

# An Overview of Mushroom Structures in Slovene Structuralism

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**ABSTRACT:** This paper is an overview of mushroom and umbrella structures in Slovenia. It starts with a brief introduction to the development of mushroom and umbrella structures. The main part of the paper describes five selected buildings in Slovenia which are all based upon the idea of a single central column supporting the roof. All of them were built between 1960 and 1971, a decade when Structuralism dominated Slovene architecture. The selection has been made according to their importance for Slovene architecture and therefore the analysis is made from the architectural point of view. At the end, various reasons for their sudden disappearance from Slovene architecture after 1970 are discussed.

## INTRODUCTION

After the Second World War, Functionalism dominated Yugoslav and therefore Slovene architecture until approximately 1960. These were so called "years of reconstruction of the homeland" with the emphasis on building residential and industrial buildings. At that time, Yugoslavia was still a relatively closed socialist society, but Yugoslav and Slovene architects managed to maintain links with trends in international architecture. After all, the last CIAM congress (The 10<sup>th</sup> International Congress of Modern Architecture) was organized in Dubrovnik (now Croatia) in 1956. Slovene architects managed to maintain links with Scandinavian (mostly Swedish and Finnish), Swiss, US, English, and Japan architects (Koselj 1995, pp. 26-29. Dolenc 2003, p. 36).

Later, as a consequence of economic improvement at the end of 1950s, Slovene architecture flourished in 1960s when many Slovene architects started to experiment in various directions. The most important of these new directions in Slovenia became Structuralism. Following the Scandinavian example, it tried to provide architectural solutions for a higher standard of living and more human architecture by bringing "a period of new sensitivity" (Dolenc 2003, p. 37). One important group of experiments introduced mushroom and umbrella structures to Slovene architecture.

To clarify the terminology the paper starts with a brief overview of the development of these structures. The core of the paper starts with a section containing 5 selected case studies, each of them representing one mushroom or umbrella structure designed by a Slovene architect. An analysis of the selected case studies is made from the historical perspective with the emphasis on the architect's point of view. At the end, some general observations about mushroom and umbrella structures in Slovenia are given.

## THE DEVELOPMENT OF THE MUSHROOM AND UMBRELLA STRUCTURES

As the mushroom and umbrella structures can be found in literature by many different names (Scott 1991, p. 287), a short historic overview of the development of these two kinds of structures seems to be appropriate. The clarification of both terms, namely a mushroom and umbrella structure, will be provided along the overview.

The development of these two structures started when Cluade A. P. Turner patented his "mushroom column system of flat-slab construct" in 1905 (RIHPHC 1981). Soon afterwards, in 1910, Swiss engineer Robert Maillart

(Billington 1991, Billington 1997) designed the first mushroom ceiling in Europe. He designed columns with mushroom-shaped tops to support floor-slabs. This structure is also called "beamless flooring" or "mushroom flooring" (Giedion 1967, p. 452).

In 1936-39, Frank Lloyd Wright designed tubular mushroom column upon which a glass ceiling was placed (Johnson Wax Administration Building, Wisconsin, USA). The diameter of each column was 23 cm at the bottom of the column and 550 cm at the top (where it expanded in a mushroom like form). It could be mentioned as a curiosity that many doubted such a column can bear 12 tons. However, when experimentally tested, a load of 60 tons (5 times of what was required) had to be used to overload the column (Giedion 1967, p. 422).

The first umbrella structures made entirely of one material were designed and tested by Felix Candela (Faber 1963). The first prototype was made in 1952 of reinforced concrete. It was a mushroom structure shaped by four hypar tympanans. Measuring 10 m by 10 m, the roof shell rose a little more than 90 cm and was 3.8 cm thick. Deflections of about 5 cm observed at the corners were attributed to the insufficient rise of 90 cm. Additionally, the structure exhibited a tendency to flutter in the wind (Faber 1963, p. 62). Another prototype from 1953 is shown in Fig. 1.



Figure 1: An experimental umbrella structure designed by Candela in 1953; (Faber 1963, p. 63)

Although mushroom and umbrella structures do not represent the mainstream in structure development, they have been never fully abandoned. On the contrary, one should just remember Palazzo del Lavoro, Turin 1961, by Pier Luigi Nervi (Sharp 1972, p. 245), EXPO roof, Hanover 2000, by Thomas Herzog (Herzog 1998, pp. 375-377; Natterer 1998, pp. 377-387), or Oriente Station, Lisbon 1998, by Santiago Calatrava (Tzonis 2007).

To conclude, the mushroom or umbrella structures are type inverted pendulum structures. More specifically, they are cantilever structures: a beam supported on one end only. The vertical beam (in this case a column) carries the load to the foundations where it is resisted by the moment and shear stress. More than 50% of the mass of the entire structure belongs to the upper part of the structure (Slak; Kilar, 2005b, p. 50; Kušar 1999, p. 91).

Thus, the basic structural scheme of mushroom or umbrella structure consists of a roof and only one column. It depends of the type of the roof whether the structure is a mushroom or an umbrella structure. The main difference between mushroom and umbrella structures is that a mushroom structure is beamless and therefore uniform while the umbrella structure consists of beams attached to the central column.

## CASE STUDIES: FIVE SELECTED MUSHROOM OR UMBRELLA STRUCTURES IN SLOVENIA

At the beginning of the sixties, a new generation of architects appeared in Slovene architecture (Slivnik; Kušar 2006a). They were all young and educated after the Second World War. Many of them graduated in the class of Edvard Ravnikar, one of the most prolific architects of Slovene postwar architecture and by any means the most influential Slovene architect in the second half of the twentieth century. The circle of his disciples is sometimes regarded as Ravnikar's School or Ljubljana School of architecture. The most important members are Savin Sever, Milan Mihelič, Stanko Kristl, and Ilija Arnautović.

### Šlajmer: Jurček Pavilion

The first mushroom construction in Slovenia, namely Jurček Pavilion at Ljubljana Exhibition Centre, was built in 1960 (Šlajmer 1960). It was designed by another Ravnikar's student, architect Marko Šlajmer and structural engineer Ivo Vodopivec. The building, named after the boletus mushroom (Jurček in Slovene), has circular ground floor of 500 m<sup>2</sup>, the reinforced concrete mushroom construction with a 6 m high pillar supporting the roof of 27 m in diameter, and a prefabricated fully glazed façade wall placed in an aluminium profile. The pavilion, build in 5 months only, is situated close to the main street thus making an appearance of a large exposition window (Ravnikar et al. 2000, p. 17).

The transparent façade of Jurček pavilion was an important novelty in Slovene architecture. Firstly, it introduced a new concept of a completely transparent building to Slovene architecture. Secondly, it exposed the iridescence between inner and outer space not familiar in Slovenia before.

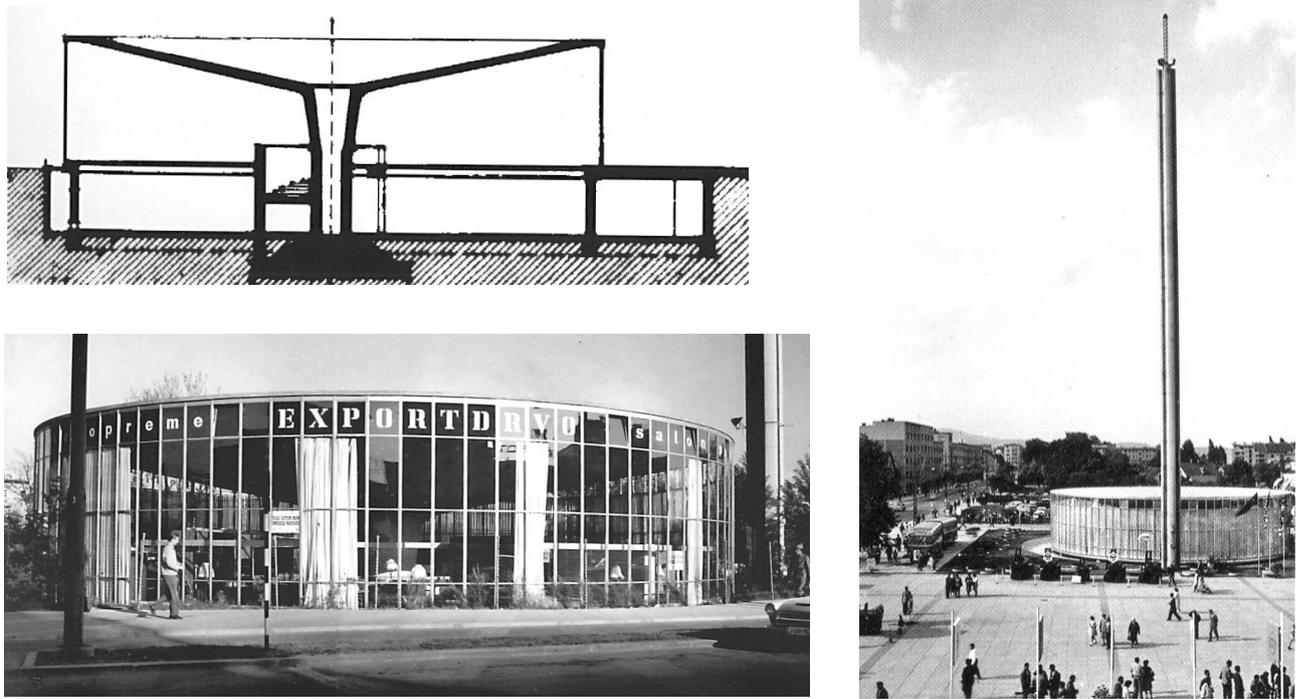


Figure 2: Jurček Pavilion, Ljubljana, by Marko Šljajmer (1960), a cross-section (above left) and a view of the façade (below left); (Koselj 1993, p. 79), and a situation (right); (Vodopivec 2008, p. 69)

Just a few years earlier, Šljajmer designed the first prefabricated steel building in Slovenia (also at Ljubljana Exhibition Centre in 1958). By designing Jurček pavilion Marko Šljajmer established himself as one of the most innovative architects of his generation.

#### Mihelič: Pavilion C

The Pavilion C of 1965-67 at Ljubljana Exhibition Centre was designed by a team of architect Milan Mihelič and structural engineer Jože Jaklič (Bernik 1980, pp. 36-39; Slivnik; Kušar 2006b, pp. 36-37). The design, influenced by Japanese Metabolist movement, incorporates the idea of an adjustable construction which can be assembled in various ways.

The pavilion is built of four elements and is the only part of the larger area supposed to be made of 26 elements. Each element is a reinforced concrete umbrella construction made of a 6 m high pillar that supports an octagonal roof with a side of 22 m.

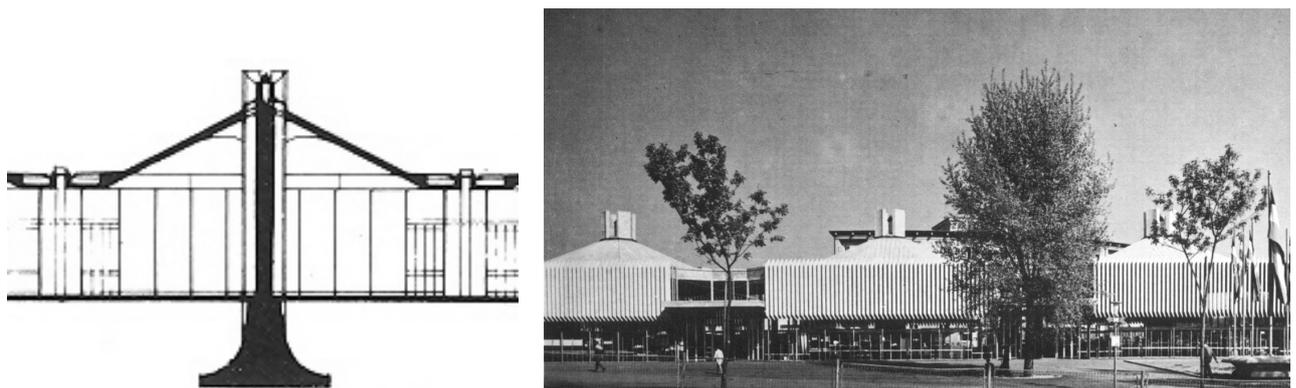


Figure 3: Pavilion C, Ljubljana, by Milan Mihelič (1965-67), a (part of the) cross-section (left) and a view of the façade (right); (Bernik 1980, pp. 36,38)

It is appropriate to compare Pavilion C with WeeGee building in Espoo, Finland, (former Weilin & Göös printing works) designed by Aarno Ruusuvuori in 1963-64 and 1967-71 (Tempel 1968, pp. 94-95). The most important characteristic of WeeGee buildings is its umbrella structure. Initially the building consisted of 4 units. In 1967 the building was extended by 4 units equal to the four existing units, and in 1971 two more units of a different (and much less impressive) design were added by Bertil Ekengren. The roof of each individual unit hangs from a thick central pillar (one per each unit), resting on diagonal beams.

Apart from the fact that they were built almost simultaneously, there is a deep similarity between the structures, dimensions, and materials. Both buildings were designed as reinforced concrete umbrella structures with a span of a single element measuring either 22 m (Pavilion C) or 27 m (WeeGee building). The decision for using the umbrella structure was based on the same requirement in both cases as well: the exhibition hall and the printing process both require as much open floor space as possible. Finally, WeeGee building was converted to a museum in 2006 thus bringing the usage of both buildings even closer together.

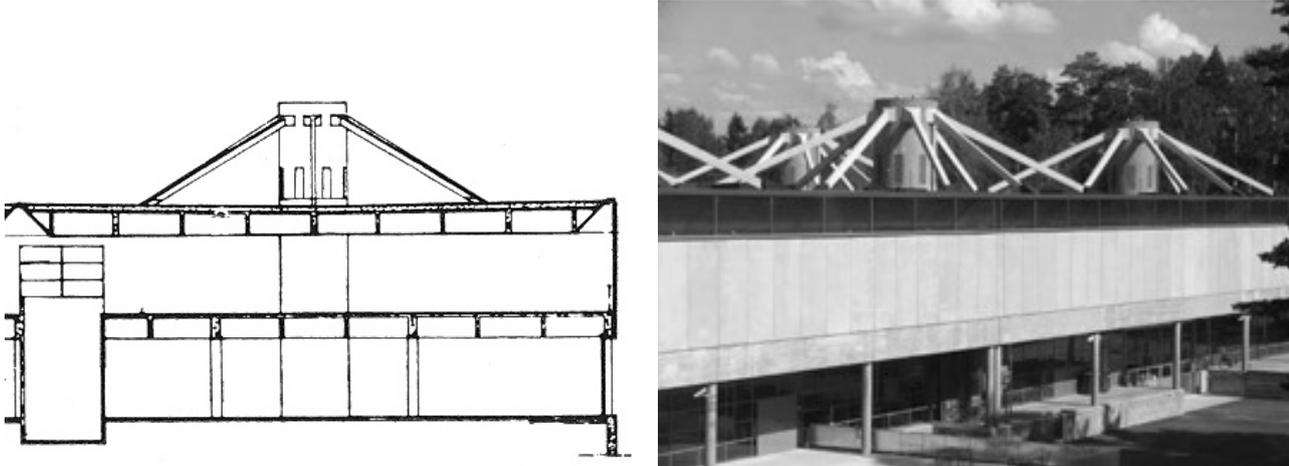


Figure 4: WeeGee building, Espoo, by Aarno Ruusuvouri (1963-64), a cross-section (left) and a view of the façade (right); (Tempel 1968, p. 68; Betoni 2008)

Although the initial part of WeeGee building was built one year before Pavilion C, there is no evidence whether the design of WeeGee building was known to Milan Mihelič or not.

As a curiosity, let us mention that Italian architect Alberto Mambriani found an architectural similarity between Pavilion C and chimneys of the kitchen of Topkapi Palace, Istanbul, which was built around 1459. In his book *Architettura Moderna nei paesi Balcanici* he has given the following observation:

Nei paesi balcanici sembra che l'opera piú ambientata anche con la "tradizione" turca in questa libera interpretazione del termine, ci sia data da Lubiana che fra tutte le citt`a balcaniche ha meno risentito dell'influsso ottomano. Nel padiglione della Fiera di Lubiana (foto -) `e stato applicato lo stesso processo compositivo delle cucine di Topkapi a Istanbul: (foto -). Elementi seriali si esprimono nelle coperture degli edifici pur con diversit`a funzionali e di materiale. Essi sono comuni all'architettura che viene dalla tradizione, come a quella che crede in una raffinata tecnologia accompagnata da una salda poetica architettonica. (Mambriani 1970, p. 189)



Figure 5: Chimneys of the kitchen of Tokapi Palace, Istanbul, 1459; (GWC 2008)

He claims that by Pavilion C Ljubljana offers the best example of Turkish, or Ottoman, tradition ("in a more relaxed interpretation" of the term tradition, as he puts it) despite the fact that Ljubljana was the least influenced by Turkish architecture (and influence in general) among all Balkan cities. However, he focuses on comparing the composition of both buildings and, as an architect, completely misses both the difference in the structure, materials, and dimensions of Pavilion C and Turkish chimneys.

Mambriani, however, was not the only author who had problems with Pavilion C. Slovene art historian Stane Bernik described it in his book on Slovene architecture of the 20<sup>th</sup> century twice, each time differently. The first time he describes it "as spreading in all directions, with an umbrella construction, glass walls and concrete ar-

ticulated cover”(Bernik 2004; p. 318). But the second time he describes its basic unit as “formed by a reinforced concrete pillar that supports the mushroom octagonal roof...” (Bernik 2004; p. 360).

### Mihelič: Gas station

The same team, namely Mihelič and Jaklič, designed a gas station built in Ljubljana in 1967-68 (Bernik 1980, p. 66-69; NN 1970b, pp. 36-37). The structure of the building is a 7.1 m high reinforced concrete mushroom construction with an umbrella like square roof with a side of 19.2 m. More precisely, a single rib column supports the roof via diagonal beams. At each side of the roof, there is concrete block bearing the logo of Slovene oil company Petrol.

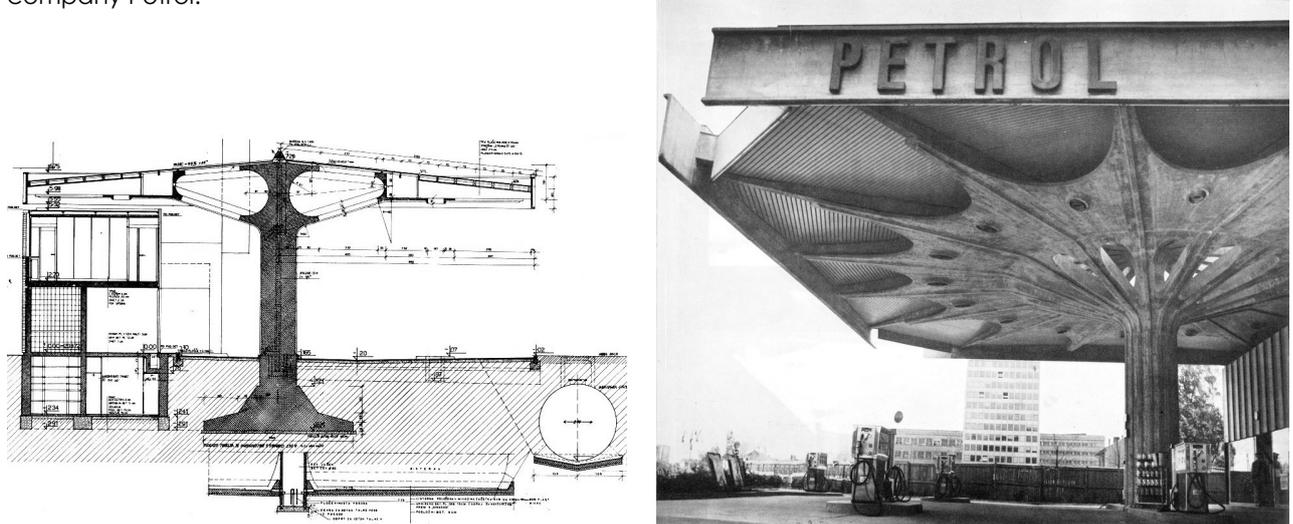


Figure 6: Gas Station, Ljubljana, by Milan Mihelič (1967-68), a cross-section (left) and a view of the façade (right); (NN 1970b, pp. 36,35)

As shown in Fig. 6 (right), the umbrella structure shows clear signs of artistic, or almost sculptural, design (Bernik 1980, p. 68). Unfortunately, only one gas station of this kind was ever built. Today it stands abandoned and is overshadowed by numerous new buildings which have been built later.

The design of this particular gas station was presented in a German journal *Bauwelt* and thus represents one of the very few buildings of Slovene postwar architecture made known abroad (NN 1970a, p. 1712).

### Ravnikar: Gas station

Another gas station built in 1968-69 was designed by Edvard Ravnikar, the most significant and influential Slovene modernist architect. It stands just across the street from the gas station designed by Mihelič and described above. Contrary to its neighbour, it has been completely renovated in 1990s and is still in use.

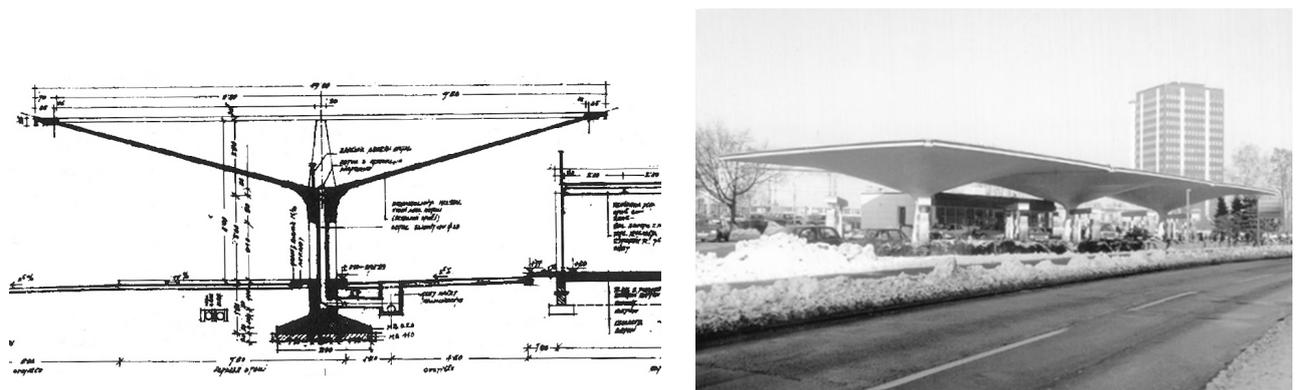


Figure 7: Gas station, Ljubljana, by Edvard Ravnikar (1968-69), a cross-section (left) and a view of the façade (right); (Koselj 1993, p. 70; Ravnikar et al 2000, p. 22)

Apart from the small service cubicle, the building consists of three separate identical reinforced concrete mushroom structures, each made of 3 m high reinforced concrete pillar that supports the mushroom square roof with a side of 19 m (Ravnikar et al. 2000, p. 22).

Ravnikar's design of a gas station outlived the decade of Slovene Structuralist experiments. Norman Foster, for instance, designed a gas station which is quite similar to Ravnikar's station from the architectural point of view. However, instead of designing a single gas station, Foster designed a highly flexible solution of a modular canopy system. This system can be used to build a number of different yet similar gas stations, each of them suited

for a configuration of each particular site. This is important as more than 200 sites around Spain and Portugal were planned by oil company Repsol which commissioned the project.



Figure 8: Repsol gas station by Norman Foster; (Flickr 2007)

The Forster+Partners webpage gives a short description of the construction:

Clusters of these structures form overlapping umbrellas sheltering each station forecourt. The canopy head is an inverted pyramid, its crisp edges balanced by the less emphatic lines of the cladding. The umbrellas vary in number, height and in the degree of overlap between them, according to the size and specifics of each site. The associated shop unit, car wash, petrol pumps and signage elements all belong to a related family of pure, box-like forms. ... All these lightweight elements are factory made and easily transported and installed on site, providing cost benefits while ensuring consistently high quality standards and rapid delivery. (F+P 2008)

Clearly both Ravnikar and Foster followed the form introduced by Candela. But as it cannot be proved that Mihelič knew of GeeWee building, Foster most likely wasn't even aware of Ravnikar's design. However, it is interesting that although they used different materials, Foster came up with the same architectural form for the same type of building in 1997 as Ravnikar did 30 years earlier.

### Sever: Exhibition ground Kranj

The largest exhibition ground in Slovenia was planned in the industrial town of Kranj. The entire project was designed by Savin Sever, whose principal architectural expression is centered on the innovative use of prefabricated structures and thus makes him the most suitable architect for designing buildings in the industrial environment.

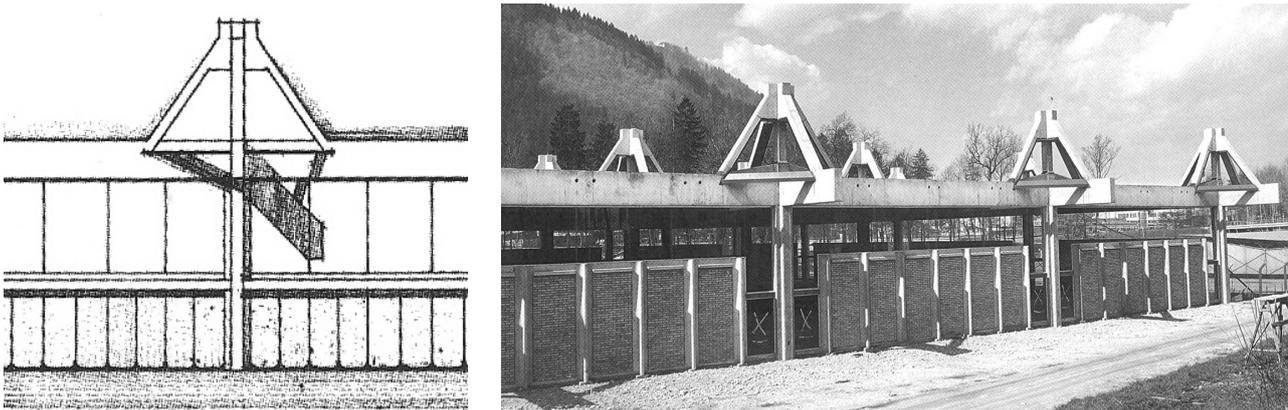


Figure 9: Exhibition ground Kranj by Savin Sever (1969-71), a façade (left) and a view (right); (Dolenec 2003, p. 104; Sever 1973, p. 82)

The basic unit of the main building was a 10.9 m high reinforced concrete umbrella construction with a square roof of 16 m by 16 m. The main building was planned to be built in several phases, adding groups of basic units from time to time as needed (Sever 1973, pp. 81–84). Unfortunately, only 30 umbrella structures, representing less than a half of all planned to be built in the first phase, were built during 1969-71, plans were not fully respected, and the building was destroyed in 2002 (Dolenec 2003, p. 102).

## CONCLUSION

Mushroom and umbrella structures became quite popular in Slovene architecture in 1960s, but afterwards no significant structure of this kind has been built in Slovenia. There are several reasons for this.

Firstly, all major Slovene construction companies has been predominantly oriented in construction of buildings made of reinforced concrete - all important structures, including all major public buildings and motorway bridges in Slovenia, are made of reinforced concrete, almost none is made of steel. However, it has been established through the years that the reinforced concrete is not a material most suitable for these structures (Zajc 1997). Due to the economic stagnation in 1970s, no advanced materials needed for further innovations could be neither produced in Yugoslavia nor imported from abroad – but recently designed mushroom and umbrella structures are made mostly using other materials including wood (EXPO roof by Herzog), steel and glass (Oriente Station by Calatrava), or other lightweight materials (Repsol gas station by Foster).

Secondly, many Slovene architects avoided mushroom as well as other advanced structures in the seventies since those designed in the sixties were too often badly produced (Dolenec 2003, p. 102). As a result, Structuralism in Slovenia gave way to Postmodernism.

Thirdly, mushroom and umbrella structures should be produced from prefabricated elements. But back in 1970s, Yugoslav market was relatively closed and too small for production of quality prefabricated concrete elements for this kind of structures.

And finally, the two earthquakes, the first near Skopje, now in FYROM, in 1963 and the second in Furlania, Italy, in 1976, triggered the introduction of much higher safety standards of earthquake-resistant design in former Yugoslavia (Slak; Kilar 2005b, pp. 52-53). And as more than 50% of the mass of a mushroom or umbrella structure resides in the upper half of the building, these structures were not considered appropriate in terms of earthquake-resistance.

But nevertheless, Ravnikar's School introduced some important new concepts to Slovene architecture in 1960s. Namely, the material most of the important works were made of in Slovenia from 1960 to 1971, is exposed concrete. This was the time of Brutalism in England where architects used raw concrete. But Slovene architects preferred more human architecture demonstrated by contemporary Scandinavian architecture. They were especially influenced by Alvar Aalto and Finish architecture in general which they became familiar with at the exhibition of Finnish architecture in Belgrade in 1959. Finish architecture with its mixture of rational and functional on one hand and of irrational and organic on the other hand, suited Slovene architects well.

Structuralism, influenced by Western and especially Finnish architecture, was the most important movement in Slovene architecture in the sixties. Three important characteristics of the architectural expression at Ljubljana School of Architecture at that time can be observed from the aforementioned case studies: exposition of the construction, inclusion of the structure into the composition of a façade or a roof, and careful handling of details.

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