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FLAT ROOF – ADVANTAGE OR DISADVANTAGE OF MODERN MOVEMENT BUILDINGS

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Abstract. *Flat roofs have been built a long time before the Modern Movement appeared in architecture. But it is the twenties and thirties of 20th century when a lot of difficulties with flat roofs and roof top gardens became visible. Flat roof was mercilessly criticized as an impractical and harmful extravagance once the first cracks appeared. The flat roof with minimum slope of about 1-3% hat to fulfill three different functions: structural, waterproofing and insulating plus occasionally working as additional floor – as a roof garden. Model Werkbund estates became the manifestation of Modern Movement in Europe. Architects introduced new materials and new technical solutions to test them in difficult climatic condition. The technical defects appeared a few years after the construction was completed. This could hardly have been avoided because new materials were not always used properly or skillfully. "Wood-cement" roof, "Gravel" roof, "Metal" roof, "Ruberoid" roof, "Paste" roof, Asphalt roof, Torket or Ceresit roofs were used but not always successfully. Today we face a difficult revaluation problem with interwar buildings which belong to avant-garde of the 20s and 30s. The goal of a future presentation based on this abstract will be demonstration of technical defects of Modern Movement flat roofs and the solution of their reparation. The authors of this paper, being involved in conservation, among others, of Hans Scharoun and Emil Lange buildings belonging to model Werkbund estate in Wroclaw (former Breslau), had to resolve the roof defects which appeared before and after the WW II. These buildings are listed on the register of historic monuments what means that not only their form is protected but also building materials and techniques, that is why the proper choice of renovation solution can preserve aesthetics of pre-war avant-garde architecture.*

1 INTRODUCTION

Flat roof, as we understand it today, is the last floor's ceiling functioning as the building's roof. It was widely used in construction since the 1920s. Various examples of that kind of constructions were known since the antiquity in the Mediterranean Region, Africa and Asia. In less hospitable, rainy climate, pitched roofs were used almost exclusively. It continued until the Renaissance, when less sloped roofs have been introduced to northern Europe. It drew inspiration from the Antiquity. In 19th century residential buildings flat roofs were commonly used, mainly in urban environment. It was influenced by the construction law introduced at that time. In the half of the 19th century the acts were initiated in the main cities of Prussia (e.g. Berlin, Breslau) that regulated the method of defining the apartment houses height. It was measured from the pavement level to the crown molding, to the bending edge in mansard roof or to the ridge level in gable roof. Consequently, the use of flat roof allowed constructing the highest number of apartment floors in the regulated height of the building. That certain solution was also dictated by the relatively low costs. Flat roof structure required much less wood than a pitched roof. It was also much lighter.

In 19th century the roof structures were constructed almost exclusively from wood. That changed with the coming of the 20th century. Flat roof became one of the characteristics of the modern architecture, with its precursors even before the First World War. A desire to adapt the form of architecture to the new needs, new materials and industrial methods caused the widespread use of the flat roof structure.

The new style characterized by simple forms and minimal decorations seemed ideal for the anonymous customer and mass methods production. Form was not considered to be an aim in itself, but a synthesis of customer's needs and technical and production capabilities. Such statements were made by architects of the European avant-garde, who called themselves functionalists.

The emerging of a new architectural style “was the doubtless influence of engineers constructing, logically and with simplicity, monumental steamers, grain elevators, bridges, cars, and airplanes, completely free of style embellishments and still imposing luxury and elegance” [1]. The sources of the new style in engineered structures where function was defined by form pointed to the influence of the Cubists and Abstractionists who portray beauty through the play of masses and values, as well as by the architects whose attitudes and social concerns were on alleviating acute postwar housing shortages and the sequential production of comfortable housing. As the predecessor of the “New Spirit” Frank Loyd Wright, August Perret, Tonny Garnier, Peter Behrens, Hans Poelzig and Hendrik Petrus Berlage were pointed [1].

Houses designed for various housing estates, by architects from different countries were so similar that the term "international style" was coined to name it. [2].

The flat roof with a minimum slope of about 3% had to fulfill three functions: constructional, waterproofing and insulating plus occasionally working as a roof garden.

Constructing a roof garden was a special challenge for the architects of Modern Movement. The construction of flat roofs proved to be difficult from the start. The problems lied not in the construction itself but in complications with proper water insulation.

Manifestations of the new solutions in residential architecture were experimental model Werkbund estates built in Germany, Austria, Switzerland and Czechoslovakia in the 5 years period. They flared up the discussion about the preference of either a pitched or a flat roof. In Berlin Zehlendorf e.g, traditional („Fischtalgrund” erected in 1928-29 by GAGFAH under Heinrich Tessenow supervision) and modern („Onkel Tom” – Waldsiedlung Zehlendorf, erected in 1926-32 by GEHAG, designed by Bruno Taut, Otto Rudolf Salvisberg and Hugo

Häring) dwelling estates were built next to each other and caused so called "Zehlendorf roof war" („Zehlendorfer Dächerkrieg") [3,4].

Walter Gropius and the Bauhaus architectural office with financial support of the German government's experimental program of the RFG ("Reichsforschungsgesellschaft für Wirtschaftlichkeit im Bau- und Wohnungswesen" – Imperial Research Society for Cost-Efficiency in Building and Housing) were working on many different methods for constructing a flat roof.

In 1926 a Bauhaus interview initiated by Walter Gropius about "technical feasibility of flat roofs and roof gardens discussion was published in several issues of the German review "Bauwelt". One of questions was: "With today's knowledge in building construction, do you think that it is possible to construct an absolutely waterproof flat roof?" Dutch architect J.J.P. Oud answered: "The technical basis of what we as architects want to create is still not developed at all" [5,6]. It shows how difficult it was, in interwar period, to build the proper roof from the technical point of view. Construction methods of that time were published in E.J. Siedler's book in 1932 entitled "Die Lehre vom neuen Bauen" (table No. X and XI), which was very important for Modern Movement designers [7]. The more frequent usage of flat roof in the twenties led to numerous patents and the development of many new forms of construction. The increased use of materials such as pumice and reinforced concrete, flat roofs in timber construction came to play a less significant role [8].

E.J. Siedler published different types of flat roofs of the construction made of wood or concrete. The author showed different construction methods for flat roofs that had been built between 1926-1929. Three years later Siedler came to the conclusion that most of the built flat roofs in Germany did not work very well.

He pointed out the "wood-cement" (Holzzement) roof as a prototype of later flat roof construction. "Wood-cement" roof was introduced in Germany in the 1870-80's, when it became technically possible to construct waterproofing out of roofing felt upon lagging on wooden beams. Minimum three layers of roofing felt were covered for UV-protection with a minimum of 10 cm sand or gravel [6].

The "gravel" roof, shown also by Siedler, was quite popular in Germany in the 1920's. It was the attempt to postpone UV-lighting and aging of the roofing felt. Several layers of roofing felt were painted with mastic, the last one covered with pressed-in silver-gray gravel that prevented the surface from drying out. This was a typical construction in the Frankfurt dwelling estates designed among others by Ernst May [6].

In Frankfurt settlements flat roof was also covered with metal sheets on shuttering above wooden beams as well as on in-situ concrete slabs. The insulation layer was cork or Torfoleum. This caused tensions within the construction with the changes of temperature and led to cracks as a result. Ernst May recommended a number of movement joints to avoid cracks.

The popular at the time "Ruberoid" roof consisted of two or three layers of asphalt-roofing felt stuck with mastic glue in wooden lagging.

Siedler defined "past" roof as roof-mastic consisting of bituminous substances such as bituminous coal tar (Steinkohlenteer), petrol bitumen or rubber-oil. Several layers of such pastes (e.g. "Durumfix" or "Awegit" roofing paste in Germany) with a dividing layer of bitumen roofing felt have been used on shuttering and wooden beams or on a leveling concrete screed on a in-situ concrete slab. This leveling concrete screed could also be made from 4 cm sloped cement flooring on cork as insulation layer or on pumice or furnace cinder concrete [6].

"Asphalt" roof was used as a natural asphalt layer of about 2 cm on a Torfoleum layer.

In the model Werkbund estate build in Wroclaw (former Breslau) in 1929 as a part of the exhibition entitled "Dwelling and Work Space" (Wohnung und Werkraum Ausstellung - WuWA) peculiar features were flat roofs with roof-top garden terraces.

Eleven Breslau architects introduced new constructions of the flat roofs in experimental model houses. At that time the flat roof presented a major challenge, not so much structural as involving damp insulation and drainage. A very popular roof covering was Ruberoid, a kind of tar board that had already been used for 35 years, and a range of similar materials (Pappoleina, Tropical and Rexitekt). It could be applied directly on a concrete surface or wooden planking. It was available in three colours: grey, red and green. As thermo insulations materials Celotex, Torfoleum, Heraklith, cork plates were used [9]. It must be mentioned that there was no obligatory thermal insulation layer within flat roofs.

The materials were tested against the vagaries of the local climate, high air humidity in the fall and spring, low temperatures in the winter and high day-to-night amplitudes. Structural defects appeared only three years after the buildings' completion, as recorded by a commentator writing for Ostdeutsche Bau-Zeitung Breslau. They were mercilessly criticized as an impractical and harmful extravagance [10].

Figure 1: The flat roof of the multifamily house designed by Mies van der Rohe, Weissenhof model Werkbund dwelling estate built in Stuttgart in 1927, roof renovation in the 1980's. Phot. J.Urbanik, 2012.

Now we face a very difficult problem with proper building renovation. In Modern Movement dwelling houses, even if on the roof garden the proper slab roof construction was applied after renovation (inverted flat roof– concrete slabs arranged on sand), the space between the slabs filled with organic remains that created favorable conditions for weeds to grow

which destroy the terrace. Such problems appeared in Le Corbusier's building in Weissenhof housing estate as well as in Tugendhat's house in Brno [11,12] and in Wienna Werkbund estates houses etc.

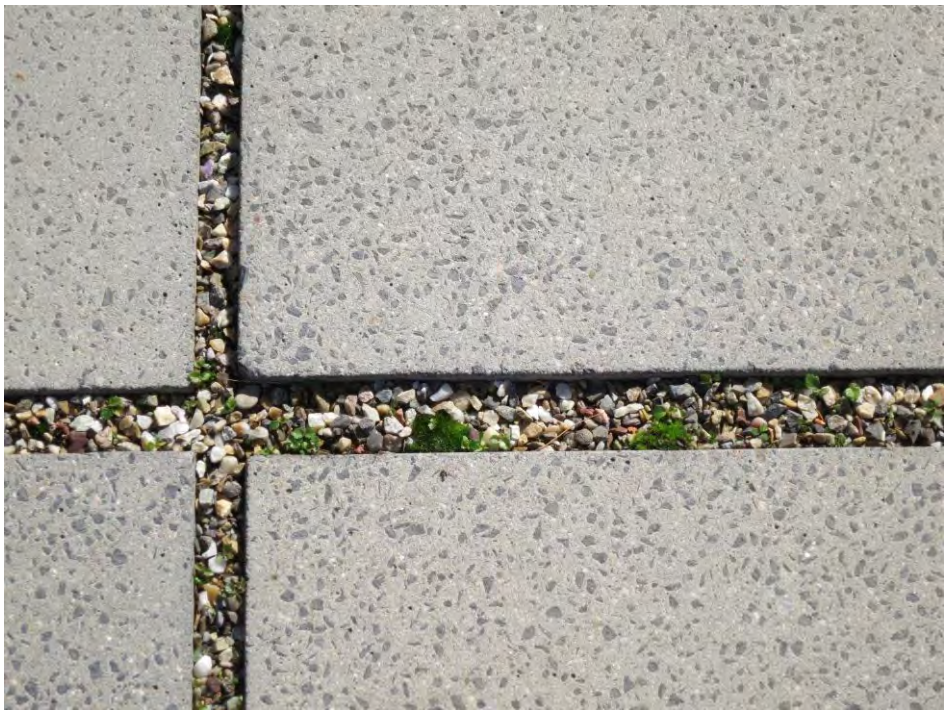

Figure 2: The flat roof of the semidetached house designed by Le Corbusier, Weissenhof model Werkbund dwelling estate built in Stuttgart in 1927, roof renovation in the beginning of the XXI century. Phot. J.Urbanik, 2012.

Figure 3: The flat roof of one family house designed by Josef Hoffmann, Wienna model Werkbund dwelling estate built in 1932, roof renovation in the beginning of the XXI century. Phot. J.Urbanik, 2012.

2 MULTIFAMILY HOUSE DESIGNED BY HANS SCHAROUN

2.1 Renovation and reconstruction of the roof top gardens in the left wing and middle part of the building

For the model experimental WuWA estate Scharoun designed house for single people and childless couples. He proposed recreation terraces with big concrete containers and steel construction for creepers on the flat roofs.

Flat roofs, used as gardens were included in the 5 rules of modern architecture propagated by Le Corbusier. In such instances special attention should have been used for its covering and drainage.

In Scharoun's building in 1993 in its middle part, the renovation of the terrace and its roofing from the garden side was carried out. The technical expert opinion on the floor, proved a perfect preservation not only of the concrete slab roof construction parts but also roofing felt insulation on pitch and two layers of pressed tar, one of them reinforced with wood (2cm and 1.5cm thick). Damages such as moistness in the hall interior were caused by wrongly made elements of terrace drainage while damages of the floor insulation in place of its contact with the building wall (during wrongly made renovations).

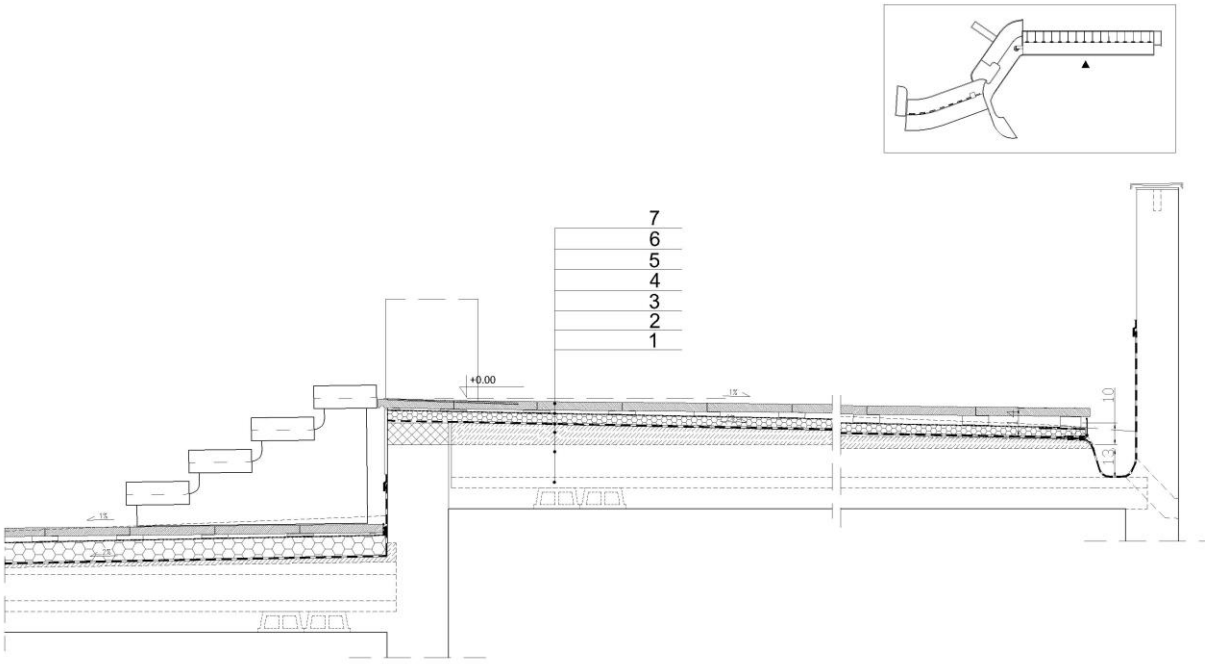

Figure 4: Multifamily house (former building for childless couples and single people) designed by Hans Scharoun, WuWA model Werkbund estate built in Wroclaw (former Breslau) in 1929. Section of left wing roof garden (renovation proposal):1 – original roof construction (Ackermann blocks 10 cm high), 2 – joint less floor 3-9 cm thick (Cerinol FM, Dietermann) on joining layer (Cerinol ZH), 3 - water insulation membrane EPDM (1.14 mm Firestone), 4 – insulation fibre, 5 - insulation level Styrodur 10 cm thick, 6 – insulation fibre,7 - concrete slabs 40 cm x 80 cm x 5 cm. Drawn by A.Tomaszewicz.

After removing a layer of post-war terrazzo from the terrace, the declivities were adjusted by adding a layer of concrete with light expanded clay aggregate. The use of traditional slab roof technology, elevation of the terrace level and its additional loading did not make the surface reconstruction from concrete slabs possible. That's why grit tiles 40x40cm were used. Materials available at the beginning of the 20th century (e.g. roofing felt, light expanded clay

aggregate, concrete screed) did not improve the thermal insulation nor guaranteed long durability of terrace covering. Materials available at that time, not resembling the originals were used what caused esthetical and technological fiasco.

Constantly expanding moistness made next off hacking in 2011 necessary. The presence of water in a concrete layer adjusting declivities was found. Floor moistness in the hall was also caused by leakage in the place of channeling water from the terrace into conductor heads.

In 2011 new renovation and conversion design of slab roofs of the left and middle wings on which recreation terraces were designed, were realized [13, 14].

During the reconstruction works the tests have been performed. They revealed original layers of the flat roof construction and also additional layers that joined them after the World War II. Overall good condition of the roof was ascertained, both from the inside and outside.

According to the architectural documentation from the 1929 the flat roof was constructed using - 10 cm high Ackermann blocks; leveling layer 5 cm thick; insulation 10 cm thick; protective concrete 3 cm thick; slag concrete 2-4 cm thick; concrete slabs 5 cm thick.

It was originally paved with rough concrete slabs measuring 40 cm x 80 cm reassembling brickwork. Between the slabs and the outer fencing (overlooking Dembowskiego street and garden) the gutter, insulated with bituminous material and probably roofing felt was placed. Rainwater from that part was channeled at three points: at the beginning of the terrace, in the 1/3 and 2/3 of the wing's length (drain pipe and conductor heads).

The concrete pavement tiles have been probably removed during many renovation works, both pre and post-war.

Figure 5: Multifamily house (former building for childless couples and single people) designed by Hans Scharoun, WuWA model Werkbund estate built in Wroclaw (former Breslau) in 1929. Roof recreation terrace of left wing during the last renovation - pavement slabs 40 x 80 cm, 4 cm thick (reinforced concrete). Phot. J.Urbanik, 2013.

The pavement tiles have been removed, probably following some damage, and replaced by a slag layer and roofing felt. The last repair works consisted of making a concrete floor over the slag layer and replacing the roofing felt. In this way, the floor level has elevated for about 5-17 cm and the roof slope changed for circa 3%.

In the Scharoun building, the original roof had the features of a traditional one. A technological mistake that led to its damage was putting concrete slabs 40x80x5 cm on mortar (probably directly on bituminous insulation layer) and sealing the joints. If the slabs had been put loosely on bituminous insulation layer, it would have been an experimental inverted flat roof. The intuition led the designer to a solution close to current technologies.

The load resistance expertise was issued assuring the possibility to open it for people and put some bowls over the reinforced concrete supporting walls. The removal of the old roofing felt and slag mortar layer (permanently damp) was recommended. Additional thermal insulation of the roof with Styrodur, lighter then former insulation material was proposed instead. Calculations has been made for additional useful load – 1,5 kN/m^2, constant load – 2,5 kN/m^2 and snow load – 0,6 kN/m^2.

According to the design it was used an inverted flat roof. It allowed to recreate the original roof covering with concrete slabs and suitable water drainage.

Roofing felt, concrete, slag and bituminous mass from the decrease layer were removed. The decrease layer and the gutter were repaired. Joint less floor 3-9 cm thick (Cerinol FM, Dietermann) was put on joining layer (i.e. Cerinol ZH). On the concrete layer the flat roof system with ballast was used i.e. water insulation membrane EPDM (1.14 mm Firestone).

Pavement slabs 40x80 cm 4 cm thick (reinforced concrete), brickwork style layout, with 3 mm joints, on regulated base were put on these layers. Concrete was prepared with river aggregate up to 5 mm and in warm grey colour.

Layers inside the gutter were placed according to the Ravago system. After the removal of the roofing felt and repairs of the gutter surface and conductor heads the surface was overlaid with black UV resistant EPDM insulation layer.

Figure 6: Multifamily house (former building for childless couples and single people) designed by Hans Scharoun, WuWA model Werkbund estate built in Wroclaw (former Breslau) in 1929. Roof recreation terrace of left wing after the last renovation. Phot. J.Urbanik, 2013.

2.2 Renovation and reconstruction of the non-useful flat roofs in the right wing and middle part and lateral staircases in the left and right wing

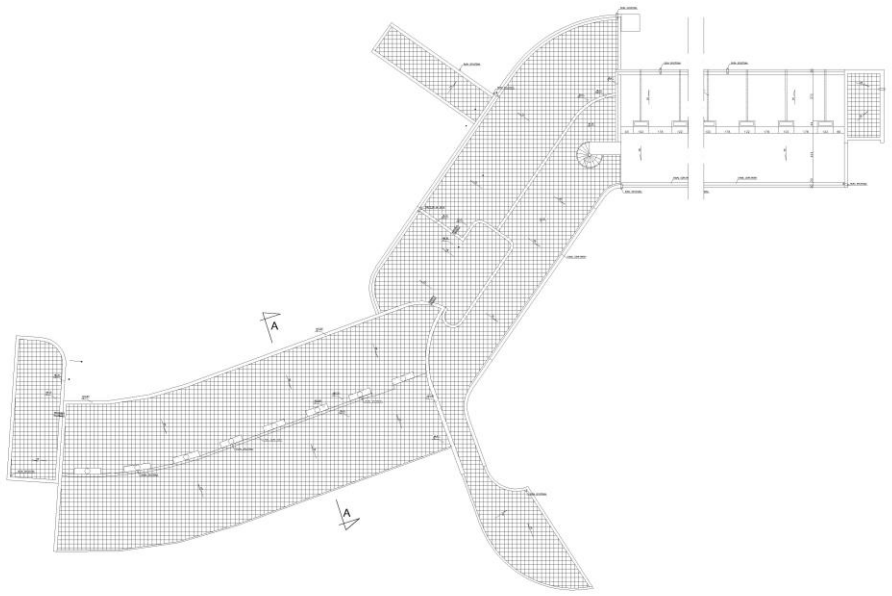

Figure 7: Multifamily house (former building for childless couples and single people) designed by Hans Scharoun, WuWA model Werkbund estate built in Wroclaw (former Breslau) in 1929. Flat roof plan. Drawn by A.Tomaszewicz.

According to the architectural documentation from 1929 the flat roof of the right wing was constructed using: asphalt roofing felt, concrete decrease layer (from 2 - 7 or 8 cm; upper and lower level), probably light slag concrete or with pumice aggregate, thermo insulation layer - cork tiles 3 cm thick, reinforced concrete slabs 5 cm thick , Ackermann blocks 10 cm height, ceiling plaster - 1.5 cm thick.

Rainwater from this part of the building was channeled with 2 gutters, put in the middle of the wing's width, along the building's axis - on lower (overlooking the garden) and higher level (overlooking the street). Lower gutter was connected with drain pipes at three points: two wing ends and in the middle. Water from the upper gutter was probably channeled through short chutes to the lower gutter. Rain water from the rest of the roof was probably channeled by drainpipes to the conductor heads along the elevations.

The flat roof was probably subject to repair and reconstruction works, both before and after WWII, during which the additional concrete layer and roofing felt were added.

The tests revealed that the original concrete and cork insulation layers (cork boards 3cm thick) over the Ackermann ceramic ceiling remained intact.

Additional layer of heat applied roofing felt was laid during the last repair works. Moisture is visible on the ceiling indoors. It is the evidence of a leak in current roof covering.

The dimensions of the building was kept after removing of the flat roof layers (both original but not functioning properly and post-war) and installing new decrease, thermo and water insulation. The project suggested removal of the layers added in the post-war period (additional concrete layer and tar paper) and two original layers that doesn't fulfill their function of thermo insulation properly - light aggregate concrete and cork tiles. Concrete decrease layer 4-10 cm thick and thermo insulation with modern and light construction materials and water insulation with double layer of heat applied tar paper should be installed instead [15]. The decrease joint less floor (Cerinol FM, Deitermann) on joining layer (e.g. Cerinol ZH) should be applied.

Gutter surface should be repaired. The decrease on the roofs over both parts of the right wing, fragments of the middle part and lateral staircases should be kept within 2 %.

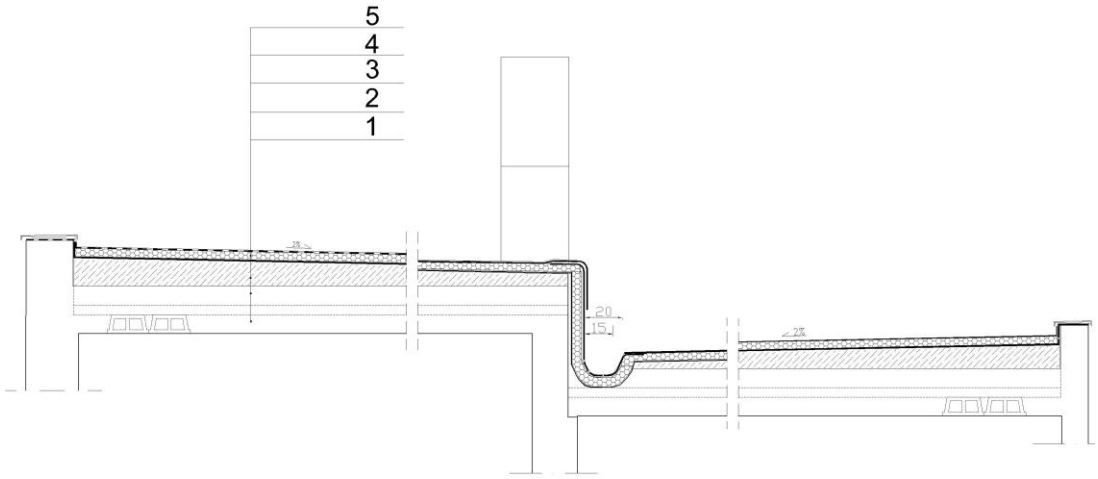

Figure 8: Multifamily house (former building for childless couples and single people) designed by Hans Scharoun, WuWA model Werkbund estate built in Wroclaw (former Breslau) in 1929. Section of right wing roof (renovation proposal): 1 – original roof construction (Ackermann blocks 10 cm high), 2 - joint less floor - concrete decrease layer 4-10 cm thick (Cerinol FM, Dietermann) on joining layer (Cerinol ZH), 3 – steam insulation fibre , 4 – insulation level Styrodur 10 cm thick, 5 - heat applied roofing felt (2 layers). Drawn by A.Tomaszewicz.

3 SINGLE FAMILY HOUSE DESIGNED BY EMIL LANGE

Emil Lange designed a 149 m^2 single family house with basement and garage for Wroclaw WuWA housing estate. It was simple in form, consisting of a composition of cuboid blocks.

According to the architectural documentation from 1929 he applied multi-layered Klein flat roof. The layers were as follows: plaster 2 cm thick, channel bricks on cement mortar 10 cm height, light concrete layer 1 cm thick, Torfoleum insulation (compressed peat insulation slabs) 5 cm thick and concrete layer 10 cm thick. A layer of compressed gravel and tar paper were placed over it to provide the 10% decrease of the roof slope.

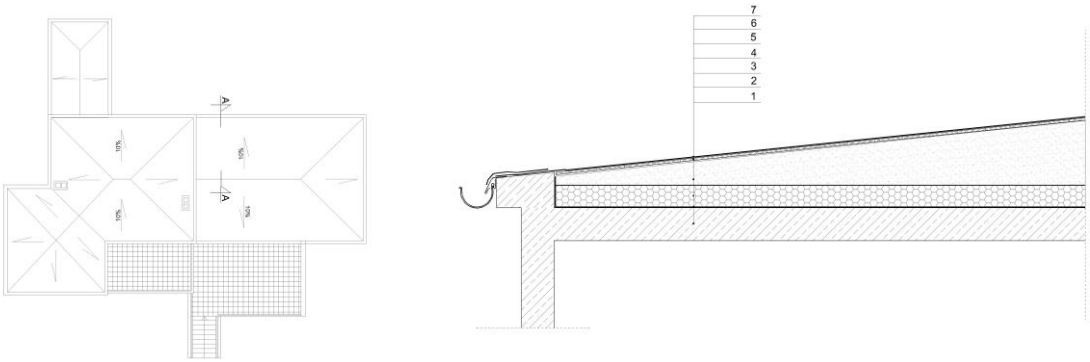

Figure 9: Single family house designed by Emil Lange, WuWA model Werkbund estate built in Wroclaw (former Breslau) in 1929. Flat roof plan and section of flat roof (renovation proposal):1 – original roof construction 26 cm high, 2 – steam insulation, 3 – Styrodur thermal insulation 15 cm thick, 4 – insulation fibre, 5 – concrete decrease layer with light expanded clay aggregate ,6 – mortar bed, 7 - heat applied roofing felt (2 layers). Drawn by A.Tomaszewicz.

Rain water were channeled through gutters along the outer walls and through geometric conductor head. The flat roof was probably subject of renovation and reconstruction works, both before and after the WWII, during which the tar paper cover was also repaired. Moisture is visible on the ceiling indoors. It is the evidence of a leak in current roof covering.

The project suggests removal of the layers added in the post-war period (additional tar paper) and original layers that does not fulfill their function of thermo insulation properly i.e. slag isolation [16]. Concrete decrease layer, thermo insulation with light, modern construction materials and water insulation with double layer of heat applied roofing felt should be installed instead.

As no extra load will be put on the flat roofs, it is possible to repair it by partially removing the roof layers and replacing them with lighter equivalents. The decrease of both parts of the roof - above the first and second floor - is going to be circa 10%.

4 SUMMARY

Most of the building materials that appeared together with the flat roof in the 1920's such as bituminous roofing felt or asphalt are still in use in today's construction practice for flat roofs. A lot of mistakes have been done while developing proper construction methods for the flat roof making the first attempts.

During the current renovation works in the modernist buildings, it is necessary to correct the methods used in the construction of flat roofs. It is still vital to preserve the original dimensions and rain water draining system, when improving the conditions of the object.

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