Published in: Building Histories: Proceedings of the Fourth Conference of the Construction History Society. Ed. J. Campbell et al. Queens College, Cambridge University.

The Craftsmanship in Construction and Transformation of Historic Tower Campaniles

Mattias Hallgren[1] and Gunnar Almevik[2]

1. Independent Building Researcher; 2. University of Gothenburg, Sweden

In Sweden there are about 450 self-standing campaniles from the nineteenth century or before and approximately 6000 preserved church bells. [1] Until recently the oldest preserved campanile was Härlöv (1485) in Växjö diocese. A survey and dendrochronological analysis of campaniles in Skara Diocese has identified at least seven campaniles from the fourteenth and fifteenth centuries. [2]

This paper aims to bring new information on the historic construction of wooden campaniles in central Scandinavia during the medieval period. In the research we investigate significant qualities of the construction and craftsmanship, how this type of medieval campaniles were built and raised and later restored and transformed. The medieval campanile in Grevbäck from about AD1300 is used as a case for in deep investigation. A model at 1:10 scale has been produced as a part of the investigation. The model is constructed with the same dimensions of material and with the same skewness and irregularities as recorded. Furthermore a working seminar was held with craftsmen specialised in the restoration of medieval wooden constructions to assess the 'inner logic' of the building process. [3]

The research method is based on semiotic pragmatism, with the building as the primary source of knowledge.[4] The numerous measured drawings are "diagrams of observations" where the whole of the building is known as a review of its details.[5] An important aspect of the method is the interplay between building investigation and the practice of craftsmanship in previous restorations of campaniles and medieval wooden constructions. The experiences and semiotic competence from craft practice is reversed in the practice of historical inquiry. The research procedure is not strictly inductive or deductively driven by hypothesis but rather abductive, using close up investigation, interpretation of toolmarks and craftsmanship in combination with the horizontal 'excavation' of the building's historical layers and inference from practical experiences.[6] The historian Carlo Ginzburg frames the methodology, calling it "a paradigm of clues".[7]

The medieval wooden tower campaniles in Skara diocese

The use of church bells is documented in early Christian practice. The bell was one of the prominent religious objects brought to Scandinavia early in the evangelisation. [8] The existence and use of solitary campaniles are described in Scandinavian provincial laws from thirteenth century. In the law for Västergötland dating to 1220's the peasants are obliged to pay the bishop for consecration, and not only for a new church but also for the campanile that is referred to as *stapul*.[9]

Figure 1. Mapping of campaniles in the diocese of Skara. Grevbäck is marked with a red ring. It is provisionally dated to AD1303 but further dendrochronological analysis is in progress. Dated by dendrochronology are also: Brevik AD1321-1336, Norra Fågelås AD1360, and Ransberg AD1383-1407. St. Levene, Marum, Vad and Ekeskog are considered to be medieval constructions. Illustration by Elisabeth Orebär Krantz.

One of the most informative image sources of a medieval campanile is the tapestry from Skogs church in the north of Sweden. The tapestry shows three different constructions for bell ringing, one small wall-mounted altar bell, a larger bell in a ridge turret with a string down to the nave, and in the same scene, a self-standing campanile with two larger bells beside each other. All bells had different functions, to regulate the day and call upon the parishioners, and provide structure to the religious procedures. The sound of the church bells was ever present in the lives of the parishioners, every day of the year.

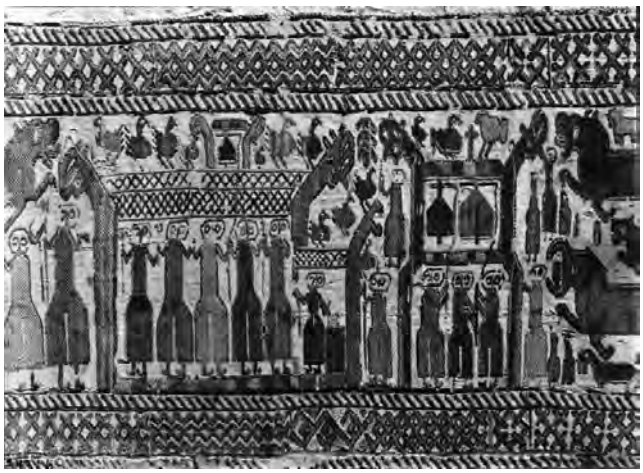

Figure. 2. The tapestry from Skogs church dated to early thirteenth century, now at the Swedish History Museum. Photograph by Carl Gustaf Rosenberg 1922, ATA.

The majority of the preserved medieval campaniles are located along the woodland border zone of the Scandinavian south-central highlands and most of them date to the fourteenth century.[10] Two campaniles in Västergötland were erected during and just after the Black Death - a period that has been identified as a hiatus in Scandinavian building tradition in previous research.[11] Through the recent discoveries we know that the people built campaniles even during the desolation of plague, thus building a sacred communication system. A recurrent feature is the pyramidal shape of a tower. To get better understanding of the construction, we will present a detailed description of the campanile in Grevbäck.

The Tower Campanile in Grevbäck

Grevbäck on the west shore of Lake Vättern belongs to Hjo parish in Skara Diocese, in the region of Västergötland. The earliest document of the settlement is a royal adjudication from AD1222, concerning land for the Cistercian monastery in Alvastra on the other side of Vättern.[12] Marie Holmström and Claes Tollin suggest that this district was colonized during late twelfth century as a Cistercien *grangie*, i.e. a satellite economic establishment.[13]

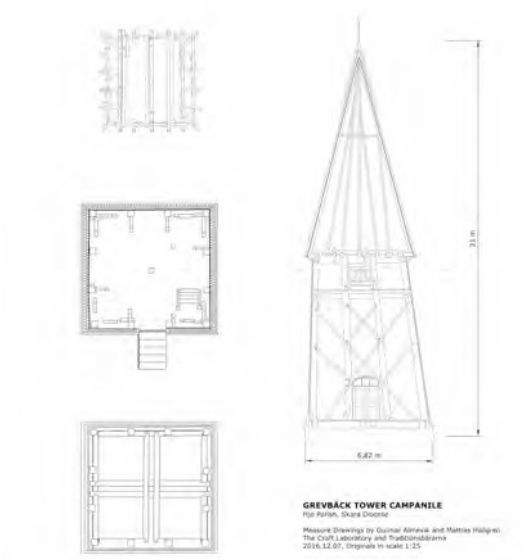

Figure. 3. Documentation drawings by Gunnar Almevik and Mattias Hallgren. Original scale 1:25.

The campanile is situated north east of the church, not more than four metres from the church walls. The location is the highest on the churchyard, and the campanile raises a further 21 metres above the ground. The walls of the tower are leaning inwards and just slightly breaking the angle at the transition to the steep pyramid roof. The building is square with sides 6.3 metres on the ground and 5 metres at the eaves. The walls as well as the roof are now covered with wooden shingles.

The structure is built of slow-grown pine and spruce. Pine is used in the timber frame construction and spruce in the trusses. The dowels are both oak and pine. The constructive material is hewn into rectangular or square shapes with sharp edges. Beams, braces and the upper plates are cleaved in pairs from larger logs and hewn with sharp edges. The roof-carrying timber frame construction consists of 12 wall posts, 10.5 metres long and about 14”x13”

in cross-section. Each wall frame, facing a cardinal direction, consists of four posts connected with crossed diagonal beams and braces.

The wall posts are mounted in a sill and continue to the top plate. The sill is constructed with an inner and an outer ground plate clamping the pillars. In the middle of the campanile is a central post continuing with a mast to the rooftop. The post is 10.5”x10.5” neatly hewn and shaped with climbing steps and hand grips. This post was evidently the stair to the bell floor. The same type of central post is found in the campaniles at Vad and Ekeskog.

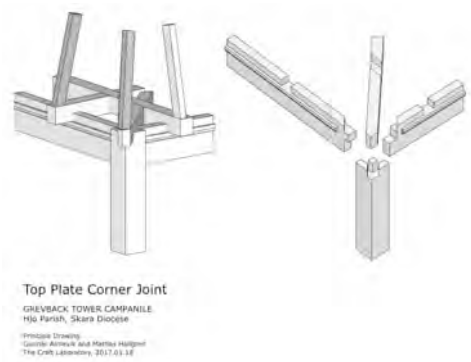

Figure. 4. Detail of the eave with top plate, bressumer and clamped soffit joists.

Figure. 5. Interior

The bell floor system of joists are fitted into a 3.5”x11” edge-up plate penetrating the wall posts. The plates are cleaved in pairs from a block and carry the four joists of 6”x5” of the bell floor. The pyramid roof spire rests on a bressumer connected to a top plate. Also the top plate 3.5”x18” edge-up plate penetrates the wall posts. The system of joists of the roof are 6”x8.5” and placed in the north and south upper plate. The joists make a 15” eave along the north and south. Along the east and west, short soffit joists, clamped between the top plate plank and an outer bressumer, form the eave.

The steep pyramid roof consists of 22 mainly spruce rafters. The dimension vary from 4.5”x5.5” in the root and 3”x4” in the top. Sixteen rafters go all the way to the top of the spire. In the top is a replaceable part, neatly joined to the mast. The wood is recycled, possibly from the Romanesque church. The roof boards are of both pine and spruce, cleaved and hewed 10”-20” broad and 1.25”-1.5” thick. Four boards are cleaved from one log. They are randomly nailed and doweled to the rafters. The roof is covered with wooden shingles of pine, cleaved 1” and hewed in diagonal.

Interpretation of construction and craftsmanship

The different types of wood are used in regard to the demands of the structure , with pine used for the timber frame building and spruce mainly for the roof construction. The structural pine is 200-300 years old, indicating access to timber forests. Some material in the construction seems to be re-used possibly from an older church. Oak dowels are found in the corner joints but commonly pine was used for dowels. Large construction nails seem to have been

used after the erection of the campanile, in order to lock joints that did not fit perfectly. The dowels are not wedged and they commonly stand out 2” to 4” from the joints.

All the material that is considered primary is hewn in a particular technique, known as *sprättäljning*. The work process of hewing in parallel or diagonal bands along the wooden fibres is significant in mainland Sweden before the Black Death in the late fourteenth century.[14] The clamped sill that is considered secondary, has marks from a broad axe cutting the fibres in a perpendicular angle. Another significant quality of the original construction material is the boxed shape and the sharp edges. This quality is consistent and must have been a norm in the historic building process. The dimensions, however, vary from base to top and within the same type of construction material. The edges are always sharp but the profile may be rhombic and the surfaces concave.

Figure. 6. Toolmarks from the particular hewing technique sprättäljning.

The wall frames of posts, diagonal beams and braces have a principle form but the locations of the joints are not standardized in measure. The design of the joints is approximately, but not exactly, the same. This character of wooden construction without fixed measures and standardised design is also recurrent in the early medieval campaniles, church attics and timber buildings. This changes when the guild system begins to affect rural monumental building in the late fourteenth and fifteenth centuries. The change in tradition is visible in the use of broad axes in hewing, lack of cleaved material but an increasing use of sawn boards and planks.[15] The constructions in the late medieval period get heavier, with less individual refinement and lightness. More materials are prefabricated. The measures in design become standardized and templates are used in cutting of the joints. We find more timber markings and traces of professionalized, time-effective working methods. Already by the end of fourteenth century and early fifteenth century, in the campaniles in Norra Fågelås and Ransberg we notice a difference in the use of the continental broad axe.[16]

Lighter construction components, like beams, planks and boards are cleaved from larger blocks. Regularly the cleaved surface is also hewn. About four boards 20” wide are cleaved from one and the same log.[17] The cleaved

planks are used standing end-up to effectively take load, and oriented horizontally north-south to withstand the pendulum of the bells.

There is evidence of problems in the process of erection. The design of the construction, mounting of the wall frames and cutting of joints was to a large extent made before erecting the campanile. The design and pre-fabricated components did not always fit when mounted. The ends of diagonal beams and braces ended up at the same position on the corner post and had to be adjusted to avoid weakening the posts. New joints were cut on the spot and nails added to sustain imperfect joints. The scribe marks for the top plates do not follow a horizontal line, indicating that the wall frames were oblique before erected.

The investigation's most important observation is that the original campanile had no sill. The wall posts stood on flat stones on the ground. The foundations of Ekeskog and Norra Fågelås have been excavated and here we see large flat stones placed under each wall post.

It hasn't been possible to uncover the whole ground construction in Grevbäck.

Figure. 7. Ransbergs tower campanile. The secondary clamped sill with inner and outer plates.

The ground floor is entirely new and dates to a later restoration. The main part of the structure is intact in its primary state with some additional braces and dowels. The skewed irregularities also seem to be from the time of primary erection. The cleaved roof boards are original but the shingles seems to be of recent date. Clinker shell horizontal panelling originally covered the walls. The panel is 2"-2,5" thick and with 3"-5" overlap. A few of these boards have been re-used in the boarding under the present shingle covering of the walls.

Originally the mid post was used for climbing up to the bell floor but today a staircase leads up to the floor. The medieval campanile had places for three bells of different sizes. Today there are two bells, one larger than the other,

dating from eighteenth century.[18] One of the joists was moved to create space for the larger bell, and both the floor and roof structures were supported with extra beams and braces. The additional elements bare marks of the same hewing technique as the clamped sill construction. Judging by an inscription there was a building event in AD1660, which may be the time for this major restoration.

The building process and erection of the campanile

The original construction had no sill and the twelve wall posts as well as the central post stood on flat stones on the ground like a chair. The clinker shell panelling had an important stabilizing function in addition to that of the crossed diagonal beams and braces. The cornerstones form an equilateral square but the inner wall posts have no standard spacing . The assumption is that the wall frames were built on the ground with reference to the flat ground stones. The horizontal level of the ground stones is therefore of vital importance in the process of erection and fitting of the wall frames. Here the medieval craftsman came to face problems.

Figure. 8. The north east corner post.

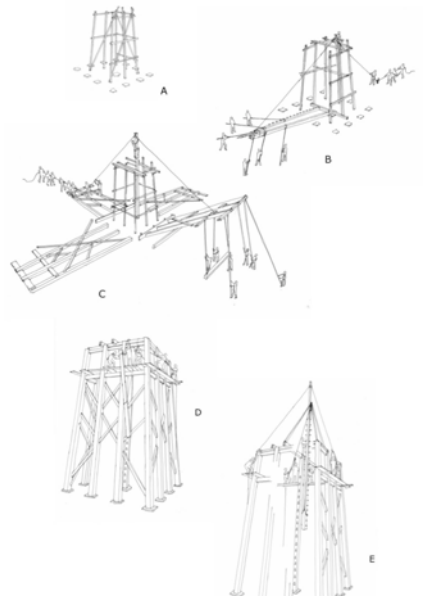

Figure. 9. Illustration of the erection process step by step. Illustrations by Gunnar Almevik and Mattias Hallgren.

By pursuing the problems we may reverse the historic building process. Various procedures of erecting and mounting the construction have been suggested and tested, but we outline one procedure with consistent inner logic in regard to the evidence in the historic building. The problems for the craftsmen accumulated in the northeast corner. This was most probably the last wall post to be connected. The wall frames were cut and assembled on the ground before the process of erection started. It would not have been feasible to raise the posts one by one and fit the crossed diagonal beams and braces afterwards.

The wall frames were erected clockwise. Each frame had one corner post and a mid post, fixed in place with crossed diagonal beams and braces and the upper plates. They started with the east wall frame, continuing with the south, to the west and finally the north.

By the time the craftsmen had raised the western wall frame they realized the problems coming, whereat they had to make adjustments. Pre-cut joints that were never used reveal the mistake. When the last north wall frame was erected, the pre-cut joint did not fit and a new joint have been cut on the spot. The rough character of the joint and the use of nails also indicate that this is what happened.

The preserved scribe marks for the top plate's corners assume a perfect horizontal level. This was not achieved. If there is a difference in angle of only one degree in the ground level between the outer posts, the top plate will move horizontally out of position 16-17 cm.[19] The first three wall frames have some flexibility but when the whole structure is connected, there is difficulty in forcing the structure into position. It is possible that they tried to level the wall posts with wedges or levers. However, the medieval craftsmen had to cut new joints and add dowels and nails to lock the structure . Maybe they had just a fraction of a degree deviation from the horizontal level resulting in this problem. Does this indicate that the craftsmen were unskilled? Was there a critical individual mistake? Were there two teams, working on different frames, who miscommunicated about the design and work process? Would another method, erecting opposite sides in turn have been a better choice? Could the depth of foundation have been too shallow, the soil unstable or the weather disruptive when erecting the heavy wall frames?

To raise the heavy frames there must have been some kind of auxiliary construction. One frame with three wall posts, crossed diagonal beams and braces and the upper plates weighed approximately 1500 kilos. The craftsmen needed some kind of lever to manage the weight of the wall frames; some kind of support to hold the wall frames in place when erected; and finally a temporary floor to work on when connecting the frames and building the permanent bell floor. The hypothesis starts from the assumption that it would have been good to erect the central post first, for use as a fulcrum for pulleys and ropes erecting the wall frames. A small tower with three sides would have been sufficient for the building objective. The minimum height of the temporary tower would be just below the bell floor, about six metres high.

Erecting the wall frame was done mainly from the ground by levers and struts up to an inclination of 45 degree, from where pulling with ropes through high placed pulleys would have been preferred. The angle of the rope to the ground cannot be to sharp, 35-40 degrees seems to be ideal in this case, otherwise the frame may overbalance and tumble over the temporary tower. The frames may have been held in place by struts tied with a withy at the top. This kind of auxiliary device is found left behind in many medieval church attics. Another device is needed as counter-stay, to hold the wall frames in position at the ground. This can be achieved by a horizontal plank, in the position of the ground stones and fixed to the ground by stakes.

There are few traces that lead us to the process of erection of the high pyramidal roof structure. This might indicate a process like the rigging of a ship with few auxiliary constructions except rope and pulleys. The components are long but not as heavy as the wall frames. The heaviest piece is the mast rising from the central post and weighs 180 kilos. The central post and the mast were probably erected together, first of all, built inside the campanile. The mast can easily be lifted up with a turning block, and loose rings of rope or withy around the central post keep the mast in position, with a few craftsmen grabbing the climbing pegs. The most critical point is to lift the mast in position on top of the central post. Guiding ropes from the top of the mast down trough all corner joints into the bell floor, held by four craftsmen, could balance the mast until locked in position.

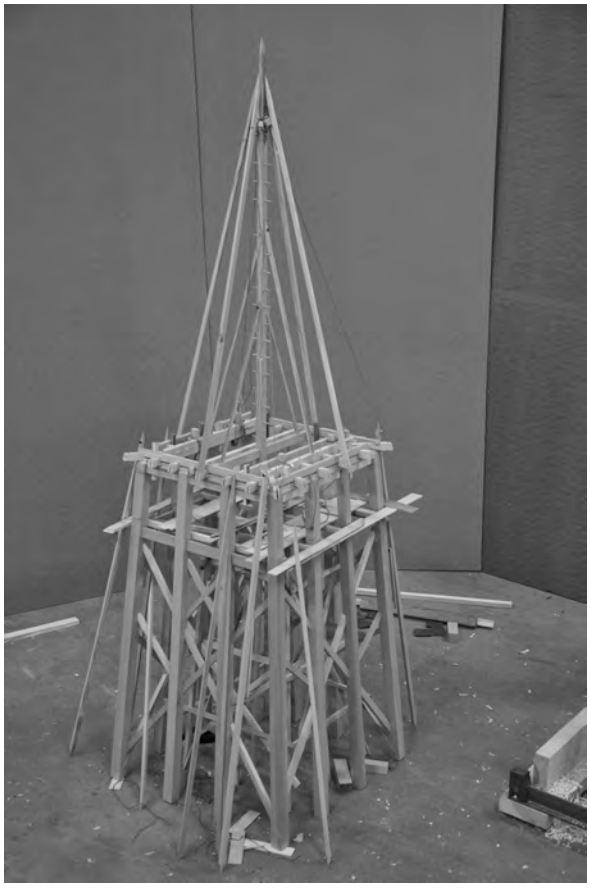

Figure. 10 The model in scale 1:10.

The rafters are light and could easily be drawn up by a block and rope from the top of the mast. A small square shaped frame of light spruce strainers is preserved at 2/3 of the height of the mast. This was probably used to get the rafters in position. The joints of the rafters for the top plate are pre-cut and so are the abutments to the mast, though some adjustments had to be done. The mast has transfixed horizontal rungs for climbing that were handy also during the process of erection. The roof boards were probably mounted from inside and as soon as possible to stabilize the rickety structure of rafters.

Conclusion and discussion

The investigation's most important observation is that the original campanile had no sill. The wall posts as well as the mid post stood on flat stones on the ground. The interpretation is that the clamped sill and system of joists at ground level is related to changed requirements in regard of the bell ringing. In the seventeenth century the small medieval bells were exchanged for larger bells, and the previous curved oscillating axles were exchanged with straight ones. The larger bells and the perpendicular swing from a straight axle gave a higher and far-reaching sound, but they also stressed the structure above its static capacity. The clamped sill construction is seen also in the other medieval campaniles in Västergötland.

Interpretation of traces and simulation of the construction process through the model have identified a plausible building method in construction and erection of the campanile. The ground plan was laid out by the ground stones and from their places the frames were positioned, cut and assembled. Each wall frame had the right side corner post and the mid posts fixed in place by crossed diagonal beams and braces and the upper plates. The frame weighs about 1500 kilos. The frames were erected clockwise starting with the east cardinal direction, continuing with the south, to the west and finally the north. The medieval craftsmen had problems fitting the wall frames in the final connection in the northeast corner post. The problem was probably caused by a deviation from horizontal level of the ground posts. Even a small difference in angle in the ground level between the outer posts has a large effect on the position of the top plate. The medieval craftsmen succeeded in connecting the wall frames but had to cut some new joints and add dowels and nails to lock the structure. To raise the heavy frames they used an auxiliary construction, probably a three-sided inner tower. First the central post and the mast were raised and thereafter the wall frames. Struts were used to push, lever and balance the posts from the ground, before being pulled up with ropes through blocks in a fulcrum placed on the temporary tower. The pyramidal roof structure consists of lightweight rafters and its erection might have been like rigging a ship, with few auxiliaries other than ropes and blocks. The clinker shell horizontal panelling and the roof boards had an important stabilising function to the construction.

The campanile in Grevbäck represents a type of construction for medieval campaniles, whereof several are preserved in Västergötland from the fourteenth and fifteenth centuries. In *Monumenta Sveo-Gothorum* from late seventeenth century by Johan Peringskiöld we find 20 engravings of similar towers, all from the forested areas in north and east parts of Västergötland.[20] Even if the appearance of the campaniles looks the same, the construction and craftsmanship reveals different qualities when compared in detail. We may see a shift in building tradition that occurs at the time of the Black Death. How did this comprehensive societal change affect buildings in terms of craftsmanship and know-how?

For future research we would also like to investigate the building history of the places where these types of campaniles have been identified. Is there a relation to the log timber churches that were built during medieval period? Is it possible that know-how from the Cistercian monasteries influenced the construction of the medieval campaniles?

Finally, this investigation shows that it is of vital importance, to understand the craftsmanship in a historic construction, to accurately record the skewness and irregularities and not *à priori* regard these qualities as results of deterioration. The investigation also shows that contemporary craftspeople and their craftsmanship can be used, not only for practical reconstruction but also as a competence in historical inquiry. The involvement of a wider range of perspectives and deeper repertoire of codes may open new types of observations and interpretations of historical construction.

Acknowledgment

The research in the article was initiated through the project *Medieval Campaniles in Skara Diocese* led by Mattias Hallgren together with Bengt Bygdén and Daniel Eriksson. Mattias Hallgren is funded by a research internship provided by the Craft Laboratory at the University of Gothenburg to investigate the campanile in Grevbäck. Gunnar Almevik's participation in the research is made possible through a research fellowship at the Royal Swedish Academy of Letters, History and Antiquities and the research project *Wooden Building Culture*. We also would like to acknowledge the contributions by Daniel Eriksson, Börje Samuelsson and Daniel Åkerman who participated in a working seminar to assess and develop the hypotheses of the investigation. Furthermore, we acknowledge the

County Heritage Board in Västra Götaland for funding the dendrochronological analysis, and not least Grevbäck parish for shelter, access to the building and for their caring attitude towards our cultural heritage.

Notes

[1] Bringéus 1958:20, Lindblad 1995, Stockhaus 1940:340, Møller 1960.
[2] Hallgren et al 2014, Hallgren & Bygdén 2014, 2013, Hallgren 2012, 2013.
[3] The seminar was held in Grevbäck 7-8 of December 2016. Participants above the authors were Daniel Eriksson, Börje Samuelsson and Daniel Åkerman.
[4] Almevik 2012.
[5] Hansen 1978.
[6] Almevik & Melin 2015, 2016.
[7] Ginzburg 1999.
[8] Hildebrand 1884:30.
[9] Wiktorsson 2011:10-11, 192-193.
[10] The oldest yet dated campanile is Härads in Sörmland from 1319. Other Swedish medieval campaniles are Härlöv (1485) in Växjö diocese, Norra Mellby, Brönnestad and Perstorplänge in Lund diocese. Söderköpings city church dates to 1582, and Trönö in Hälsingland and Häverö in Uppland are considered to be late medieval. The Norwagian campaniles in Borgund, Rinde and Årdal are also considered to be from the fourteenth century, see Hauglid 1976:394-397.
[11] Bartholin 2001, Lagerås et.al 2016.
[12] SDHK 412.
[13] Holmström & Tollin 1990.
[14] Almevik & Melin 2015, Hallgren et al 2014, Sjömar 1988.
[15] Almevik & Melin 2015, Hallgren et al 2014.
[16] Hallgren et al 2014.
[17] Almevik & Melin 2015.
[18] Nimar 1975.
[19] The situation has been simulated and measured in the sketchup model.
[20] Peringskiöld 2012.

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