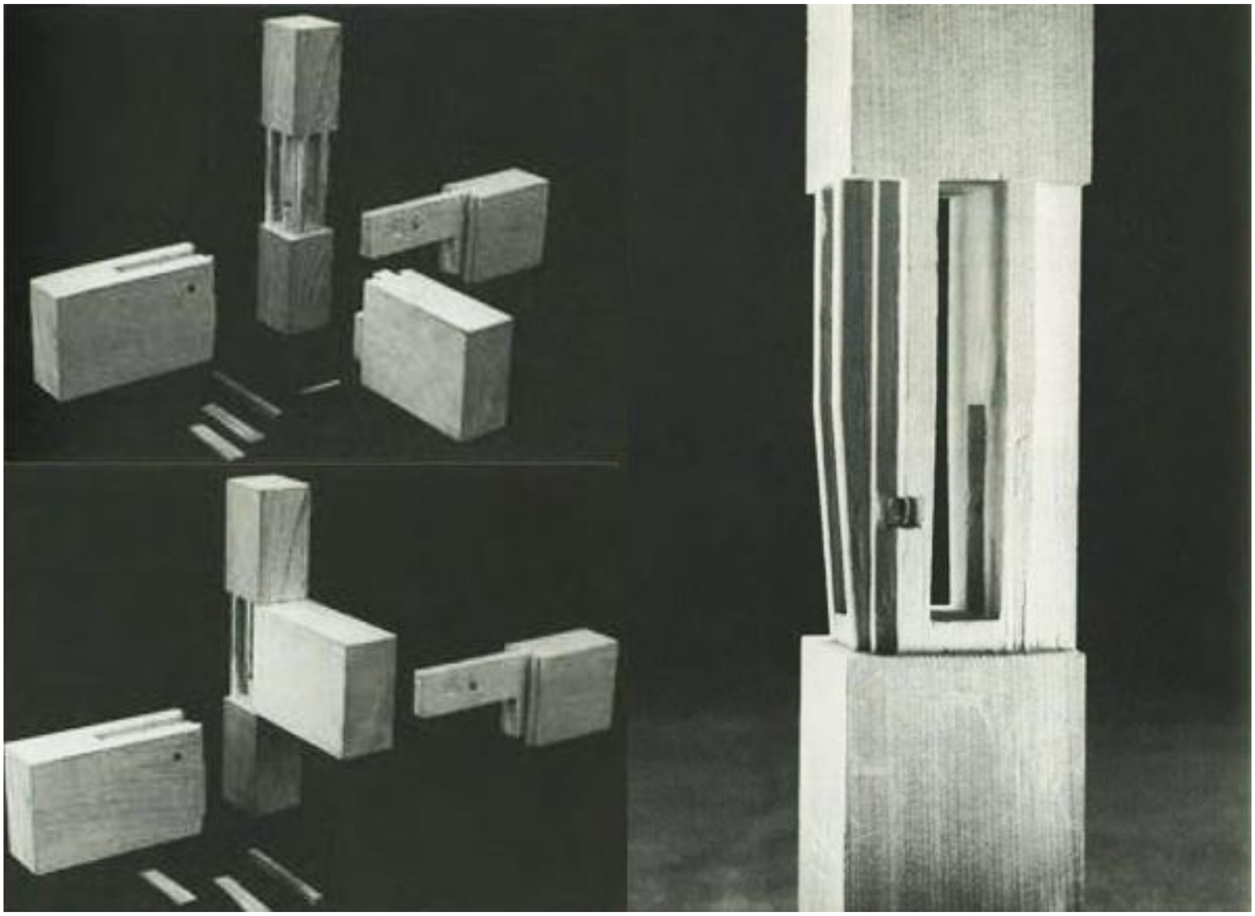


Fig. 7.1.6 Wooden joint, [23]

In the past joint there were heavy beams that were grafted together within a slimmer pillar; in particular the pillar was carved, allowing the beams to get into the created hollow and to join by means of special geometries. Only thin profiles of the carved pillar remained where the beams joined. This particular section of the pillar could resist vertical loads, because, through an interplay of geometries, the hollow part was filled by the beam, so the useful section was not only the pillar one but it was composed by the pillar-beam bonding and therefore the loads were distributed on the lower elements. This type of joint was weak under the bending forces of the pillar because the useful section capable of counteracting this stress was too undersized; in addition, it was necessary to consider the pillar as a continuous, not broken, element in its verticality, and then the inflection was quite frequent. Another identified weakness was to be found in the support of the beam to the abutment, in fact as we can see from the figure, only a few centimeters of the pillar supported the beam. Even in this scenario, without horizontal loads, the system worked properly, but under the influence of special forces, even through a simple warping of the pillar, the joint could easily give in.

The strengths of this system are also praised, the horizontal diaphragm that was created was closed and very stiff, this was due to the fact that the beams, in the area of junction of the pillar, were all joined and blocked, and the closing elements contrasted the rafters' flowing along the main axis. In the proposed solution the closing elements that help create a closed box-effect system are preserved, but the pillar is cut and divided, and instead of thin profiles meant to house the joint of the beams, we have the insertion of a steel mesh capable of connecting the pillars and give continuity to the discharge of the forces. Moreover, the support surface of the beam on the pillar is increased by a cross-shaped steel system that facilitates the discharge of the beam to the abutment. The same principle is applied to the study of the corner joint and the joint of the external beams by inserting a mask of closure instead of the beams, by tightening the system and ensuring the box effect.

Another joint that reminds the historical one is the junction of the joists with the main beams; in the past, the builders created a particular section that could withstand pull up stresses parallel to the principal axis of the element and this concept is reflected in the modern proposed joint.

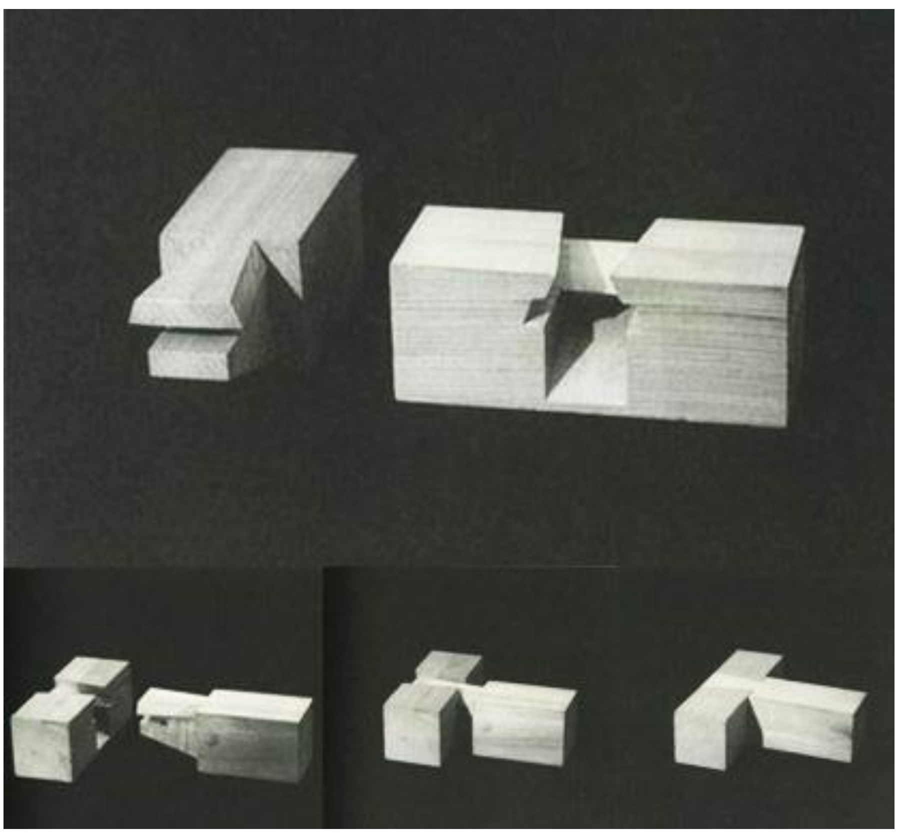


Fig. 7.1.7 Wooden joint [23]

This technique has been resized according to the geometry of the system, in particular, it has been chosen not to pierce the main girder but to support only the top of the joist in a recess of the beam. This technique is also used on the roof joists.

As to the roofing system, there is a primary and secondary warping frame. This joint task, part of the secondary coverage, is to create a dense mesh limiting horizontal warping under the effect of the earthquake. To do so, the following joint has been taken into account:

Fig. 7.1.8 Wooden joint [23]

As just seen, the system has, unlike in the past, the combination of steel and wood. The steel is mainly used for its yielding characteristics in the most stressed parts of the joints, in particular, it should be noted that, according to modern Japanese regulations, some wood-wood joint systems are banned, and so the use of plates and bolted elements is required for regulatory constraints. The considerations regarding the general structure are reported after listing the possible joints.

For the foundations a more modern and common japanese method has been used, that is a slab of reinforced concrete below the ground level and a closed frame, consisting of plinths and connecting beams. The Japanese residential building is often raised above ground level, then plinths and connecting beams, with regard to the underlying slab, rise above ground level. The particularity of this method however consists in the direct union of the wooden beams to the reinforced concrete beams and of the bind wooden beams to the concrete ones, using neoprene pads as infra layer. The beams that connect the plinths are often interrupted due to the passage of pipes and service works, so it is not only the reinforced concrete system that creates the closed mesh but the system of wood and reinforced concrete does.

Fig. 7.1.9 Typical Japanese system

The structure of a traditional Japanese building is designed differently in comparison to a European building's, irrespective of the materials. Here follows a comparison between two buildings in the public domain, as far as the Western world is concerned we are taking the Milan cathedral as example. The Church has a solid and heavy foundation, then it becomes lighter and lighter going up to the roof, by doing this you get a huge advantage, statically speaking, because the base, which must support the whole structure, comes out as something stiffer than the other elements. As to the Japanese world, we are considering the Temple of Kyoto Honganji Temples. In traditional Japanese wooden frame, the base of the building consists of elements lighter than those which follow, that is the coverage.

Fig. 7.1.10 Honganji Temples

It’s possible to argue that the most important and most characteristic element of Japanese architecture is precisely the roof. The image that ancient architects wanted to convey is that a huge massive body is supported by a multitude of light and slender elements.

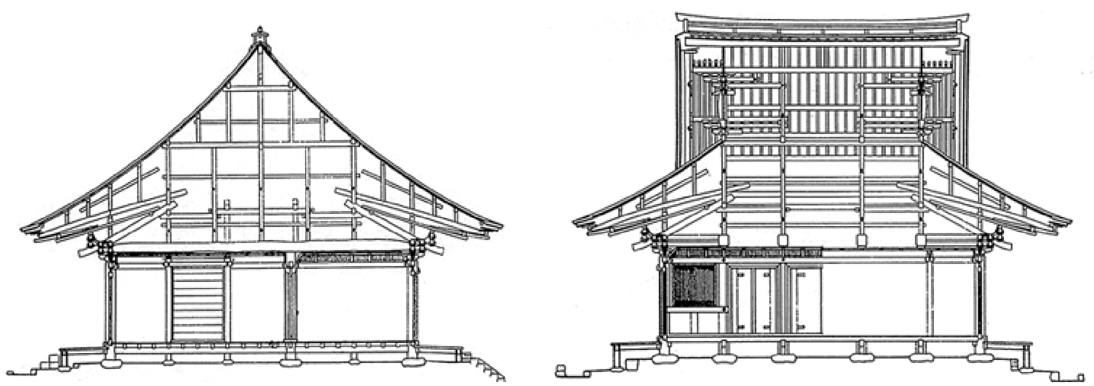


Fig. 7.1.11 Section of a traditional building

Such excessive covers primarily complied with a practical reason: to cover as much as possible, by means of the layer length, the walls hit by sunlight, leaving the base of the building more aerated, and giving rise to convective air cycles. In addition, the roof was mainly formed by straw, a screen for bad weather, lighter than clay or rock materials, which allowed a perspiration in the building. Moreover, in the past, a fire pit was often lit inside the home, but without specific flues to exhale the fumes outside the building, then the height of the ceiling were increased allowing the smoke to go up and not to remain in the living areas, dry off the moisture from the straw, and low the weight.

Subsequently, mainly for public buildings, this concept of stateliness has been overindulged up to the achievement of an actual style/of a style of its own.

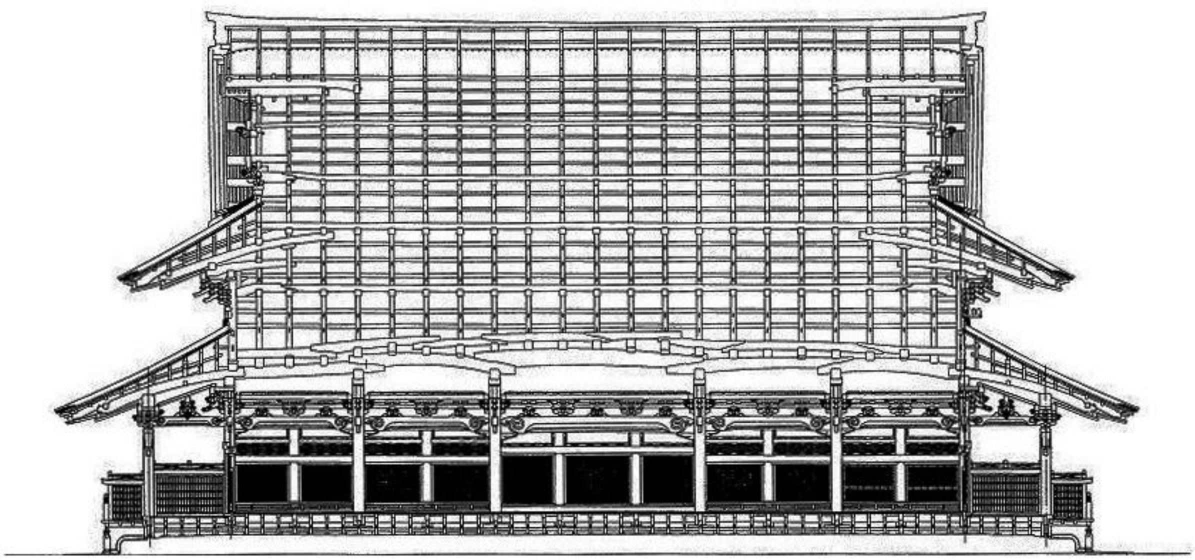
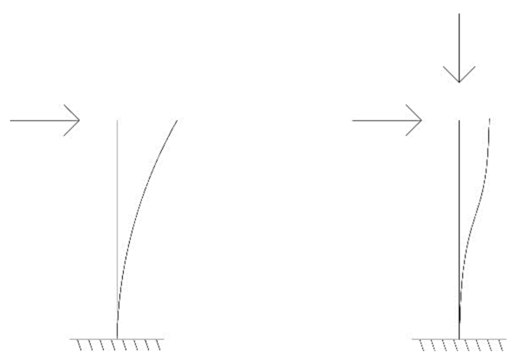


Fig. 7.1.12 Building section

Seismically speaking, the coverage, as the heaviest element, reveals some important issues. A pillar attached to the base and free to move horizontally, under seismic action, is more easily warped when discharged vertically than when it has vertical loads, and this might seem like a point in favor of heavy coverage. The real problem arises when the seismic force exceeds a limit of warping of the light structure, and the inflected pillar, under the heavy load cover, collapses and, needless to say, the chances of death increase when the collapse pertains to a heavy coverage in comparison to a lighter one.



It's important to consider that earthquakes were seen in Eastern philosophy in a completely different way when compared with a more Western vision, and as a result the building safeguard was far less effective than today's. The Japanese, as the Shinto doctrine teaches, see a divine spirit in nature, it is not a creation of the divine but the divinity itself, and then each event related to the natural world is seen as a divine action that is to be respected and accepted. Moreover, Japan during its geological life has always been subject to catastrophic events, including typhoons, volcanic eruptions, earthquakes and tsunamis, so it's not a rare occurring.

According to the Japanese mythology earthquakes are caused by a giant catfish called Namazu, that lives in the mud beneath the Japanese islands, it is guarded by the God Kashima who keeps it crushed under a colossal stone, but when the god does not pay attention, the fish wiggles around trying to break free and causing earthquakes.

Fig. 7.1.13 Manga rappresentation of Kashima

This aims to explain how the risk perception is different depending on where we are, paradoxically it becomes something subjective in relation to the society in which you live and in Japan, the earthquake is an event more easily accepted. Nowadays the earthquake regulations for the safety of life are among the most efficient in the world, but they are also relatively recent, dating back to the year 2000. The last big earthquake took place in Kobe, in 1995, with 6434 dead people and more than 150’000 destroyed buildings, a basic event for the creation of stricter regulations.

Fig. 7.1.14 Kobe earthquake

Continuing on with the structural analysis, it's possible to see another basic concept which means that the Western structure, especially for religious buildings, mainly shows a vertical connotation, the vertical elements acquire more importance than the horizontal ones, as vaults and colonnades. In fact, referring again to the Milan Cathedral, the main purpose of Gothic cathedrals was to create a solid link between the terrestrial and the celestial world and architecture was intended to elevate the human being vertically. In Japanese religious buildings, for example in the Nishi Hongan-ji, the concept of elevation is of lesser important, the sense of crushing is almost stronger, you can feel the weight of the roof and the other horizontal elements. There is a concept of horizontal linearity that very clearly interrupts the natural verticality of the structure. The symbolism of slender vertical elements that support huge horizontal elements refers to a social metaphor where the power of a united population can hold all evil, even the heaviest ones, joining a common destiny.

One example that reinforces the concept of what has been previously said is symbolized in Byōdō-in, a Buddhist temple, where man is called to pray not observing the structure that rises in the sky, but the horizontal reflection of the architecture in the facing lake, to make strong and clear the image of an architecture that drives man towards the horizontality of the earthly world and not to the verticality of the celestial world. This philosophy was later retracted as regards residential buildings, in fact the beams became the dominant character compared with the pillars that became something secondary.

Fig. 7.1.15 Byōdō-in temple

Even nowadays it's easy to find many old buildings with square section pillars 15 x 15 cm, disposed with interaxes measuring 180 cm, which support larger section beams. A single beam is supported by the two main pillars placed at the end, but even by different secondary pillars placed along its main axis. This scheme, anyway, has been amended in the proposed system, it has been decided to remove the side pillars in order to meet the requirements of building speed and to be able to have wider free lights.

Then the new proposed system is designed following the fundamental principles that have characterized, in the past, the culture of a good building technique, but with a few changes, sometimes substantial, to meet the new needs of Japanese architecture.

7.2 Materials

The technical characteristics of the structural materials used, namely wood and steel are analyzed below. With regard to the wood it must be stated that the type used, that is laminated wood, greatly differs from the wood most commonly used in Asia, both in the past and in more modern times. In fact in Japan the use of solid wood is still preferred since this is the element which best embodies the spirit of this architectural culture. However, laminated wood is used to guarantee greater security with regard to the structural characteristics certified by manufacturers.

The wood used is laminated wood GL24h:

$E_{0,g,mean}$=	11600	N/mm²
$E_{0,0,5}$=	9400	N/mm²
G=	720	N/mm²
$f_{mg,k}$=	24	N/mm²
$f_{vg,k}$=	2,7	N/mm²

The steel used as a structural element is S235:

$E_{0,g,mean}$=	210000	N/mm²
G=	81000	N/mm²
f_{yk}=	235	N/mm²
f_{uk} =	360	N/mm²

With regard to the wood, it is essentially necessary to take into account the effect on the time-span behavior of the load action and wood humidity. The wood tensile strength depends, in general, on moisture itself: an increase in moisture causes a reduction in tensile strength. Japan is a particularly rainy country, but the wood, used here as a structure, is always protected by an insulating coating and therefore it is mostly subject to indoor climatic conditions. For these reasons, the first class of service is considered. It is characterized by the balance between the material humidity and the surrounding environment at a temperature of 20° C and a relative humidity of the surrounding air exceeding 65% only for a few weeks per year.

Even the time-span of the load action affects the strength of the material. In particular, in the case of very high stresses, there is a decrease in the strength of the material in case of long-term loads. This means that you can count on a higher material strength in case of short-term loads. The effect of load duration and hygrometric content are summarized in a single correction coefficient, called k_{mod}, which determines the values used to calculate the material strength.

	1	2	3
permanent	0,6	0,6	0,5
long term	0,7	0,7	0,55
middle term	0,8	0,8	0,65
short term	0,9	0,9	0,7
instant	1,1	1,1	0,9

Even the deformation of structural elements depends on the wood humidity content and is subject to the effects of the material viscosity in case of loads acting over an extended period of time. Even in this case there is the definition of a coefficient called $k_{dif,}$ which simultaneously takes into account the two aforementioned effects.

	1	2	3
Layered wood	0,6	0,8	2

Then the value used is k_{dif} = 0.6.

As previously explained, the steel is used only in the presence of joints for its ductile capacities. In fact in a country with such a risk of high seismicity, it is very important to design a system that develops an elasto-plastic behaviour according to the acting forces. In the elastic range the system should provide a degree of elastic load cycles, and then once deformed, it must return to its initial stage, it may deform in the plastic range, yet maintaining an added intrinsic resistance in the steel material that resists to acting loads.The biggest problem the system has to face is fire because the strengths of both materials significantly degrade at high temperatures, steel more than wood, but in a prefabricated system, a damaged item is more easily replaceable when compared to a traditional one.

7.3 Load analysis

The loads acting on the structure are discussed below. It is necessary to point out that all the Italian and European laws have been followed and adapted, since they are the framework studied throughout the author's educational background. The suburban context of Tokyo and their most unfavourable acting loads or factors have been chosen in each category, due to the fact that this project, not having a real lot, must follow a large scale of possibilities.

7.3.1 Permanent structural loads

All the structural elements and their loads are stated below.

Interfloor level:

Element	b [m]	a [m]	l [m]	[kN/m]	[kN]
Summer beam	0,30	0,40	5,70	0,451	2,5992
Secondary beam	0,30	0,40	3,90	0,451	1,7784
Joist	0,12	0,20	3,60	0,090	0,32832
Pillar	0,30	0,30	3,10	0,338	1,0602

Roof level:

Element	b [m]	a [m]	l [m]	[kN/m]	[kN]
Beam	0,3	0,30	6,60	0,338	2,2572
Joist	0,12	0,20	3,60	0,090	0,32832
Pillar	0,30	0,30	3,75	0,338	1,2825
Secondary pillar	0,20	0,20	2,50	0,150	0,38
Secondary beam	0,30	0,40	5,70	0,451	2,5992

7.3.2 Permanent non-structural loads

Interfloor:

Material	Thickness [cm]	Density [kg/m^3]	Load [kg/m^2]	Load [kN/m^2]
Wooden planking	3,0	376,0	11,3	0,11
Thermal insulation coating in wood wool	6,0	110,0	6,6	0,06
Dust coat	0,015	-	0,105	0,001
Filling substrate of perlite	10,0	100,0	10,0	0,10
Gypsum fiber panel	1,0	1150,0	11,5	0,11
Wooden floor	2,0	850,0	17,0	0,17
	22,2	TOT	56,5	1,75

Tab. 7.1 Permanent non structural load for interfloor

Roof:

Material	Thickness [cm]	Density [kg/m^3]	Load [kg/m^2]	Load [kN/m^2]
Vapor control membrane	0,1	770	7,7	0,08
Insulating layer in wood wool	4,0	160	12,8	0,13
Insulating layer in wood wool	8,0	160	12,8	0,13
Insulating layer in wood wool	4,0	250	10,0	0,10
Breathable membrane	-	-	0,135	0,00
Ventilation layer	8,0	-	-	-
OSB panel	3,00	550	16,5	0,16
Waterproof membrane	0,2	-	3,5	0,03

External coating layer				
	-	-	40,0	0,39
	28,2	TOT	91,9	0,90

Tab. 7.2 Permanent non structural load for roof

Exterior wall:

Material	Thicknes s [cm]	Density [kg/m³]	Load [kg/m²]	Load [kN/m²]	[kN/m]
Coating Material	1,25	1450	18,1	0,18	0,53
TNT Barrier	0,00	0	0,0	0,00	0,00
Insulating layer in wood wool	8,00	140	11,2	0,11	0,33
Plywood Panel	1,80	740	13,3	0,13	0,39
Double Insulating Panel	8,00	130	10,4	0,10	0,31
Double gypsum fiber panel	2,50	1150	11,5	0,11	0,34
	21,3	TOT	82,7	0,81	2,43

Tab. 7.3 Permanent non structural load for exterior wall

A long, floor-to-floor window was also integrated to compare all the loads per meter, but, as you can see below, the most unfavorable load is the one above, in the outer wall.

Material	Load [kg]	Load [kN/m]
Shueco Ass 48 250 x 260	230,0	0,92

Interior wall:

Material	Thickness [cm]	Density [kg/m^3]	Load [kg/m^2]	[kN/m^2]	[kN/m]
Double gypsum fiber panel	2,50	1150	14,4	0,14	0,42
Insulating layer in wood wool	6,00	55	3,3	0,03	0,10
Double gypsum fiber panel	2,50	1150	14,4	0,14	0,42
	11,0	TOT	68,3	0,67	2,01

Tab. 7.4 Permanent non structural load for internal wall

An assumed load per square meter, distributed throughout the attic, has been used for the internal partition load. According to the NTC, 1.2 kN/m^2 is assumed value, having a load per meter of 2.01 kN/m.

7.3.3 Operating loads

Category A, or residential establishments with a load value of 2.00 kN/m2, has been used for the operating loads, according to Eurocode 1.

Category	Specific Use	Example
A	Areas for domestic and residential activities	Rooms in residential buildings and houses; bedrooms and wards in hospitals; bedrooms in hotels and hostels kitchens and toilets.

Fig. 7.3.1 Eurocode 1 Tab

7.3.4 Snow load

The snow load NTC has been followed, in particular, the equation:

$$q_s = \mu_i \times q_{sk} \times C_e \times C_t$$

Where:

- μ_i is the shape factor:

Having a sloping roof of 35° it is defined as follows:

$$\mu_i = 0,8 \times \frac{60 - \alpha}{30} = 0,667$$

- q_{sk} is the characteristic load of snow on the ground;

The city of Tokyo is at and above the sea level, but being so wide, it has both areas mainly located on the coast, and also several areas far from it, which extend up to the heights. These last ones, however, have nothing to do with mountainous areas, they do not exceed even the limit of 200 m above sea level imposed by the standard, which is why we have used q_{sk} = 1,50 kN/m^2 as value.

- C_E is the exposition factor. Not having a single case under investigation, 1.0 has been used as coefficient;

- C_t is the thermic factor. Not having a single case under investigation, 1.0. has been used as coefficient;

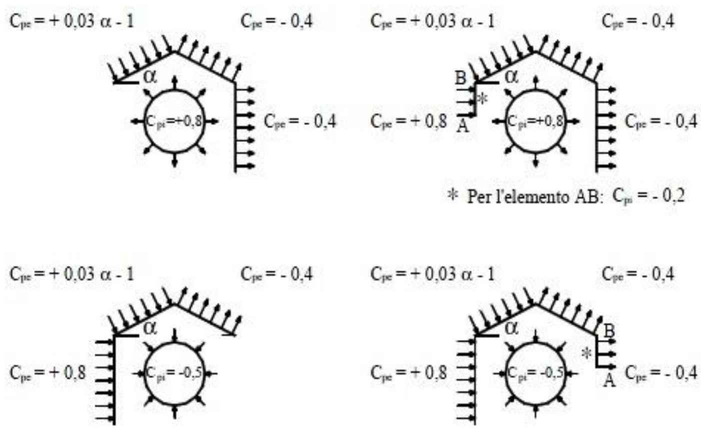
To sum up:

q_{sk} =	1,50	kN/m^2
c_E =	1	-
c_t =	1	-
μ_i =	0,667	-
$q_s = \mu_i\ q_{sk}\ c_E\ c_t$ =	1,00	kN/m^2

The snow load value is: 1,00 kN/m^2.

7.3.5 Wind load

For the calculation of wind pressure, a spreadsheet that can calculate the wind pressure acting on specific areas of the city of Tokyo has been used. The worst pressure, that is the coastal one subject to perturbations, has been taken into account. For a speed of 28 m/s there is an acting pressure of 1.01 kN/m2. It is taken into consideration both the internal and external pressure coefficients applied to the structure for buildings that have a wall with openings ≥ 33% of the total surface.



7.3.6 Seismic force

Over 10% of the world's earthquakes occur in the Japan and the surrounding region. Earthquakes have caused enormous loss of life and property. Traditionally, the most feared things in Japan have been earthquakes, lightning and fires. The ability to withstand earthquakes is an especially important requirement for buildings in Japan. [2]

For the seismic analysis, a more detailed study on the system has been made, in particular it has been meant to calculate the shear stress acting on single node, and then carry out the evaluation. It's also due to point out that Japanese legislation provides, especially for wooden buildings, a finite element analysis specific for each designed building, then you will find the seismic answer of the single joint below, not of the structure as a whole.

The design spectrum has been analysed, according to the Japanese seismic June 2000 code:

The design response spectrum at engineering bedrock has been calculated as follows:

$S_0(T) = (3.2 + 30T)$ for $T < 0.16$

$S_0(T) = 8.0$ for $0.16 < T < 0.64$

$S_0(T) = \frac{5.12}{T}$ for $T > 0.64$

With:

$S_0(T)$ = basic design acceleration response spectrum at the exposed engineering bedrock m/s^2

T = natural period s

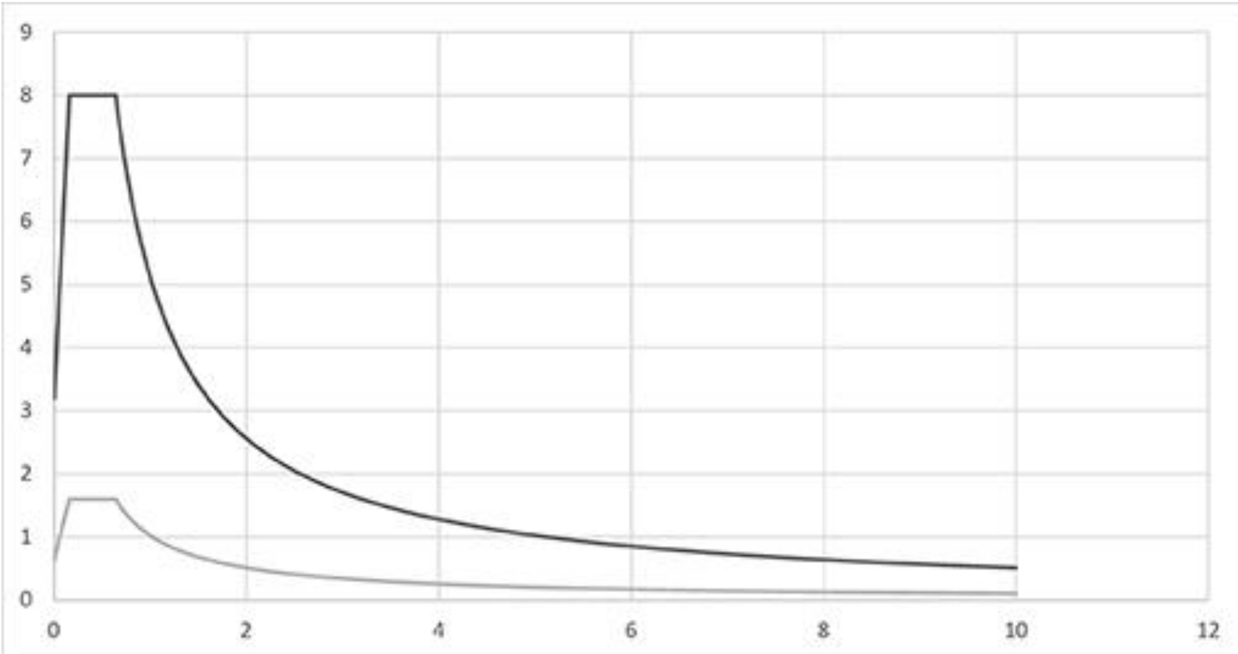


Chart 7.1 Earthquake response spectrum at engineering bedrock

This chart represents an extremely rare earthquake response spectrum, which occurs, roughly speaking, every 500 years, so comparable, in our case, to a seismic event with a return period of 475 years, with a reference period of 50 years and a probability of exceedance of 10% , considering the No-collapse requirement as limit measure.

For what concerns the spectrum for operating limit requirement, notably the damage limit measures, it can be derived dividing the no-collapse spectrum equation in 5.

$$T_R = -\frac{V_R}{\ln(1 - P_{V_R})}$$

With:

T_R = Return period

V_R = Reference period

P_{VR} = probability of exceedance

The engineering bedrock is assumed to be a soil layer whose shear wave velocity is equal to 400m/s, so once obtained the response spectrum at engineering bedrock, it's possible to proceed, adaptating it to the concerned project as follows:

$$S_a(T) = G_s Z S_0(T)$$

With:

$S_a(T)$ = design acceleration response spectrum at ground surface m/s^2,

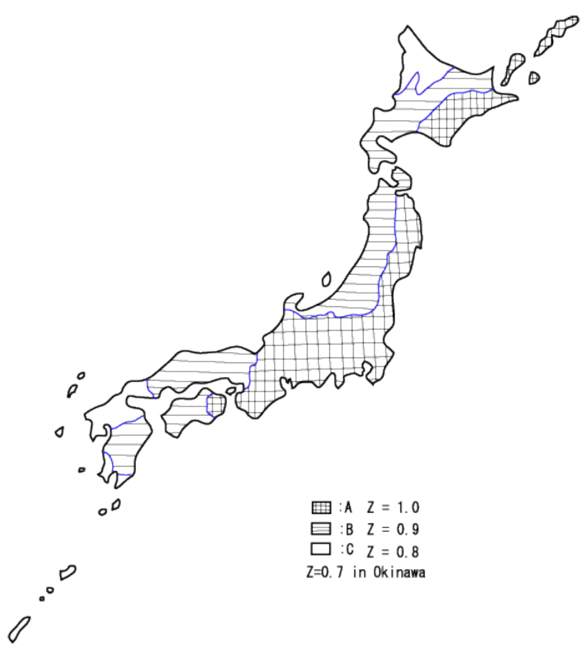
G_S = surface soil layer amplification factor

Z = seismic zone factor

T = natural period s

Here is the elastic response spectrum for the area assumed, in particular, it depends on two factors:

The Z-factor is the factor of zoning, similar to the European system, which acts on a large scale and divides the areas by degree of seismicity, in the case of Tokyo it is 1,00.



G_S is the coefficient that depends on the type of soil in question; in fact, the different layers of soil affect the nature of the seismic wave from the hypocenter to the epicenter. The geological analysis of the city of Tokyo shows a really interesting peculiarity , in fact the study of G_S factor has been entirely developed by two metropolitan transport bodies “deprived” of the city, that having to build the stations of a subway, analyzed the different areas and the types of soil to be excavated. To every subway station is given a G_S coefficient, here follows the graphic for Tokyo area and for its different soil types.

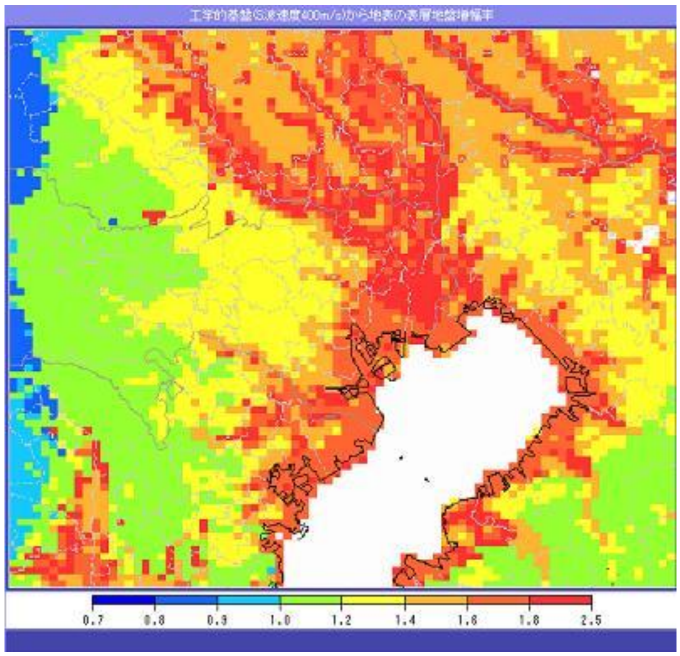


Fig. 7.3.2 Gs coefficient

In this case the most unfavorable one has been considered which, belongs to the District of Edogawa and is 2,41. Therefore, the obtained graph results as follows:

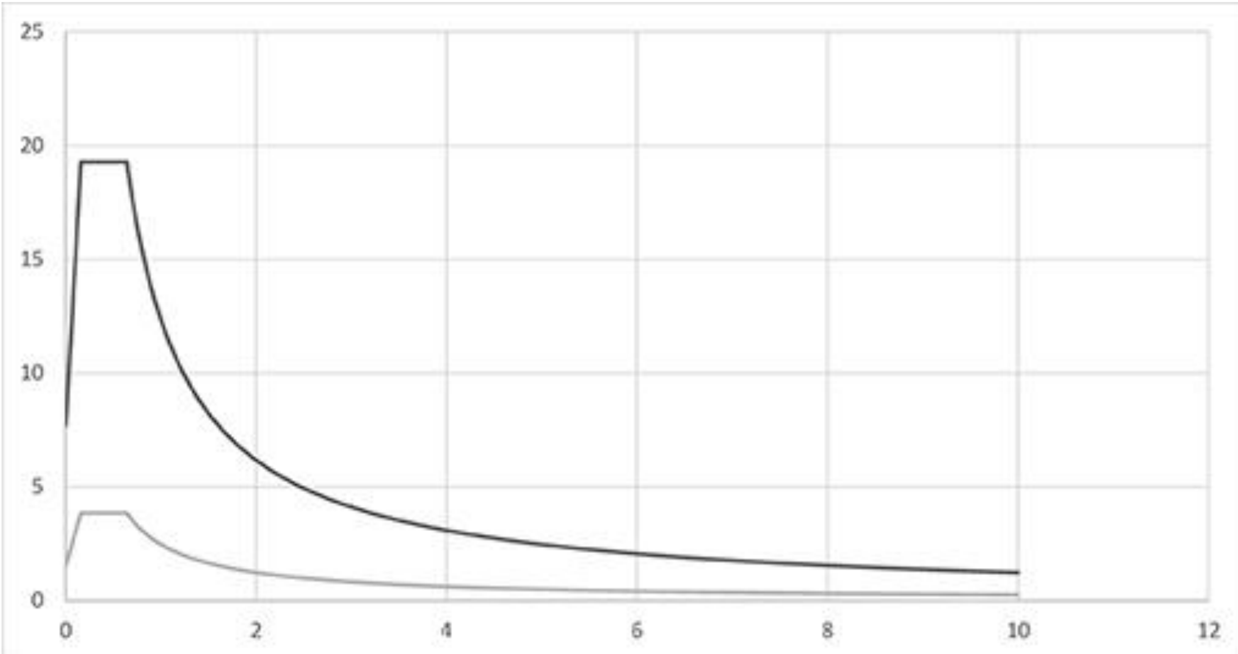


Chart 7.2 Earthquake response spectrum for Edogawa District

Once obtained the elastic response spectrum, it's easy to obtain the design response spectrum.

Essentially, the elastic spectrum will be separated for the behaviour factor of the structure analysed.

$$S_d(T) = \frac{S_0(T)}{q}$$

Where q, behaviour factor is calculated as follows:

With:

$$q = q_0 K_R$$

q_0 is the maximum value of the behaviour factor

K_R is the factor which depends on the regular height of the structure and counts/is:

1.0 for regular structures in height,

0.8 for structures not regular in height.

As regards the timber structure, the behaviour factor depends primarily on the type of steel connection realized and the type of structure built. According to Eurocode 8, the value given to the structure factor is: 2.5, explained later.

Design concept and ductility class	q	Examples of structures
Low capacity to dissipate energy - DCL	1,5	Cantilevers; Beams; Arches with two or three pinned joints; Trusses joined with connectors.
Medium capacity to dissipate energy - DCM	2	Glued wall panels with glued diaphragms, connected with nails and bolts; Trusses with doweled and bolted joints; Mixed structures consisting of timber framing (resisting the horizontal forces) and non-load bearing infill.
	2,5	Hyperstatic portal frames with doweled and bolted joints (see **8.1.3(3)**P).
High capacity to dissipate energy - DCH	3	Nailed wall panels with glued diaphragms, connected with nails and bolts; Trusses with nailed joints.
	4	Hyperstatic portal frames with doweled and bolted joints (see **8.1.3(3)**P).
	5	Nailed wall panels with nailed diaphragms, connected with nails and bolts.

Fig. 7.3.3 Eurocode 8 Tab

The design response spectrum for the system designed is:

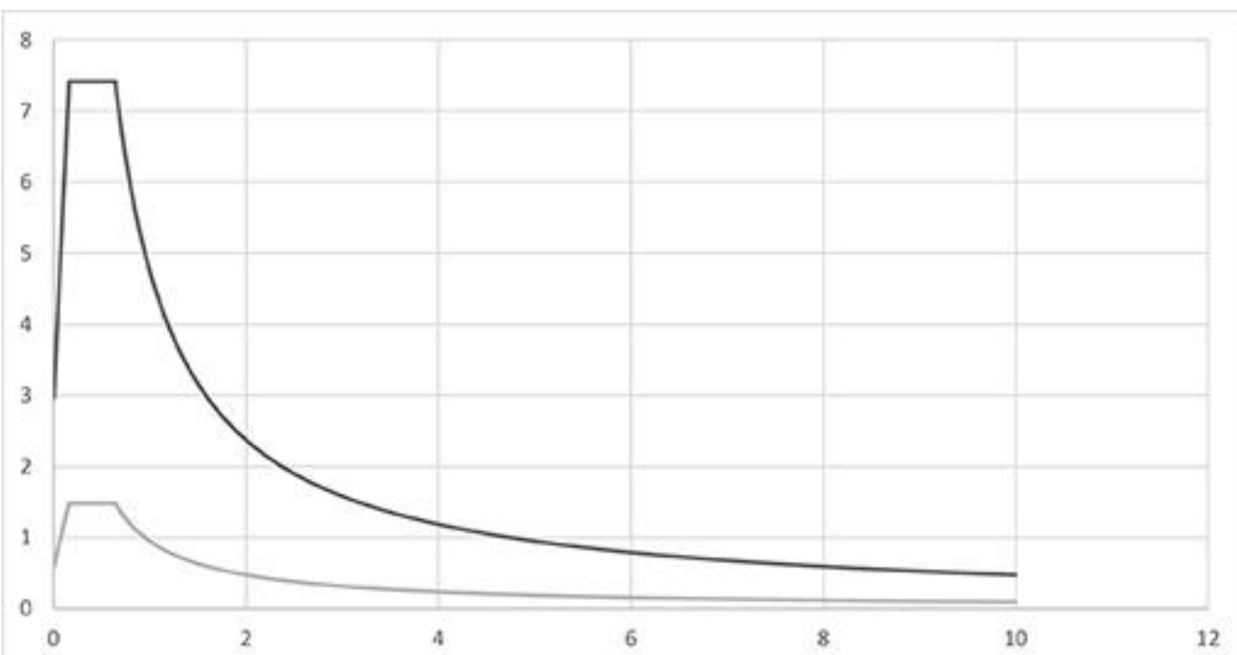


Chart 7.3 Design response spectrum

7.4 Loads combination

ULS: Ultimate limite state combination

$$\gamma_{G1}G_1 + \gamma_{G2}G_2 + \gamma_P P + \gamma_{Q1}Q_{k1} + \gamma_{Q2}\psi_{02}Q_{k2} + \gamma_{Q3}\psi_{03}Q_{k3} + \cdots$$

SLS: Serviceability limite state combination: characteristic

$$G_1 + G_2 + P + Q_{k1} + \psi_{02}Q_{k2} + \psi_{03}Q_{k3} + \cdots$$

SLS: Serviceability limite state combination: quasi-permanent

$$G_1 + G_2 + P + \psi_{21}Q_{k1} + \psi_{22}Q_{k2} + \psi_{23}Q_{k3} + \cdots$$

Seismic combination:

$$E + G_1 + G_2 + P + \psi_{21}Q_{k1} + \psi_{22}Q_{k2} + \psi_{23}Q_{k3} + \cdots$$

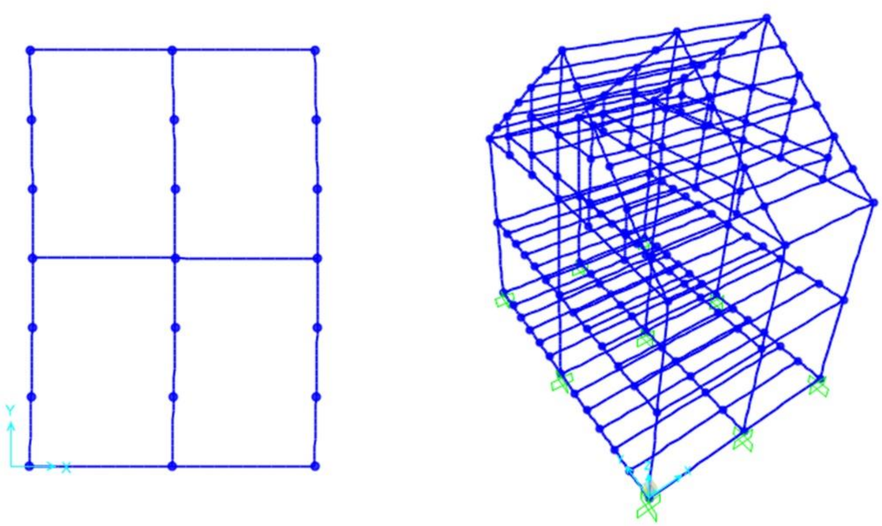
7.5 Joint analysis

The first analysis to be performed is the one related to the joint. The entire structure and all the elements that compose it were sized only after sizing the main joint. A preliminary analysis has been done on possible ways of breaking, the results have not been verified by laboratory tests, as required by the norm for non-classical joints, this because it does not fall within the purpose of this thesis. The behavior under horizontal seismic efforts is studied first and then there is the study of the vertical loads, this because the ductility of a wooden structure mainly depends on the ability of the connection system to develop ductility. It is therefore essential, especially in the case of a new joint, to understand at first glance what happens in the joint under earthquake loads. For the preliminary analysis, it was not possible to perform a finite element modeling of the node, as it would have led to conclusions not completely trugthful, being a field still in a stage of development.

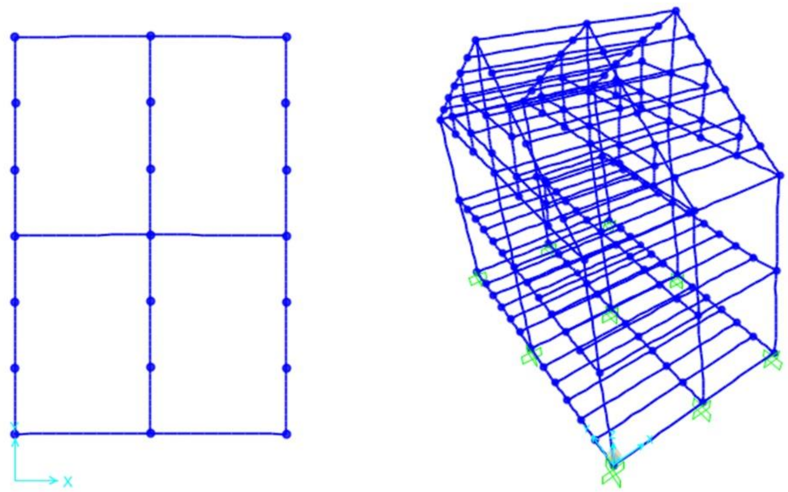
A more analytical approach was then followed, that is, the possible collapsing mechanisms were taken into consideration and then they were compared with known breaking points. Subsequently, the strained elements were analyzed and treated as single corresponding parts, not counting the over-strength of the overall structure. A case study was designed and a finite element analysis was performed using SAP2000 software to try and better understand the dynamicity of the structure, obtaining a more precise analysis showing the efforts acting on individual nodes.

This is the analysis result:

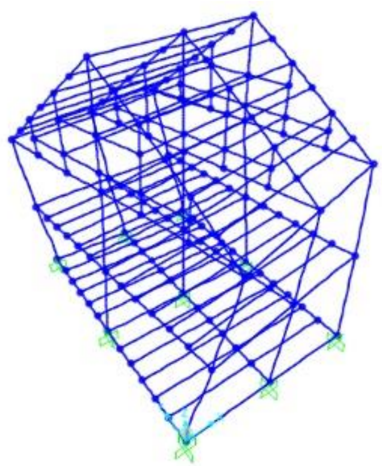
Mode 1: $T = 0.26861$, $f = 3.72283$



Mode 2: T = 0.24777, f = 4.03593



Mode 3: T = 0.20372, f = 4.90866



As it can be seen from the pictures, the first mode shape is along X, along Y as second and only as a third way of vibrating along Z —that is torsionally. All load combinations were then applied, in particular it should be noted that the elastic response spectrum on No-collapse requirement was considered to test the ultimate limit state of the element. Once the shaping had been initiated, the data relating to the node efforts have been extrapolated and then the nodes under the greatest stress have been verified.

For the main central joint:

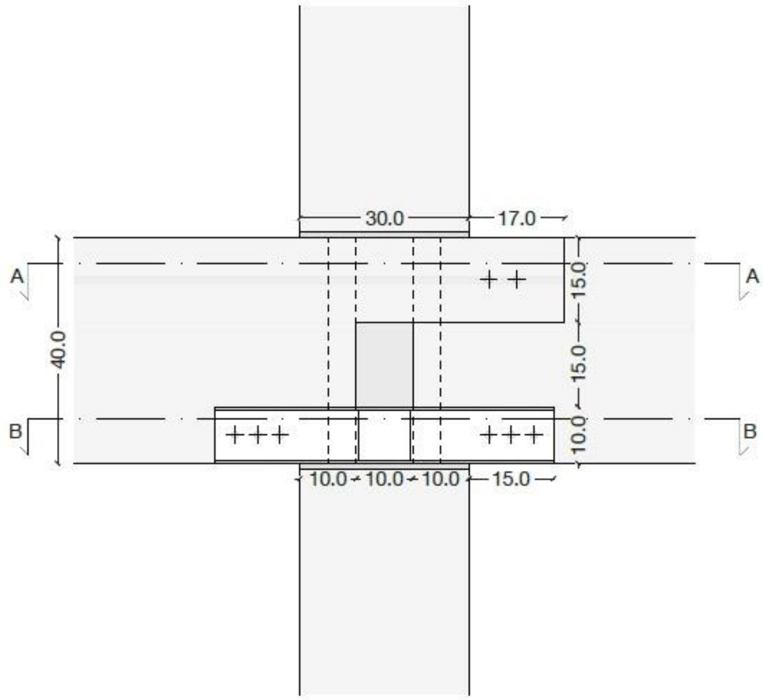


Fig. 7.5.1 Central joint

The most stressed node suffers of a shear stress of 110.5 kN.

As first step, there is a geometric analysis of the basic elements, namely wooden frames and connectors. The legislation sets certain minimum requirements to enforce the hypotheses of behaviour factor, and in particular, the European legislation, equal to the Italian one, says:

a) in doweled, bolted and nailed timber-to-timber and steel-to-timber joints, the minimum thickness of the connected members is $10{\cdot}d$ and the fastener-diameter d does not exceed 12 mm;

b) In shear walls and diaphragms, the sheathing material is wood-based with a minimum thickness of $4d$, where the nail diameter d does not exceed 3,1 mm.

If the above requirements are not met, but the minimum member thickness of $8d$ and $3d$ for case a) and case b), respectively, is assured, reduced upper limit values for the behaviour factor q, as given in Table 8.2, should be used.

Table 8.2: Structural types and reduced upper limits of behaviour factors

Structural types	Behaviour factor q
Hyperstatic portal frames with doweled and bolted joints	2,5
Nailed wall panels with nailed diaphragms	4,0

(5) For structures having different and independent properties in the two horizontal directions, the q factors to be used for the calculation of the seismic action effects in each main direction should correspond to the properties of the structural system in that direction and can be different.

A bolt of diameter d = 12 mm is chosen, this would imply a thickness of at least 120 mm, in the connected items, but as it can be seen from the above image, the thickness of the connected items is 100 mm. This is possible considering the last sentences of the legislation, which calls for a minimum thickness of 8 d, which is 96 mm, lowering the structure factor to 2.5.

Of course all this was possible only after a careful analysis of the capacity of the connection plastic behaviour, explained below. Looking at the node section, it can be realized that under horizontal effort, more elements are stressed, namely: the metal connectors of the beams, the cage of vertical steel profiles and the portions of beams perpendicular to the efforts which intersect within the node.

This last contribution is left out, while the remaining two are analyzed. Considering the mesh, you can imagine that when the steel cage collapse, the whole node suffers, indeed with the mesh warping, the whole node warps and even the pillars, resting on no longer flat elements, would tilt.

When, instead, the fazing elements are represented by the beams steel connectors, the node does not particularly suffer those effects, only the beams separate from each other, and this does not create significant effects within the node itself. This is the reason to make the steel connector that links the beams the item brought to collapse.

The previous pictures shows that the connectors are present both at the top, wood-wood, and at the bottom, wood-steel. Below there is the analysis of the connectors for the connection wood-wood, with two cutting plans, since, as it is easy to deduce, in the wood-steel connection, the bolt bearing of the square steel profile is unlikely to take place before the yield strength of the connector.

In fact, as regards the connection wood-wood, it has been decided that the first item to go into crisis, under the moment of yield strength, is the steel bolting and the woody material under the tension of bolt bearing will operate only as second. This causes the node to be able to exploit a certain ductility and contribute more to the dispersion of the seismic forces.

The procedure has followed the formulas shown in the manual *Strutture in legno* [24]:

The type of connector used is Φ12 x 300 mm, class 8.8, that is:

$f_{y,k}$ = 649 N/mm^2 yield stress,

$f_{u,k}$ = 800 N/mm^2 tensile strength,

While the laminated wood being used has a density ρ_k = 380 Kg/m^3

The three connected wooden elements have the same thickness, t1 = t2 = 100 mm.

The characteristic value of bolt bearing, then, has been calculated as:

$$f_{h,k} = 0.082(1 - 0.01d)\rho_k$$

In this case, $f_{h,k}$ = 27.42 N/mm^2 is valid for both connected members.

The formulation also includes a factor β defined as the ratio of the values characteristic of bolt bearing of two wooden connected elements, in our case, being equal, it is β = 1.

Then the time characteristic of the connector yield strength has been calculated:

$M_{y,k} = W_{pl} \times f_{y,k} \cong 0.1 f_{u,k} \times d^3$ for round shank connectors.

In our case, it is $M_{y,k}$ = 179'712 Nmm.

Once obtained the resistance values, the modes of breaking of the elements are assessed, in particular:

mode I: bolt bearing of one of the wooden parts connected.

mode II and III: bolt bearing of one of the wooden parts and simultaneous yield strength of the metallic connector, with formation of one or more plastic hinges.

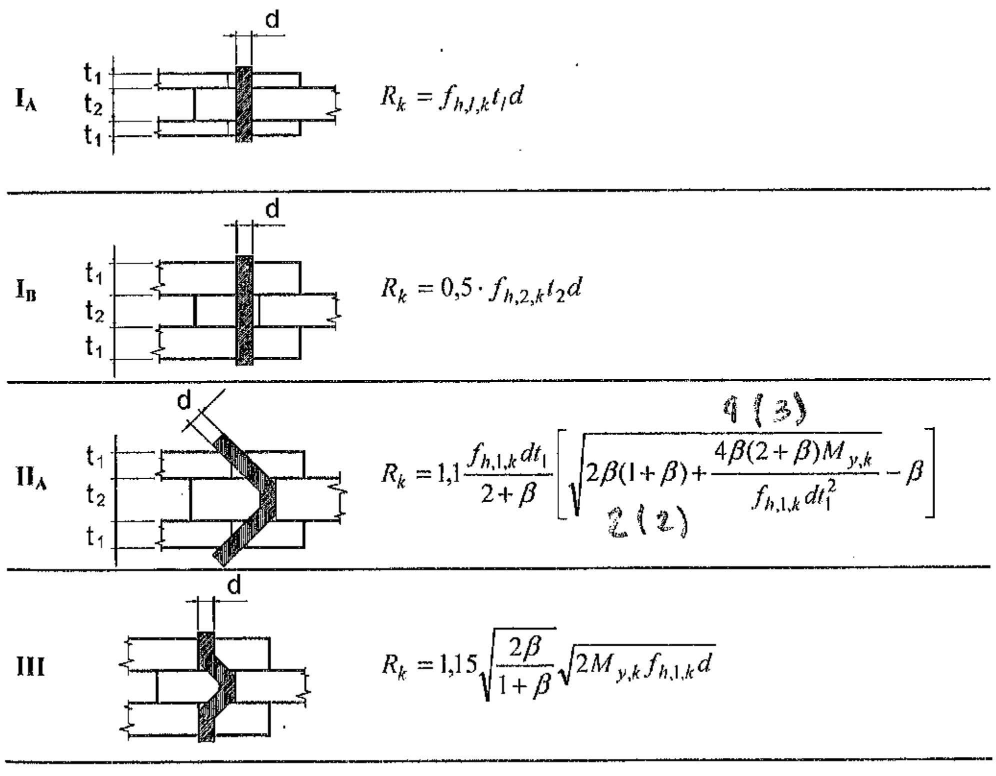


Fig. 7.5.2 mode of crisis

The values obtained are:

I_A) R_k = 36195 N

I_B) R_k = 18098 N

II_A) R_k = 15364 N

III) R_k = 13757 N

Then, from the specified values it can be seen that the first way to reach a crisis point is the fourth (III), which is the lower resistance point, and this implies that, in the structure, the connector yielding takes place earlier than the bolt bearing of the wooden material.

To calculate the effective number of connectors:

$$n_{R,eff} > \frac{N_d}{2R_{d,conn}}$$

With k_{mod} = 0.9, for short-term actions, like the seismic one, and γ_k = 1.3

For a stress of 100’500 N, the number of effective connectors is 3, respectively in two rows.

Considering what was previously said, that actually more elements come into play, reducing the stress caused by the earthquake, it was decided to:

Put 2 connectors at the top and 3 below, for the central joint, for a total of 5, respecting the geometric limits imposed by the legislation for wooden connections.

Placing 2 rows of connectors, for ending joints, for a total of 6 but only below, respecting the geometric limits for connections on steel plates imposed by the legislation.

See Annex D

As regards to the vertical loads, tests and reasoning concerning, first of all, the metal crosses are carried out. In fact the latter serve to increase the supporting surface of the beam on the pillar and increase stability. The static schema of the cross can be traced back to a cantilever beam stuck on one side and free to flex on the other, with a precise point load. The point load will be proportional to the cut that the beam downloads on the pier, which is equal to 60.4 kN, according to ULS, particularly it can be noticed that the diagram of the supported beam has a linear trend, and then a reduced cutting effort that, according to a geometric proportion, is 55.3 kN. will act on the ends of the cross.

The shear analysis for the steel element is largely verified, the shear strength is:

$$V_{Rd} = \frac{A_V \frac{f_y}{\sqrt{3}}}{\gamma_{M0}}$$

With AV, shear-resistant area for a 10 x 10 cm profile, 2 mm of thickness equals 7.84 cm2 and steel S235, VRd = 92.5 kN.

Regarding the strains, the max deformation on the free end is:

$$f = \frac{Fl^3}{3EI}$$

The cutting resulting from the beam is now considered at the operating limit state, for the nearly permanent scheme and holds: 26.37 kN.

Considering the section first quoted:

I = 125.54 cm^4

E = 210000 N/mm^2

The deformation holds 0.0013 m and then the analysis is satisfied.

Another reasoning to take into account, pertains to the way in which the joint static schema is analyzed. Two hypothesis can be made:

-The joint is considered as a simple support, and then the bending of the beams in the middle section is greater.

-The joint is assumed to be perfect, and then the beam and a jointing portion will suffer a negative moment right in the presence of the joint.

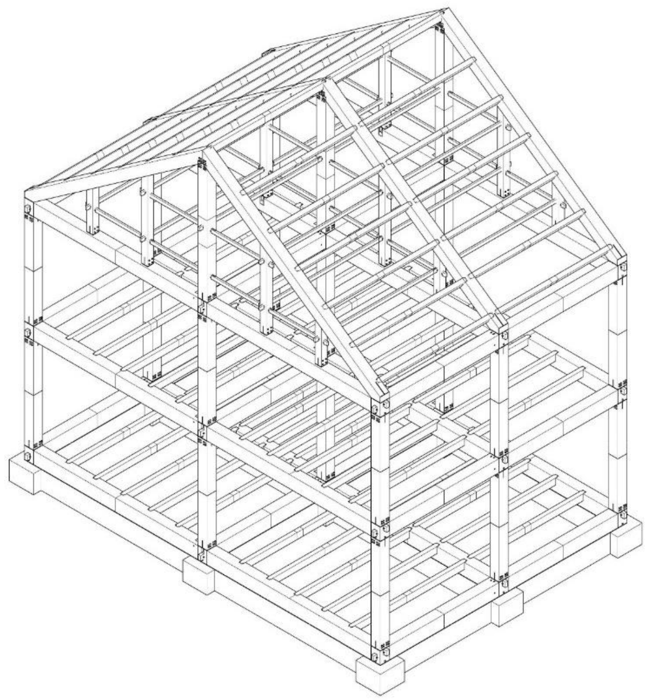
The truth about what really happens must be in the middle of these two hypotheses, in fact the joint studied can be considered as a semi-rigid one, that is capable of transmitting part of the angular deformations present on the elements.

The static schema used to check the beams is precisely that of the supported beam, to maximize the moment, however, the geometry of the node is analyzed below, hypothesizing a static scheme of a beam perfectly jointed at both ends.

As it can be seen from the geometry, the most vulnerable element is the extension of the beam which continues along the joint up to its own blocking with the other beam, in fact if we considered only the wooden portion of the beam section which continues within the joint we would notice that the section would not be able to counteract the negative moment.

However, when considering the geometry of the whole system it can be seen that the beam changes its section rather serially, due to the deformation by bending loads.

7.6 Elements analysis



The individual elements that make up the structure are subsequently investigated.

The following chapter will review the following items

- main beams, central and perimeter floor and floor covering
- joists, floor and roof
- floor planking
- pillar

The foundations will not be discussed since they too much depend on the type of soil on which they are realized nor the secondary structure concerning the roof because it is accepted as verified on the basis of historical referemces. The verifications proposed by Eurocode 5 have been followed:

For beams under bending:

$$\sigma_{m,d} \leq \frac{k_{mod} f_{m,k}}{\gamma_M}$$

where:

- $\sigma_{m,d}$ bending stress

- k_{mod} correction coefficient

- $f_{m,k}$ characteristic value of bending stress

- γ_M safety coefficient, for laminated wood is 1.3

This is the procedure for the verification of the beams subject to simple bending, however, possible problems related to warping are considered as well, and this is the procedure:

$$\sigma_{m,d} \leq k_{crit} f_{m,k}$$

With:

K_{crit} coefficient of sideways swinging:

$$k_{crit} = \begin{cases} 1 & per\ \lambda_{rel,m} \leq 0{,}75 \\ 1{,}56 - 0{,}75\lambda_{rel,m} & per\ 0{,}75 < \lambda_{rel,m} \leq 1{,}4 \\ \dfrac{1}{\lambda_{rel,m}{}^2} & per\ \lambda_{rel,m} > 1{,}4 \end{cases}$$

$\lambda_{rel,m} = \sqrt{\frac{f_{m.k}}{\sigma_{m,crit}}}$ slenderness related to warpin;

$\sigma_{m,crit} = \frac{\pi}{l_{eff}} \frac{b^2}{h} E_{005} \sqrt{\frac{G_{mean}}{E_{mean}}}$ critical stress of warping;

The shear analysis takes place in the mostly stressed section according to the formula:

$$\tau_d \leq \frac{k_{mod} f_{v,k}}{\gamma_M}$$

Having rectangular sections:

$$\tau_d = \frac{V_d 1{,}5}{bh}$$

This explained is the analysis process for bending actions, now the compression stress parallel to timber grain is analysed.

This is the case of the bars subjected to pure compression, the formulas have been used to test the pillars:

$$\sigma_{c,0,d} \leq k_c \frac{k_{mod} f_{c,0,k}}{\gamma_M}$$

$$\sigma_{c,0,d} = \frac{N_d}{A_{lorda}}$$

K_c oefficient of critical listing tension

$$K_c = \frac{1}{K_z + \sqrt{{K_z}^2 + {\lambda_{rel,z}}^2}}$$

$$\lambda_{rel,z} = \sqrt{\frac{f_{c,0,k}}{\sigma_{c,crit,z}}}$$

$$\sigma_{c,crit,z} = \frac{\pi^2 E_{0,05}}{{\lambda_z}^2}$$

$$\lambda_z = \frac{l_k}{i}$$

$$i = \sqrt{\frac{I}{A}}$$

$$K_z = 0{,}5\left(1 + \beta_c(\lambda_{rel,z} - 0{,}5) + {\lambda_{rel,z}}^2\right)$$

with:

i = inertia radius of the section;

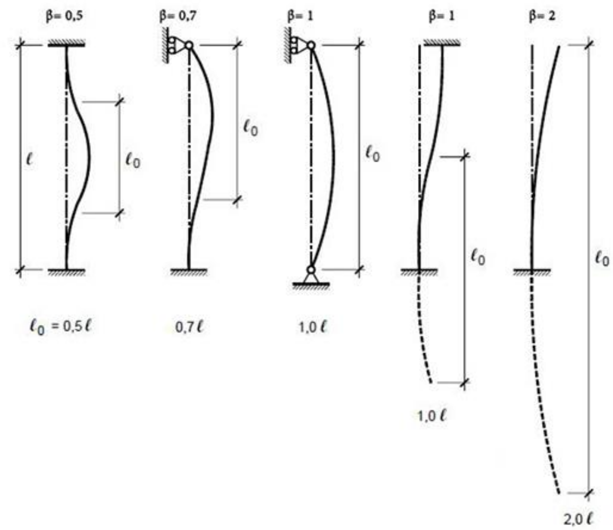
I = moment of inertia of the section (concerning the the axis perpendicular to the plan where lilting takes place);

l_k = critical length of lilting , in our case 0.5 * l;

β_c = 0.1 in the case of laminated wood;

λ_{rel} = relative slenderness;

λ_z = geometric slenderness compared to the axis considered



For the verification of the instability of simple support beams, the following equations have been used, found on a design manual in accordance with Eurocode 5: [24]

$$u_{fin} = \frac{5}{384}\frac{Q_{qp}l^4}{\left(\frac{E_0}{1+k_{def}}\right)J} + \chi\frac{Q_{qp}l^2}{8GA}$$

$$u_{ist} = \frac{5}{384}\frac{Q_{rara}l^4}{E_0J} + \chi\frac{Q_{qp}l^2}{8GA}$$

The limit value of strain for beams is l/250.

7.6.1 Structural planking

The load combinations are:

G1	0,03	[kN/m]
self load	0,11	
G2	0,41	[kN/m]
interfloor slab	1,64	
Q	0,50	[kN/m]
load uso	2,00	
ULS		
Q_{ULS}	1,40	
SLS		
Q_{qp}	0,59	
Q_{ch}	0,94	

The deformation analysis is:

Max deformation

Combination of Loads: SLS

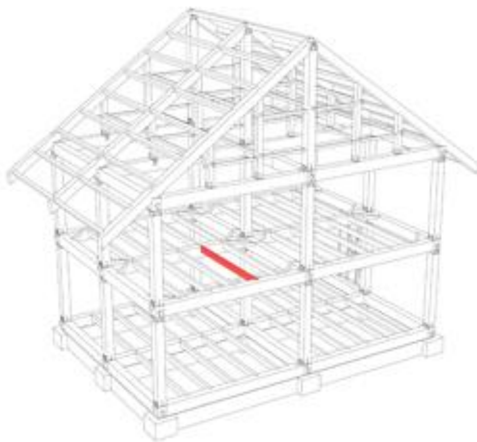
$U_{net,fin}=U_{fin}+U_{ist}=$ 0,0014 < 0,0036 U_{lim}

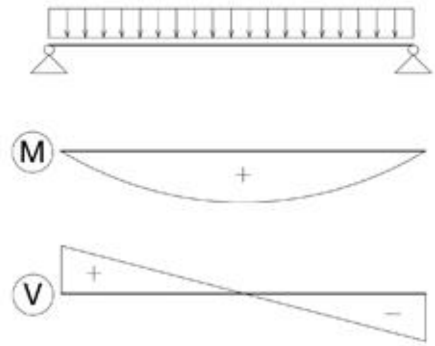
Q_{qp}	0,59	KN/m	*combination quasi-permanent*
Q_{ch}	0,94	KN/m	*combination characteristic*
l	0,78		*span*
l_{eff}	0,9	m	*real span*
h	0,03	m	*thickness*

b	0,25	m	*depth*
A	0,03	mq	*Area*
K_{def}	0,6		*wood viscosity factor*
χ	1,2		*shear factor*
J	0,00	m4	*moment of inertia*
U_{fin}	0,0007	m	
U_{ist}	0,0007	m	

The analysis is undertaken.

7.6.2 Floor joist





The load combinations are:

G1	0,19	[kN/m]
interfloor slab	0,11	
self load	0,09	
G2	1,48	[kN/m]
interfloor slab	1,64	
Q	1,80	[kN/m]
load uso	2,00	
ULS		
Q_{ULS}	5,17	
SLS		
Q_{qp}	2,21	
Q_{ch}	3,47	

The analysis deals with bending strenght and shear strenght:

Resistence bending moment

Combination of loads: ULS

$\sigma_{m,d} < K_{crit} \times f_{m,d}$

$\sigma_{m,d}$	10,46	<	11,52	$K_{crit} \times f_{m,d}$	[N/mm²]
Q	5,17	kN/m			
M	8,37	kNm			
$f_{m,k}$	24	N/mm²			
K_{mod}	0,6	-			
$f_{m,d}$	11,52	N/mm²			
$\sigma_{m,d}$	10,46	N/mm²			
$\sigma_{m,crit}$	147,1448	N/mm²			
$\lambda_{rel,m}$	0,403862	-			
K_{crit}	1	-			

Resistence shear stress

T	9,3	kN			
τ_d	0,58	<	1,12	$f_{v,d}$	[N/mm²]

The deformation analysis is:

Max deformation

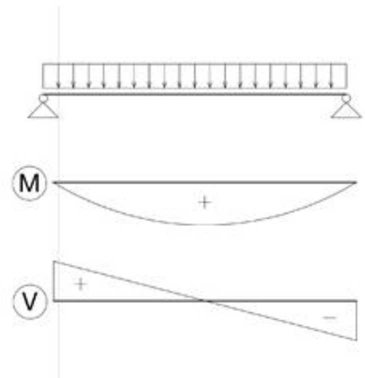
Combination of Loads: SLS

$U_{net,fin}=U_{fin}+U_{ist}=$	0,0136	<	0,0136 U_{lim}
Q_{qp}	2,21	KN/m	*combination quasi-permanent*
Q_{ch}	3,47	KN/m	*combination characteristic*
T-T	0,90	m	*interaxle spacing*
l	3,6	m	*span*
l_{eff}	3,8	m	*real span*
h	0,2	m	*thickness*
b	0,12	m	*depth*
A	0,02	m^2	*Area*
K_{def}	0,6	-	*wood viscosity factor*
χ	1,2	-	*shear factor*
J	0,00	m^4	*moment of inertia*
U_{fin}	0,0068	m	
U_{ist}	0,0067	m	

7.6.3 Interfloor beam

The different types of beams are analyzed here, namely: central, perimetral and coverage support beam. Then these have been sized equally based on the results obtained about the one with the most unfavourable load.

Perimetral beam:



G1	0,98	[kN/m]
interfloor slab	0,11	
joist	0,32	
self load	0,45	
G2	5,39	[kN/m]
perimetral wall	2,43	
interfloor slab	1,64	
Q	3,60	[kN/m]
load uso	2,00	
ULS		
Q_{ULS}	14,76	
SLS		
Q_{qp}	7,45	
Q_{ch}	9,97	

The analysis deals with bending strenght and shear strenght:

Resistence bending moment

Combination of loads: ULS

$\sigma_{m,d} < K_{crit} \times f_{m,d}$

$\sigma_{m,d}$	7,49	<	14,40	$K_{crit} \times f_{m,d}$	[N/mm²]
Q	14,76	kN/m			
M	59,92	kNm			
$f_{m,k}$	24	N/mm²			
K_{mod}	0,6	-			
$f_{m,d}$	14,40	N/mm²			
$\sigma_{m,d}$	7,49	N/mm²			
$\sigma_{m,crit}$	290,4174	N/mm²			
$\lambda_{rel,m}$	0,287471	-			
K_{crit}	1	-			

Resistence shear stress

T	42,1	kN			
τ_d	0,53	<	1,12	$f_{v,d}$	[N/mm²]

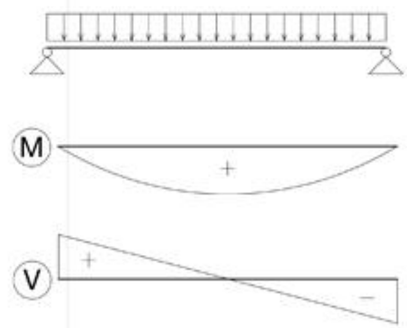
The deformation analysis is:

Max deformation

Combination of Loads: SLS

$U_{net,fin}=U_{fin}+U_{ist}=$	0,0138	<	0,0216 U_{lim}
Q_{qp}	7,45	KN/m	*combination quasi permanente*
Q_{ch}	9,97	KN/m	*combination rare*
T-T	1,80	m	*interaxle spacing*
l	5,4	m	*span*
l_{eff}	5,7	m	*real span*
h	0,4	m	*thickness*
b	0,3	m	*depth*
A	0,12	m^2	*Area*
K_{def}	0,6	-	*wood viscosity factor*
χ	1,2	-	*shear factor*
J	0,00	m^4	*moment of inertia*
U_{fin}	0,0075	m	
U_{ist}	0,0063	m	

Central beam:



G1	1,17	[kN/m]
interfloor slab	0,11	
joist	0,32	
self load	0,45	
G2	5,92	[kN/m]
interfloor slab	1,64	
Q	7,20	[kN/m]
load uso	2,00	
ULS		
Q_{ULS}	21,20	
SLS		
Q_{qp}	9,25	
Q_{ch}	14,29	

The analysis deals with bending strenght and shear strenght:

Resistence bending moment

Combination of loads: ULS

$\sigma_{m,d} < K_{crit} \times f_{m,d}$

$\sigma_{m,d}$	10,76	<	14,40	$K_{crit} \times f_{m,d}$	[N/mm²]
Q	21,20	kN/m			
M	86,11	kNm			
$f_{m,k}$	24	N/mm²			
K_{mod}	0,6	-			
$f_{m,d}$	14,40	N/mm²			
$\sigma_{m,d}$	10,76	N/mm²			
$\sigma_{m,crit}$	290,4174	N/mm²			
$\lambda_{rel,m}$	0,287471	-			
K_{crit}	1	-			

Resistence shear stress

T	60,4	kN			
τ_d	0,76	<	1,12	$f_{v,d}$	[N/mm²]

Here the deformation analysis:

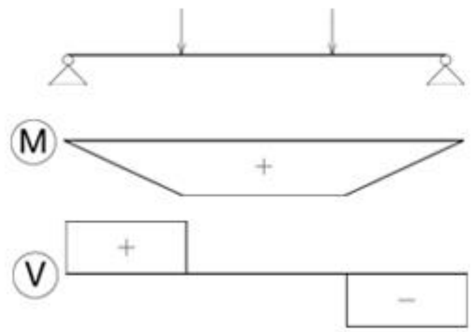
Max deformation

Combination of Loads: SLS

$U_{net,fin}=U_{fin}+U_{ist}=$	0,0183	<	0,0216	U_{lim}
Q_{qp}	9,25	KN/m	*combination quasi permanente*	
Q_{ch}	14,29	KN/m	*combination rare*	
T-T	3,60	m	*interaxle spacing*	
l	5,4	m	*span*	
l_{eff}	5,7	m	*real span*	
h	0,4	m	*thickness*	
b	0,3	m	*depth*	
A	0,12	m^2	*Area*	
K_{def}	0,6	-	*wood viscosity factor*	
χ	1,2	-	*shear factor*	
J	0,00	m^4	*moment of inertia*	
U_{fin}	0,0093	m		
U_{ist}	0,0090	m		

Roof support beam:

The forces acting on this beam change and the static scheme changes as well. In particular the pillars of secondary weave for the roof coverage will download the stress acting in coverage directly on the beam at a distance from the supports defined as ‘a’.



The analysis deals with bending strenght and shear strenght:

Resistence bending moment

Combination of loads: ULS

$\sigma_{m,d} < K_{crit} \times f_{m,d}$

$\sigma_{m,d}$	3,17	<	14,40	$K_{crit} \times f_{m,d}$	[N/mm^2]
P	14,08	kN			
M	25,34	kNm			
$f_{m,k}$	24	N/mm^2			
K_{mod}	0,6	-			
$f_{m,d}$	14,40	N/mm^2			
$\sigma_{m,d}$	3,17	N/mm^2			
$\sigma_{m,crit}$	290,4174	N/mm^2			
$\lambda_{rel,m}$	0,287471	-			
K_{crit}	1	-			

Resistence shear stress

T	14,1	kN			
τ_d	0,18	<	1,12	$f_{v,d}$	[N/mm²]

As the static scheme changes, the equations of instability changes as well. The deformation is then found with a dummy load Q = 1 and then multiplied by the actual load. The maximum deformation is given by the following equation:

$$u_{max} = \frac{Pa}{24EI}(3l^2 - 4a^2)$$

Here the deformation analysis:

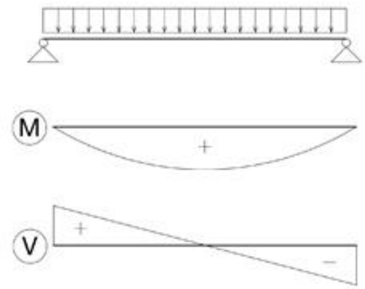
Max deformation

Combination of Loads: SLS

T-T	3,60	m	*interaxle spacing*
l	5,4	m	*span*
l_{eff}	5,7	m	*real span*
l_{load}	1,8	m	
h	0,4	m	*thickness*
b	0,3	m	*depth*
A	0,12	m²	*Area*
K_{def}	0,6	-	*wood viscosity factor*
χ	1,2	-	*shear factor*
J	0,00	m⁴	*moment of inertia*
U_{max}	0,00424	m	
U_{lim}	0,0216	m	

So a beam of section 30 x 30 cm proves to be the final solution.

7.6.4 Roof joist



β	35,00	
cos(β)	0,82	
G1	0,17	[kN/m]
interfloor slab	0,11	
self load	0,09	
G2	0,81	[kN/m]
roof slab	0,90	
Q_W	0,53	[kN/m]
Q_S	1,10	[kN/m]
ULS		
Q_{ULS}	3,57	*Snow*
SLS		
Q_{qp}	0,99	
Q_{ch}	2,41	

The analysis deals with bending strenght and shear strenght:

Resistence bending moment

Combination of loads: ULS

$\sigma_{m,d} < K_{crit} \times f_{m,d}$

$\sigma_{m,d}$	7,24	<	11,52	$K_{crit} \times f_{m,d}$	[N/mm²]
Q	3,57	kN/m			
M	5,79	kNm			
$f_{m,k}$	24	N/mm²			
K_{mod}	0,6	-			
$f_{m,d}$	11,52	N/mm²			
$\sigma_{m,d}$	7,24	N/mm²			
$\sigma_{m,crit}$	147,1448	N/mm²			
$\lambda_{rel,m}$	0,403862	-			
K_{crit}	1	-			

Resistence shear stress

T	6,4	kN			
τ_d	0,40	<	1,12	$f_{v,d}$	[N/mm²]

Here the deformation analysis:

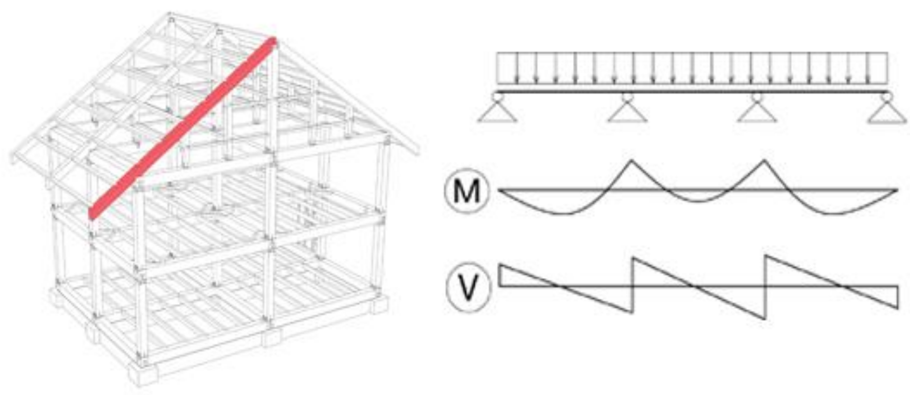
Max deformation

Combination of Loads: SLS

$U_{net,fin}=U_{fin}+U_{ist}=$ 0,0077 < 0,0136 U_{lim}

Q_{qp}	0,99	KN/m	*combination quasi permanente*
Q_{rara}	2,41	KN/m	*combination rare*
T-T	1,10	m	*interaxle spacing*
l	3,6	m	*span*
l_{eff}	3,8	m	*real span*
h	0,2	m	*thickness*
b	0,12	m	*depth*
A	0,02	m^2	*Area*
K_{def}	0,6	-	*wood viscosity factor*
χ	1,2	-	*shear factor*
J	0,00	m^4	*moment of inertia*
U_{fin}	0,0031	m	
U_{ist}	0,0046	m	

7.6.5 Roof beam



β	35,00	
cos(β)	0,82	
G1	0,87	[kN/m]
interfloor slab	0,11	
roof joist	0,32	
self load	0,34	
G2	2,66	[kN/m]
roof slab	0,90	
Q_W	1,75	[kN/m]
Q_S	3,60	[kN/m]
ULS		
Q_{ULS}	10,52	*Snow*
SLS		
Q_{qp}	3,53	
Q_{ch}	7,13	

The analysis deals with bending strenght and shear strenght:

Resistence bending moment

Combination of loads: SLU

$\sigma_{m,d} < K_{crit} \times f_{m,d}$

$\sigma_{m,d}$	1,11	<	11,52	$K_{crit} \times f_{m,d}$	[N/mm²]
Q	10,52	kN/m			
M	5,00	kNm			
$f_{m,k}$	24	N/mm²			
K_{mod}	0,6	-			
$f_{m,d}$	11,52	N/mm²			
$\sigma_{m,d}$	1,11	N/mm²			
$\sigma_{m,crit}$	334,4200435	N/mm²			
$\lambda_{rel,m}$	0,267891831	-			
K_{crit}	1	-			

Resistence shear stress

T	13,7	kN			
τ_d	0,23	<	1,12	$f_{v,d}$	[N/mm²]

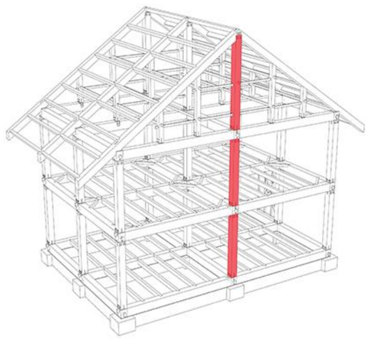
A calculation software that has divided the beam into small segments, one millimetre long, has been used for the strains; it has reported the worst strain, which does not exceed the set limit.

Max deformation

Combination of Loads: SLE

$U_{net,fin}=U_{fin}+U_{ist}=$	0,0040	<	0,0088	U_{lim}
T-T	3,60	m	*interaxle spacing*	
l	6,6	m	*span*	
l_{eff}	6,6	m	*real span*	
l_1	1,4			
l_2	5,2			
h	0,3	m	*thickness*	
b	0,3	m	*depth*	
A	0,09	m^2	*Area*	
K_{def}	0,6	-	*wood viscosity factor*	
χ	1,2	-	*shear factor*	
J	0,00	m^4	*moment of inertia*	

7.6.6 Pillar



The pillar element is here studied, in particular the specification that the loads on the pillar result from shear stress acting on the beams.

Roof column

Q	10,37	kN			
height	3,75	m			
l x	2,20	m			
l y	3,60	m			
Surface of inluence	7,92	m^2			

Resistance axial force and instability analysis

$\sigma_{c,0,d}$	115	<	12730,14	$K_c * f_{c,0,d}$	
$f_{c,0,d} = (K_{mod} * f_{c,0,k})/\gamma_m$	15360				
K_{mod}	0,8				
γ_m	1,25				
$\sigma_{c,0,d} = N_d/A_{lor}$	115				
A_{lor}	0,09	m^2			
k_c	0,82878539				
k_z	0,553042378				
$\lambda_{rel,z}$	0,348227016				

$\sigma_{c,crit,z}$	197918,4669	
λ_z	21,65063509	
l_k	1,875	
c_k	0,5	
i	0,08660254	
I	0,000675	
A	0,09	
β_c	0,1	

2nd floor column

Q comb	16,41	kN
Q tot	26,78	kN
height	3,10	m
l x	2,20	m
l y	3,60	m
Surface of inluence	7,92	m²

Resistance axial force and instability analysis

$\sigma_{c,0,d}$	298	<	13536,78	$K_c * f_{c,0,d}$
$f_{c,0,d} = (K_{mod} * f_{c,0,k})/\gamma_m$	15360			
K_{mod}	0,8			
γ_m	1,25			
$\sigma_{c,0,d} = N_d/A_{lorda}$	298			
A_{lorda}	0,09	m²		
k_c	0,881301056			

k_z	0,53082728
$\lambda_{rel,z}$	0,287867667
$\sigma_{c,crit,z}$	289617,9439
λ_z	17,89785834
l_k	1,55
c_k	0,5
i	0,08660254
I	0,000675
A	0,09
β_c	0,1

1st floor column

Q comb	66,62	kN
Q tot	93,40	kN
height	3,10	m
l x	2,20	m
l y	3,60	m
Surface of inluence	7,92	m²

Resistance axial force and instability analysis

$\sigma_{c,0,d}$	1038	<	13536,78	$K_c * f_{c,0,d}$
$f_{c,0,d} = (K_{mod} * f_{c,0,k})/\gamma_m$	15360			
K_{mod}	0,8			
γ_m	1,25			

$\sigma_{c,0,d} = N_d/A_{lor}$	1038	
A_{lor}	0,09	m^2
k_c	0,881301056	
k_z	0,53082728	
$\lambda_{rel,z}$	0,287867667	
$\sigma_{c,crit,z}$	289617,9439	
λ_z	17,89785834	
l_k	1,55	
c_k	0,5	
i	0,08660254	
I	0,000675	
A	0,09	
β_c	0,1	

These are verifications relating to normal forces and the warping deformations of the pillar. It should be pointed out that with regard to horizontal loads, the pillar is the only element that resists them. In fact, getting a good design means that it is necessary to analyze each project singularly, because other planning concepts, as for example the regularity in the drawing and the number of stories, come into play and they could increase or reduce the total stiffness of the structure.

8 Energy analysis

8.1 Past and present, face to face

Given the unique climate of Japan, its inhabitants suffer more from the heat than from the cold weather of the winter months. This phenomenon, both nowadays and in the past, has therefore influenced the way in which people experience the comfort of inhabiting a space. Specifically, it is not the high temperatures that make the summer heath so insufferable, rather, it is the very high percentage of relative humidity in the warmer months, which sometimes exceeds 90%.

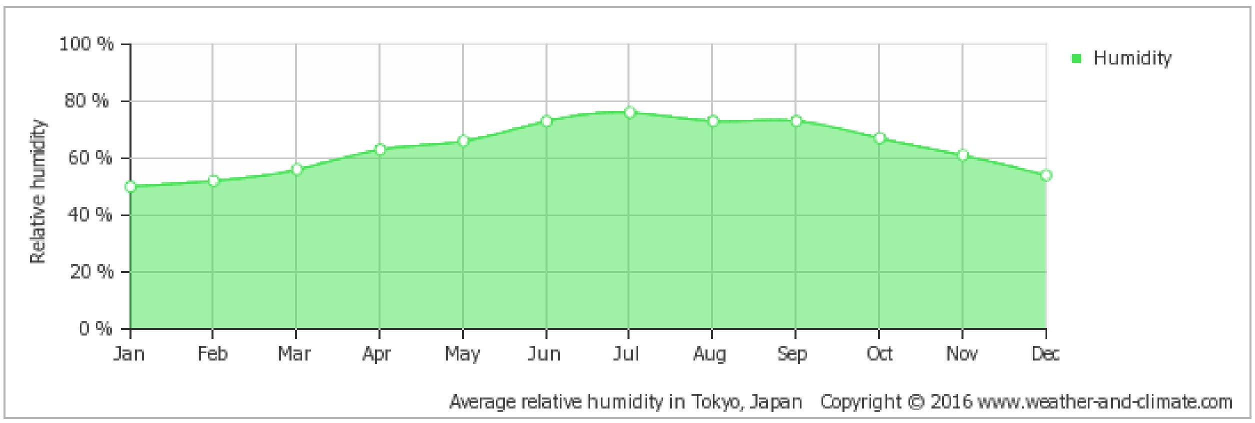


Chart 8.1 Avarage relative humidity in Tokyo [2]

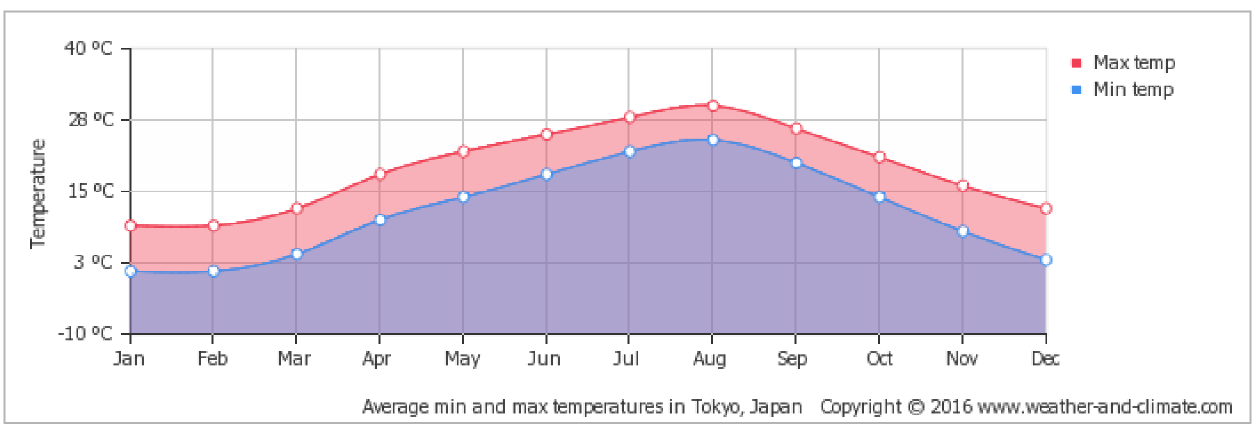


Chart 8.2 Avarage min and max temperatures in Tokyo [2]

Traditional Japanese architecture advanced keeping this issue at its very core, and therefore managed to develop *passive systems* to improve the internal comfort provided by buildings. To this aim, a thick straw roof, able to ventilate naturally the warmer spaces, became integral part of every building in order to counter act the summer heat. While the roof is indeed directly hit by sunlight for most of the day during the summer, and the straw (present in it) would grow warm and dry out. When the thatch dries out, it reduces the amount of water present within its fibers, reducing in this way its own volume, and creating very small fissures in the coverage that are capable of giving rise to convection, where the warmer air goes up, sticking out of the straw coverage.

In the event of a rainy day, the clouds shield the sun rays, and the straw reabsorbs a percentage of water that increases the volume back. So during rainy days the straw could also seal the cover, preventing the water from filtering inside.

Fig. 8.1.1 Straw roof

Therefore, Japanese houses were designed to be completely open in the summer and closed in winter. The sliding walls allowed just that, when they were all aligned in the same corner of the house there was the creation of a huge opening, greater than the one that could be created by opening a standard window, the house was open to the world of nature. This happened in the summer during the most sweltering period, during the monsoon and rainy season instead, in addition to the usual sliding walls the amado (あまど), special wooden shutters, which protected the thin paper walls from heavy rains and winds, were used.

Fig. 8.1.2 Engawa

It follows that the traditional Japanese house was able to “breathe”, and somehow control the air flow movements. Another element of passive thermal conditioning is represented by the extended pitched roof. The size of the pitched roof extension may seem totally disproportionate if studied according to a Western eye, but in Japanese architecture it represented the exact balance between solar shading and architectural identity.

In fact the main purpose was to limit the incidence of the solar rays that would affect the exterior walls, made of bamboo wood and mud, so poorly insulated from a thermal point of view. In our contemporary society, this technique has been abandoned. Primarily because today's technologies allow us to make walls with higher thermal inertia, but also because, in Japanese city planning, houses are often tightly packed, only separated by narrow spaces (30 cm) and therefore already shielded from sunlight.

Covering the solar radiation also means having less natural light available to the illumination of the interior. It is for this reason that the *shoji* (しょうじ) were created — that is, walls of rice paper inserted in a wooden frame. It was a system also used as exterior wall and, then, being wind resistant, it worked both as a kind of sliding door and window. The main reason for its use was to allow the light rays to reach the inner spaces of the house, normally away from a light source, while maintaining a visual privacy. The difference with windows also lies in the fact that, with the use of the paper there is no greenhouse warming, and thereby the interiors never overheat.

Fig. 8.1.3 lights and shadows

Several studies and experiments concerning light were made in ancient Japan. More than the study of light, it could be defined as the study of shadow. Light radiation treatment systems are even more wisely designed in Religious buildings, as compared to residences, since it was a natural element covering a great sacral value.

Let us now consider the famous Japanese rock gardens (枯山水), close to temples made of wood. As mentioned above, the extended pitched roofs of the buildings protected the outer walls from direct sunlight, however, the gardens next to the main building were exposed to direct sunlight. During the darkest hours of the day, that is the morning and the evening, with the Sun lower than at noon, the sun's rays hit the white rocks of the gardens and were reflected inside the temple. Thanks to this stratagem, the Interior parts of the temple were always lit.

This happens, for example, in the famous precinct of Ryoanji in Kyoto:

Fig. 8.1.4 Ryoanji temple in Kyoto

During the winter, the benefits deriving from living the Japanese house fell short. During the colder months, the tenants simply switched on the *irori* (いろり), a fireplace inside the house where the family gathered after the working day, to have a meal or just to warm up and heat the house, even leaving it on all day long. The most negative thing, though, lies in the fact that they have not made great significant progress from the past to today; it seems paradoxical that in a country as advanced as Japan, the heating systems have not been studied or developed. Nowadays it is extremely difficult, in Japan, to find buildings with a central heating system, but it is easier to find situations where, unlike what is common in Western buildings, each room is heated in an autonomous and independent way. Usually they warm up the living areas, such as the living room, kitchen and bedrooms and leave the connecting areas, such as hall, stairs and corridors without heating. Luckily, the average house is not very big so a single heated area conveys warmth to the cooler interiors as well, of course if dispersions to the outside are minimized.

The Japanese often use kerosene burners as heater blocks, however, for the strong odour released from its burning, it is better to use electric heating units. Another example of typical Japanese dwellings' heating unit is the kotatsu (こたつ), which is a table with a blanket and an electric heater (now it is electric), hid in the hollow of the table, to warm the person while having a meal.

Fig. 8.1.5 Ancient version of Kotatsu

This calls to mind the concept of *irori*, but at the same time it has little to do with the thermal control of a zone, in fact the most commonly used systems are not able to control the moisture percentage of a location, and then the comfort linked to it. It is also important to explain that, when it comes to indoor comfort, it is not only a matter of "feeling good in a place", but also of health. In fact, recent studies have shown that living in an uncomfortable environment can lead to cardiovascular disease, bone and lung problems. The use of these systems does not guarantee any possibility of comfort, they are also very dangerous; the probability of death from fire due to the use of these obsolete technologies is very high, because the Japanese residence, which often houses *tatami* and timber structures, is very prone to fire hazard. Moreover, breathing the fumes produced by kerosene stoves is also dangerous for people's health in the long run.

Prefabricated systems on the market have slightly different, more refined engineering technologies. More commonly, with respect to the conditioning of the rooms, it is possible to find air handling units sold along with prefabricated systems, while electric boilers are used for the production of domestic hot water. It should be noted, however, that the final choice is always up to the buyer, and so they often fall back on the systems mentioned above. This way of life, far from ours, can be explained with the following statement: In Japan, the residential unit is seen as a machine. A machine instantly responds to an impulse, and the air conditioning in the Japanese House, both in winter and summer, works according to the same concept: when an area is cold, the heating machine is turned on, when the environment is warm, the heating machine is turned off. It is difficult to come to a happy medium, usually it is common to find conditioners that heat the house with dry air while, at the same time, the windows are open, to find the thermo-hygrometric balance.

This leads to high heat loss with equally huge economic cost, what is lacking is just an education to the well-being that comes from living the spaces in a proper way our own spaces. To understand the home-machine concept, you can imagine to get in a car left in the summer sun at 12 in the afternoon. The first instinct is to turn on the air conditioning to combat the high temperature. The car does not have any insulation, just a metal frame easily heatable. Even the concept of comfort changes, it becomes something more instantaneous: it is nor conceived as extended in time, it carries on a continual dissatisfaction leading, in the absence of a real comfort, to a continuous search for it. In Japan is even possible to buy air conditioners that divide the air jet, both warm air and cold air are emitted at the same time, in two different directions.

The modern framework, however, provides for regulations which move towards completely different horizons. From the 80s to date, Japan has decided to reduce CO2 emissions; this policy is linked both to environmental protection and to the protection of the country's economy. In fact, in the 70s, Japan has badly suffered the world oil crisis since oil was the main source of energy and it was fully imported. Japan has improved its energy efficiency by about 40% after the oil crises since 1970s as a result of positive action by both public and private industrial sectors.

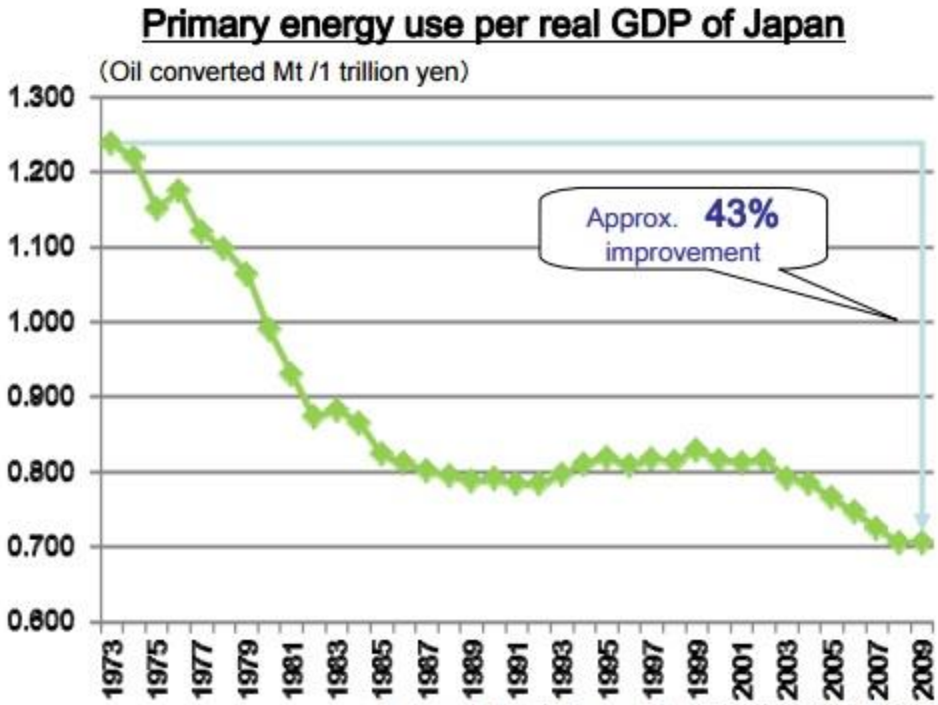


Chart 8.3 Oil demand [25]

With regard to the energy consumed by the buildings, "the energy conservation law" was drawn up in 1979, it is a national legislation which promotes buildings with low environmental impact, such as low carbon-emitting housing and zero-energy housing, through economic incentives. So a future plan, completely different from the current one, seems to be planned; the proposed system is closer to the future than to the present.

8.2 Air conditioning systems

A good energy design is known as such when the housing and building systems used are able to integrate with the chosen plant system in a balanced way, in order to reduce both economic and energetic consumption while maintaining an ideal level of comfort.

8.2.1 Active climate control contributions

Before explaining the choices regarding the plant systems, it is necessary to raise some points. The prefabricated system leaves the customers free to choose the building size as they wish and according to their needs. This involves many variables, such as the square metres of surface to be heated or the number of the building floors. It is therefore impossible to sell as a kit, a single installation system, it must be sized on a case-by-case basis; however, the system to use, which perfectly fits in with the reality described above, can anyway be defined. First, it is possible to define the energy source to be used: in Japan almost everything is electric. This happens because the piping maintenance, in a country with high levels of seismicity, is very expensive (you may note the kilometers of overhead cables that run through the city streets). Gas plants may increase the risk of explosions and fires during a seismic event.

The proposed system consists of an air-water heat pump, for winter heating, summer cooling and sanitary hot water.

The heat pump falls within the renewable systems, in fact in this case it uses a natural source — the air, ensuring a good energy saving. This equipment, using a minimal amount of electricity or gas, can produce a higher quantity of thermal energy: specifically, 1 kWh of electricity could produce up to 5 KWh of thermal energy. The heat pump takes the temperature from one area and raises it to get more heat. In this case the pump should assimilate the external heat to keep warm the interior of the building. The heat pump works thanks to the action of a compressor that creates a pressure difference, which generates heat. Prior to this, there are several steps: the evaporator draws the refrigerant fluid, then the low pressure will get it to evaporate due to the low pressure accumulating the heat; at this point the thermal heat is compressed and sent to the condenser, where, because of the condensation effect, the high pressure will release all the heat.

Then the cooler fluid gas regains its liquid state and is ready to start a new cycle, passing through the expansion valve where it returns to the steam condition. During the summer, to get a cooler thermal state, the same process is simply reversed. As already noted in previous chapters, the terminals used are radiant floor panels. This solution wholly integrates with the choice of a dry, light weight system and with the choice of energy saving. In fact, the low supply temperature (approximately 35°) means using less energy for heating. Also the particular way of living the Japanese dwelling, that is, for example, the habit to remove the shoes when they enter the house and to walk barefoot inside the house, perfectly combines with this technology. The panels can be used also in summer as cooling elements.

A ventilation system is necessary to control effectively humidity. Particularly during the summer heat, a ventilation system will contribute to the cooling down of internal spaces, thanks to the power coming from a battery plugged into the air conditioning system. On the other hand, during the winter months this controlled mechanical ventilation system is not meant to contribute to the heating up of the house. However, in order to avoid thermal dispersion, it is engineered to gather and store heat.

This is the case as humidity control is essential in the summer, where the humidity levels reach very high percentages that need to be brought down for comfort. The opposite is true during the winter months, such as keeping the heating on during a windy day could lead to the internal air to be very dry and damaging for health. However, there is an aesthetics issue that arises from this, which is the matter of where to place in the air fans. In the context of a minimalist architecture like the Japanese one, the instalment of a flow tunnel is not ideal. Therefore, there are two solutions that could be advanced. The first one would be moving towards the conception of buildings as open spaces. In the case of buildings without a lot of internal walls and barriers stopping the potential airflows, it would be possible to eliminate a flow tunnels and create a single emission point. When taking into account traditional Japanese styles, this is also the most appropriate solution. In addition, where it would be necessary to move air from one room to the other, that would be done through textile tunnels, which would be less invasive than classic solutions.

Fig. 8.2.1 Textile tunnels

8.2.2 Passive climate control contributions

Systems that interact with the conditioning of the spaces in a passive way were investigated as well. In particular, it should be stressed that in today's vision of the Japanese house these systems, closely linked to the logic of the past, have been lost. This again comes from the old logic of the home-machine: in a frenetic vision of home living the intervention costs are reduced to zero, with positive results in the long term. In the 90s, the houses were built and demolished in cycles of twenty-five years so Japanese people preferred to spend no more than what was strictly necessary, did not consider economic investment for long-term interventions, such as creating a centralized plant or using a better insulation of the walls. This is why, even nowadays, there are many houses having single glass windows. Insulation and thermal inertia of the external wall are studied as first intervention.

Uncontrolled heat exchanges taking place between the external environment and internal environment are studied in the attempt to minimize them, in order to maintain the comfort created. This can be done by studying the casing insulation. The thermal inertia depends on the mass and on the specific heat of the materials. In a system like the one proposed, it is evident that the mass is scarce, it can be considered a lightweight wall, being less than 230 kg/m^2; what must be considered, anyway, is the fact that these technologies are going to compete in a market that displays other technologies of lesser or equal entities. For this reason, much has been invested on the materials used and the total insulation of the wall.

We have considered the U transmittance of a generic opaque element consisting of a series of different layers, defined within the UNI EN ISO 6946 as:

$$U = \frac{1}{\frac{1}{h_i} + \sum \frac{s_i}{\lambda_i} + \sum R_a + \sum \frac{s_i}{\lambda_{i.eq}} + \frac{1}{h_e}}$$

With:

U: thermal transmittance, measured in W/m^2K;

hi: convective heat transfer coefficient (coefficient threshold) between the air inside and the element, expressed in W/m^2K;

he: convective heat transfer coefficient (coefficient threshold) between the outside air and the element, expressed in W/m^2K;

si: the i-th layer thickness which is the component, expressed in m;

λ_i: i-th homogeneous sheet thermal conductivity, expressed in W/mK;

Ra: resistance of air cavities in m^2K/W;

$\lambda_{i,\ eq}$: thermal conductivity equivalent i-th heterogeneous layer, expressed in W/mK.

In our case:

For the exterior wall:

Layers	Thickness (s) [m]	Thermal conductivity (l) [W/mK]	Specific heat (c) [J/kgK]	Density (ρ) [kg/m3]
internal coating plaster	0,013	0,900	840	1400
gypsum fiber panel	0,010	0,320	1100	1150
insulation wood wool	0,160	0,038	2100	160
plywood panel	0,018	0,120	2700	450
insulation wood wool	0,080	0,038	2100	160

The thermal transmittance is: 0.150 [W/m^2K]

For the internal wall:

Layers	Thickness (s) [m]	Thermal conductivity (l) [W/mK]	Specific heat (c) [J/kgK]	Density (ρ) [kg/m3]
internal coating plaster	0,013	0,900	840	1400
gypsum fiber panel	0,013	0,320	1100	1150
insulation wood wool	0,060	0,038	2100	250
plywood panel	0,013	0,320	1100	1150
insulation wood wool	0,013	0,900	840	1400

The thermal transmittance is: 0.514 [W/m^{2}K]

For the attic floor:

Layers	Thickness (s) [m]	Thermal conductivity (l) [W/mK]	Specific heat (c) [J/kgK]	Density (ρ) [kg/m3]
wooden floor	0,012	0,120	2700	450
insulating panel with radiants	0,030	0,040	2100	170
gypsum fiber panel	0,010	0,320	1100	1150
substrate of perlite 1-5 mm	0,100	0,050	1100	100
wood fiber insulation	0,060	0,038	2100	160
wooden planking	0,030	0,120	2700	450

The thermal transmittance is: 0.204 [W/m^{2}K]

For the ground floor is: 0.206 [W/m^{2}K]

For the coverage:

Layers	Thickness (s) [m]	Thermal conductivity (l) [W/mK]	Specific heat (c) [J/kgK]	Density (ρ) [kg/m3]
wooden planking	0,030	0,900	2700	450
insulation wood wool	0,040	0,038	2100	160
insulation wood wool	0,080	0,038	2100	160
insulation wood wool	0,040	0,038	2100	250
ventiation layer	0,080	-	-	-

osb panel	0,030	0,120	2700	650

The thermal transmittance is: 0.197 [W/m^2K]

As regards the transparent closures, a solution with the right price quality relationship, that is a double glazing window and aluminium frame has been chosen. The glazing consists of a clear tempered external glass, toughened with selective coating in the face 2 with 4 mm thickness, cavity filled with argon at 90% with 16 mm thickness and a low-e coated tempered inner glass in face 3 with 4 mm thickness.

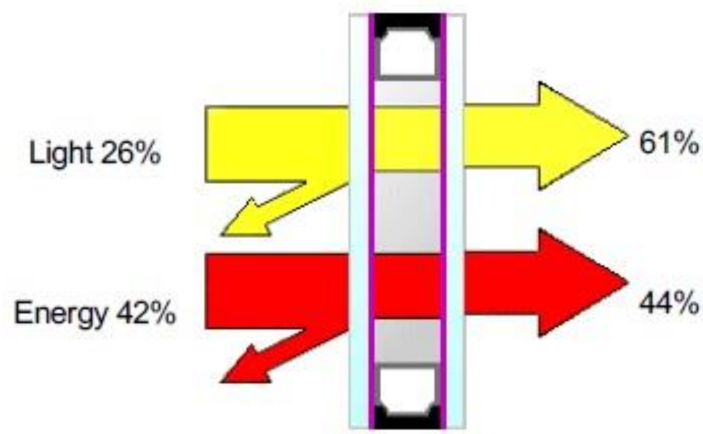


Fig. 8.2.2 Proposal for glazing

It can be specified that a triple glazing system would of course be more efficient, but the initial outlay would be covered after more years because in the residential field the number of glazing is not high, and hence even the possible dispersions related to the insulation of the glass surfaces are less when compared to those of the walls.

The main feature of selective glazing lies in their conveying the light radiation perfectly while rejecting the infrared radiation, especially the lowest wavelength one. Since this radiation, not surprisingly called thermal, is responsible for the transmission of heat, it is understandable why it excellently contributes to prevent interior overheating in summer. However, it is important to avoid the interior heat dispersion towards the outside during the winter season. To do this, low-emissivity glasses have been used. They, as the selective ones, allow the transit of the light radiation, but avoid the passage of infrared light, in this case the one with longer wavelength frequency, inhibiting heat loss towards the outside. The combination of these two systems is very powerful in a varied climate like the Japanese one.

The following results will be achieved with the chosen solution.

Light		
Transmittance	LT	61%
	UV %	26%
Reflectance Out	LR out	26%
Reflectance In	LR in	23%
Energy		
Direct Transmittance	ET	39%
Reflectance	ER	42%
Absorptance	EA	19%
Total Transmittance	g	44%
Shading Coefficient Total		0.51
Shading Coefficient Shortwave		0.45
Sound Reduction	R_w dB ($C;C_{tr}$)	31 (-2; -5)
Thermal Transmittance	W/m^2K	1.0

Fig. 8.2.3 Data from double glazing proposal

Note that these data mainly relate to the glazing, and not to the window.

Another important element, linked to transparent closures, concerns the blind item. In fact in summer weather, a sunlight shielding affects much on the thermal balance of the environment. It is however difficult to impose shutters systems and for this reason more performing glasses have been used. We recommend a case by case study of shielding solutions, which mainly depend on the orientation of the building and on the context in which it is inserted.

Finally, it was decided to give importance to a natural ventilation system, particularly during the summer. The roof of the building plays an important role, in fact a ventilation chamber has been created in the stratigraphy studied. The coverage and the huge space created, gets the hottest indoor air to rise up and clash with the inside of the cover. During the night, the inner cover is cooler than the hot air present in the place, as it is externally ventilated and then cooled. The air will exchange heat with the cooler surface and then it will start moving down, where it will regain warmth and go up again. All this creates convection movements, which cool down the environment by exchanging heat with surfaces made cooler by a natural ventilation.

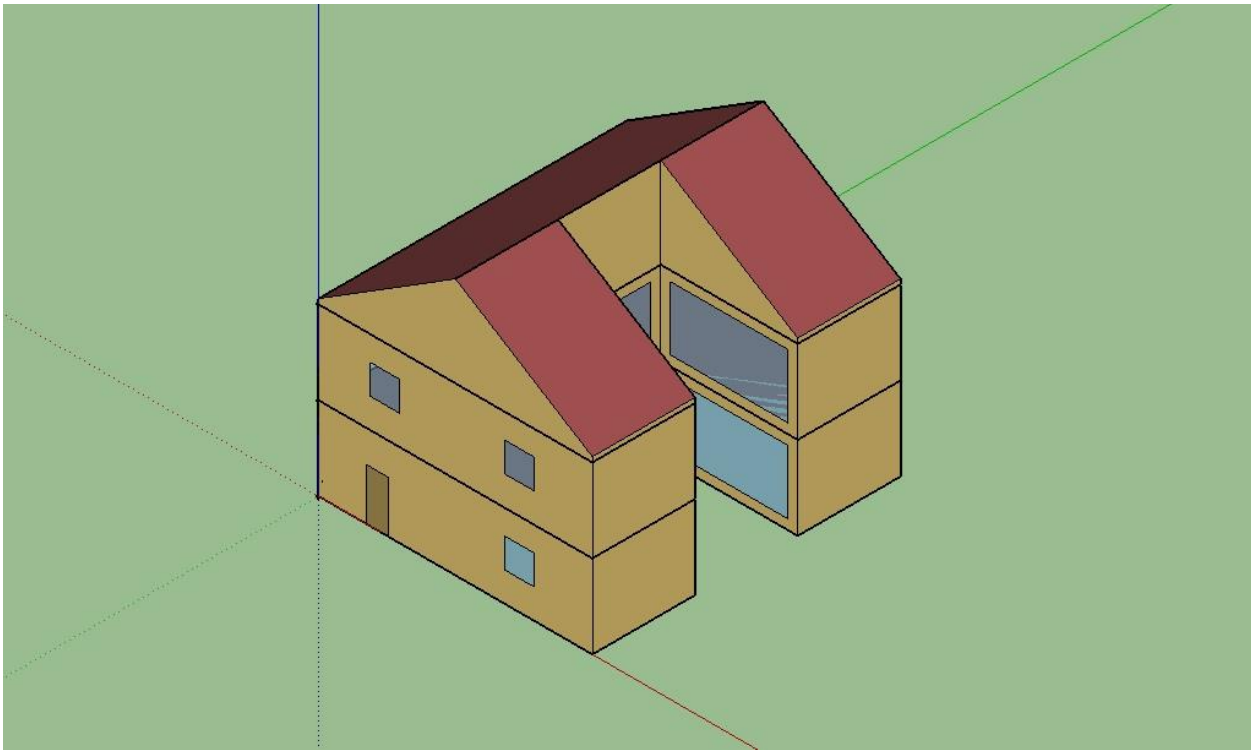
8.3 Case study and analysis

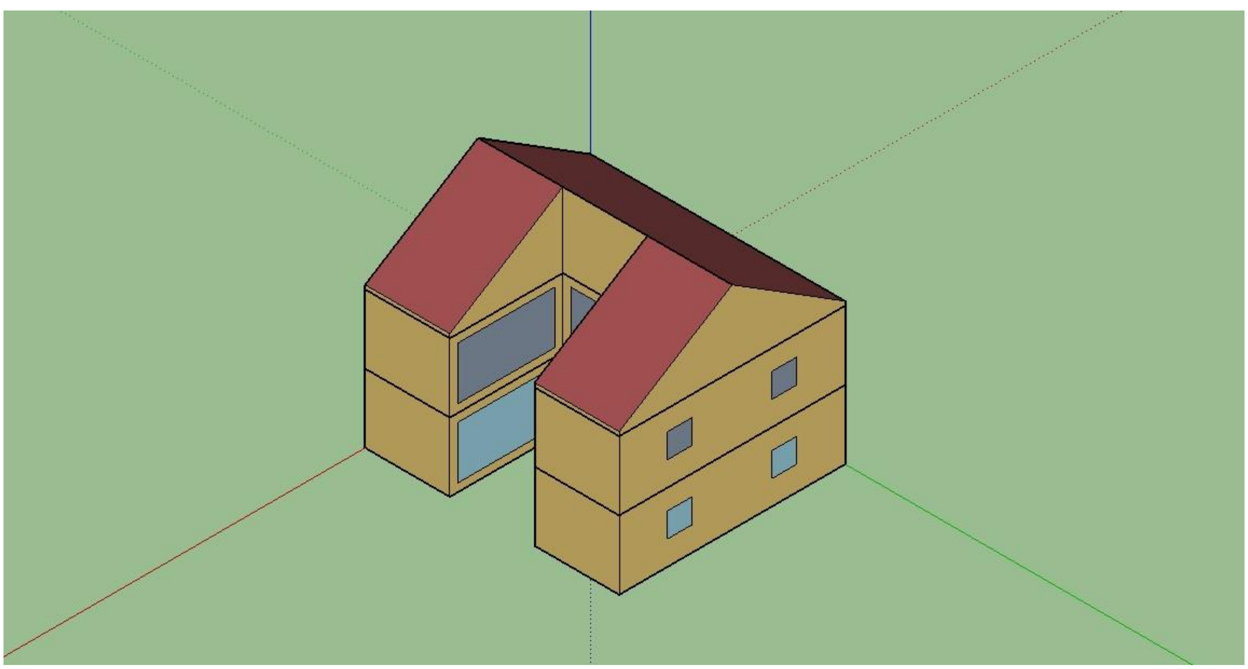
An analysis based upon two dynamic energetic models has been conducted, in order to set up a comparison between those and the impact on the yearly thermal and energetic balance of passive technologies. The intent was not that of carrying on a total analysis of the building's energetic consumptions, rather, the focus is on the comparison of what would happen with the usage of passive technologies. This is the case as a total analysis would not have led to any conclusive data, as the building changes depending upon the buyer's needs.

The software Openstudio has been used to create two different energetic models to be employed within the same system: one represents the traditional solutions to be found within prefabricated buildings, while the other one embodies the passive technologies described above. What this is seeking to discover is just how much energy savings can be achieved through the use of passive systems, when compared with more traditional ones within the same settings. Over the space of one year, air conditioning systems are most employed in "critical" times such as the summer and winter months, rather than during milder periods such as autumn and spring. The overarching question that this thesis seeks to answer is: is it possible to lengthen the periods without the use of conditioning systems, therefore decreasing costs and energy consumption, through the use of passive systems?

Let us now proceed with an analysis of the data gathered for the purpose of this study. The case study this research proposes is the following:

A building constituted by two floors has been divided into three spaces in order to have greater control on what goes on in each of them, these being: the ground floor, the first floor, and the second floor.





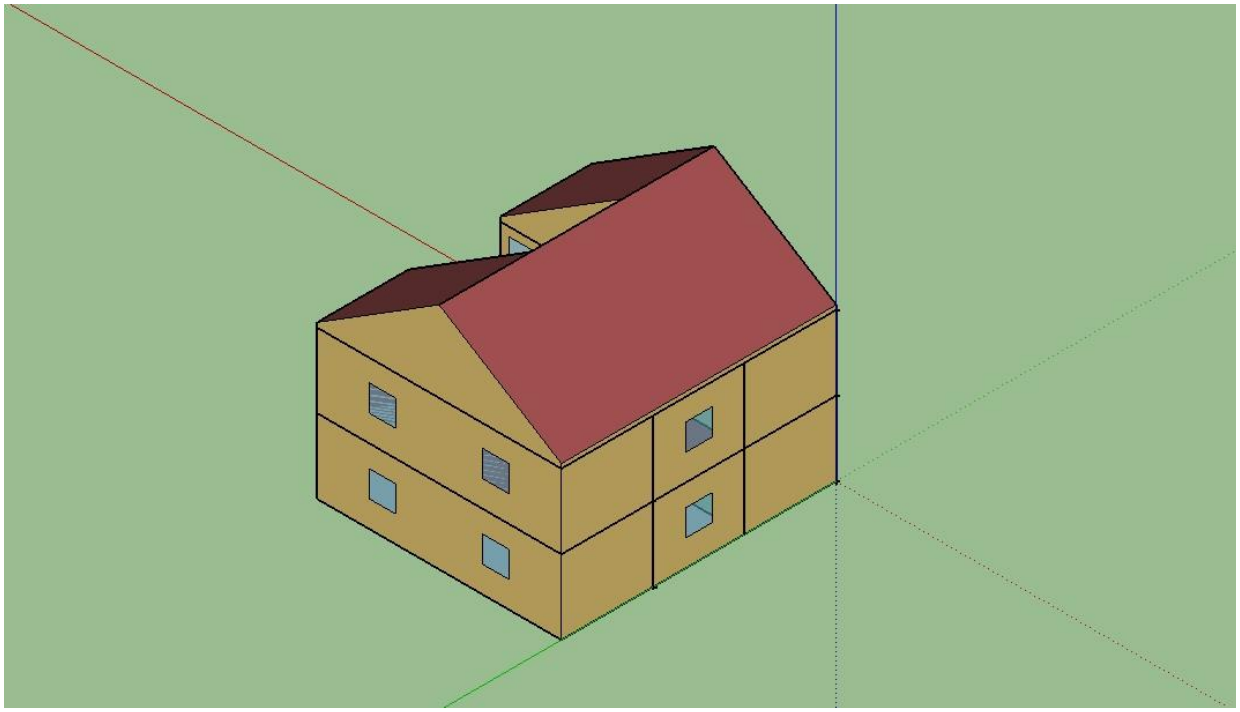


Fig. 8.3.1 Case study building

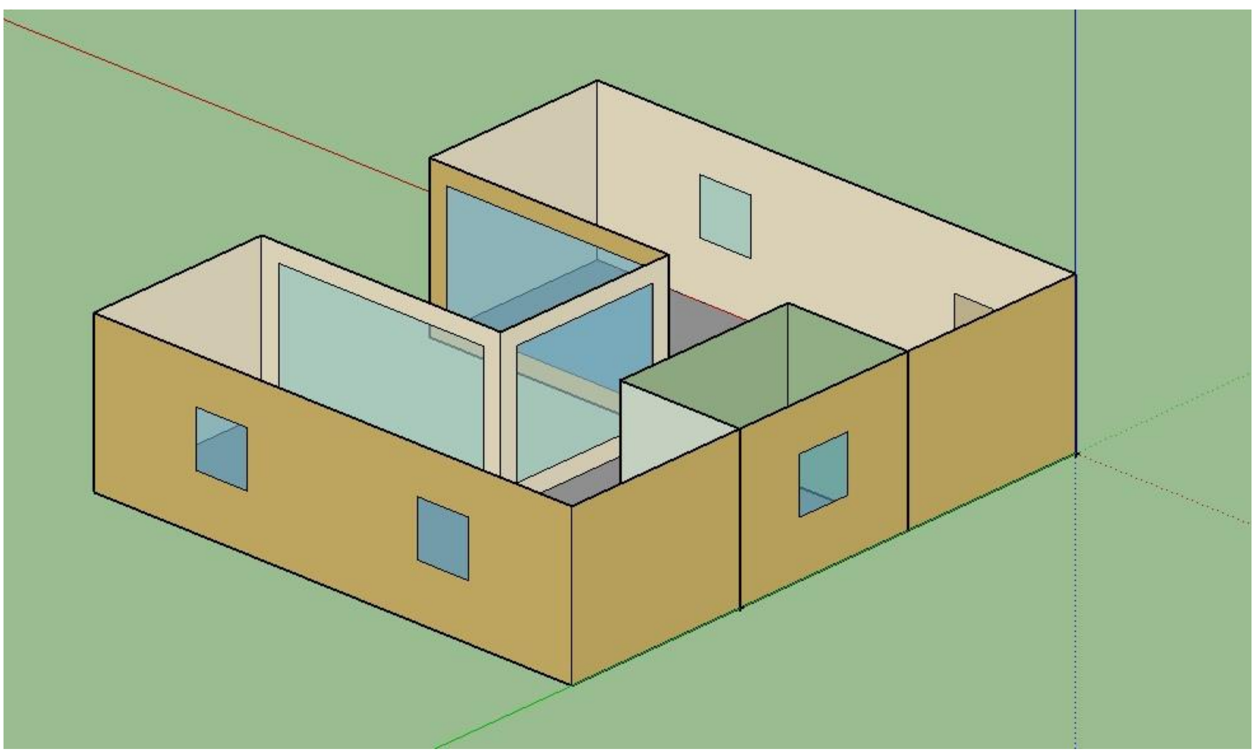


Fig. 8.3.2 Case study building interior

The building is situated in the Hyakuri area, in Tokyo's north east periphery. The total area to be conditoned is 352.80 m^2. The starting hypothesis regarding the average usage time of the Japanese house are drastically different from the western ones, as longer distances and a frenetic lifestyle bring the average Japanese to spend way less time at home than, for example, the average European.

The house is also supposed to be occupied:

From 00:00 to 09:00, and from 19:00 to 24:00 during working days.

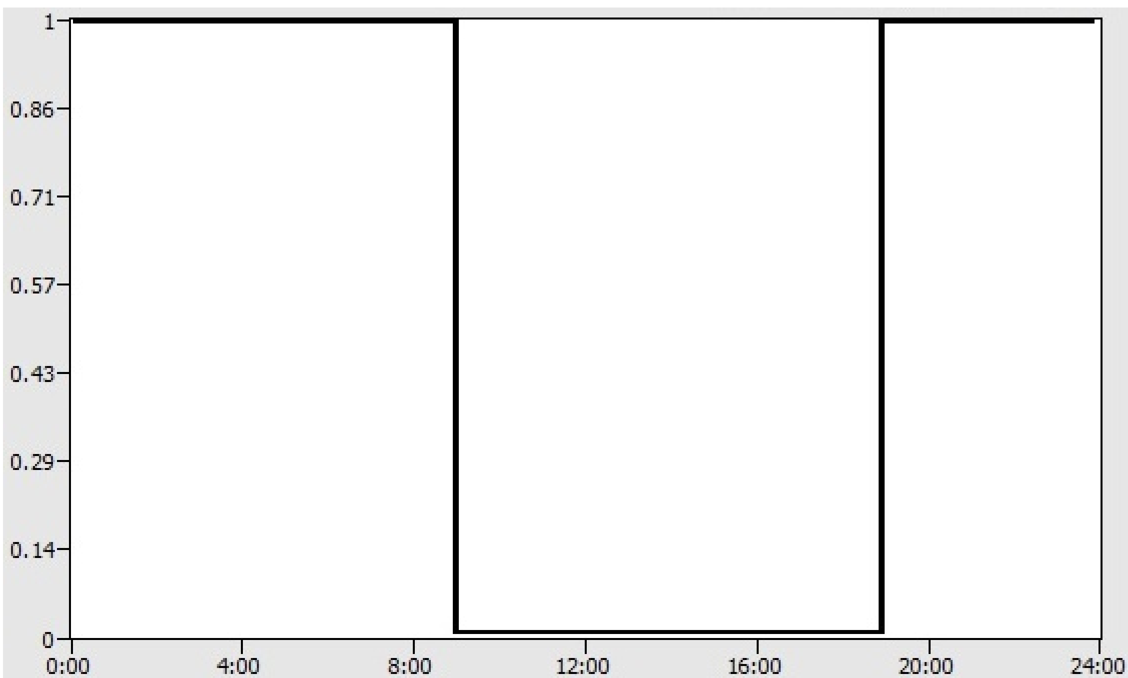


Chart 8.4 Occupation during weekdays

From 00:00 to 15:00 and from 18:00 to 24:00 during the weekends.

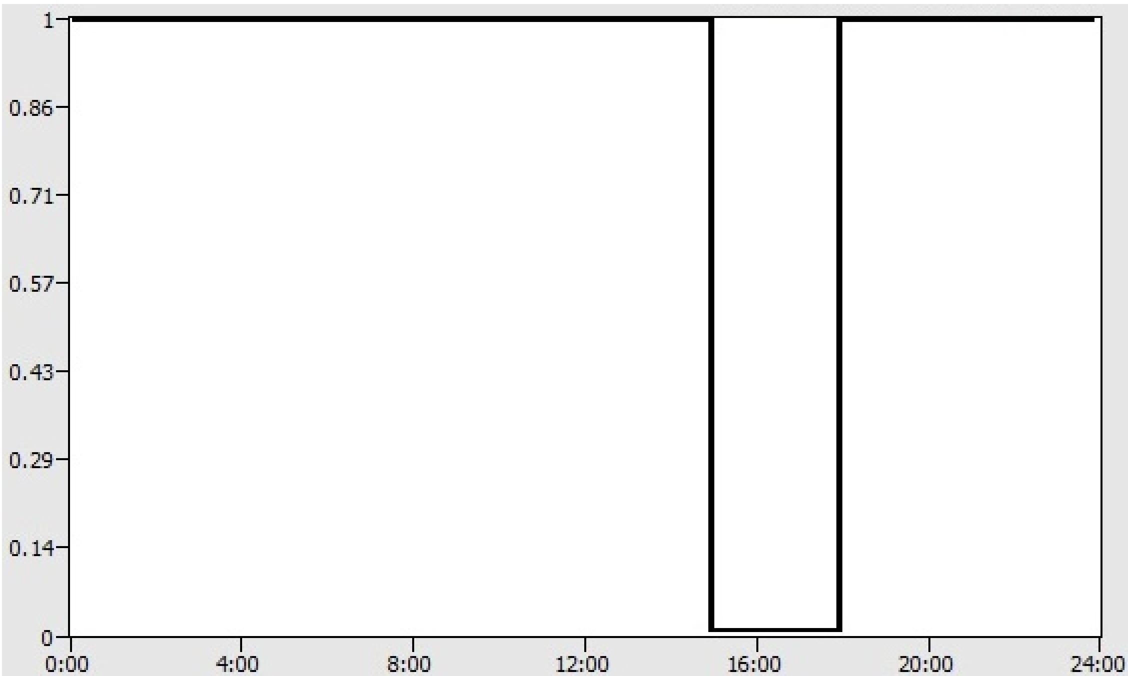


Chart 8.5 Occupation during weekend days

The internal thermal loads are then examined.

People: According to the norm UNI EN 10349 for residential buildings, by hypothesis we will consider 0,04 people/m^2, engaged in a metabolic activity that burns 120 W/person.

Lights: the estimated energetic consumption is of 2.0 W/m^2, for a usage time during an average working week:

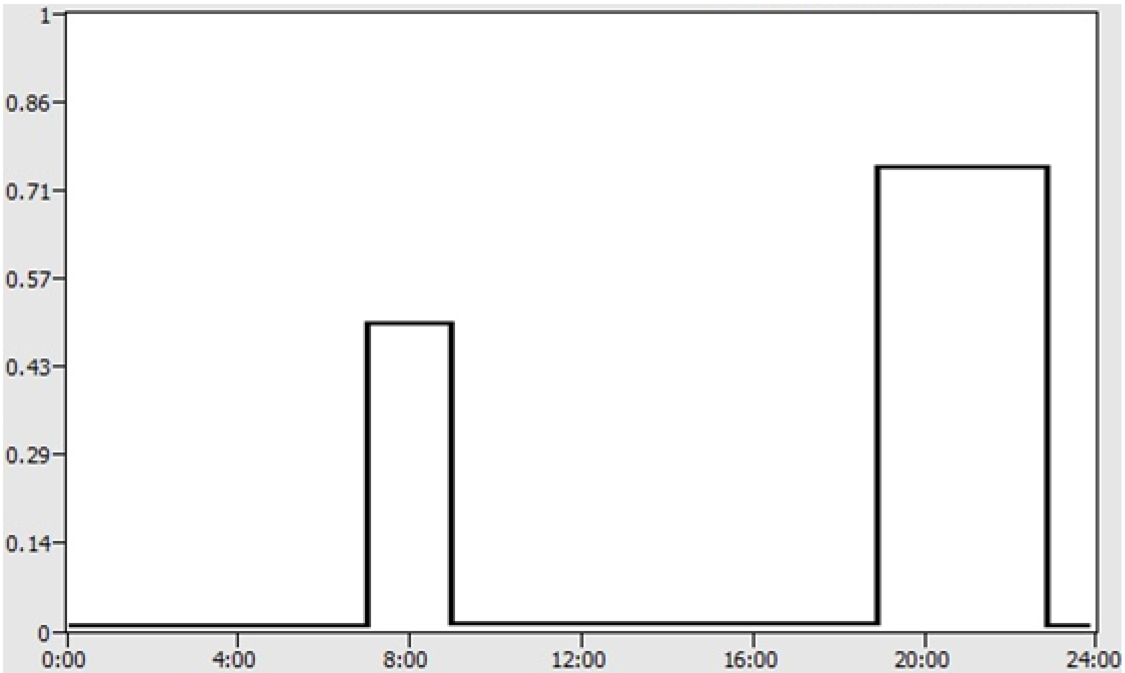


Chart 8.6 Lights schedule during weekdays

Over the weekend:

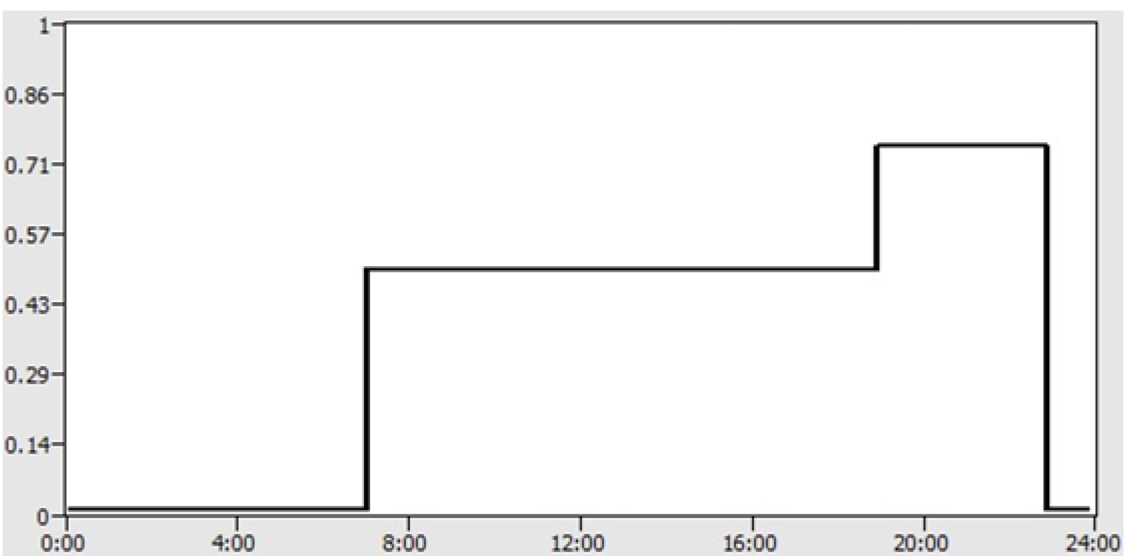


Chart 8.7 Lights schedule during weekend days

Electric equipment: the estimated energy consumption is of 1.5 W/m^2 during the working week.

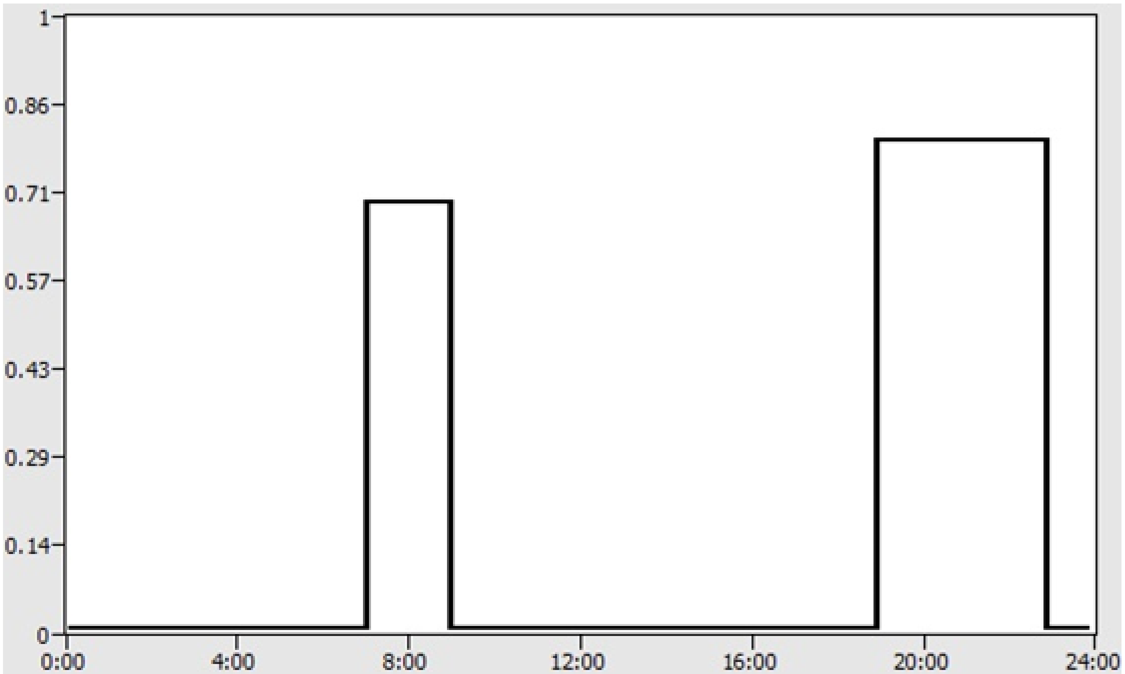


Chart 8.8 Equipment schedule during weekdays

Over the weekend:

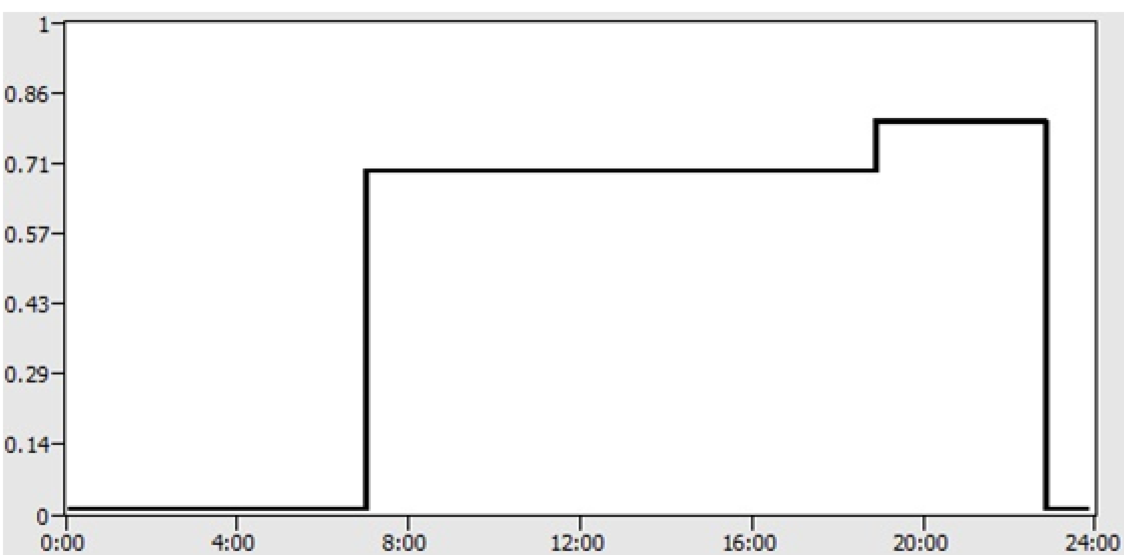


Chart 8.9 Equipment schedule during weekend days

Once the internal loads and the respective timings taken to act have been defined, the thermal zones and the desired winter and summer temperatures are set, without needing to undertake a full on implants study, for this reason the *Ideal air loads* are chosen. This is the case as said before, this model is thought out to compare passive elements rather than active ones.

Air conditioning implants are turned on:

The heating system period of use is from the 1st of Jenuary to the 1st of April and from the 15th of October to the 31st of December.

The air temperature request is about 21 degrees.

For the weekdays:

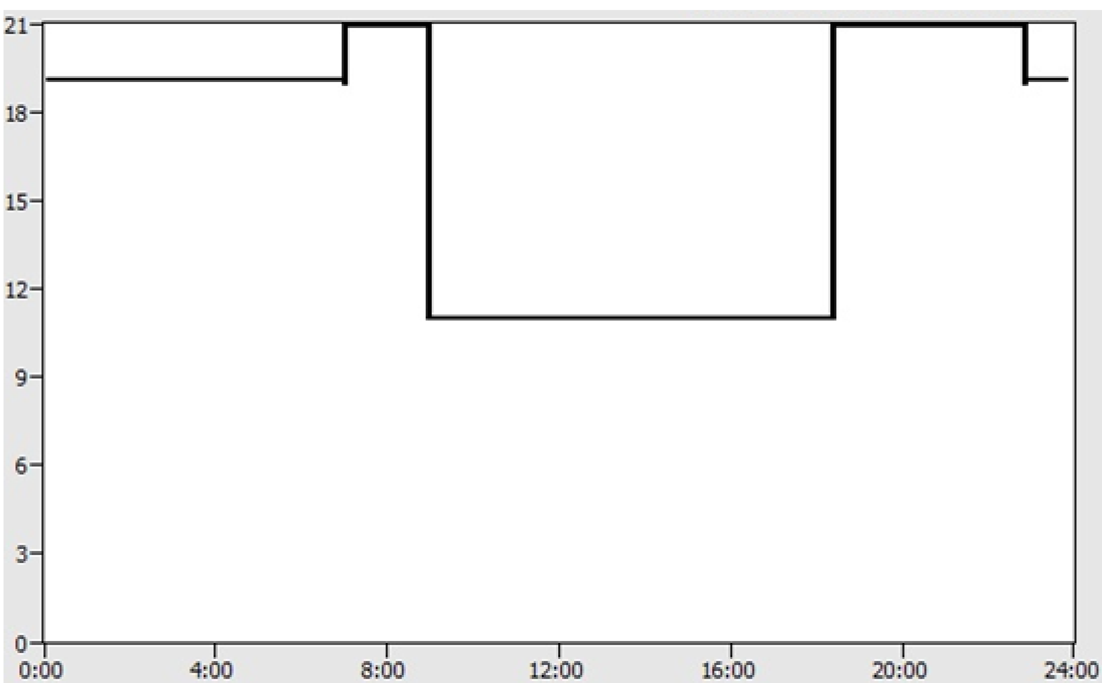


Chart 8.10 Heating schedule during weekdays

For the weekend days:

Chart 8.11 Heating schedule during weekend days

The cooling system period of use is from the 15th of June to the 15st of September.

The air temperature request is about 26 degrees.

For the weekdays:

Chart 8.12 Cooling schedule during weekdays

For the weekend days:

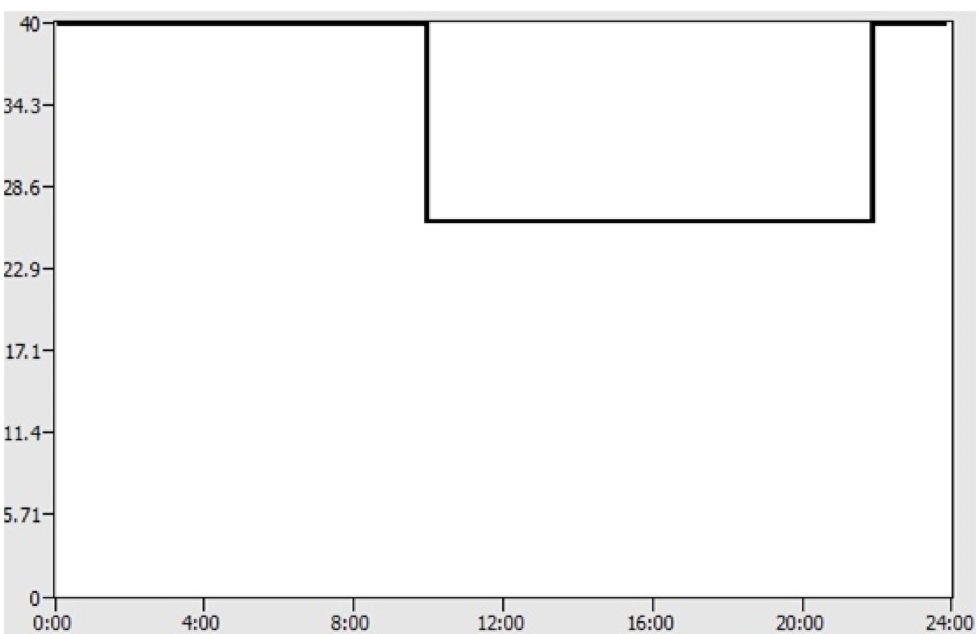


Chart 8.13 Cooling schedule during weekend days

Once the common parameters have been set, two different models are created.

The first model employs passive conditioning systems, which are:

Natural summer ventilation.

When it comes to ventilation, it has been hypothesised that air change-overs would take place at 10 volumes per hour during the night. The period taken into analysis goes from 15th June to 15th September, where the change-overs take place from 11om to 7am.

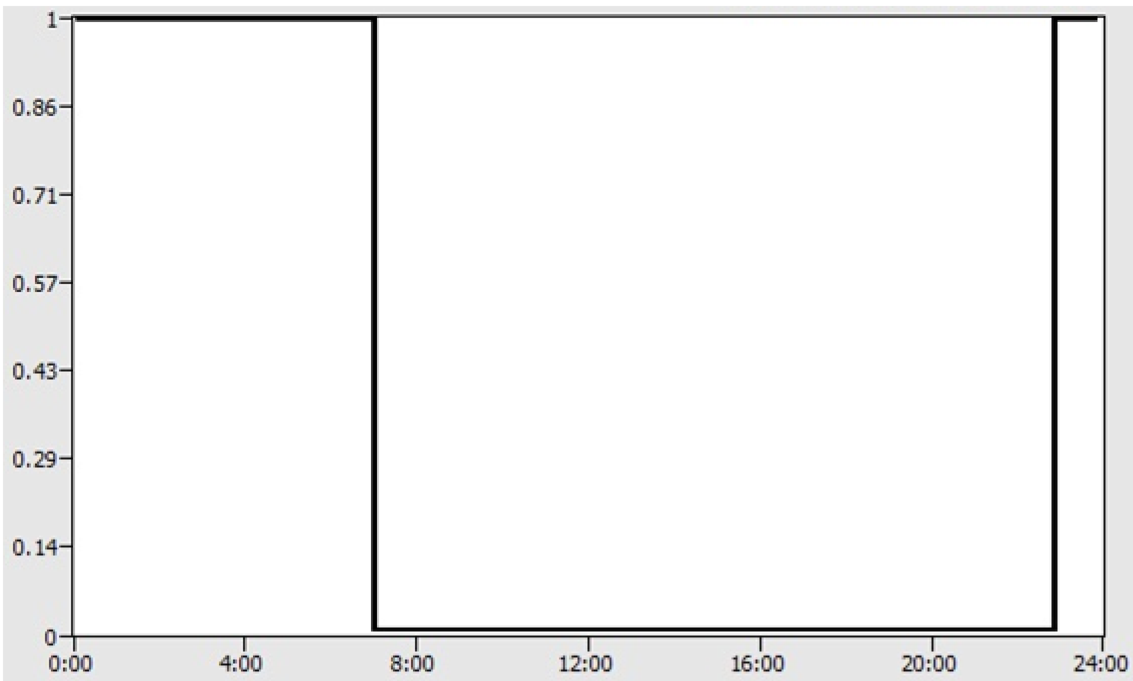


Chart 8.14 ventilation schedule

1. Bigger thermal isolation of opaque walls.

The walls and floors mentioned previously mentioned have been employed here, where the values align with those considered earlier.

Construction	U-Factor with Film [W/m2-K]
N_EXTERIOR WALL	0.153
EXTERIOR FLOOR	0.238
N_EXTERIOR ROOF	0.220

Tab. 8.1 Casing elements

2. Usage of insulation glasses, low-e and selective coating.

Construction	Glass U-Factor [W/m2-K]
N_WINDOW	1.152

Tab. 8.2 Windows

Here we consider the second model, it being the traditional one:

1. the hypothesis is that there is no natural nocturnal ventilation during the summer months.

It is obvious that, this being a traditional system, it would be possible to open the windows to achieve a natural summer conditioning. However, this analysis seeks to not only compare the two systems, but also to assess the efficacy of potential passive systems.

2. The walls and flooring utilised are of the traditional type, while those on the outside vary more, these being:

Construction	U-Factor with Film [W/m2-K]
O_EXTERIOR WALL	0.251
EXTERIOR FLOOR	0.238
O_EXTERIOR ROOF	0.229

Tab. 8.3 Casing elements

The external wall is therefore composed as such, choosing from a traditional package:

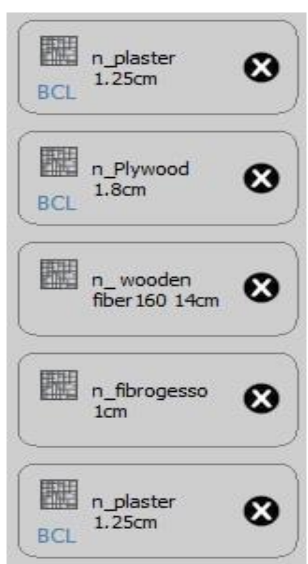


Fig. 8.3.3 External wall for 2nd model

When it comes to the roofing, the ventilation layer is simply removed.

3. When it comes to the windows, normal glasses have been used, such as:

Construction	Glass U-Factor [W/m2-K]
O_WINDOW	3.122

Tab. 8.4 Windows

Here the results obtained from the two simulations.

Starting from the energy consumption, it can be seen already that heating is more epensive when it comes to the traditional system:

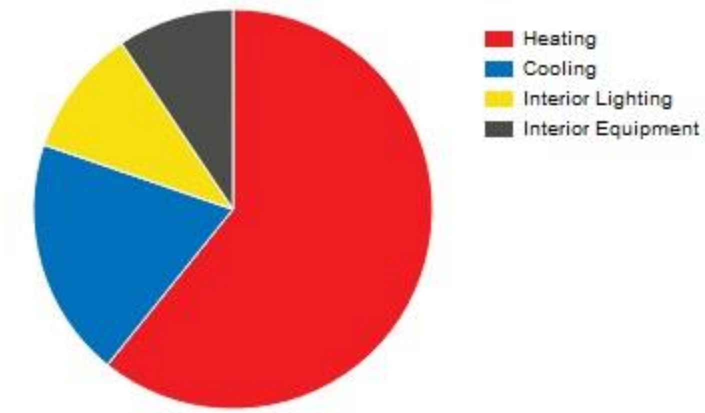


Chart 8.15 First system

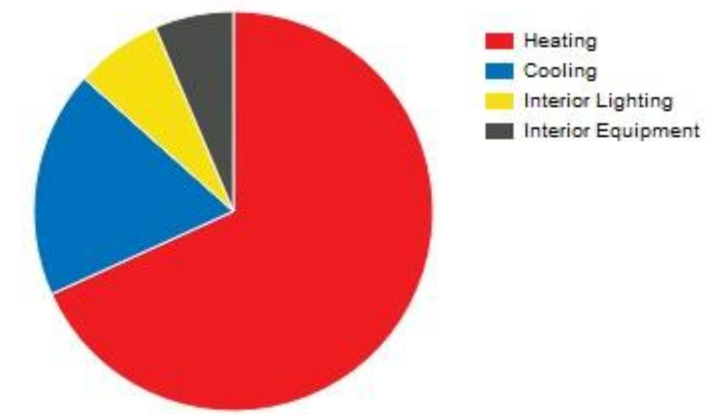


Chart 8.16 Second system

Below an analysis of the energy consumption:

For the *first model* these are:

	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]
Total Site Energy	48.73	138.11
Total Source Energy	147.58	418.30

Tab. 8.5 Energy consumption

DISTRICTHEATING:FACILITY {Maximum}[W]	DISTRICTHEATING:FACILITY {TIMESTAMP}
January	25194.09
February	25587.68
March	22376.92
April	0.00
May	0.00
June	0.00
July	0.00
August	0.00
September	0.00
October	12360.92
November	18737.86
December	25412.05
L` wlh t l neL nmsgr	14476-57

Tab. 8.6 Heating peak demand

DISTRICTCOOLING:FACILITY {Maximum}[W]	DISTRICTCOOLING:FACILITY {TIMESTAMP}

January	0.00
February	0.00
March	0.00
April	0.00
May	0.00
June	35799.44
July	36800.81
August	41620.71
September	45406.99
October	0.00
November	0.00
December	0.00
Maximum of Months	45406.99

Tab. 8.7 Cooling peak demand

For the *second model* these are:

	Total Energy [GJ]	Energy Per Total Building Area [MJ/m2]
Total Site Energy	56.13	159.09
Total Source Energy	188.39	533.99

Tab. 8.8 Energy consumption

DISTRICTHEATING:FACILITY {Maximum}[W]	DISTRICTHEATING:FACILITY {TIMESTAMP}
January	34516.09
February	36865.08
March	31879.97
April	0.00
May	0.00
June	0.00
July	0.00
August	0.00
September	0.00
October	17135.52
November	24741.63
December	32801.17
Maximum of Months	36865.08

Tab. 8.9 Heating peak demand

DISTRICTCOOLING:FACILITY {Maximum}[W]	DISTRICTCOOLING:FACILITY {TIMESTAMP}

January	0.00
February	0.00
March	0.00
April	0.00
May	0.00
June	21379.14
July	50269.54
August	50465.25
September	50770.18
October	0.00
November	0.00
December	0.00
Maximum of Months	50770.18

Tab. 8.10 Cooling peak demand

From these results it s possible to understand that there is a huge difference between the two systems. When it comes to the cooling system it can be found that there is a drastic energy saving, given in part by the open windows.

When it comes to periods when the implants are not in use, the internal temperatures have been measured during the spring season, from the 15th of March to the 15th of June.

For the *first model*:

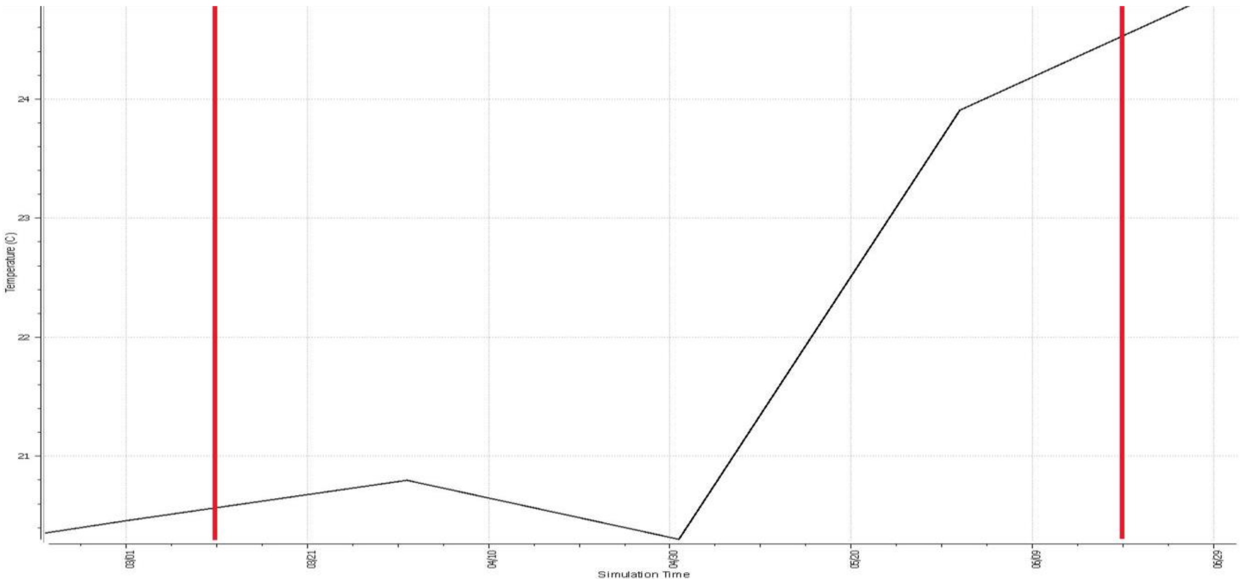


Chart 8.17 internal air temperature from the 15th of March to the 15th of June

For the *second model*:

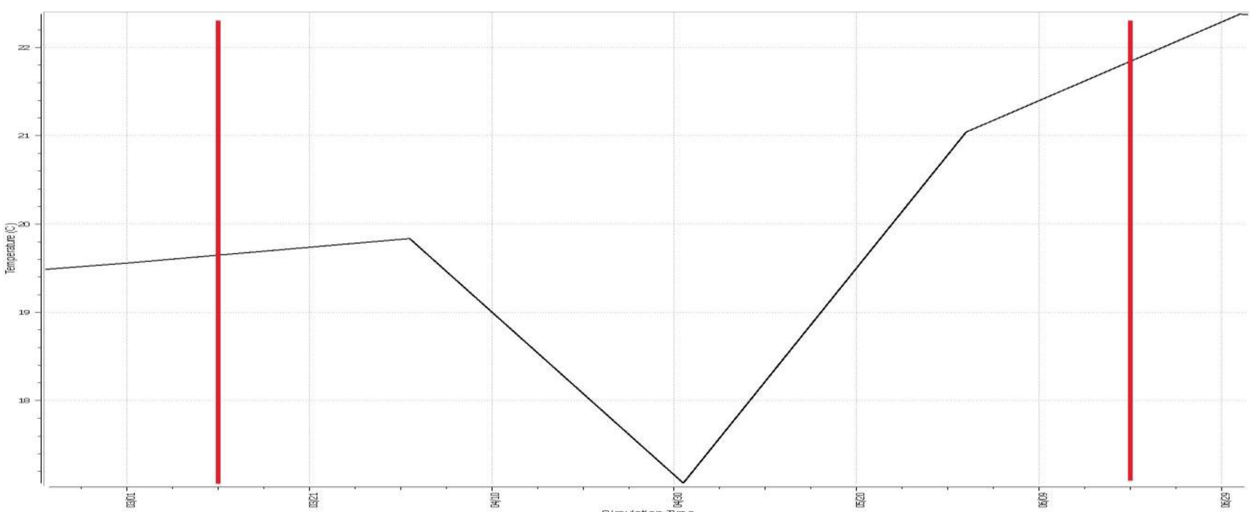


Chart 8.18 internal air temperature from the 15th of March to the 15th of June

It can be seen that in the first model the temperatures are around 21 degrees, while in the second one we can detect peaks of up to below 18 degrees, which would trigger the need to turn the heating system on.

Autumn, from the 15th of September to the 15th of October.

For the <u>first model</u>:

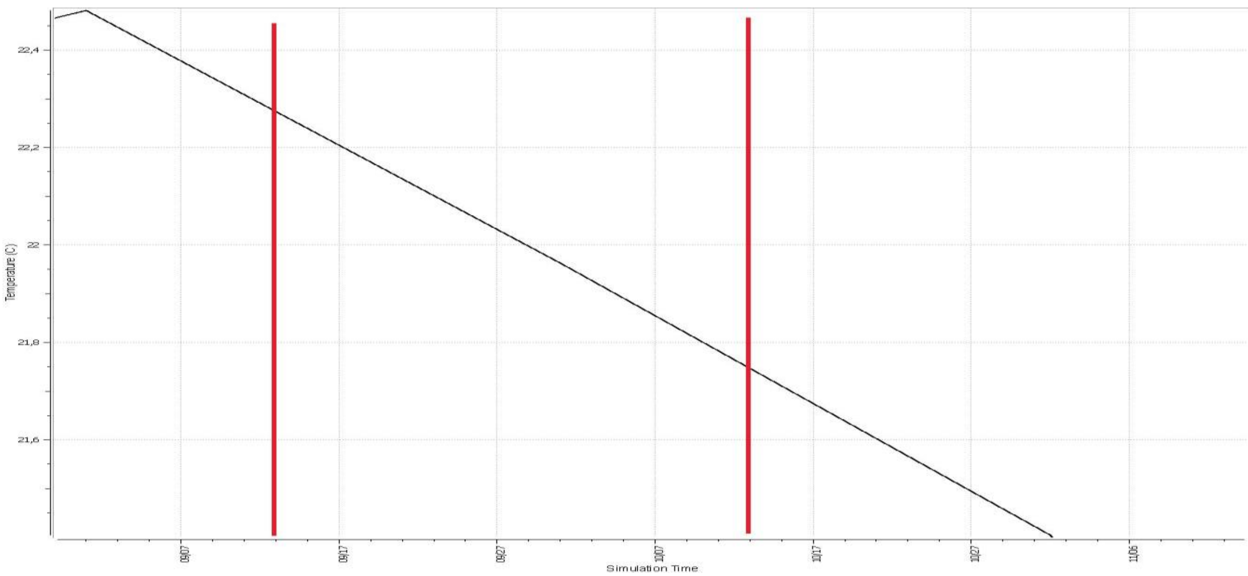


Chart 8.19 internal air temperature from the 15th of September to the 15th of October

For the *<u>second model</u>*:

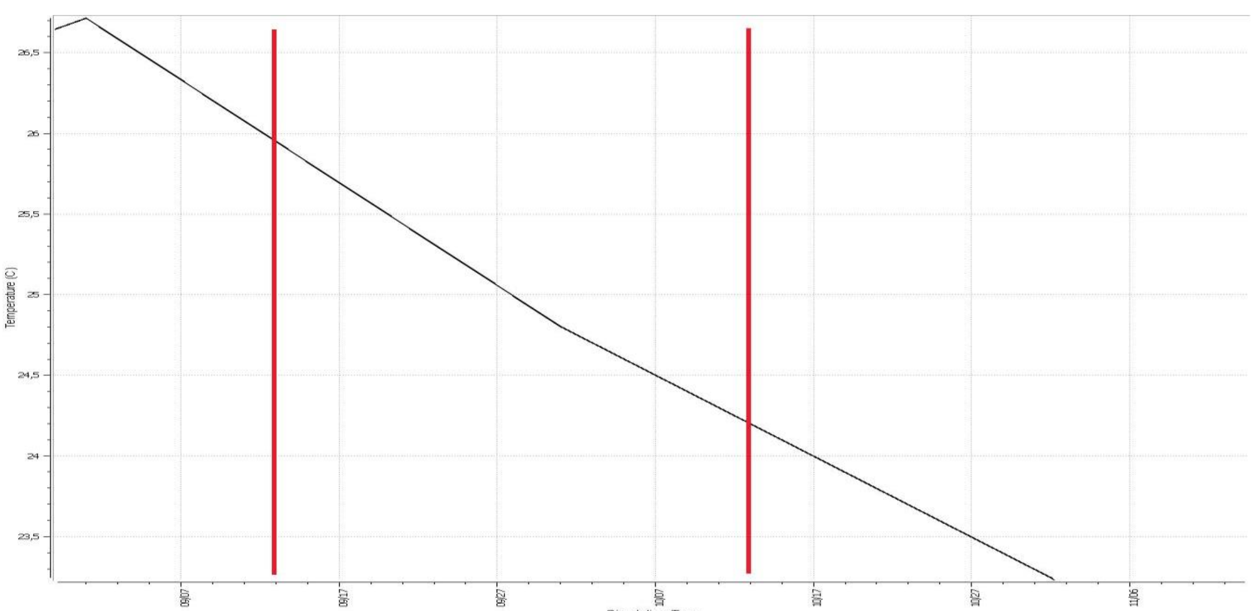


Chart 8.20 internal air temperature from the 15th of September to the 15th of October

The temperatures variations remain similar, but it can be seen that in the first model the range is way more uniform, meaning that the consumption would be less when compared to the second one.

Therefore, one can conclude that a well thought out system based on passive elements can play a key role when it comes to energy savings.

9 Conclusion

This thesis has demonstrated that it is indeed possible to reconcile Japanese traditions and style with a modern prefabricate system. It has done so by proposing a new prefabricate model that meets the needs of the contemporary Japanese housing market without straying away from the country's traditions, while also bringing together the best aspects and characteristics of both worlds.

This system has been developed starting from an historical excursus of Japanese architecture, in order to fully unpack and understand the needs that were at the very roots of the traditional Japanese house. Having done so, it has been possible to combine its various elements under an analysis of its core components, such as the *shoji* or paper walls, with the aim to question how these traditional elements could be developed and made more effective and functional by modern architectural and building techniques.

The model proposed has therefore left the key components of these traditional elements unvaried, as this is the best way to combine the ancient and the modern. This thesis in fact aimed at respecting and keeping the traditional elements of the Japanese house almost untouched, when possible, while finding innovative ways to reconcile them with the needs of modern society and lifestyles. For example, the dimensions of the house that strictly guided traditional building techniques have been respected and indeed applied to the model, as these did not need to be revolutionised in order to fit within the current housing market. At the same time, while traditional Japanese houses did not feature a centralised heating system, if one at all, this undeniably is a key requirement that needs to be part of modern housing establishment. The model proposed by this thesis has addressed this by installing a heating system hidden underneath the floor panels, which therefore assures modern comforts without negatively impacting on the aesthetics of the traditional Japanese house.

This thesis aimed at proposing a model that, rather than reinforcing the gap between old and new, seeks to fill this gap by starting with tradition itself, and arguing in favour of an evolutionary process that happens according to thought-through, meaningful stages, rather than skipping them altogether. This is what makes this model unique.

This model successfully answers the questions interrogating whether a return to the traditional could fulfil the needs of the ever developing Japanese housing markets, as it does not stray away from the prefabricated reality, but rather proposed a new version of it. However, some would say that this system still fails to address the societal problems outlined above. In response to this criticism, it could be said that this model opens up the space and also encourages a debate on how the current, anachronistic Tokyo's aesthetics, is also directly related to many of the societal issues its inhabitants are experiencing. The argument proposed by this thesis is that, by adopting a prefabricated model that is more in line with both Japanese traditions and psyche, several of these issues could start being resolved. Since many of these residential quarters are often erected in previously deserted areas, if they were developed following a more traditional style, they would appear much less anachronistic and alien. Subsequently, these areas would not only meet the needs of the contemporary housing market, but would also positively impact on the psyche of its inhabitants, and possibly even attract tourism, such the Yanaka quarter in Taito, Tokyo.

This is the case as it is possible to *live* and *experience* Japanese spaces if there is the will to bring back ancient rituals that have fallen victim to modernity. While this is undeniably an individual journey, it could also easily translate into a social process if the right circumstances are put in place.

To conclude, the employment of this model would allow for the successful search of a contemporary Japanese identity, which is not only philosophical, but also mirrored in the environment of cities. "Identity" comes from the Latin *identitas*, meaning "same". Therefore, by following this model, new residential areas could reclaim a Japanese identity that is not a copy of the ancient one, but rather, would be a modern and collective claim to a Tokyo-ness that is in line with both the ancient and modern characteristics of the country.

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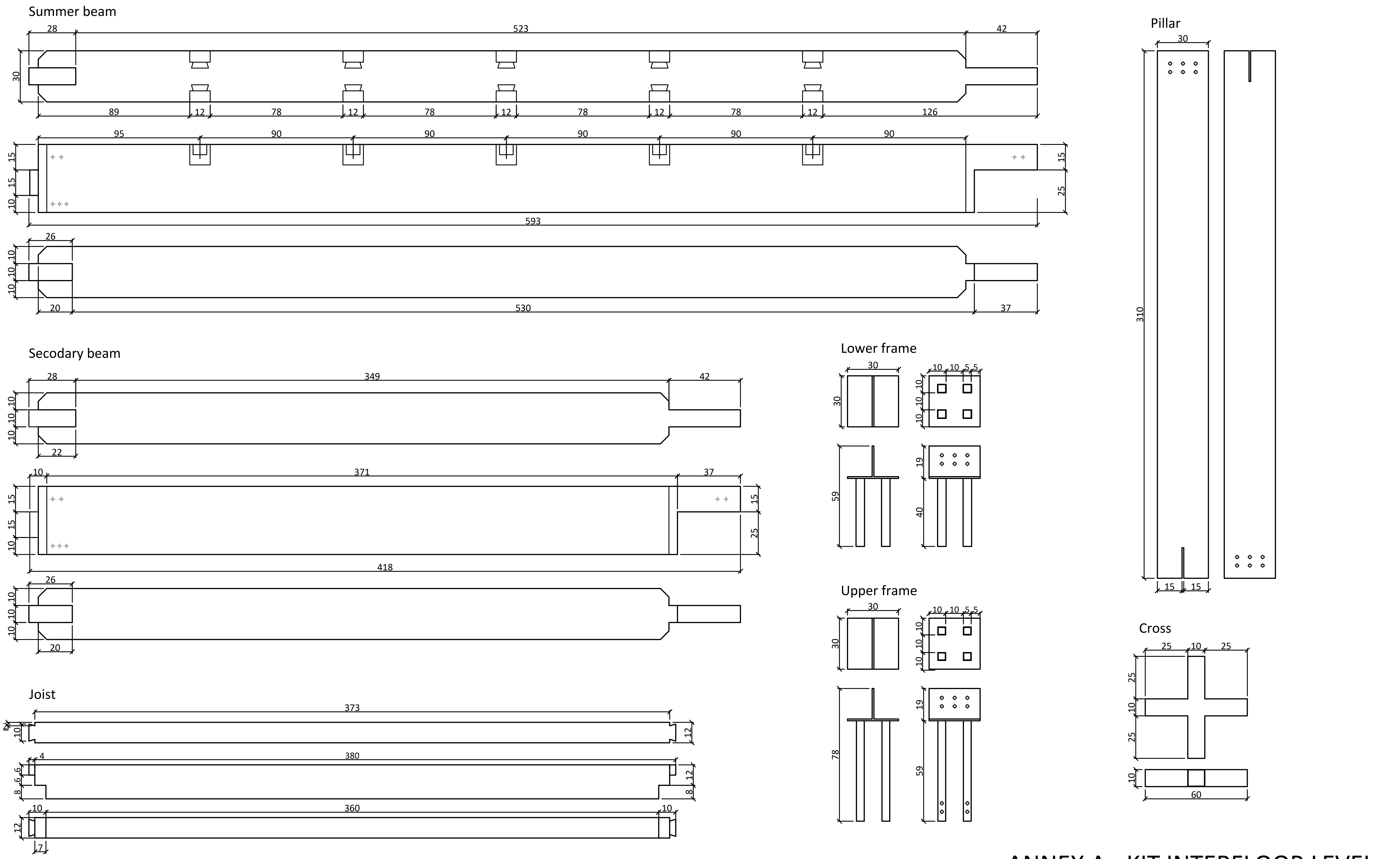
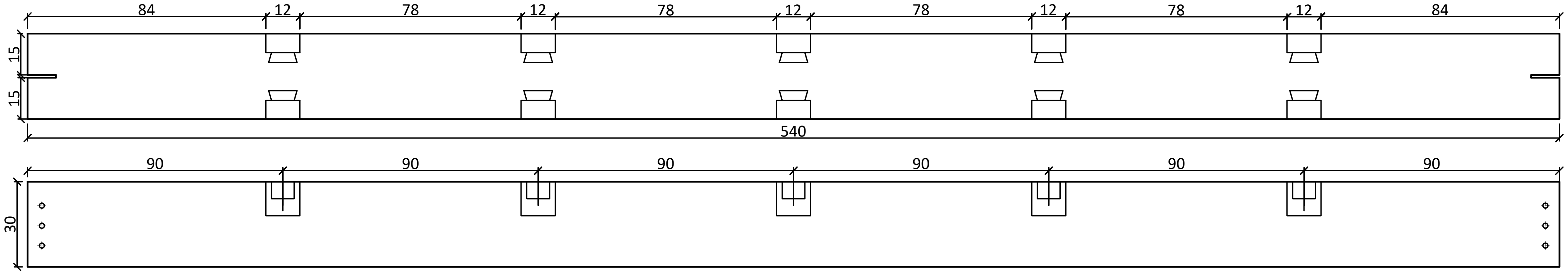
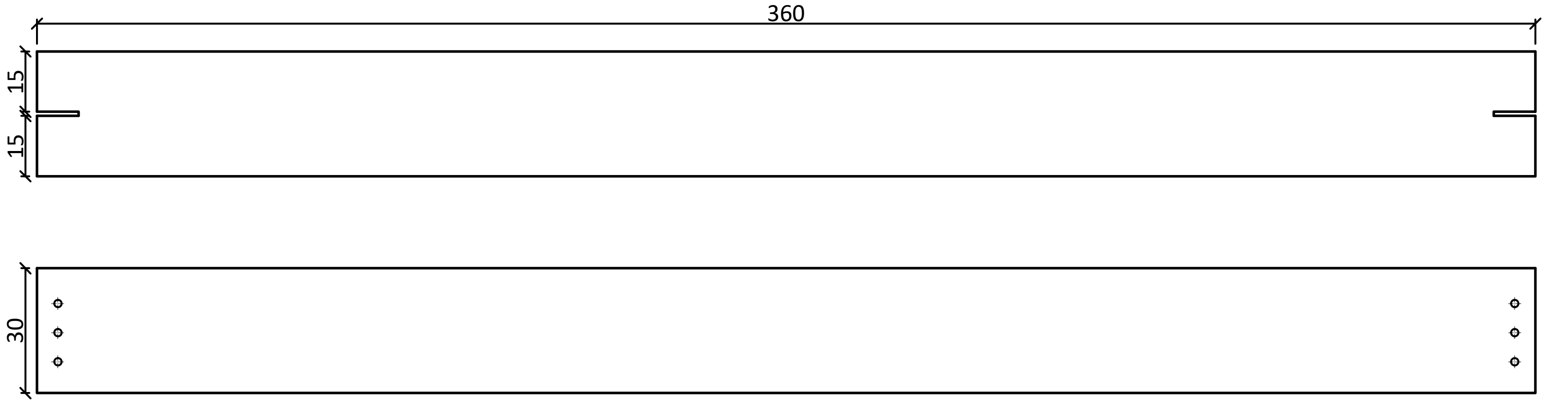


ANNEX A - KIT INTERFLOOR LEVEL

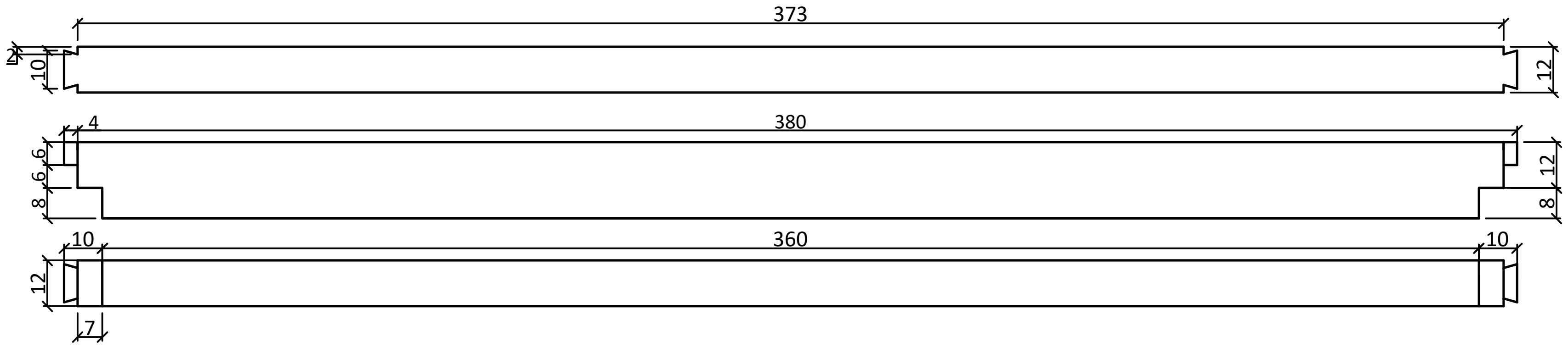
Summer beam



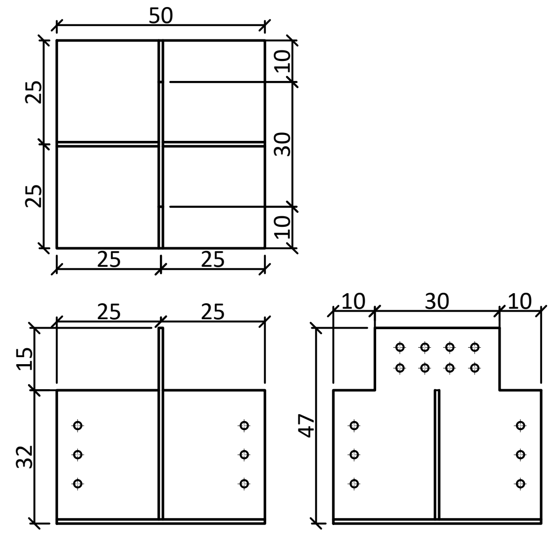
Secodary beam



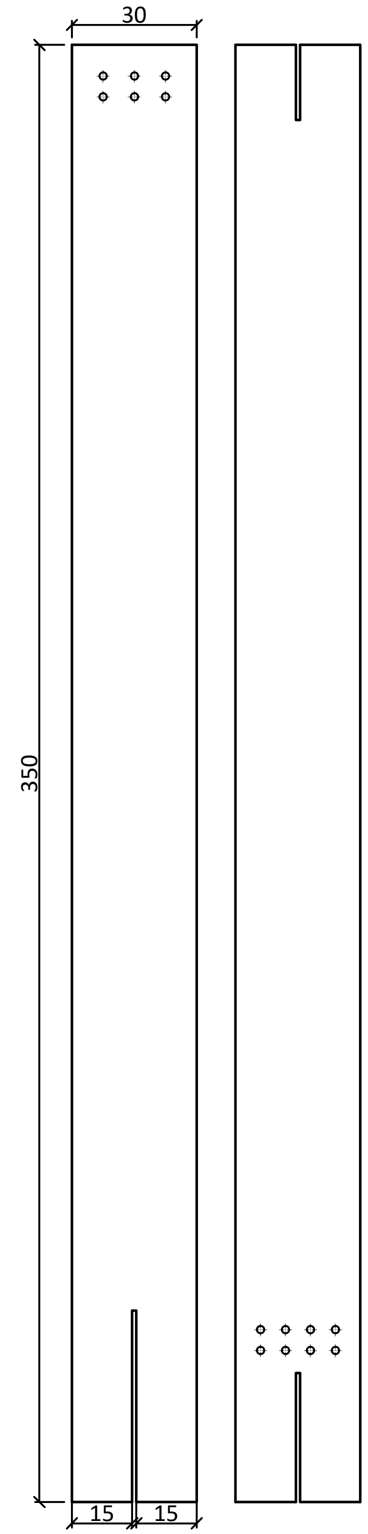
Joist



Bracket

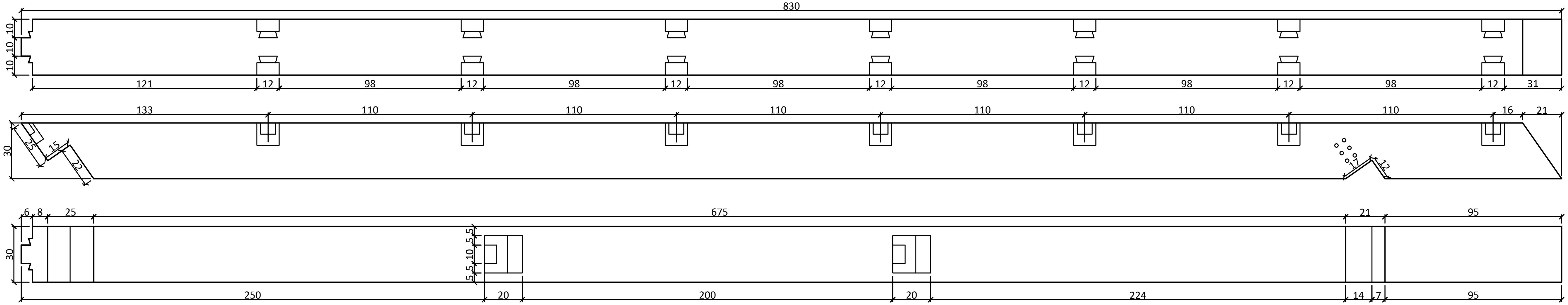


Pillar

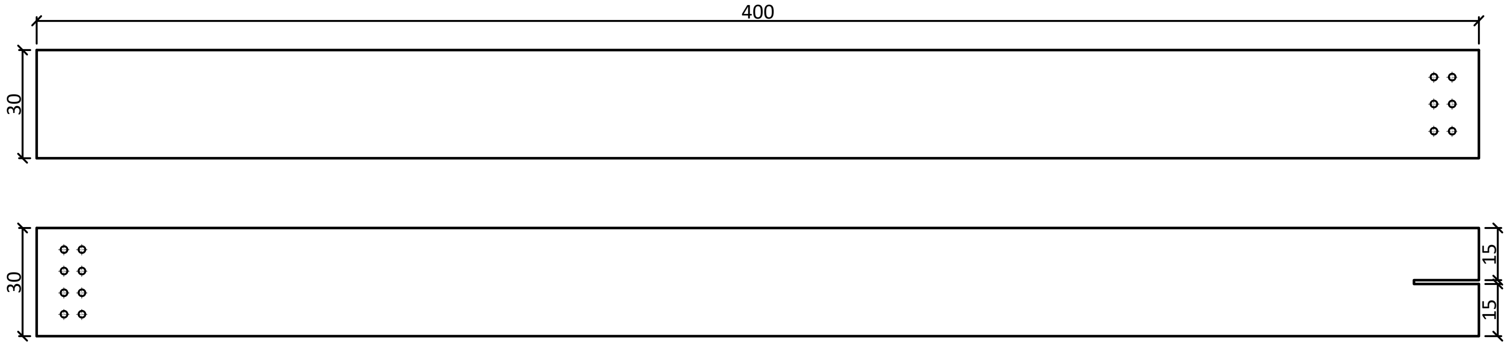


ANNEX B - KIT FOUNDATION LEVEL

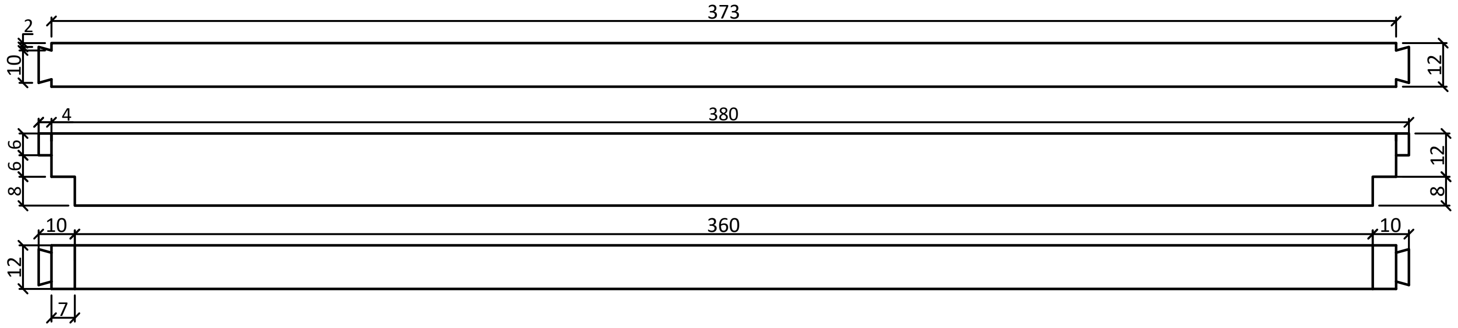
Roof beam



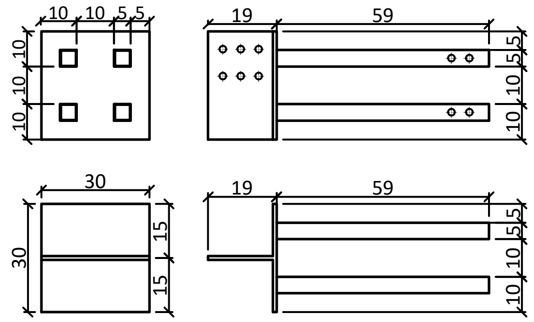
Pillar



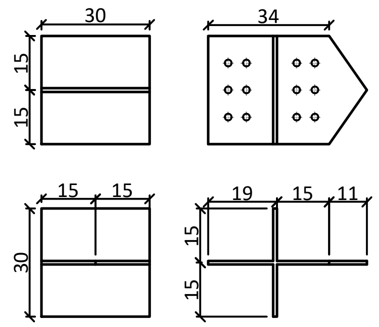
Joist

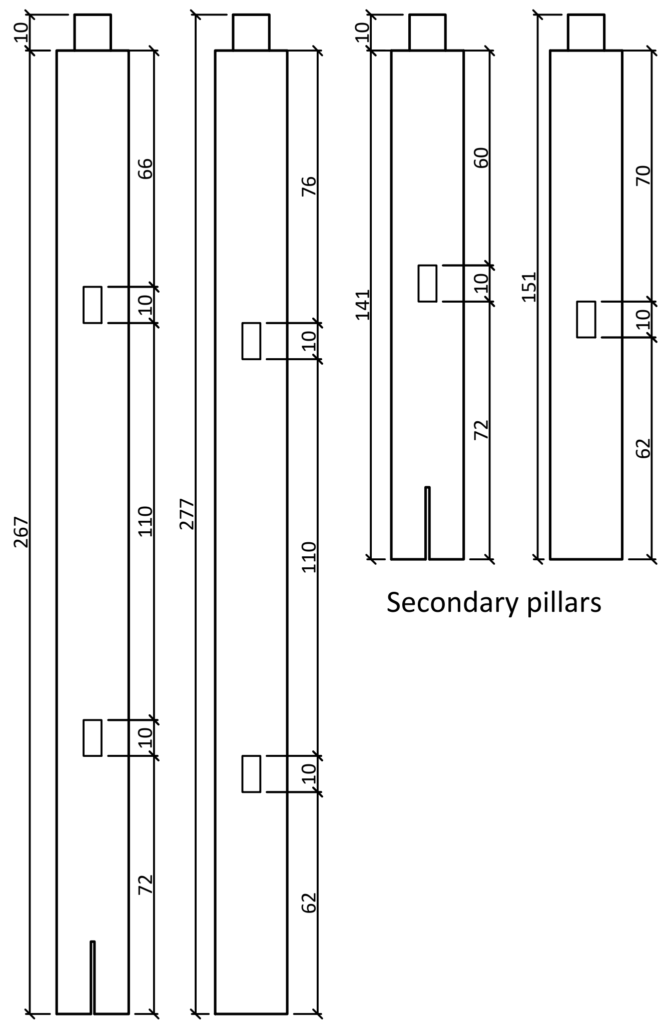


Lower frame



Ridge line frame

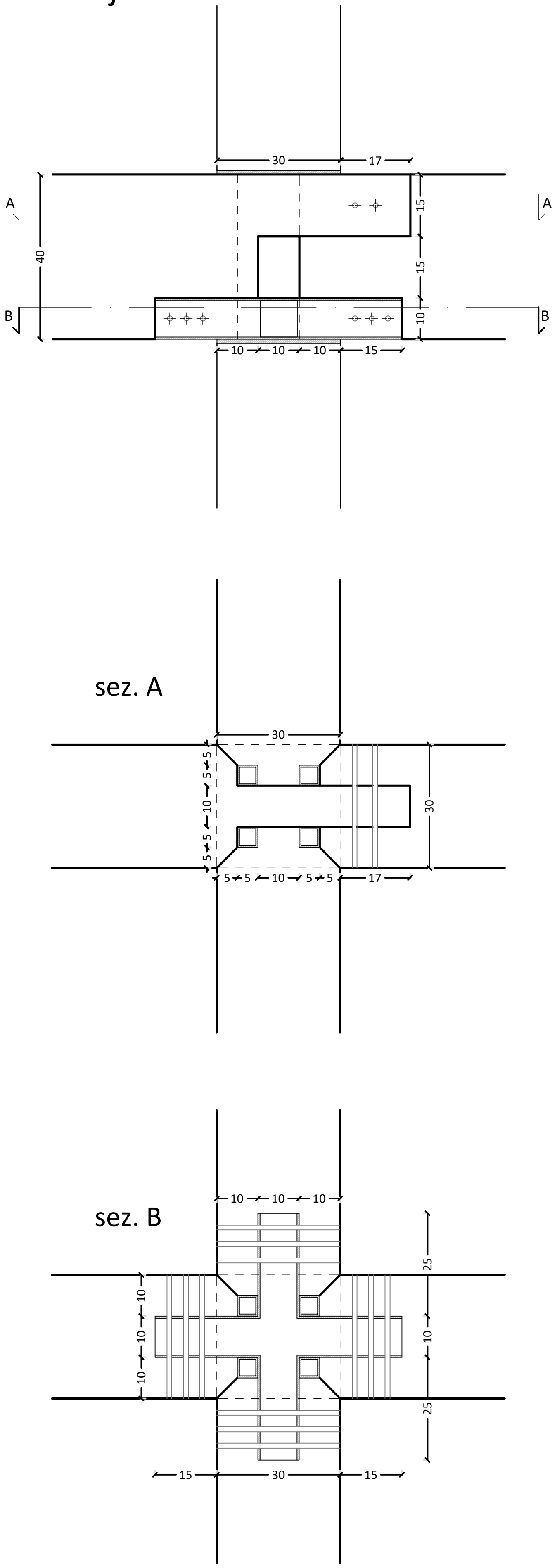




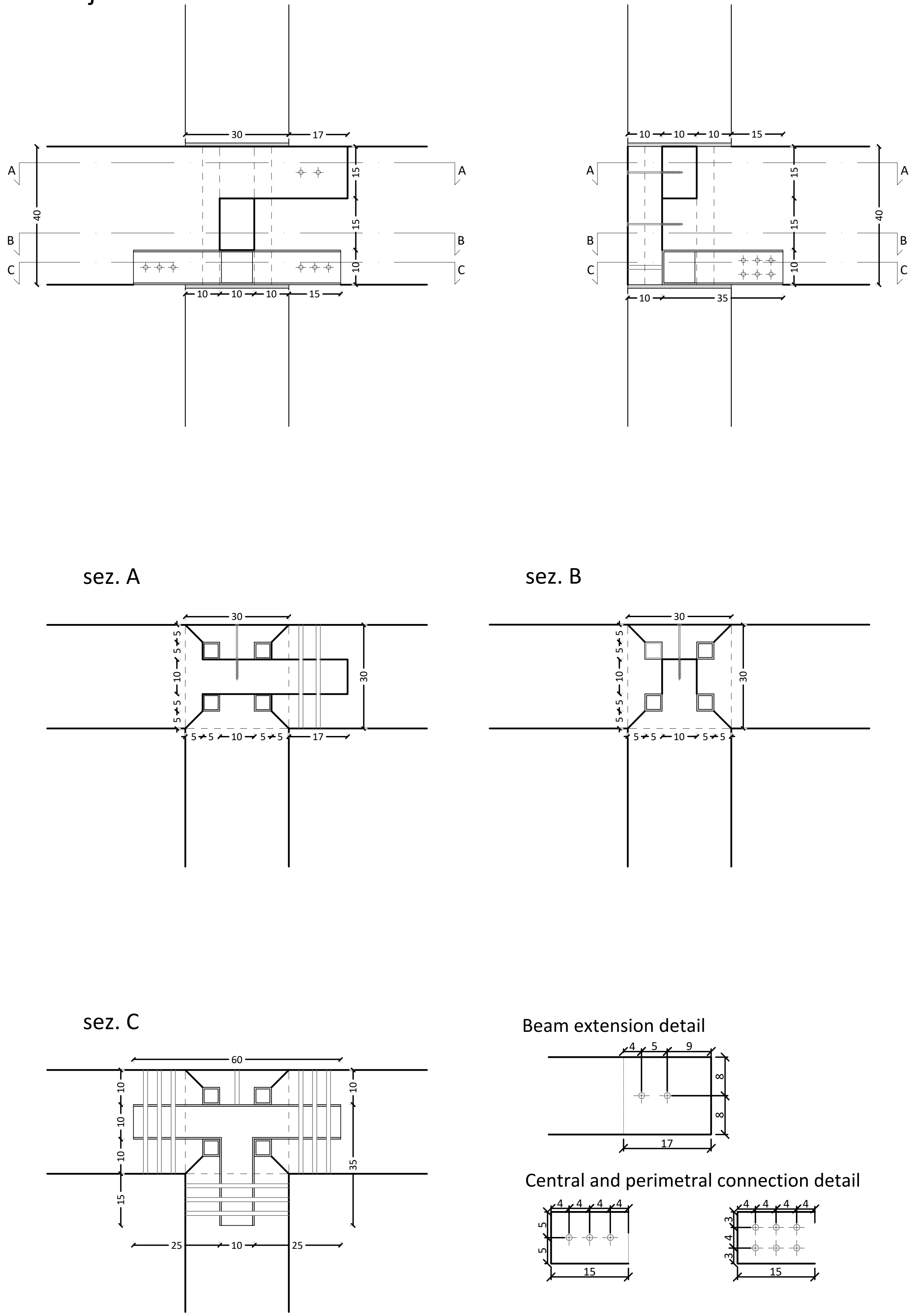
Secondary pillars

ANNEX C - KIT ROOF LEVEL

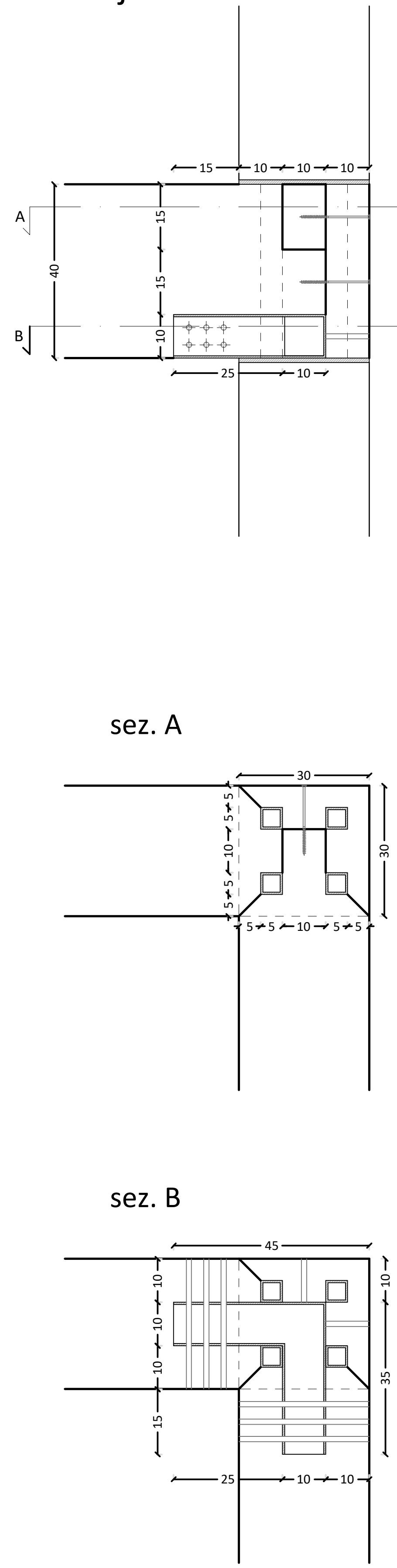
Central joint



Lateral joint



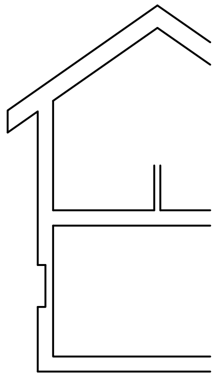
Corner joint



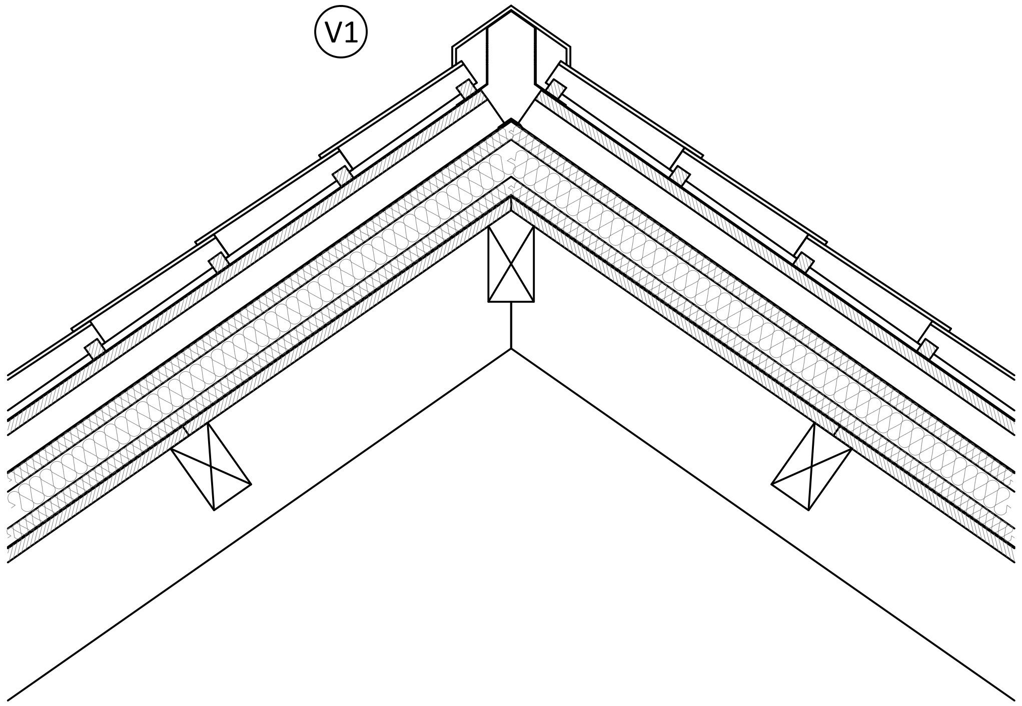
ANNEX D - JOINT DETAILS

Details list. Scale 1:20

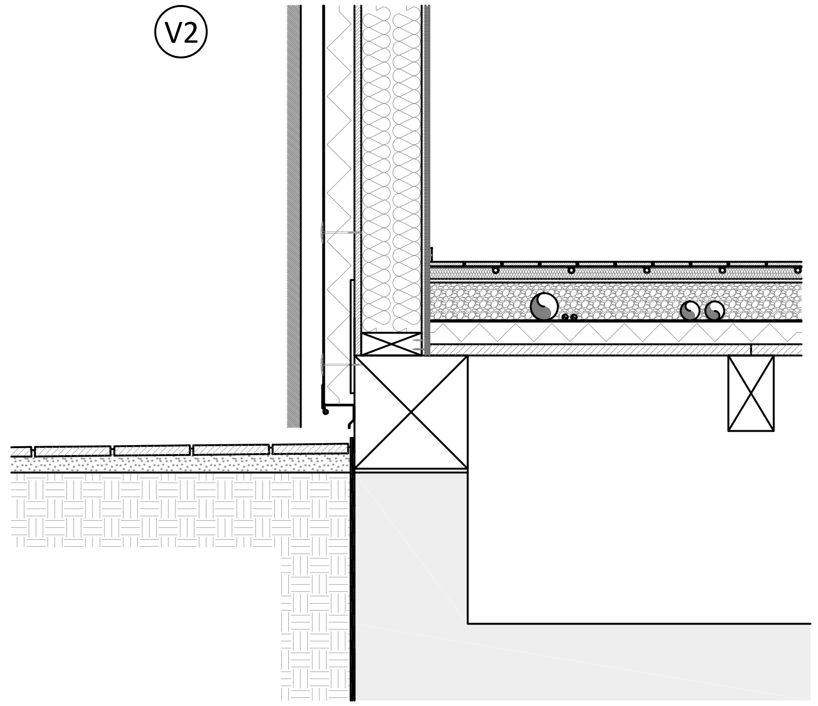
V1 : Vertical construction detail, Ridge line
V2 : Vertical construction detail, Ground perimeter
V3 : Vertical construction detail, Node roof and exterior wall
V4 : Vertical construction detail, Exterior wall
V5 : Vertical construction detail, Windows installation
V6 : Vertical construction detail, Interior wall
O1 : Horizontal construction detail, Exterior wall



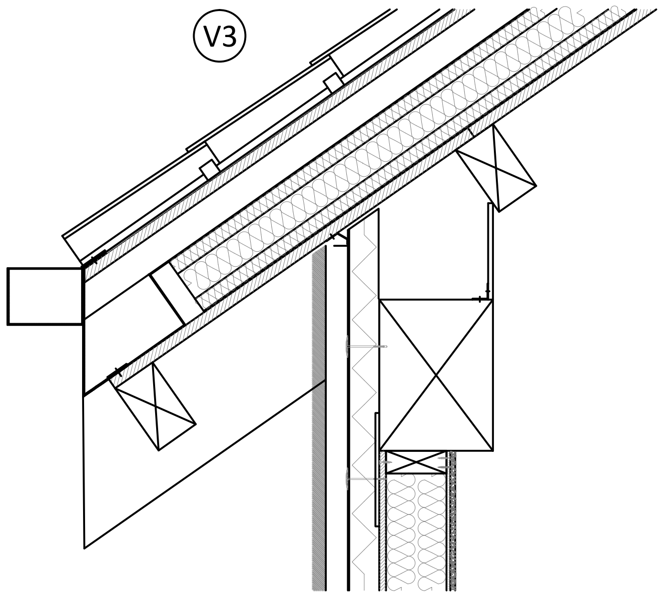
V1



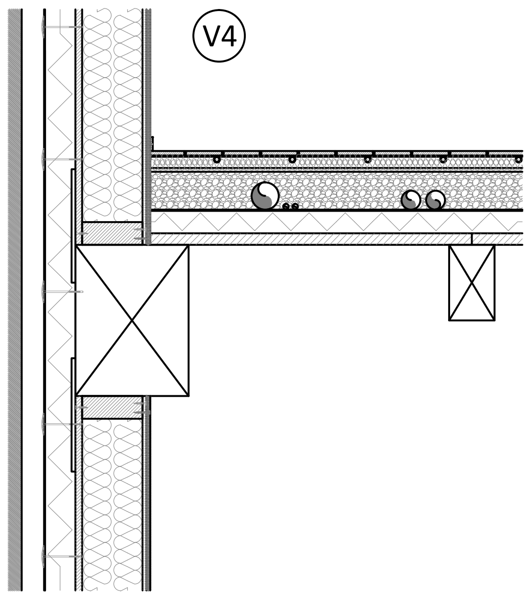
V2



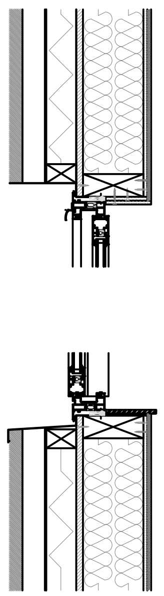
V3



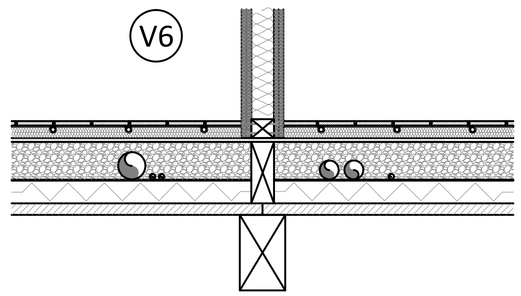
V4



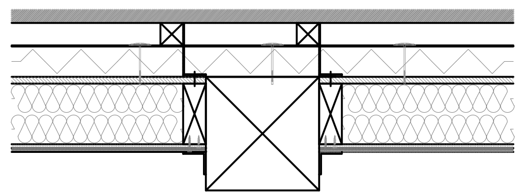
V5



V6



O1



ANNEX E - CONSTRUCTION DETAILS