# Historic roof structures

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**Abstract**

The usability, valuableness, appearance, environmental adaptation is decisively determined by the roof forming, roof design (roof constructions). The *systematisation of roofs and their structure* helps the recognition process of the basic elements of our environment.

The analysis of structure development, besides founding authentic structure renovations, can also determine the ways for the *development efforts*. Since the two efforts do not exclude each other, moreover they can be harmonised, a good example for this is the roof structure created during the reconstruction of Bánffy palace at Bonchida, which was "designed in mass on the basis of old photos and analogies..." and in which *the combined board crossed rods work according to the baroque roof structure load cycles*" [6]

The roof form meeting the roofing solutions and the local conditions is the token of the secure drainage. Besides the use of even, flat and arched surfaced, sloped roofs the historic ages and the dominant roof forms of nowadays are the *double pitches* or their derivates, modifications. "... they were forced to form the roof of their houses pointed, thus raising them in the middle. These roof peaks should have been built high or less high, depending on the region they are building the house" wrote *Palladio* Andrea. [1]

## 1 Old, purlin roofs

The simplest load cycle and the possibility of construction requiring the least expertise motivated the ancient purlin types of pitched roof such as the development of the *roof with ramified prop and purlin* well-known in the Hungarian folk construction. Like in the roof structure with ramified prop and purlin, they also used the natural branches of trees - hardly processed - for fixing the rafters hanged on purlins (load purlins, hook purlins, roof purlins) loaded by bending and with widely supported rafter distribution. The rafters, as *secondary structural elements*, do not deliver lateral thrust to the ramified props deriving from the vertical load. For discharging the intermediary supports bellow the ridge line, "probably the early-medieval innovation "cruck" or "Big cross brace" served, frequently used in Western Europe, especially in the British Isles" /[2] Dr. Nándor *Gilyén* /, the lateral thrust of which the ground do not receive. (During structure development different types of bent-roofs frame solutions were adopted, with buried or foot-type constructions, to receive horizontal forces. In the case of the *cross-braced purlin roofs* established in the balks reinforced by X-braced stems, lumberwork joints provide horizontal power transmission at the joist-ends.)

## 2 Roofs with rafters and joint double-rafter roofs

In the simplest version of *roofs with rafters* the bottom ends of two rafters braced together by joints or porked mortice and tenon at the top, bearing against each other, are loaded directly to the beraing wall (or frames, frame elements). This arrangement discharges horizontal lateral thrust to the supports even under symmetric, vertical and gravitational load, the receiving of which often causes difficulties, and can be source of structure deterioration. Therefore the roofs with rafters can be used only with strictly limited spans. The span of the common rafter roofs, popular also in England, cannot be more than 20 feet /[10] Charles *Schapcot*/, therefore they intend to brace them with collar-beams, corner and angle joists.

## 3 Closed coupled roof

An ideal structure version of forming double pitches is the *closed coupled roof*. The rigid triangles formed by tie-beams and two-two rafters, and the raw of rafts give the framework. The basic elements made of wood can be considered as rods - although bent a little bit. The closed coupled raft is an independent, closed, plane unit, the rafters of which are also of total value having *primary structural funtion*, with a simplified, idealised static model of a three-hinged frame, and in which the lateral thrust of the rafter ends is received by the joist. "The closed plane system constructed from rafters and joist is able to transmit the original values of the vertical and horizontal components of the resultant of the loads." [9] stated Imola *Kirizsán* and Dr. Bálint Szabó using the method of framework synthesis. The structural- and structural aspect innovation lead to the development of the *medieval (gothic or gothic-type according to other terminology) roof structures*. The limited room covering can be implemented without any intermediary supports, with free internal and architectural space forming. The joist capable of hinge-like power transmission junctions (with part-capture, in fact) appeared in the form of traditional lumberwork connections.

First conclusion: Structure development trends

The presented **two structure development processes** - having different starting points (namely aiming at *rod-element construction and using bent purlins)*, but living beside each other several times and at several places in history, interacted and crossed each other at several points **(age and place) and lead to similar result**. At the beginning the independent structural elements (ramified prop roofs, big cross-braced, roofs with bents, framed roof, cross-walls,...). Were used to support the purlins. The demand for bigger space was eliminated the purlin discharging into the loft, so they became the parts of the roof structure. A good example of this is the already mentioned cross-braced (cross-stem) roof frame, frequently used in Hungarian folk construction, the primary, transversal plane framework units of which were constructed of closed triangles timbered from tie beams and cross stems.

## 4 Medieval, gothic and gothic-type roof structures

Even with the closed coupled roofs only buildings with 5-6 meters of clear span can be built. The demand for covering longer spans lead to the application of *braced rafts* with (drawn-compressed) horizontal collar-beams and top beams, with compressed angle bracing, as well as drawn-compressed (corner) joists in medieval roof structures. The primary aim was to make the plane of rafting deformation-free, that is to support rafters at several points (5-7-...), at the same time they attached great importance to the longitudinal stiffening of the structure, too.

The additional increase of clear spans required the "co-operation" of the braced raft units (often constructed to be multi-storey by inserting intermediary collar beams), which was solved by a great idea by longitudinal frames settled on the brow/joist posts thus providing longitudinal stiffening.

In certain braced rafts, namely in principal-rafts, the truss posts of longitudinal frames appeared, which are also the elements of the interlocking *cross- and longitudinal frame-units*. Between the principal-rafts one or maximum two less braced secondary raft are situated, but in certain cases they can be eliminated. The secondary rafts are also operation as independent closed plane system, although "without the help of the principal raft the deflection of its horizontal units would be bigger." [9]. The "help" of course supposes/requires the contribution of the longitudinal frame.

Second conclusion: The funtion of truss post

The uncertain estimation of the form of mechanic cooperation of the longitudinal and cross brace units is reflected even in the limited professional literature of this topic.

In the proposal published in the publication of the 3rd Scientific Session on HISTORIC FRAMEWORKS, organised in 1999 in Kolozsvár, titled "Historic roof structures terminology - proposal" the vertical elements of the longitudinal frame bracing structure were referred to as *"truss rods"* and "truss-tree", but other referenced professional articles indicates *"posts"*.

*Dr. András Vándor* emphasises that the "brow post ... holds the longitudinal frame", on the "crown plates of which the tie-beams are generally settled, built in by storeys" [5], moreover "the connection of the two plane stiff structures is implemented in general at the transversal longitudinal frame posts by inserting bracings and knees. Additional connection piece is the collar-beam or collar-beams, which are only leaning on the crown plates, but there are not tied together"[3].

According to *Dr. István Pomozi* the connection of the pole-plate and the joist is implemented by pin gear joint (usually the pole-plate is indented, and the brow-joists do not contain any grove), while the post is connected to the longitudinal frame-pole plate by a tenon [4].

Due to the above-mentioned the **suspension** can be implemented only as a **secondary function** of the post-supporting bracings and joists (only in well-built, not deteriorated structures, by power transmission over several structural units and connections). This is especially true in case of the secondary rafts "the horizontal supporting units of which are only suspended through the pole plates of the longitudinal framework (truss-tress of the principal rafts)"[9]. (In fact the tie-beams only when they are/would be connected to the pole plate as binding girder) "The suspension effect appears only in case of the gravitational loads and when the units or the junctions of the plane system are not damaged; in opposite cases the truss-tree often mediates pressing force" [9].

In my opinion, according to one of the principal aims of the original structure philosophy, namely preferring longitudinal truss, the common elements of the longitudinal frames and principal-rafts can be considered posts, whereas due to their suspension function presented also by the framework analysis the application of truss post terminology would be justified.

The usually "pined", hard-wooden guest-tenon, half deep, entire or third widths, dovetail or half-dovetail and cross lap joints are proved to be able to transmit the forces of varying direction, while their polled feature permits the axial-sectioned connection of maximum three elements situated in one plane. This way the designable grids can be only "quasi-type", by using double units, by-pass and detour-axis solutions. The unit-end connections can be considered only part-capture of the given unit; the connections and junctions operate as flexible support of the intermediary, reduced flexural stiffened bracings.

As the connection of the post, pole-, and crown plate, the tertiary tenon appears, and sometimes the rafter also connected to the joist by a tertiary tenon. The frequent sprocket piece is fitted to the joist-ends sometimes by crocheting (even if it braces, then it is lap-jointed, or "pined" tenon). At the connection points of the grids the by-pass axed joist, pole plate, collar-beam and crown-plates are grooved on each other like in the case of wall plates and tie-beams.

The bended usage of tie-beams (and often of collar-beams) (and of course rafters) is also contradicts to clean, rod unit structure operation. The application of truss-post emphasises this contradiction rather than dissolves it. The different structural elements are exposed to several types of bearing forces from dynamic point of view. "The brow post clamps the walls and supports the longitudinal frame (bending). The collar-beams clamps the rafting and braces the crown plate of the longitudinal frame (drawing and compression) " [5] The transversal structural units, which are already big and braced in plane (principal and secondary rafts) and the longitudinal frame-structures are not stable, their stiffness vertical to their own plane is minimal. They form a *dimensional roof structure* only built together, with stiffened, stable and permanently limited deformation.

The professional historic analysis are still uncertain in the respect that structure construction was realized by which extent *of joining yard construction and pre-fabrication* of certain frame- units or which extent of *joining them on-site*.

The found joiner's marks evidence the more frequent application of the former methods, according to which " the fixing of the roof structure was performed on joining yard... they used the letters of runes, series of Roman and Arabic numerals, the peak and circle marks, applied mixed at several places" Dr. István Pomozi. [4]

However, the application of the latter is seemed to be proven by the common, equivalent joining of the dimensional elements of the frame-units, in spite of the unimaginable difficulties of the onsite joiner work due to the huge and heavy (usually hard-wood) beams. According to András Vándor "Working above the already placed tie-beams and the on-site cutting also verified by the individual-geometry binders and their bindings..." [3], moreover that the "living material (especially oak-wood) significantly changes its form in between cutting and building-in. The exact joining of the cross and longitudinal elements can be provided only when constructing the entire structure "dry". In addition "This fact is justified by the special size of the roof structure of the church of Avas, and that the structure was often adapted to curved, twisted tree-forms." [5]

Later, very dense longitudinal frame without any crown plate and pole-plate was experienced as major modification, although in *medieval-like* roof structures. (Kömörő, Calvinist Church 1801! [5]), the application of longitudinal frame posts supported even above the low-lying crown-plate, driven onto the roof ridge. (over the Roman-aged chancel of the Calvinist Church of Piricse [5]).

The structure-forming of the medieval raft-roofs is basically intuitive, which probably resulted in dimensional structures working uniformly through an empiric development process, while it genially felt how to take advantage of the bearing advantages due to the multiply static uncertainty.

We can register as a mark of the trend of conscious structure forming, the appearance of the clearly separated functional units, namely the collar-beam rafting and the effective, dimensionally operating bearing structure in the baroque roof structures.

## 5 Baroque and baroque-type roof structures

The ideally clearly-constructed baroque roof is capable of covering 6-8 m of spans. The baroque *collar-beam rafting* appears in every raft of the roof structure, in the same form, emphasizing its independent function of supporting the crust (and its base), although the rafters joined together by collar-beams were also taken in by the tie-beams. Into those brow posts which also form part of the effective frame structure.

The function of the stiffened, independent frame-work unit is to support the identical rafting units bearing the crust on every point in every raft, and in the same way, and at the same time to ensure the reception of the horizontal forced generated inside them. These clamping points were given at the end of collar-beams and rafters. The horizontal seatings and simple-pin gear joints of the collar-beam ends and the notched joints of the compressed-cut rafter-ends of tertiary tenon provide clear and apparent (vertical and horizontal) force transmission. The raftings and the supporting structure do not have contact with each other at other places, due to the voluntarily established connection system.

During the construction of the rafting freed from the function of the primary framework and having clear dynamics, the builders of that ages could even afford the "luxury" to build the otherwise rather big rafters laid down with their face, because they feared more the bending of the sprockets than that of the rafter" [5].

The dynamic-geometric construction of the *framework unit* directs to close-support force transmissions, and power take-off, therefore the plane truss of the longitudinal stiffening is smoothed diagonally under the rafting. The characteristic baroque structural elements, the pentagon-sectioned pole and crown plates were born on the basis of the intention of the clear dynamics of the so realized supporting frame. For the building-in of the beams feasible with clear dynamics, the surfaces parallel to rafter planes were also needed besides the horizontal and vertical side plates, so that the supporting frame and the rafting could freely "move" alongside each other. The plates vertical to the rafter planes permitted the vertical, diagonal, tertiary tenon of big back props, diagonal braces tilted towards each other and/or built in the form of diagonal crosses. Often the intermediary, longitudinal half-beam also appears in the tilted-plane longitudinal frames. The back props leaning towards each other, built in principal rafts are braced together by a bracing closing beam, breast-beam. The hammer brace and the posts, together with the brow post for a closed trapezoid plane square, in spite of the fact that the back props are in direct binding connection only with the pole plate (compressed tenon). The pole plates are laid onto the brow posts by deep cross grooving (at Dr. András Vándor: by double dovetail joints [5]) transmit also the drawing bearing forces. The frame feature of the principal rafts is given by the angle binders (knees) by stiffening the upper, obtuse angle corner.

## Third conclusion: Brace and truss constructions

In spite of the formal and operational similarities I do not consider favourable the denomination "joggle-truss" and/or bracing construction roof structures often appearing in professional literature without referring to the historic character. (During the renovation and establishing a communal house from a tithe-barn built in Zuffenhausen, near Stuttgart in 1564, the enviable renovation of the recognisable baroque-type roof structure simply tended to safeguard an "unusual, truss roof-construction and cross brace, double bond on two levels" as published in a report in the Issue 0 of the magazine Construction Renovation /Hungarian version Bausanierung 1993 [7]/.) This denomination also reflects the uncertainty, which can be felt also in professional literature and other professional materials. Namely, the older historic structures - unfortunately forgotten by the public - are nowadays forced to the known, instructed classifications of eclectic and modern structure types by the authors or translators.

The established and known historic roof structures came down to us are often really working with truss- and/or bracing constructions. The **truss of the gothic principal-rafts could have developed during a long development process due to the pretension of a double-plane stiffening, or parallel to this**, although it is not sure that by conscious bindings from the beginning. On the basis of medieval experience (and maybe influenced by the renaissance which was not felt uniformly everywhere) in the **baroque roofs the intention to tie-up and truss became more conscious and evident**, which is also proven by the application of the double swing-posts and metal truss binders.

**The development of the bracing construction** in these roof structures, however, was maybe due to the bracing of the angle longitudinal frames providing the space requirement of arches, and to the frame-corner stiffening of the principal rafts. The correctness of the above hypothesis can be proved by fact that in the historic roof structures the elements of the recognizable truss and brace constructions are multi-functional, and often bent. For instance, the characteristically big back props built in the principal rafts are the bent legs of the square frames and their longitudinal-frame posts at the same time.

Only the upper section of the principal raft including knee-trees too, can be considered as bracing construction. (Following the example of COMMON RAFTER- CLOSE COULE ROOF : UPPER TRUSS; [10] Charles *Schapcot*). In my opinion the primary objective is the bracing, and the **truss and/or bracing effect was just a structure-forming side-result**.

We can not forget the fact that a lot of technical solutions had to be invented in the "dark" middle ages which had been already known in Antiquity. Andrea Palladio reported already in 1570-ben a truss-construction bridge construction [1], although the compressed angle posts are also "*bracing arms*, which are counteracting to support the entire building" (Also Palladio presented the roofs in his section plans of antique buildings [1] as frame structures of triangle-construction, namely series of truss-constructions in an almost engineering way.)

In later roof structures designed from engineering point of view, the real truss-, bracing and truss-bracing constructions operating of hinged rod-chains, comprising of compressed-drawn elements suspended and supported the tie-beams as independent structural units, since they transmitted the power right next to the supports. (The primary task of the bracketed and/or saddle-backed independent bent purlins having new function was to bear and to discharge the cross-girders onto the principal rafts, as in the old, simple purlin / [8] Sobó Jenő/. (which are called very expressively by *Sobó* as binder-rafts)

## Fourth conclusion: Purlin-functions

Jenő Sobó has already clearly differentiated in his studies on public building projects in 1898 collar-beam roof from roof structures with purlins, saying that "the direction of the purlins....is the identical with the......binder, but its position and function is totally different..... With the collar-beam roof the binder was located *under the collar-beams, and supported them*, while the common rafters were supported by the collar-beams; whereas with the roof structures with purlins the purlin's purpose is to directly *support and hold all common rafters*, that is to take over the collar-beam functions. (8)

Dr. András Vándor writes it too: "The development of the roof structure means the introduction of the purlin playing an *all new function* (let say: once again*) ...at the beginning of the 19th century. This bent part directly supports the spars. The so-formed roof structure is rightly called the distinctive name of *hammer-beam roof*, since its purlins are supported by *posts***".

* it has already appeared on the early simple roofs with purlin (roof with ramified prop, roof with bent), but with support separate from the roof structure

** the posts were directly connected to the clamp beam and weight on them (no more support beam!)

Considering the above **we can see a threefold function of the purlins. On direct (curved) old rafter roof structures**, roof with ramified prop and roof with V-shaped props and on new (19th century) hammer-beam roofs; on **direct** collar-beam rafter transition hammer-beam roofs. **In Baroque roof structures** the spacers and the pole purlins (pole plates) taking place in the support of the collar-beam rafters **divided** with other elements of the longitudinal frame, namely in the collar-beam rafters propped up by the hip rafters (by the crown plates or by the binder), without a direct joist.

In case of Baroque roof structures we cannot talk about purlins with old/ new functions as not about hammer-beam roofs and rafters either. Though the rafters bearing beam, the spacer and the hip purlin can be called the structure element of the Baroque support unit, but the rafters in every case mainly rest on ends of joint and collar-beams. That is to say that the Baroque hip purlin - after all we can call the crown plate like that - primarily is the element of the diagonal brace. Considering the collar-beams, it classifies as binder.

As the one-time master carpenters aimed at to be free of changing shape of the medieval roofs' main and common rafters and to longitudinally prop the structure so the builders of Baroque roofs strived for forming the separate, actual support structure rigidly in space (have a feeling to the fact that the closed flat squares are rigid because of symmetric gravitation load only, not to mention side positions propped by main positions and opened in their own dimension). Therefore the doubled, inclined ("converged") Baroque longitudinal prop level system supports as structural sub-element and *crosswise props* the common rafters more efficiently than the gothic longitudinal frames.

The especially *rigid support structure element* of space is still *waiting for a simple, expressive* name, which fits into the historic roof structure terminology. Considering the separated rafters, which are the same in every position, and agreed with Dr. András Vándor, I would myself talk about *principal and common rafters*, which can be distinguished within the support structure unit, instead of common and principal rafters. The sharp differences between principal and common rafters are stressed by the joint beams, which can be discharged in the common rafters. (Considering the principal function of the rafters in gothic roof structures this discharge was/would be possible only with the serious violation of the structure guidelines!)

From another perspective "the Baroque structure principle is a starting point in the structure development - the roof is built above a closed, high-vaulted* space, with the help of common rafters without joists"/(11) Dorottya Makay), considering at the same time, that "With the elimination of the pulled element - joist - naming it common rafters is in doubt, since the elements are supported along such an axis".

Further propping and strengthening were needed *on bigger size roofs* with building in additional elements. *Double coigning* increased the rigidity of the frame; *axial beams* run between breast-beams and collar-beams increased the longitudinal space rigidity. We have many examples of the *multi level* structure too, where the collar-beams of the rafters serve as joists for the upper levels (Baroque roof structure of the building in Budapest, Uri Street 47. [5])

The multi level solution provides ideal opportunities for developing broken angled *attics*. (Baroque style roof structure of the Bethlen Gábor College boys' boarding school in Nagyenyed [12]).

* the headstone is above the wall plate

For the purpose of minimising bending of the longer straight archers *floating posts* have been built in, in couples, usually with metal joining elements. In case of the application of dense brow posts *axial binder* can be connected to the *king posts* in the principal rafters with iron joists, to prevent excessive bending of the brow posts built into the common rafters. (Vasszécsény, roof structure of the new Ebergény Mansion [3;5]) (In case of some building functions it was possible to support the brow posts in the middle too, instead of slings, with the construction of wooden structure of the inner space: Zuffenhausen, barn [7]; Mosonmagyaróvár, grain).

The listed additional item are already suggest the obstacles of the Baroque structural possibilities, since the increase of the span was possible only with compromised solutions at the expense of the clear structure operation, same as in combined roof-shapes, the forming of half-principal rafters built-into the lines of hips and valleys.

# 6 Roof Structures with mixed or interim systems

As the result of the already mentioned parallel structure developmental processes, which often were built on each other, characteristics in shape, material, construction and connection might appear in the same time, on the same roof. They carry signs of Medieval and Baroque structures as well, for example the roof structures of the Reformed Churches in Túristvánd and Tarpa (Its east part, built in 1796-98), which were called by Dr. András Vándor *mixed system* [5].

Both roof structures are applied with joists with Gothic characters, at the same time Baroque style plane frames, formed with inclined props cling under the rafters, appear next to the vertical longitudinal frame, under the ridge, from where the lower, fivefold pole plates are missing. The crown plates have square cross-sections even in the inclined plane frames, therefore the double grooved bearing of the rafters at the collar-beam ending, the correct, "Baroque style" loading is not provided.

The strengthening of the principal rafters is considered by its rare division different from Medieval structures and many installed common rafters (for example three in the roof in Túristvándi). The angle-brace of the inclined props and the breast-beam were connected with medieval dove-tail joints. The principal rafters of the roof in Tarpa, which contain Baroque elements, are propped by lower joists featuring Gothic characteristics. The slings of the vertical plane frames posts are sitting on timber joists, with the Medieval/indirect method and on dove-tail wooden joists' diagonal braces, which crossing each other. Along the existence of obvious Baroque features the use of steep roof structures (-60) and oak structure material suggest medieval characteristics.

We can consider the broken roof structure, attic type space cover of the Bethlen Gábor College boys' boarding school building in Nagyenyed as interim, but much more Baroque style, structure too. The basic doubt is raised in the structure identification the *common rafters possible self-support in their own level*, where they are capable of independent self-support and they have joist beams - similar to the Gothic common rafters. The structure identification was supported by support structure analysis too ([11] Dorottya Makay) with the identification of the typically Baroque and not Baroque structure characteristics. The model analyses revealing shape modifications have proved too, that the cross section rigidity of the common rafters (where the rigidity of its level squares are closed, but not rigid to horizontal load) can be provided by the *principal rafters connected with longitudinal frames*, and even the common rafters, which are considered fully rigid (and can function as self-supportive) would be bent to load the longitudinal frames too, consequently they are suitable to take over/pass on individual load only, but cannot be considered rigid in their own level or self-supportive.

So the roof structure is *basically Baroque*, although its formation is compact in beaming, then again its upper level, closed triangle rafters are propped by Gothic joists and top beams. The vertical longitudinal frame posts under the ridge are connected to the collar-beams (joists) without pole plates, and the grades are formed by knee-timbers instead of braces and joists. The suspension of the posts is "Gothic". Because the above my opinion is that this roof structure can be considered as *partly interim*.

We could state similar conclusions about the two-level roof structure above the nave of the Reformation Church in Nagyenyed, where its lower level "bears evident marks of the Baroque with the longitudinal propping built into the doubled rafters level and the doubled angle-brace. But *eclectic* upper longitudinal propping system (purlins sitting on posts) can be traced in the upper level". The nave of the roman catholic church in Ótorda is "covered with a structure partly resembling Baroque and partly resembling eclectic characteristics. The structure covering a large span has a 45 angle only... The upper lever is eclectic already, and back prop... is present in the vertical level." (issue under [2]).

Therefore the provisionality can be traced not only in regard of Gothic and Baroque structure characteristics, but it can indicate seeds of the development of the new, namely the eclectic structure system too, building into the traditional solutions.

"The biggest problem with the Baroque roof structures... was that its building needed a lot of work, high skills and professionalism. The forces of the structure was extremely difficult, with high demand on wooden material." ([13] *Dr. Alica Horváth - Dr. Ádám Ábrahám Pattantyús*) Despite all of these the roof structure of the riding hall has been built in Moscow with 44,6 m length between walls in the first decade of the 19th century, based on the plans of *de Betancourt*, French architect and with the use of Baroque structural guidelines. During further development of the roof structures *the aspiration to individual, artistic space forming/covering* can be traced with the use of brilliant, nearly engineering approach with a firm hand of the accumulated, traditional professional knowledge in master carpenter level. This group of historical roof structures are called by the suggestion from the already quoted (under issue [2]) terminology as *eclectic like roof structures*. (The later purlin, hammer-beam roofs can be addressed as traditional varieties of modern roof structures as a special condition.)

## 7 Eclectic, eclectic like roof structures, 19th century hammer-beam roofs

The 19th century has brought revolutionary changes after the industrialisation not only in the sphere of increase in constructional demand and possibilities, but in the appearance and the general use of new structure material (wrought iron, steel), the new measured steel structures and the industrialisation of the wood process (steam saw mills). The basically traditional - perhaps with engineering help - but clearer construction, the development of the real planning by engineers and the mixed material usage (wood, wrought iron, steel) all meant the developmental possibilities of wooden roof structures.

The eclectic, or eclectic like wooden roof structures following the traditions may be called *historical*, not because the planning by engineers did not have historical background (see Palladio's suspension combination but clearly triangular structured bridge studies following ancient examples and roof structure illustrations [1]), and the early mixed material or steel structure roofs would not be subjects of (industrial) historical building appreciation.

The eclectic roof, similarly to the earlier historical roof structures, is supported by the outer wall of the building, without props in the middle, and " it is formed to operate if it is propped up by the outer wall" (under issue [2]). The roofs *with standing posts* with previous historical background first appear in France in the first decades of the 19th century as roof structures of buildings with large span. Eclectic structured roof structures survived from the second part of the century in the Carpatian-Basin, like the *suspended hammer-beam roof* of the catholic Kálvária Church in Kolozsmonostor.

The original roof structure constructed by the traditional way with 18 m open interspace reflects engineering approach, which covered the main nave of the Basilika in Esztergom and unfortunately got burned down in September 1993. The architect, *Mr. József Hild*, was such an architect, who had nearly engineering thinking and had highly developed sense in static and who "was the master of the structure new fro him, and that is why the roof of the eastern nave, designed by him, is a economically and statically clear-construction structure." [13] The purlins supporting the collar-beam rafters are supported by double stretching in the principal rafters. The bending of the collar-beams and joists are restricted by the single suspension.

The double stretching under the joists and supported by the side walls was loaded by the interim load of the working level and took part of the crossway propping too. Carrying the load can be worked out with the cooperation of the clearly *separated functional units*. The propped purlins, directly on the roof posts, supported and passed on the load of the common rafters.

*In the early purlin hammer-beam roofs*, following the structural guidelines the collar-beam rafters remained in every position. Now the straight or leaning roof posts directly load the joists. The rafters connected by collar-beams create a rigid triangle above the purlins, the purlins support the corners of this triangle, therefore no horizontal tension develop in the line of the eaves." [13] Because of the termination of the bridging as joiners, connected to rafters, beside the joggle-joint, which is suitable to horizontal transmission of forces, often appear putting the rafters on pole plates providing the possibility to creating eaves with hanging rafter endings.

The uncertainty of the historical judgement of the *purlin hammer-beam roof* is indicated (eclectic or modern structure?) that the double cellar is not mentioned as the element of the eclectic like (and other historical) roof structures in the many times cited terminology, but it is mentioned the general element definition line of the historical roof structures: "Building structural element fixing geometrical position of inserted purlins". The appearance of the double cellar with the disappearance of the collar-beam rafters can be connected to the usage of separate rafters. In the principal rafters, under the purlins, it is capable of *fixing the relative geometrical position of rafters, purlins, roof posts*, but it rarely serves to transmit real force. (not able to pick up pressure, bends out; tensile load develops in special cases only).

## Fifth conclusion: Historical roof structures, range of hammer-beam roofs

The hammer-beam roof and the difference in the terminology in roof structures can be subject to a dispute. For me it seems that - during the **professional agreement** - the **historical buildings have roof structures**, which are made up by cross way and longitudinal plane frame units (with close support structure units / Gothic structure /or separately / Baroque structure), while the posts of real purlin hammer-beam roofs sitting on joists without pole plate installation.

It is a fact that truss constraction, purlin hammer-beam roofs appear in 19th century structures too (in 2001 we can not say that it is only in the last century), often in forms with stretching and suspending, in large open areas. Beside the medieval/Gothic/Gothic like Baroque/Baroque like eclectic and eclectic/ eclectic like roof structures the 19th century **double collar, purlin hammer-beam roofs would deserve special attention**, with special regard to the hammer-beam roof of these roof structures, or despite of it.

(Please note, that the German professional language uses the word "Dachstuhl" as Baroque historical roof structure, but we have Hungarian example too: according to Dr. Nándor Gilyén " the Hungarian language does not draw any distinction between the two type rafter, while, as we have seen, this is a secondary structure with the *purlin hammer-beam roof*, while it is primary, determination element with the *rafter hammer-beam roof*.)

The *static basic* model of the historic roof structures is a double support, according to the definition, since " usually they sit on the outer walls of the buildings (with the lack of middle support)" /issue under[2]/ "Their characteristics are that they *structure is tight*" [12], and some of their elements play a *trussing function too.* Their structural system *can be divided into longitudinal and cross way subunits*, which have different rigidity and sometimes are stable only when built together in space.

## Sixth conclusion: Support structure modelling of historical roof structures

*The subunits of the smaller rigidity common rafters* of the **Gothic roof structure** are individual, closed level systems, where its vertical elements were put to principal rafters (too) with the intervention pole plates of longitudinal frame(s), but they are able *to balance themselves too.* The Gothic longitudinal frame unit is rigid in its own level and stiffen. Only the built *space roof structure unit* will be steady (together with the rafters playing the function of primary support), it is rigid in space and permanently keeps it form (changes its form in limited degree).

The best model would be the full space support structure unit, but it can be taken apart to level subunits (principal and common rafters, vertical plane frame(s) too.

*The common rafters* of the ***Baroque roof*** *space support structure subunits* are able to balance themselves - not even with the collar-beam rafters built on them - since they do not have their own joists. Therefore *the bending, inclined longitudinal subunits* play *a cross way stiffening function*, beyond the longitudinal stiffening and the vertical unloading of common rafters (to principal rafters) (cooperating with the tie-beams), so the **space support structure subunit** is *stable, rigid in space* and permanently keeps its form *by itself* (without the collar-beam rafters with secondary loading function).

The best model would be the space support structure subunit, which props the collar-beam rafters, but it can be easily taken apart to level subunits. (principal and common rafters, inclined plane frames).

According to Dr. Bálint Szabó "the static behaviour ***in the eclectic roof structures*** mainly corresponds to the Baroque structures", but "the efficiency of the structure is better" [12], although in solutions nearly reflecting engineering approach and constructed in the traditional way ***we can recognise further functional dividing of the support structural unit***. Independent truss constructions appear and bent purlins supported by *trusses and/or roof posts*, which supported collar-beam rafters at the beginning and later rafters (in position fixed with double collars).
During *development in the 19th* century cross way load bearing more and more concentrates in the levels of principal rafters. Common rafters containing rafters only (complete with pole plates and often with ridge purlins) are discharged and supported by purlin lines. The position of the rafters and the middle purlins are provided by the double collars, which are free of their supporting function. The supporting function of angle-braces participating in the longitudinal stiffening is limited to the decrease of the bent purlins' span. We can **rank** the support rolls, since beside the **principal supportive function of the principal rafters, the purlins' secondary and the tertiary function of the rafters supporting the crusts** are indisputable.

The ever increasing consciousness in structure development is justified the possibility of ever simplifying creation of models, since the level operated subunits which can be divided (truss constructions) give clearer approach too. Some elements (purlins, rafters...) can be created as models separately and simple too. (The later, clear triangle structured and other real engineered structures are created in model forms.

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Figure 1: Gothic principal and secondary rafts, longitudinal frame *("plane-stiff" units)*

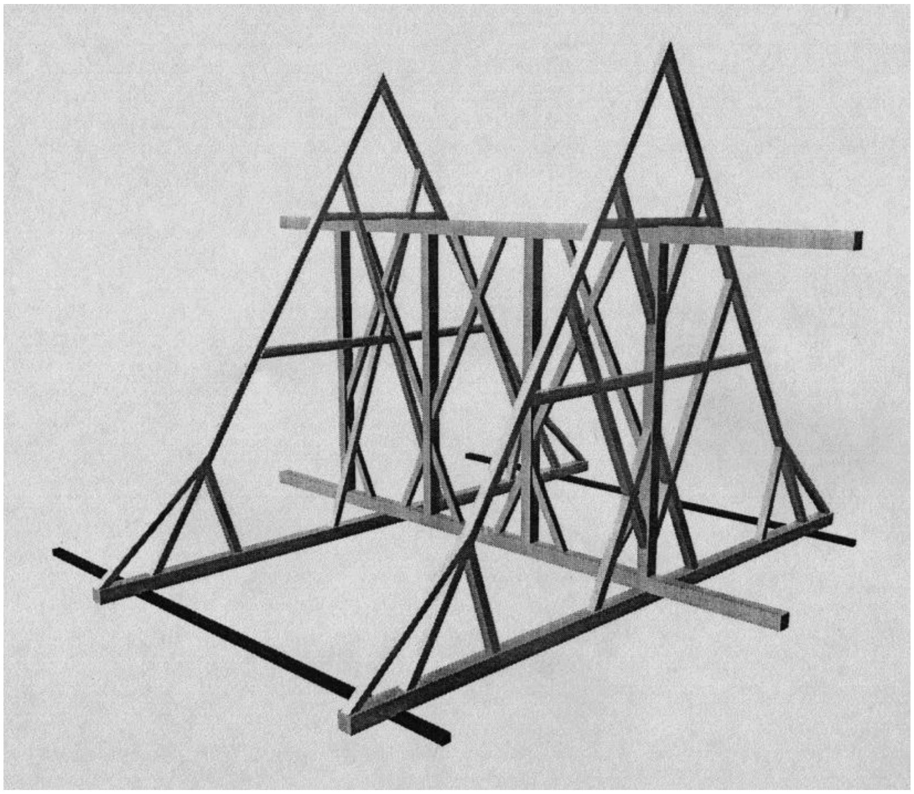

Figure 2: Medieval roof structure

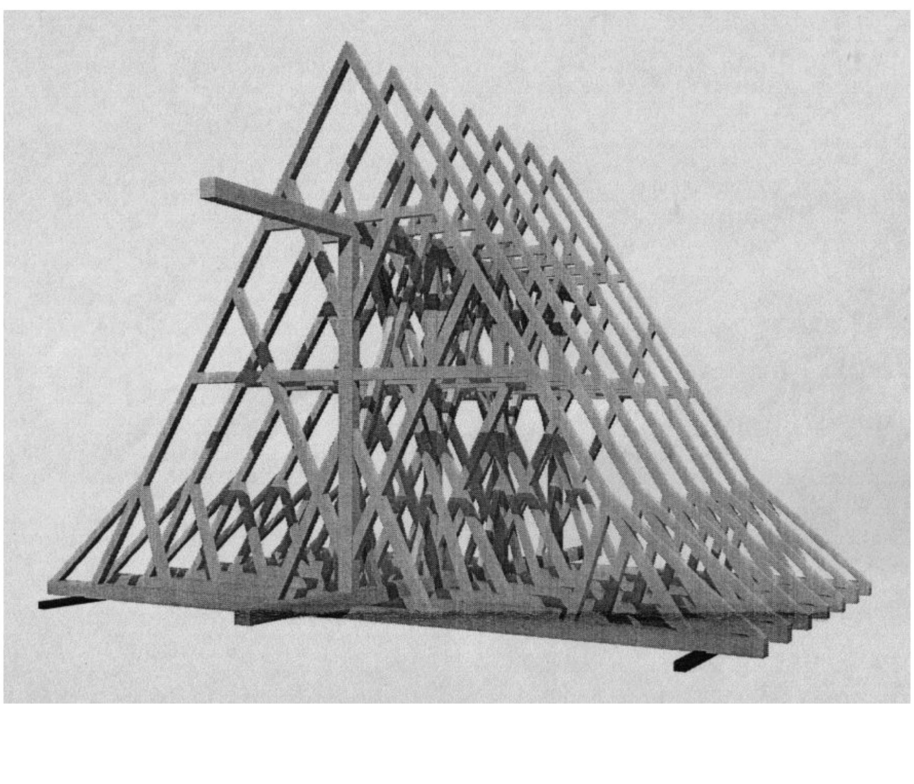

Figure 3: Dimensionaly self-stiff *baroque framework unit*

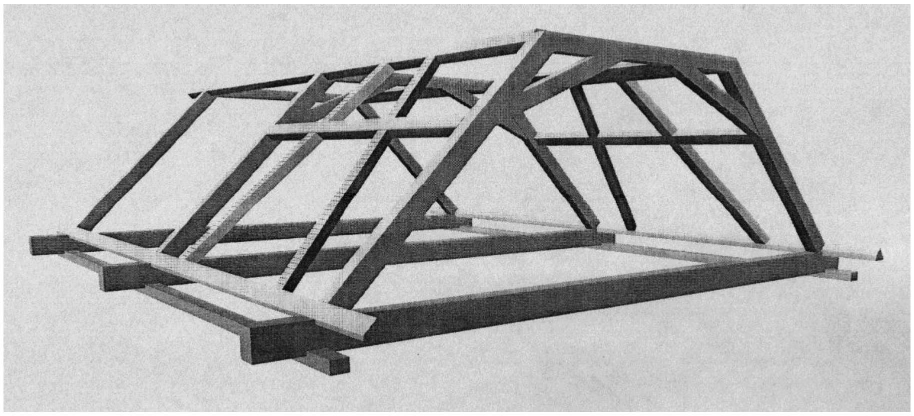

Figure 4: Baroque roof structure bearing identical trusses

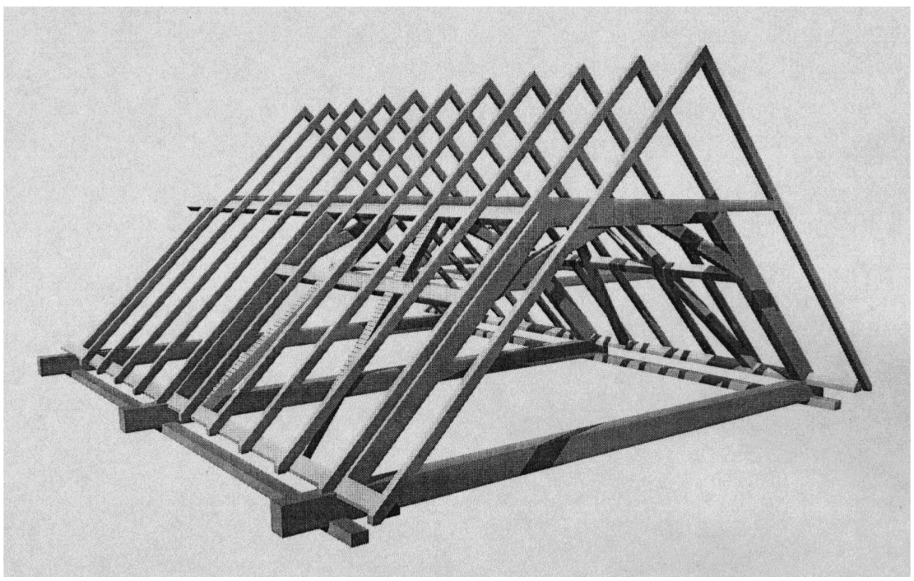

Figure 5: Basic elements of the roof structure with purlin and double collar

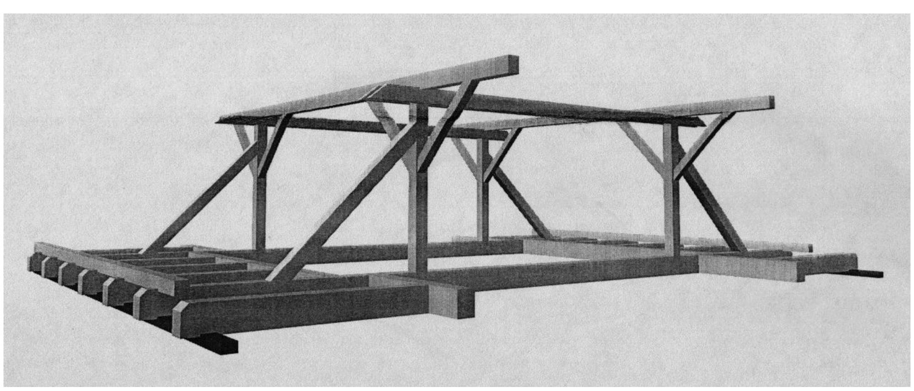

Figure 6: Roof structure with batten and purlin bearing crocheted rafters