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CONSTRUCTION OF RESIDENTAL BUILDINGS ON COLUMNS AS AN ALTERNATIVE TO CONSTRUCTION IN AREAS EXPOSED TO FLOODS

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Abstract: *Floods that have in recent years become a constant in developed areas are raising the issue of how to adapt to nature when constructing housing. The construction of retarding basins and high dikes are the most frequently used alternatives of protecting the urban environment. Such a practice is most commonly found in Europe where it however, has unfortunately shown itself on several times, not to be the most effective. People from North America who live in areas often affected by floods, build their housing on columns. In Slovenia, not much thought is given to this, which is probably the result of the traditional mentality that promotes the building of massive residential houses and the issue of structural engineering that involves the so-called soft ground floor. New materials and new structural principles make construction on columns possible, which has been proven by the example of the residential building on low bearing soil in the seismic and flood risk area of the Ljubljana Marshes.*

Keywords: *Architecture, Residential Buildings, Flood, Columns.*

1. INTRODUCTION

1.1. Flood risk of residental buildings and the problems of solving the issue with dikes

A flood is a disaster that occurs when water flows over the limits of channels or banks. A flood is most frequently the consequence of a sum of various unfavourable events. First, a great quantity of precipitation falls in a relatively short amount of time. If the precipitation falls on a frozen, impermeable or a well-saturated base, the channels of watercourses quickly fill up. Because the channels can no longer draw off the increased quantities of water, the water then flows over, beyond the channel. Other causes of floods are the collapse of dikes and dams that impound water. In this situation, the contained water spills through. Thus, the increased water level destroys field crops, infrastructure and buildings. If the terrain is sloped, the water has a big falling force and also much destructive power.

Regardless of the Gams classification of floods, supplemented in 2005 by Karel Natek [1], which classifies floods into five groups (torrent, lowland, Karst field, coastal and urban floods), water affects a building in two ways:

– as a destructive force affecting the building
– by the presence of water in the building.

Figure 1. A lowland flood.

The first form of damage is characteristic of buildings in the headwaters of rivers in a hill area or a mountain area. Due to the slope of the terrain, the water has a lot of destructive power, which means the damage can be great. According to Federal Emergency Management Agency (FEMA), “moving water” is defined as water moving at low velocities of 1.6 meter per second (5 fps) or less. Water moving at velocities greater than 1.6 mps (5 fps) may cause structural damage to building materials [2]. A flood occurs in a short amount of time and does not last long. In the event of such a flood, the buildings act as a barrier to the water flow. The rushing water tries to remove this obstacle (undermine, collapse) or simply goes around it. Damage occurs in either case.

The other type of damage occurs during the lowland flooding of larger rivers, the sea, etc. For these types of floods, the response to precipitation is slow (several hours or even days), helped by successful weather forecasting providing adequate warning of the impending dangers. Typical for this type of flood is that the water rises slowly and has no special force. But usually such a flood lasts longer, because the outflow of the water is also slow (Figure 1).

Notwithstanding that a forecast provides adequate warning, the material damage is usually large, because such a flood affects a larger area and also lasts longer. The flood water does not affect the buildings with its force, but with its presence. It damages the elements of buildings such as, for example, the soil, hydro-insulation, thermal insulation, the walls, cladding and equipment in the building and the inability to use the building.

According to FEMA, floodwater is assumed to be considered “black” water; black water contains pollutants such as sewage, chemicals, heavy metals, or other toxic substances that are potentially hazardous to humans [2]. A similar situation occurs with floods on Karst fields, which are also consistent since they occur almost every year. Here, the main characteristic is the delay, which is dependent on the capacity of the Karst springs, and can last several hours or even a few days. This affects the flood wave (the peak of the flood wave is lower, but the duration of the flood is longer. Due to their constant nature, man adapted his activities to the seasonal floods, thus they do not cause any damage, except in exceptional circumstances. Coastal and urban floods can also be placed in this category. Coastal floods are the consequence of natural factors, those being astronomic (the influence of the moon and the sun), meteorological (air pressure and wind) and the sea’s own fluctuation. Floods occur regularly at high tides and in exceptional situations such as the consequence of the shifting of tectonic plates (e.g. tsunamis) and can be, in part, forecast. Urban floods occur as the consequence of specific conditions in a built-up (urban) environment, as the consequence of an infrastructural disaster (the outflow of water from a water distribution system) or the inability (natural or man-made) of water outflow (flooded basements, underpasses etc.).

In 2012, 17 major floods occurred in Europe and caused 223 fatalities. More than 1,000,000 km^2 of surface areas were affected from which approximately 35,000 people had to be evacuated. On a global level, the numbers are significantly higher (157 major floods, 4783 casualties, 13 million people evacuated) [3]. Most damage was caused by hurricane Sandy ($50,000 million) and most casualties were caused by the Bopha typhoon (over 1000). In both cases, the damage was caused by strong wind and precipitation – floods. The most damage occurs in the “developed world” and the most casualties in the “developing” countries [4, 5].

Throughout history, man has built structures in areas that have provided the best possible life conditions. Locations near rivers were popular, because rivers made it possible to survive (defence, irrigation, and drinking water), enabled transportation, provided water energy for driving devices, etc. With the development of trade, the importance of water resources increased further. Despite troublesome experience with intermittent floods, people built their housing next to rivers. Despite frequent recent discussions about climate changes and floods as the consequence of these changes, it should be emphasized that floods in the past were just as frequent as they are today. Unfortunately, measurements of the heights of rivers only began sometimes ago in the past two centuries, and thus not enough evidence is available for the past. The only exceptions are the Nile and the Tiber rivers for which records of floods throughout a longer period of time exist. Despite this, there are descriptions about the highest water levels for certain places (Melk, Mainz, Köln) (Figure 2). These records are proof that the highest water levels have already been reached in the past [6, 7]. Even some places in Slovenia already witnessed disastrous floods in the past. A large part of the ancient Celeia was destroyed by the Savinja river, which also changed its current while doing so. Floods also occurred in the Celje region in 1550, on the Radensko field, Falska pečina at Lent in Maribor and in 1851 in Ptuj and in the entire area of Slovenia in 1901, 1990 [6], 2007 and 2010. Despite the fact that floods are a frequent event in Slovenia, it should be emphasized that they only endanger approximately 5 % of the territory of Slovenia or only 25 km^2 of urban surface area [8], which confirms the fact that people accept the risk of flood damage, even if other advantages are greater.

Figure 2. Markings of the high water level in Melk on the Danube.

The prevention of the impact of floods on buildings should be looked at from several angles. Floods are usually a natural occurrence that people can contribute to, or reduce the effects of, with their actions. Here, it should be mentioned that a failure to perform or partially performed such measures can significantly accentuate the situation, as was shown in the case of the flood in Celje in 1990 [9].

The technique now allows more solutions to reduce flood damage. At the level of the major areas is primarily for the construction of dikes, dams, reservoirs, afforestation, renaturalization of water courses. Newer systems for flood protection include the installation of flood barriers. These are made of prefabricated panels. In the case of rising water, they are placed in pre-prepared foundations. Time setting is a few hours. This system requires the prior construction of the base of the socket. In Austria, this method proved to be effective during the floods of the Danube in 2013 [10].

However, these protection measures will be very expensive to construct and maintain. At the same time, there is also the problem of placement of such objects in space due to various concerns (economic, legal, ecological ...). In this strengthens the awareness on the prevention of excessive flooding impact on neighbourhood areas. A current example is the flood in 2012, when the managers of reservoirs on the river Drava in Austria increased the flow of the river by releasing water from reservoirs and thereby increase the volume of flood [11].

There are several different types of measures in the field of the protection of individual buildings. They have good and bad qualities. In the case of the so-called dry protection is necessary to prevent the ingress of water into the building. This is possible with building measures, which include the construction of waterproof boundary elements, the use of pumps and the like. Usually a costly procedure requires a special design and implementation.

The more frequent the wet method of protection, which means that water can flood a certain (lower) parts of the building and then drain. In this case, the materials are used in a range of water-resistant to the effects of flooding.

FEMA [2] indicated classification of the materials for use in the event of flooding. These materials are classified into five groups:

Unacceptable not resistant materials (group 1) are materials, which are not resistant to clean water damage or moisture damage. Materials in this class are used in spaces with conditions of complete dryness. These materials cannot survive the wetting and drying associated with floods (paper, vinyl wall coverings, linoleum...).

Unacceptable poorly resistant materials (2) are not resistant to clean water damage. Materials in this class are used in predominantly dry spaces that may be subject to occasional water vapour and/or slight seepage (most wooden elements…).

Unacceptable less resistant materials (3) are resistant to clean water damage, but not floodwater damage. Materials in this class may be submerged in clean water during periods of flooding. These materials can survive wetting and drying, but may not be able to be successfully cleaned after floods to render them free of most harmful pollutants (paper-faced gypsum board, mineral wool…)

Acceptable partially resistant materials (4) are resistant to floodwater damage from wetting and drying, but less durable when exposed to moving water. (Non-paper-faced gypsum board, brick – clay).

Acceptable resistant materials (5) are highly resistant to floodwater damage, including damage caused by moving water. These materials can survive wetting and drying and may be successfully cleaned after a flood to render them free of most harmful pollutants (concrete, stone, steel).

The installations must be carried out that the water does not hurt. Wet mode means less water pressure on the supporting structure, but at the same time be aware of all the consequences that flood waters brought into the building. As has already been written the floodwaters is “black”, so may be contaminated by sewage, mineral oils and the like. Notwithstanding the fact that the construction itself remain undamaged, it is necessary remediation (disinfecting) of the building after the flood [12].

The use of concrete or steel columns instead of walls mean reduction in the area it reaches the water, which means less material is exposed to the influence of water. In this case, an open space on the ground floor, which is usually allocated parking of vehicles or storage of materials and equipment necessary for the smooth functioning of the house and its surroundings. In the event of flooding, the material and equipment can be moved to a safer place. In addition to the buildings on fixed support, there are also cases it is possible to lengthen the pillars and thus raise the building. Where the height of the floodwater is difficult to distinguish system is used in the construction of pontoons that in the event of flooding to allow the entire building floating on the water. In recent cases, the building should be adequate light, which means that this method is useful for individual houses [12].

Today, riverside and flood-bound areas are recognized as quality ecologic areas. In the past, its use for construction was limited due to floods. This way of thinking is still persistent today, since construction is generally forbidden in flood-risk areas. Despite the above, limitations of the utilization of areas of environmental nature also apply since such an area can be recognized as an area under special protection due to the preservation of nature (e.g. Nature 2000) which can make it difficult to use the area for any other purpose. An example of this is the old channel of the Drava River that usually has a minimal rate of flow due to the construction of a channel for the hydroelectric power plant. In the past, interventions and maintenance of the channel were hindered for the purposes of environmental protection. The result of this is the overgrowth of sandbanks and thus the further decreased capability of facilitating larger rates of water flow [11]. The consequences of the flood waters in 2012 were thus even more severe, because the old channel could not carry off all the high water.

The structure of soil in flood-risk areas shows the effect of water which is reflected in the accumulation of various types of deposits. Usually these are rubble, sand, gravel and also sludge, while other deposits can also be organic. From the perspective of construction, this is a structure of soil that is not ideal for building or which requires special foundation work. The subsidence that can occur due to the non-homogenous structure of the soil is also a difficulty. Due to the above mentioned characteristics, flood-risk land is cheaper than comparable land in areas where there is no flood risk.

Considering the issue of protective measures, the question arises of whether with today’s technology it would be possible to build residential buildings that floods could not endanger or where the damage would be minimal in the event of a flood and if such a construction would also be economically justified.

A typical example of a flood-risk and low bearing capacity terrain is the southern part of Ljubljana, located on the Ljubljana Marshes. The Ljubljana Marshes is an area with a more than 200 m deep late Pliocene depression filled with more than 100 m thick layers of river, marsh and lake sediments. The soil has a low bearing capacity, as this is an early depression that is still sinking. Due to the low fall of water that flows through the marshes (the lower part of the Ljubljanica river, near the spring on the western part of the Ljubljana Marshes, is 285.31 m above sea level yet approximately 20 km away in the north-eastern part of Ljubljana, it is only 1.5 m lower), floods are frequent (Figure 3). On a larger scale, floods occurred in the area of the city of Ljubljana in the 1930s (1926 and 1933) and then once again in 2010 [13].

The seismic risk of Ljubljana is one of the highest in Slovenia (Figure 4). The seismic intensity for the area on the Ljubljana Marshes for the return period of 475 years is IX, according to EMS-98.

Irrespective of the above, this area was heavily urbanized, especially after the Second World War. The urbanisation is still continuing.

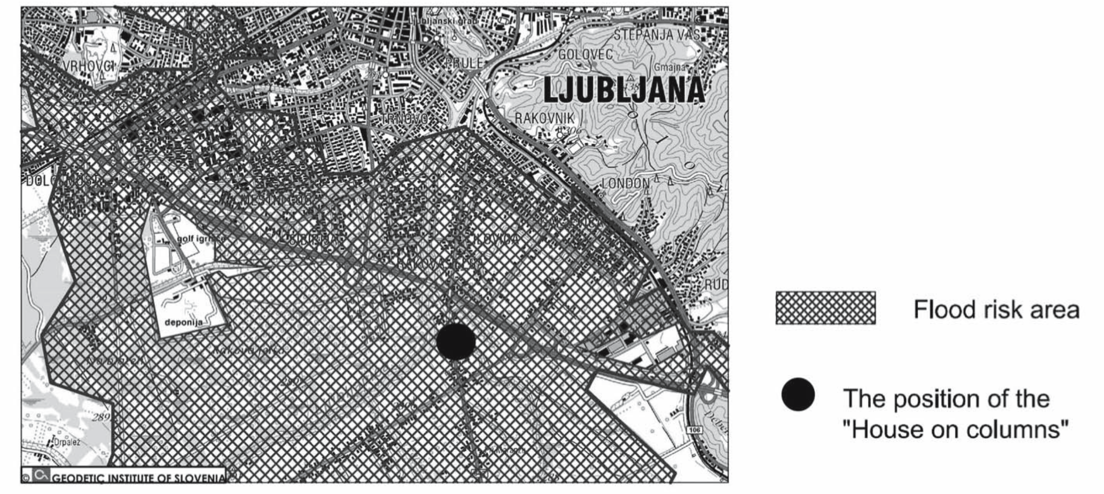

Figure 3. The flood risk of Ljubljana.

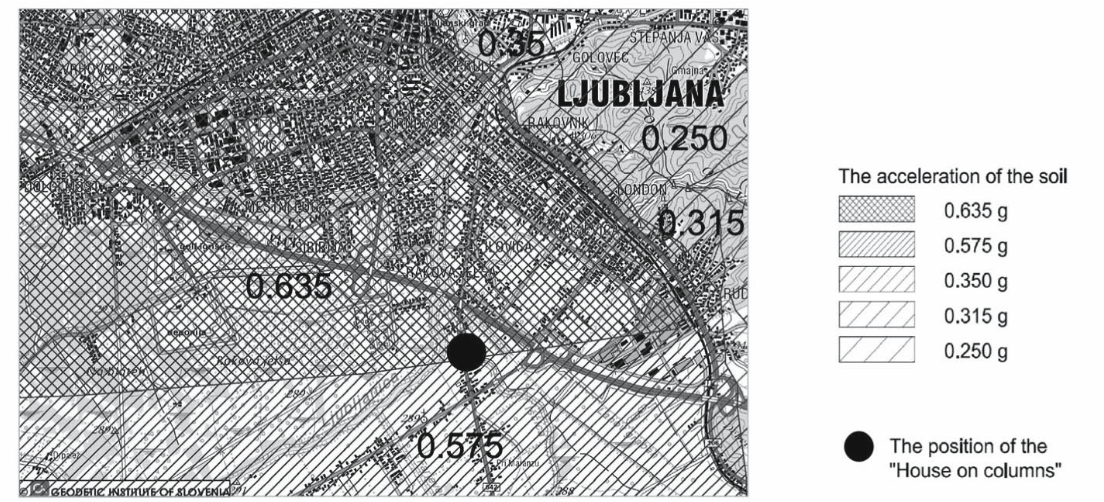

Figure 4. The seismic risk of Ljubljana.

1.2. Residental buildings

The basic purpose of a residential building is to provide inhabitants with suitable housing conditions. Based on historical reasons and tradition, two types of residential buildings were created: single-family (also two-family) houses and multi-family apartment buildings. According to the Surveying and Mapping Authority of the Republic of Slovenia, of the 463029 residential buildings, the majority are single-family houses, namely, 379519 or 81.9 % [14]. This share of such buildings in Slovenia is partially the result of the past social system. Back then it was possible to obtain favourable loans for constructing houses. The construction method was most frequently done by owners themselves according to a standard or partially adjusted (at the request of the investor) standard design. The typical building/house of the time could be described as a multi-storey gabled house made of brick and concrete. The house was built on a building land in accordance with the urban planning and architectural requirements, or not. The main condition for construction was the ownership of the plot where the building was being built. The former authorities for the most part tolerated this situation, and the new government after democratic changes, legalized all these illegal buildings. The legalization was carried out regardless of the fact that some buildings were built on flood-risk areas. This also applies to the settlements in the southern part of Ljubljana. The majority of these buildings were flooded during the 2010 flood (Figure 5). A question arises whether it would be possible to build on these, now already urbanised areas in a way that the damage in the event of a flood would be minimal and at the same time seismically safe, economically acceptable and would enable a quality living environment.

Figure 5. Flooded house on the Ljubljana Marshes.

2. CONSTRUCTING HOUSES ON COLUMNS

Examples of construction of traditional dwellings of some of the peoples in South East Asia show some interesting solutions. In areas where floods are frequent, but where other advantages of the location despite this make it possible to live, one can often see buildings built on columns. There are several advantages of these buildings. In the event of a flood, such a house is namely above water. Besides that, such buildings have a longer service life in damp tropical places. Wood is namely not constantly in touch with the damp soil, but instead with air, and thus rots slower. A raised house is also harder to access by various pests, especially rodents and reptiles. Also, during the time when there are no floods, there is an additional shaded and dry space under the house for various activities. The closest thing to these buildings are said to be the Stone Age pile dwellings on the Ljubljana Marshes and some other lakes of the Alpine area. In the opinion of historians, these buildings were built on piles. A similar solution was used in 2010 by the architects of the Monte Rosa mountain lodge in Switzerland. To ensure better thermal characteristics of the energy self-sustaining lodge, the entire building had to be separated from the permanently frozen ground at an altitude of 2883 m. They built it on a framework made of steel profiles that were anchored with low columns into the rocky base [15]. In this way, the predominantly wooden pre-fabricated building was constructed quickly and simply.

In Slovenia and the wider neighbouring region, construction on columns is not conventional, which is the result of a natural, social, economic and technological situation. Maybe our only indigenous buildings on columns are “kozolci” (hayracks) which are entirely made of wood and are intended for drying and storing hay (Figure 6). Due to this chosen method of storing hay they are made on columns that at the same time serve as part of the drying structure. In residential buildings this method of construction was not used. Due to fire hazards, wooden residential buildings in the past acquired a bad reputation. Only masonry buildings were deemed to be good buildings. Also due to the substantial weight and lack of technology at the time, such buildings could not be built on columns. Instead, people avoided flood risk areas and built their dwellings where the lowlands merged into the hill slopes, and not on the plain itself.

Figure 6. Kozolec (hayrack).

Because Slovenia is located on a seismically very active area, a mind-set developed over the centuries, that only a masonry building is a good building. The structural design of traditional masonry buildings in the greater area of the seismically endangered Mediterranean, from the viewpoint of seismic safety, is relatively beneficial, because the walls are usually thick and evenly arranged in both perpendicular directions [16, 17]. Damage that appears on such buildings is in most cases the result of the inappropriate connection of individual walls and the poor quality of the binding material (mortar). This can be successfully avoided by using modern construction materials and structural details. The classic construction in combination with the requirement for seismic safety thus does not make it possible to build a house on columns in an economically justifiable way. Such a house must above all have a relatively low weight, due to earthquakes. At the same time, the construction of a house on columns, from the perspective of seismic safety, represents a significant risk. The so-called "soft ground floor", when the weight of the entire building is supported only on the columns without suitable wind bracing, generally performs very poorly during earthquakes [18].

a. Background information

The development of various new technological procedures in the last century, especially during the last decade, has enabled a series of various new possibilities for construction, also due to the economic availability of new materials. This also enables a greater freedom for architects, while still complying with all the safety principles. Globalization makes it possible to get to access to solutions of use elsewhere, and the transfer of ideas. Thus, an idea that was unacceptable a few decades ago now becomes acceptable. This also applies to buildings on columns. A few examples of constructing houses on columns are listed below. The first example, by the architect Le Corbusier, is not a complete house on columns, because the ground floor contains a few walls and some rooms, but it is important because it presents the idea of modern construction on columns. The following examples, especially the recent example by John Pardney Architects in contrast, shows the essence of the idea of a house on columns in a flood-risk area. The last example is from the Ljubljana Marshes and proves it is possible to build in the flood and seismic risk area of the southern part of Ljubljana. It serves as an example of adapting to the conditions in Slovenia, and is shown in more detail, due to its affordability.

b. The Savoye house

The Savoye House was designed by the architect Le Corbusier, and was built in 1930 and represents a step towards the use of new principles and materials in residential construction [19]. The lower part contains an open covered parking area and a part for essential rooms. The main residential rooms are located on the floor above. Long horizontal openings enable a direct contact of people with tree tops and other nature surrounding the house. It should also be added that the villa was not constructed as an example of a building in flood-risk areas, but it is an excellent example of a structure that counters the myth of the needlessness and unsuitableness of residential architecture on columns (Figure 7).

Figure 7. Savoye Villa.

c. The Hind house

On the contrary, the Hind house built in 2008 by John Pardney architects, located next to the Loddon river at Wargrave was designed for the flood-risk area, since it was built on columns and is above the ground [20]. The basic concept is based on three elements: life, rest and socializing. The triple nature is reflected in the arrangement of rooms with large wings, which besides sleeping and living rooms and the central hall also include a room for exercise, an apartment for guests and a large terrace. The covered ground floor rooms are intended for parking. The house has a steel frame structure and the facades are covered with wooden and zinc lining. The roof is flat. Large glass windows represent an invisible barrier between the green of the embankment and the interior of the house. It enables the residents and guests an intensive experience and observation of changes in the nature, one of which can also be a flood. During a flood, the house is transformed into a home on the water and no longer a house next to the river (Figure 8).

Figure 8. The Hind house
http://www.mymodernmet.com/profiles/blogs/i-love-this-house-hind-house?context=tag-architecture)

d. Raised house

Houses on columns in the coastal region of the USA, especially Florida are related to the comfort of living on the coast, and the fear of floods. Due to a pleasant climate with plenty of sun, this region is known as a popular destination for the elderly. For the elderly, climbing stairs to the storey where residential rooms are located can be troublesome. This issue is resolved by increasingly cheaper lifts installed into raised houses. Such a house is made in combination of a concrete or steel column frame and a slab and wooden superstructure. An example of such a house is the Raised House built by Naillon Construction. It is built on 8 concrete columns and is raised above the level of flood water. The top part is built as a wooden house and the bottom part serves as a garage. The house replaced a house destroyed in a flood in 2007.

e. Wooden Country Club

The reasons for building a house on columns in Sweden were not floods, but the protection of the wooden structure against the effects of dampness of the ground. The Wooden Country Club building in Örkelljung in Sweden (by Henning Larsen Architects) is a response to the architectural requirements of a building located in a natural environment of a lake in the middle of the woods. These are wooden buildings with many glass surfaces built on columns right next to a lake which is an ideal space for living and observing the picturesque ambience of a golf course.

3. PROJECT OF A “HOUSE ON COLUMNS” ON THE LJUBLJANA MARSHES

a. The Architectural Concept

The “House on columns” was built in 2003 by architects D. and J. Kusar. Characteristic for the location of the building (Figure 9) is the natural marsh region with a flat landscape and rich willows next to drainage ditches. The basic concept of the structure followed the example of the dwellings of old inhabitants of this area who lived in pile dwellings, where instead of ancient canoes there is now enough space to park cars between the columns. The covered ground floor area and the storey are connected together with external single-flight stairs. The residential area has a rectangular layout with external dimensions of 10.24 x 12.7 m and is stands on nine round steel columns. The rooms are sensibly structured and connected according to their purpose and the marginal elements also comply with the structural requirements for low weight (Figure 10). This was made possible only with the use of light but strong materials. In this case, the load-bearing steel frame structure set up on nine round hollow steel columns, the composite plate and wooden roof beams and light partitioning drywalls. The load-bearing structure between the storey and the attic is made of wooden supports fixed to the inserted thermal and sound insulation. Because the entire house is “standing on air” the layer of external thermal insulation also has a suitable thickness (20 - 25 cm) which envelops the entire building.

Figure 9. Picture of the house.

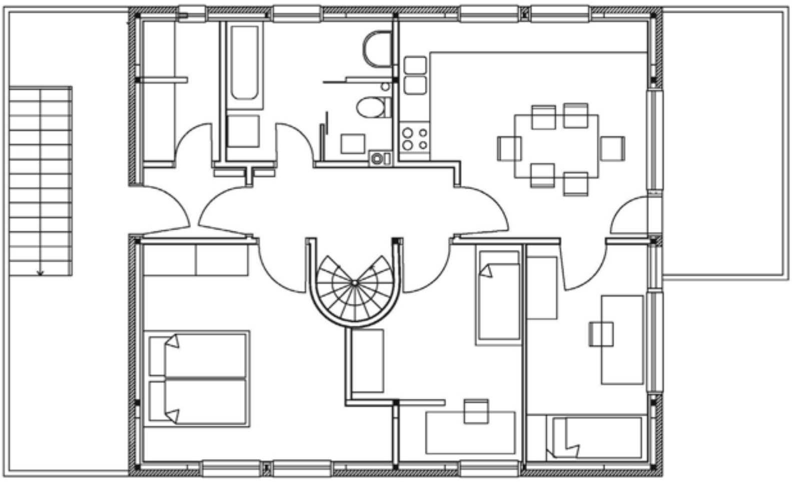

Image 10. House floor plan.

b. Static Evaluation of the "House on columns"

The house on columns was primarily made due to safety against floods. Despite that, it had to comply with today's safety requirements. For flood-risk areas it is characteristic that they, for the most part, do not have good soil for the foundation, but instead a combination of various sediments of clay and loam, an accumulation of gravel sand and river sand, and organic sediments (peat). Together they form a very low bearing capacity foundation soil.

The capacity of the soil is additionally impaired by the seismic risk of the terrain. The expected seismic intensity of the location for the 475 year return period of an earthquake is

VIII on the EMS scale. Taking into account very poor mechanical characteristics of the soil, the acceleration of the soil in the event of an earthquake is 0.635 g (Figure 3) [21]. Combined, this is a poor basis for making quality foundations, then columns and the supporting plate. Thus, a version of the support structure was selected which is founded on wooden piles that bear the load. At the level of terrain, the piles are linked with AB strip foundations into a foundation joist end onto which round, hollow steel columns are installed.

The main structural issue of the building (Figure 11 and 12) is the soft ground floor which is made of a grid of nine steel columns without horizontal wind bracing. The columns with a diameter of 324 mm and with a cover, having a thickness of 6 mm, are fixed to the foundation joist end and the composite plate of the first storey with moment screw joint. The screwing also enables the balancing of eventual differential subsidence as the result of the low bearing capacity soil. The grid of columns is 500 cm in one direction and 570 cm in the other. The main measure with which the dangerous effects of the soft ground floor were reduced is reducing the weight of the building on columns. Thus, a low-energy wooden house was built on the composite panel of the ground floor. By selecting and implementing the combined structure made from different materials, it was possible to achieve a weight of slightly less than 60 tons or approximately 800 kg/m^2. The static calculation of the support structure of the house takes into account additional amplifications of seismic accelerations that are created at the top of the ground floor (the so called "ground floor spectres").

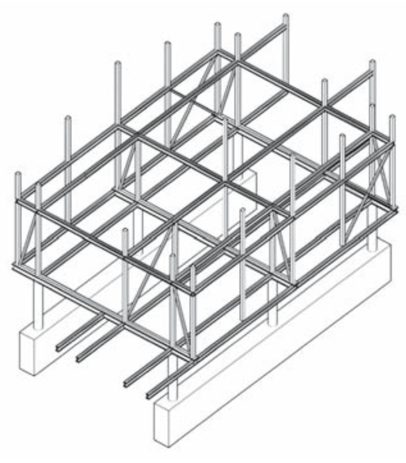

Figure 11. Structure diagram.

Figure 12. Picture of the structure during construction.

c. Economic valuation

Based on the schedule of works, a calculation of the value of construction and craftsman work was also prepared. The price without the purchase of the land, the public utilities charge and internal equipment amounted to approximately 750 EUR/m^2. The actual price was lower due to competitive offers and work that the investor performed by themselves and with the help of relatives. Compared to the real estate prices in Ljubljana that currently on average amount to 1751 EUR/m^2 and the price of comparable land which is approximately 300 EUR/m^2, we can state that such a way of construction does not exceed the price of other houses, or is even lower.

4. CONCLUSION

The flood waters that in 2010 affected the Ljubljana Marshes and the southern part of Ljubljana in the night from the 26th to the 27th of September also flooded the parking space below the house, but the house functioned normally.

The "House on columns", with the possibility of balancing differential subsidence thus provides an alternative to the existing way of thinking about constructing residential houses in flood-risk areas. The structural system of balancing differential subsidence in the heads of the columns is also patented as a structural solution of construction on low bearing capacity soil. It confirms that it is possible to build on less than appropriate locations, if the architecture and the residents' way of living are adapted to the limitations of the location. What is most important is that with the use of available technology and materials, such construction is not any more expensive than normal construction, but it does require a leap in thinking away from the traditional architecture of residential houses. Taking into account the tendencies in thinking toward a rational use of sources, means, energy and especially space, the houses on columns represent an innovative solution for flood-risk areas and new possibilities for construction in such areas. Compared flood protection with dikes to flood protection with buildings on columns, the second has several advantages. It doesn't need additional approvals and permits, major earthworks. Construction may be progressive and therefore cheaper. This is particularly true in the case of dispersed building. At the same time, the water still has enough place under the houses. This is preventing flooding elsewhere. At last, buildings on columns have an important psychological advantage. People, who lived in, are aware of the fact that they can flood, so they are better prepared.

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