



Examining earthen building methods at the Nyarma monastery in Ladakh

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SUMMARY

The accessible adobe brick ruins of Nyarma in Ladakh provide a unique opportunity for research on earth building traditions up until ca. 1000 years ago. The monastic compound which today is in ruins with no remaining wooden structure is composed of one main temple and four free standing temple structures. According to literature sources, only the main temple is dated (Feiglstorfer 2016). Mineralogical research on material qualities together with an examination of the construction of the temples revealed the relation between material qualities and properties of construction.

Results include knowledge on the origin of the temples' earth material and the processing of such material as an economic working practice. Aspects of construction, like the width of the walls, the different kinds of brick bond, the sizes of the bricks or the tapering of walls, are analyzed and the results juxtaposed to mineralogical analyses on factors such as bulk- and clay mineralogy, grain size distribution, grain shapes, color and organic additives. With a package of constructive and material features, the individual characteristics of each temple are uncovered and the results compared. Conclusions are made on the use of different brick sizes and '3-bricks' and '2-bricks' brick bonds, and their relation to a certain group of temples. An explanation for the method of tapering walls and the use of tapered walls within the whole monastic compound is determined. Certain analogies in constructive and material characteristics allow for a hypothesis on the grouping of temples within a common period of foundation.

The stating of an interrelation between certain methods of construction and the quality of the building material is a methodological step forward in research on the interrelation between historic and recent methods of construction, and is a basis for further research on vernacular Himalayan structures.

INTRODUCTION

The monastery at Nyarma is one of the three first West Tibetan monasteries founded in the year 996 AD. Nyarma was the monastic centre of Maryul, the most western part of the empire which is similar to today's territory of Ladakh. The foundation of this monastery may be evidence of an introduction of a new architectonic program in the Western Himalayas. Since the monastic site of Nyarma is in ruins, only a study of the adobe brick construction is possible. Its constructive features mark the earliest existing examples of a monastery in Ladakh and are examples of early traditions in using adobe in this region. The whole site consists of five temples of which only the oldest – the main temple – is dated to 996 AD (Fig. 1 / Fig. 2). Whether or not the other temples were erected at the same time as the main temple or successively at a later period is still unknown. To obtain a closer understanding, early traditional methods in building with earth in the Himalayas, the methods of construction and the used earthen material are studied, analyzed and compared.

This investigation is based on several field studies conducted within the FWF-project 'Society, power and religion in pre-modern Western Tibet' at the Austrian Academy of Sciences. It is further based on material research within the 'Clay mineral analyses' project sponsored by the Austrian Research Promotion Agency (FFG) and the Austrian Academy of Sciences (ÖAW). Lastly, it is an excerpt from my doctoral thesis 'Mineral building material-traditions in the Western Himalayas'.



Fig. 1 View from the east over the ruins of Nyarma.

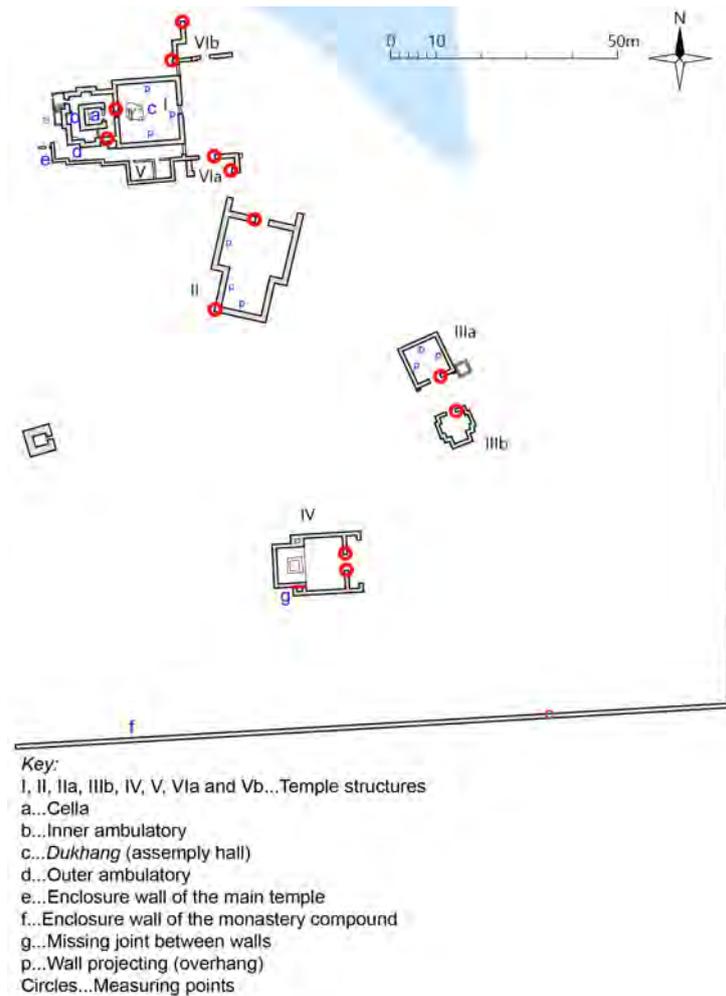


Fig. 2 Ground plan of the ruins of the monastery of Nyarma.

1. RESEARCH QUESTION AND METHODOLOGY

When considering the use of particular earthen material, like bricks, for building purposes up until 1000 years ago, the question exists of whether the raw material currently still used in close vicinity to the site matches with the historically used material or was this material delivered from another site. An answer to this question gives the first proven statement for the hypothesis that a main factor in choosing the site for such an important religious structure was related to the availability of proper building material – meaning an economic and practical decision. It is conspicuous that the central cores of the earliest three monasteries in West Tibet – Nyarma, Tholing and Khorchag –which were all founded in 996 AD, were all erected with adobe bricks and all related to a similar environmental situation like that of the monastery in Nyarma. This raises questions about the way particular raw material was used for construction purposes in regard to brick bonds, wall thicknesses, the sloping of walls and methods for static reinforcement.

For each temple specific constructive characteristics, like brick size, brick bonds, organic additives, layers of plaster, types of foundations, use of wooden inlays or the thickness of the mortar, are documented and compared with each other. In the field of material research, samples of each temple are analyzed according to the used raw material regarding organic additives or mixtures of several different types of clay. Laboratory analyses are conducted at the University of Natural Resources and Life Sciences in Vienna in order to observe bulk and clay mineralogical features of the used material, to become familiarized with grain size classes used for different building purposes, and learn about related mixtures and possible ways they were prepared. With this package of constructive and material features, the individual characteristics of each of the temples can be determined.

The method of introducing constructive and particularly bulk- and clay-mineralogical data supports the traceability of constructive continuities and also changes between the temple structures. Analogies and also in-conformities inconstructive and material characteristics support efforts to find relations between periods of construction of the single temple structures.

2. MATERIAL QUALITIES

2.1. Examination of raw material

Being that written evidence of the material used for construction is not available, we start with an examination of locally known and still recently used raw material for adobe bricks. Such material is found along the link road to the monastery. To ensure that the recently produced adobe bricks in Nyrama equal the material from the clay pit, two samples of bricks and two samples from two different clay pits are examined and juxtaposed.

The grain size analysis of the material from the clay pits compared with the material used for recently produced adobe bricks matches, and we are able to state that the recently produced raw material used for bricks was not manipulated by sieving or mixing. The content of gravel ranges between 3.9% and 9.3%, the content of sand between 51.6% and 65.9%, the content of silt between 17% and 28.7%, and the content of clay between 10.6% and 14.9%. The median of the grain size classes ranges between 95 µm and 180 µm and the <2 µm fraction contains between 11% and 15% of the whole sample (Fig. 3).

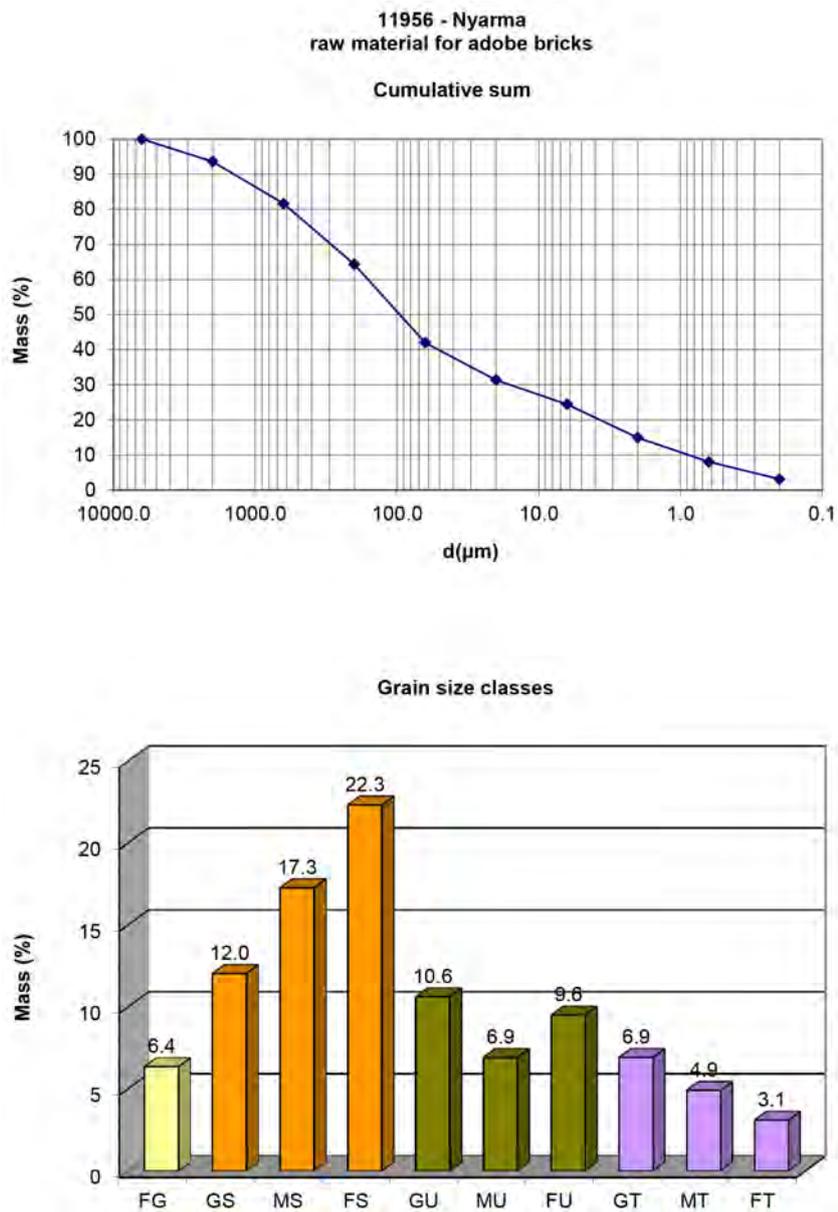


Fig. 3 Grain size distribution of a still active clay pit.

2.2. Examination of original bricks

Next, the material used for original bricks of all the temples is analyzed and compared with the raw material. For this purpose at least one brick sample from each of the temples is examined. In total eleven samples, including the enclosure wall which still exists in fragments primarily in the south of the monastery compound, are used (see Fig. 2). In most cases, the sampling point is along the reveals of the entrances of the temple structures since most of the walls are plastered and just the reveals remain uncovered. This enables the measuring of brick size and the examination of brick bond.

An analysis of the grain size distribution of the original bricks shows a content of gravel between 1.3% and 12.2%. The strongest fraction is sand, ranging between 40.6% and 64.5%. Silt is the second strongest fraction, ranging between 19.4% and 37.7%, and the clay fraction ranges between 10% and 20.8%. The material is relatively coarse ranging between medium gravel as the largest, and fine clay as the smallest fraction. The medians are located between app. 28 μm and 180 μm, and the <2 μm fraction contains between

app. 10% and 21% of the whole sample. In comparison with the afore described samples from clay pits and recently produced bricks, the bricks from the monastery show similar features regarding grain size classes. The bulk mineral analysis of all recently and also historically produced bricks likewise shows strong similarities amongst the bricks. 14Å minerals, mica, 7Å minerals and phyllosilicates appear as traces or in small amounts. Amphiboles range between traces and medium amounts, quartz primarily as small amounts, K-feldspar ranges between traces and medium amounts, and plagioclase appears up to a medium amount. Except for three out of 15, all samples show traces of calcite which points towards its natural availability and not an anthropogenic addition. Regarding the clay mineral properties, a small content of swellable clay minerals – in particular smectite – of an amount of 2% to 5% is determined. The content of illite ranges between 59% and 68%, the content of kaolinite between 6% and 10% and the content of chlorite between 21% and 30% (Fig. 4).

Comparing the average values of examined original adobe bricks from the monastery with recently produced bricks, the used material follows a similar pattern regarding grain size distribution as well as bulk and clay mineral content. With this result we make the important statement that the building material used for the monastery originates from a location in close vicinity to the site or from the site itself.

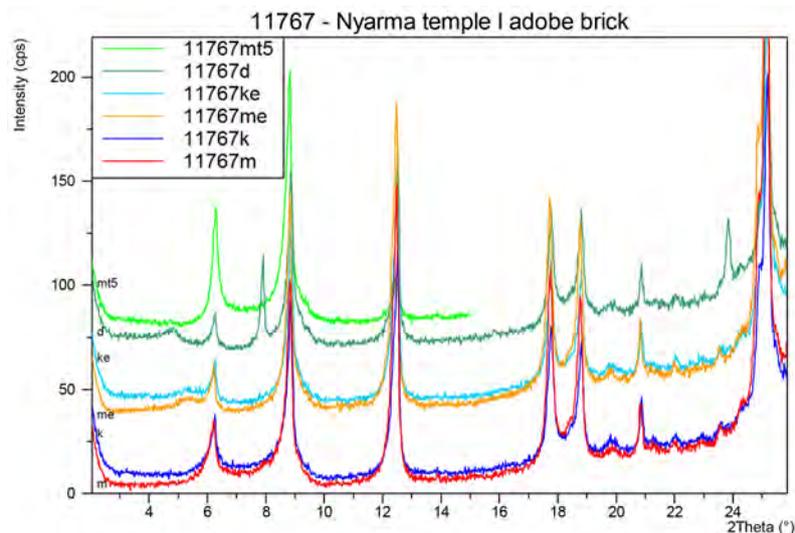


Fig. 4 Clay mineral analysis of a brick sample from the main temple.

2.3. Comparison of original bricks from the single temples

In a further step the single original bricks are examined regarding possible differences in grain size composition. Apart from the previously made general observation, we still find slight differences in the single brick's grain size distribution. Grain size distribution on the one hand could still range within the general features of the area close by but on the other hand point towards the use of different clay pits and show similarities or dissimilarities between raw material used for a group of temples. As a result of this analysis we achieve a hypothetically intermediate result showing the following similarities or dissimilarities, respectively:

Structures with matching features:

- o Regarding a small content of gravel, temples I, IIIb and VIa are comparable to each other. Regarding a relatively small content of sand, temples I and VIa show similarities,

and regarding a relatively high amount of clay, again temples I, IIIb and VIa show similarities with the <2 μm fraction containing between app. 18% and 21%. Such results clearly show more content of clay than the average samples. Structures with reduced matching features, i.e. structures where the used material shows clear evidence of being taken from different pits, concerns the following structures.

- o Temple I versus temple VIb
- o Temple I versus temple II
- o Temple I versus enclosure wall

At this point the constructive features of the adobe brick structures are explained and compared with the results of the material observation given above.

2. CONSTRUCTIVE FEATURES

2.1. Comparison of brick sizes

Brick sizes found at the main temple, not considering its side temple VIb, range between 38–42 x 26–29 x 10 cm (LxWxH) (see Fig. 2). Parts of the side temple VIb contain bricks of a length of up to 45 cm which clearly exceeds the average size of bricks found in the main temple. Such a bigger brick size is also found at temples II, IIIa, IV and at parts of VIa with 46 x 26–27 x 12 cm, 49 x 28–29 x 11 cm, 41–48 x 26–29 x 10 cm and 3.5–45 x 29–30.5 x 8–10 cm, respectively. Some of the bricks are higher by 1 to 2 cm (12 cm instead of 10 cm) but their width remains similar. In this regard we can confirm the presence of two different brick sizes. Bricks with a length of app. 40 cm are found in all the accessible parts of the main temple, such as the *dukhang* (assembly hall), the inner and outer ambulatory, temples V and VIa, and also temple IIIb. The second brick size with a length of up to 49 cm with an average length of app. 45 cm is found in temples II with a size of 46 x 26–27 x 12, IIIa with a size of 49 x 28–29 x 11, and IV with a size of 45 x 26/11 cm. With a length of 43 cm and a height of 11 cm the enclosure wall ranges between these two groups.

Regarding the results of the mineral analysis, the previous hypothesis regarding similarities of structures applies to temples I, IIIb and VIa. Interestingly, these are also temples which have a comparable brick size. For these structures we state the same tradition of using a specific locally available raw material and producing bricks of a rather similar size. Parts of temple VIa show a relative strong wall at 116 cm, and a brick size of 43.5–45 x 29–30.5 x 8–10 cm which exceeds the average length of the first mentioned group of bricks with a length up to 40 cm but with a grain size distribution still matching the results received for the main temple.

The length of bricks of several religious structures in the Western Himalayas in the beginning of the second millennium such as in Khorchag, Chigtan, Mundig, Basgo, Nako, Tabo or Alchi also ranges between 42 and 49 cm, with a width between 21 and 29 cm and a height between 10.5 and 12 cm. In general, brick sizes found in Nyarma range within these brick sizes of early Western Himalayan structures.

2.2. Comparison of brick bonds

In the main temple, the oldest part of the monastery, we find adobe brick walls with a thickness between 100 cm and 110 cm. This concerns walls of the *cella*, the *dukhang* and the side temples VIa and VIb. The enclosure wall of the main temple shows a reduced wall thickness of app. 73–75 cm. Temple II has the highest wall thickness at 132 cm. All other walls range below 100 cm, like temple IIIa with 89–91 cm, temple III b with 74 cm, and

temple IV with 89–91 cm. Further, at 74 cm, the enclosure wall around the whole compound is similar to the wall thickness of the enclosure wall around the main temple. After comparison, temple I shows unity in itself, and temple II again steps out of line compared to the whole compound.

It is again temple II which differs from the other structures as the only temple with unplastered outer surfaces. Such construction allows us to gain good insight into the brick bond. At all structures it is possible to examine the brick bond in a cross section of the walls, primarily in the area of the reveals at the entrance openings. The different types of used brick bonds differ (1) in the amount of bricks in one raw, (2) in the orientation of the bricks (if stretcher or header), and (3) in the width of filled gaps between bricks. Regarding (1), the amount of bricks in one raw, we differentiate between two kinds of walls used in Nyarma, a '3-bricks' and a '2-bricks' bond, which refers to the number of uncut bricks in one layer. Regarding (2), the orientation of the bricks when using a '3-bricks'-bond, two kinds of orientations are used: a) '1 stretcher - 2 headers' and b) '3-bricks' bond type. The '1 stretcher - 2 headers' orientation is used in the main temple, e.g. at the west wall of the *dukhang*, at the outer wall of the inner sanctuary and at temple VIb which is an extension of the main temple towards the east (Fig. 5). At these structures the bond is mirrored layer-wise, always beginning with a stretcher on one surface of a wall. These kinds of walls show earth filled gaps between the bricks with a width of up to 5 cm on average. Together with these gaps these walls reach the mentioned thickness between 100 cm and 110 cm. The second '3-bricks' bond type which we only know from temple II and at the rear side of temple VIa is by far the thickest (Fig. 6). Its width of up to 132 cm is reached by using a '2 stretchers - 1 header' system with gaps between bricks of up to 16 cm which are filled with earth and river stones.

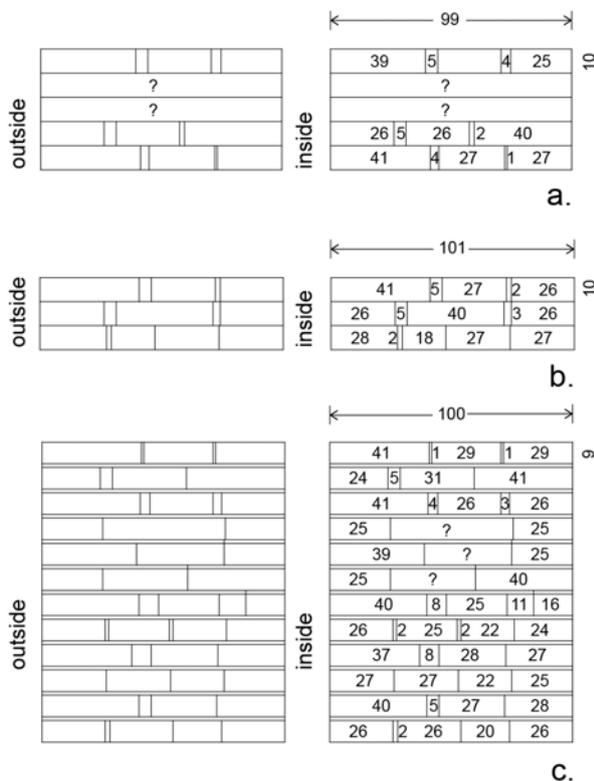


Fig. 5 '3-bricks' bond type. 1 stretcher - 2 headers.
a) West wall of the *dukhang*.
b) Outer wall of the inner ambulatory.
c) Temple VIb. All measurements in cm.

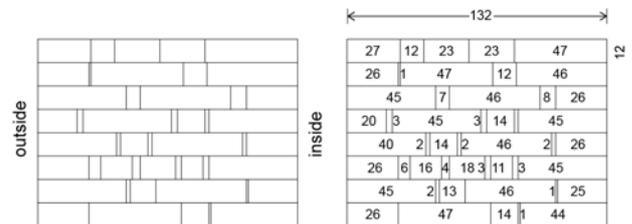


Fig. 6 '3-bricks' bond type. 2 stretchers - 1 header.
a) Temple II.
b) Rear wall of temple VIa.

All other temples follow a '2-bricks' bond type. Most of the walls of this type follow a '1 stretcher - 1 header' system which is mirrored layer-wise to avoid gaps resting above each other. Wall thickness again is generated by different widths of earth and stone filled gaps. At the enclosure walls around the whole compound and also around the main temple, a wall thickness of 74 cm is reached by using rather small gaps of up to app. 4 cm. The situation is similar at temple IIIb with the use of gaps with a width of app. 7 cm being relative regular practice. At temple IIIa and VIa (front wall) a similar system is used but with gaps of up to app. 15 cm, reaching a wall thickness of app. 90 cm and 86 cm, respectively (Fig. 7). Fig. 7d shows the first and third bottom layers completely as stretchers. We find an exception at temple IV where a '3-bricks' bond type (3 headers/no stretcher) is layer-wise changing with a '2-bricks' bond type (2 stretchers) with filling gaps of up to 9 cm. As such, a wall thickness of 94 cm is reached (Fig. 8). The finding of this system, which is defined by rhythmically variations of '3-bricks' and '2-bricks' bonds, and the knowledge gained from observing the adjustment of the width of walls by leaving spaces between bricks, should be an important focus of further research on early Western Himalayan adobe structures. This method also reduces effort in the production of bricks.

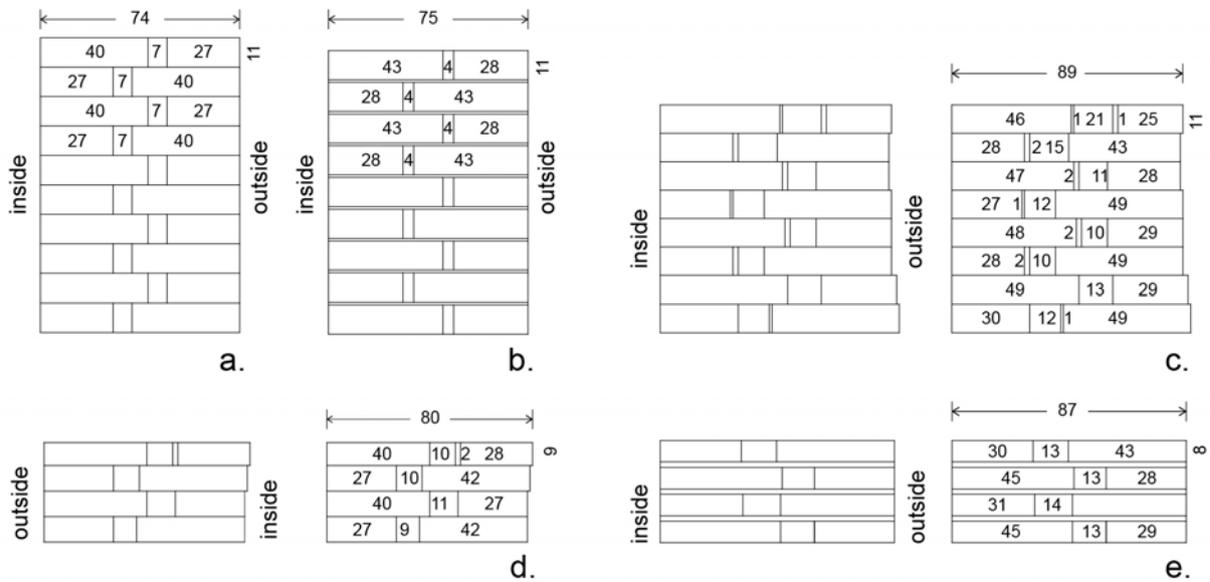


Fig. 7 '2-bricks' bond type. 1 stretcher - 1 header. a) Temple IIIb. b) Enclosure wall of the whole compound. c) Temple IIIa. d) Enclosure wall of the main temple. e) Front wall of temple VIa.

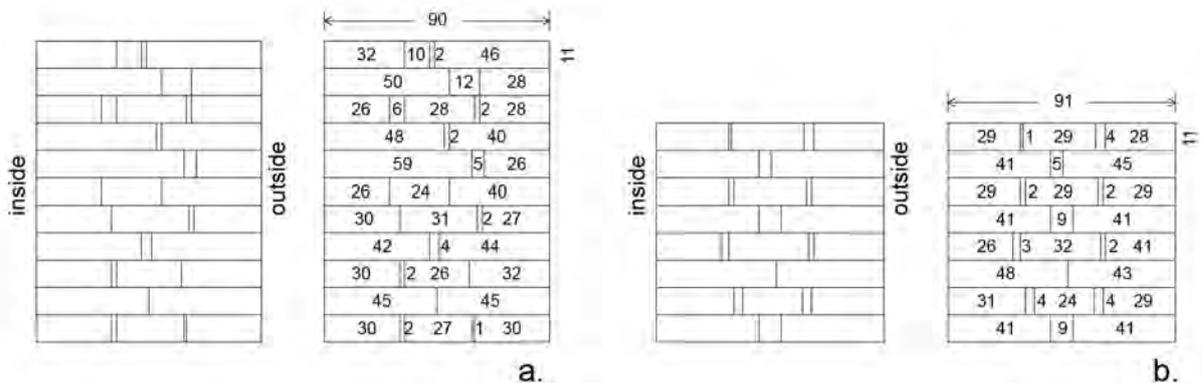


Fig. 8 '3-bricks' changing with '2-bricks' bond type. Temple IV. a) left reveal. b) right reveal.

2.3. Tapering and stabilizing adobe brick walls

Bearing joints are generally made with an earth mortar of up to 2.5 cm. Butt joints are gaps filled with earth or river stones with a width up to 15 cm. This method allows for the regulation of the thickness and length of the wall, and by this its inclination. This method is applied across and also along the wall, as seen at the western facade of temple II with a layer of stretchers alternating with a layer of headers (Fig. 9). A survey of the different inclinations provided an interesting result. Contrary to common knowledge, which states that Himalayan walls are primarily inclined along the outer surface, at Nyarma we also find inclinations along some of the inner surfaces, and at other sites a slight projection inwards is observable. At first glance this tapering seems to be either arbitrary or caused by a setting of the wall but this would have generated much more cracks along the corners. Finally, the hypothesis is – probably to counteractive settings and deformations – that different inclinations were chosen. In Fig. 2 the projecting inclination of walls is marked on the side of the wall projection with “P”.

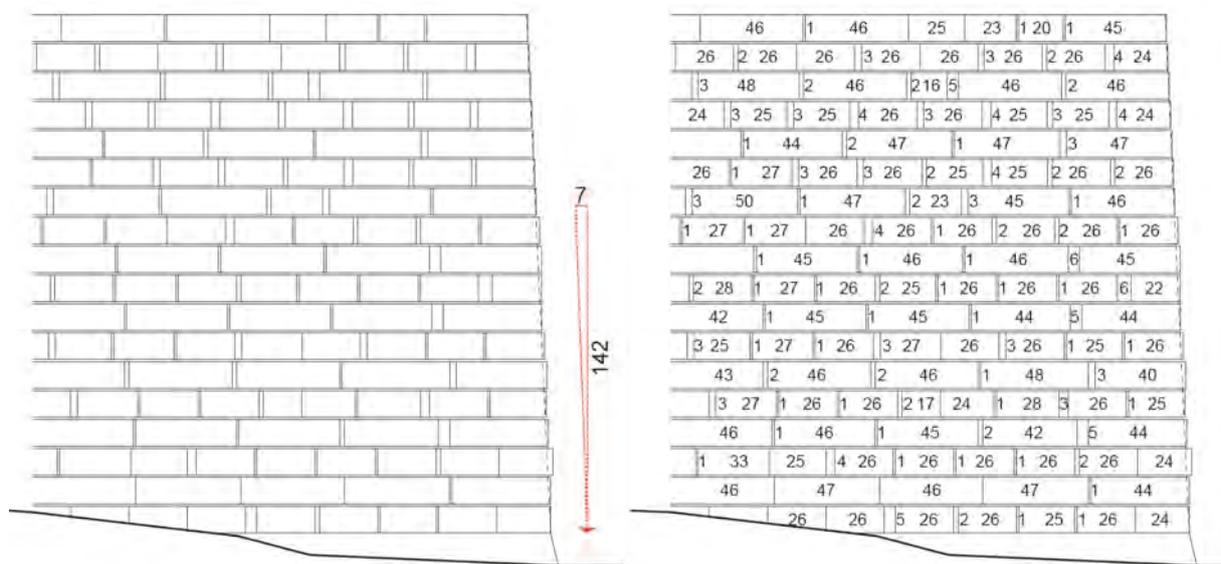


Fig. 9 South-west corner of temple II. Tapering of the wall.

At the main temple the outer surface of the walls around the inner ambulatory is sloped at app. 1° similar to the outer surface of the *cella* (except for its eastern wall) and to the outer surfaces of the *dukhang* walls. The inner surfaces of the walls are straight, however in the *dukhang*, the north, east and south, walls project inwards while the west wall, which borders the west located inner ambulatory, is again sloped. This is according to the sloping of the outer walls of this ambulatory and contrary to the *dukhang*. At temple IIIa all walls are sloped along the outer surface but project inwards. At temple IIIb several of the outer and inner surfaces are sloped. At temple IV also the inner surfaces of walls are sloped by app. 1° and the east, south and west walls are sloped along their outer façade by up to 2°. Again, temple II shows an exceptional feature with a relative continuous strong sloping of up to 2° along all the outer surfaces and three inner surfaces projecting inwards. This is the first finding of this kind that walls are not just tapering along the outside but also along the inside or that they show an inclination, most probably for static reasons.

For stabilization of walls, besides the method of sloping, the inlay of horizontal wooden beams into the walls is seen at several early Himalayan structures such as the early core of the Khorchag monastery in West Tibet, also founded in 996 AD. In Nyarma we observe a timber lacing only at temple VIa. This method seems not to have been applied on a wider scale at Nyarma. Specific wall joints are an interesting finding in regards to the strengthening of walls. Exemplarily in the accessible niche of temple IV, the two walls

which laterally touch the *cella* wall do not show a joint of any kind (Fig. 10) – a method which we also know from rammed earth constructions in the Himalayan region which enable movements within the building (Feiglstorfer 2005: 70, 71).



Fig. 10 Temple IV. Side niche without a brick bond to the adjoining cella structure.

CONCLUSION

The material which is still in use for the production of adobe bricks in close vicinity to the temple site matches in its mineral and grain size properties with the original material used at the temples of Nyarma. With this result it also becomes clear that traditions in the use of particular material as raw material for the production of bricks has remained the same over the last thousand years. It is further obvious that the question of how to limit distance for transport has always been an important matter. It can also be stated that the raw material used for the production of adobe bricks was chosen in such a way that processing without sieving or mixing was possible, i.e. minimizing the effort for production.

The walls at Nyarma are built as a '3-bricks' bond type and '2-bricks' bond type, with stretchers and headers arranged in a particular system. The first and much more elaborate bond type is related to the main temple and again as specific for temple II. We observe the use of two different brick sizes, one with a size of up to app. 40 cm at temples I and IIIb, and a second brick size with more than 40 cm up to app. 49 cm (app. 45 cm in average) at temples II, IIIa and IV. Due to several variations of brick sizes within the monastery compound, a particular proportional system for brick sizes is not currently stated.

Categorization according to brick size matches with a categorization based on different mineral properties. This emphasizes the hypothesis that for the structures of these groups, slightly different types of raw material and different approaches in processing bricks were made that point towards distinct periods of construction. In particular temple II stands out with its missing plaster, the thickest walls, a particular brick bond and also the biggest continuous inclination of the sloping walls. Wooden inlays were not common. For strengthening walls against movements inwards but also outwards, tapering walls were erected, and at particular positions within structures, walls were not joined with each other.

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Biography

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