

IV. HIMALAYAN COMPOSITE CONSTRUCTIONS AND ENVIRONMENTAL INFLUENCES

This chapter is subdivided into four parts:

- In the first part (1), the chapter begins by presenting certain types of composite constructions. In this part, first a general historical context of timber frame structures (1.1) and, secondly, of the bracing of solid walls (1.2) is discussed, both also looking beyond the borders of the Himalayas. In part (1.3) of this chapter, the relation of composite constructions to building traditions in the Himalayas, and in part (1.4) the diffusion of composite constructions are observed. In part (1.5) the relation between the evolution of composite constructions and seismic culture is treated.
- The second part (2) of this chapter deals with a general consideration of the importance of the material diversity of vernacular architecture with reference to the Himalayan region.
- This leads to the third part (3), which focuses on material diversity in vernacular structures.
- In the fourth part (4), constructive developments are shown under the influence of climatic conditions and the local availability of raw material.

1. COMPOSITE CONSTRUCTIONS: A GENERAL VIEW

The roots of composite constructions⁹⁶ extend into the early beginnings of building culture. In this context, wood has played a central role from the very beginning. For early dwellings, wattle with clay or hide as composite structures were used. In Kastoria in West Macedonia, pole foundations of wooden huts with probably wattled walls have been found dating between 4570 and 4330 BCE (Hatzitriton 2016: 6). According to secondary literature sources (ibid. 8), the use of wattle and daub during the time of ancient Greece is evident. Archaeological remains of stilt houses, e.g. along the lake side of Lake Constance (Fig. 4.1), demonstrate an early use of wattle as infill material. Wattle and daub constructions also point towards an understanding of the positive aspects of the flexibility of structures related to an early awareness of seismicity. In Caral in Peru, for example, from about 3000 BCE we know of a flexible technique using wattle and daub besides solid structures made of rope bags filled with stones – both techniques showing an awareness of structural movements (Baca, Neumann 2015: 61, after Vargas et al. 2011; Fig. 4.2). As a kind of wattle and daub, in Venezuela, Uruguay, Colombia, Costa Rica, etc. we find clay-pocket-walls in the form of pre-Columbian construction called *bahareque*. This is similar to *quincha* in Peru (Fig. 4.3) and Chile, and similar to *taquezal*⁹⁷ in Nicaragua and *tabique* in Portugal. This technique is widely used and occurs in Europe predominantly in southern and south-eastern Europe. In particular, such use is found in north-western Europe, its verifiability starting in the late 16th century and onwards (Hatzitriton 2016: 13, after Swindells 1987: 68), in the Iberian region

96 *Composite constructions* are mentioned as a constructive family and not as a particular single type of construction. Within this family, particular constructive typologies have become evident.

97 Cf. Langenbach 2000: 5.



Fig. 4.1 Unteruhldingen, Germany. Pfahlbau Museum. Reconstruction of wattle walls of sunken structures of a lake dwelling settlement (975–953 BCE). The reconstruction of the technique is based on remaining imprints.



Fig. 4.2 Caral, Peru. Example of the early use of wattle and daub (*quincha*) (c. 3000 BCE).

Fig. 4.3 (Below) Lima, Peru. *Quincha* wall.



towards the Balkans, and in Turkey (known as *bağdadi*⁹⁸). Wattle was consistently used for infill and still is today, and may be considered as the oldest, most widely used and still commonly used building technique.

The origin of the German word “Wand” for wall as a constructional boundary of a space, which derives most probably from “winden” (“braiding”) (Kluge 1989: 776), refers to an early distinction between the light-weight, braided boundary within a load-bearing timber frame construction and a “Mauer” (“wall”; Lat. *murus*), i.e. a solid, walled boundary. The development of the wall in general is connected to a technology development, and following the given terminological interpretation, a “Mauer” (solid wall) is generally more rigid than a “Wand” (light wall construction), which does not have high load capacity to tensile stress and torsion. This circumstance may have supported an evolution leading to these two design principles being connected to each other for mutual support.

1.1 Timber frame structures

Early evidence for timber frame structures found over parts of the later Turkish territory are timber frame constructions used in the second millennium BCE during the Hittites. Their defence walls are known to have been built with a lower stone part of a height of app. 3 m to 4 m and an upper timber frame construction with adobe bricks of a similar height (Nossov 2008: 16). For residential houses, the use of framework construction on a solid base is reported (Burney 2004: 25). In early Greece until the 1st century CE, the use of timber for construction was common (Hatzitrifon 2016: 8).

98 At the *bağdadi* (Turk.) technique, the space between the timber elements is filled with light material, or with a kind of plaster / lime rendering on wooden lath (Gülhan, Özyörük 2000: 4). The use of laths (or reeds) either mounted on one side or on both sides of the vertical timbers is known as *shanashil* (Hatzitrifon 2016: 6).



Fig. 4.4 Herculaneum, Italy. Casa a Graticcio. Photo: Erich Lehner.

Fig. 4.5 Quedlinburg, Germany. Post and beam construction (c. mid 14th century CE) filled with wattle and daub.

Fig. 4.6 Vacha, Germany. Side wall of a four-storey half-timbered house.

Early discovery of a half-timbered structure is reported in Herculaneum where it was conserved after the eruption of Mount Vesuvius in 79 CE (Fig. 4.4). This Roman half-timbered construction was erected without diagonal bracing. Such bracing was also not mentioned by Vitruvius for the *opus craticium* (Osthues 2014: 306). The infill of this half-timbered house was carried out with stones. The word *cratitii* (cf. *opus craticium*) does not refer to the framework of the construction but to the infill, and we can conclude that a wattle and daub construction is being referred to.⁹⁹ The half-timbered building in Herculaneum, which was built of stone on the ground floor and half-timbered on the upper floor (Osthues 2014: 304–306), is an early version of the later development of European *Fachwerk* constructions. During the Roman era, an additional use of diagonal bars was also practised, as found in the upper level of the Diomedes Villa in Pompeii (Hatzitrifon 2016: 9, after Adams 2007: 134).

The combination of a solid basement and an upper flexible construction brings an additional structural requirement. It has several advantages, for example, saving timber, making the basement fireproof or giving the upper half-timber construction a solid basement. On the other hand, the rigid stone construction has to be braced with timber.

In Central Europe, half-timbered construction represents the development of building on stilts (Ger. *Fachwerk*). Between the 13th and 15th century, different regional building types developed (described for the Czech Republic by Kuklik 2008: 5). In Germany, the early form of a half-timbered house is the post and beam construction (Ger. *Ständerbau*) that appeared in Germany at the beginning of the Late Middle Ages (13th century; Steiner-Welz 2007: 10).¹⁰⁰ This technological

99 Huts in early Rome during Roman rule may have primarily been made of wattle and daub (Edlund-Berry 2013: 413). Already the houses of the early Cretans at Knossos were wattle and daub huts (Rider 1965: 266). The use of clay for Greek houses is reported for structures on the Pnyx Hill in Athens during the 5th and 4th century BCE, where walls, floors and roofs were made of clay (ibid. 212).

100 Forster (2004: 96) reports on early wattle and daub techniques connected to post and beam constructions in Austria in the 12th/13th century.

development enabled the increase of the building height (Fig. 4.5). The posts were set on a beam, making them more durable. In Great Britain, two-storey buildings have been reported since the 15th century (Hatzitrifon 2016: 18, after Swindells 1987: 15, 17).

In the north-western part of Austria in the Late Middle Ages and during the Early Modern Age, a development from light constructions (including timber and wattle and daub) to solid structures (including stone and later fired bricks) took place (Forster 2004: 96). Stone constructions for rural houses and also the beginnings of fired brick constructions can be traced back to the Middle Ages (Kühnel 1984: 254–257). Timber constructions still remained common in the 19th century (Forster 2004: 96).

Around the end of the Middle Ages (15th–16th century) in Central Europe, the post and beam technology was replaced by a half-timber construction, where at each floor the posts were separated by horizontal beams (Ger. *Rähmkonstruktion*; Fig. 4.6). Each floor was a separate segment of construction. This enabled better utilisation of trees and increasing the building height. A common infill-method was the use of wattle and daub. In addition, adobe brick, fired bricks and stones were frequently used. The choice of the infill material was related to the expression of social status.

Between the 2nd and the 16th century, for the region spanning over the Balkans and today's Turkey, insufficient scientific facts allow us only to speculate about the transmission of the half-timber frame construction, e.g. in Constantinople in the 4th, 11th or 13th century as described by Hatzitrifon (2016: 10). Returning to the Roman half-timbered construction, it seems to anticipate a development seen again in the Balkans and the Ottoman region. It remains unclear if transmission of this type of construction had already settled in the Balkans and / or Anatolia before the spread of the Ottoman Empire, or if the main phase of transmission followed the expansion of Ottoman influence. Contrary to the early post and beam development in central Europe, the Balkan-Ottoman building type shows a solid basement and a half-timbered upper floor, similar to the house mentioned in Herculaneum. Therefrom this it is not possible to exclude a different technical development.

Derivation of the Balkan-Ottoman building type (Figs. 4.7, 4.8) from a post and beam construction is not evident. The half-timbered construction in the upper floor is in Turkey known as *himiş*¹⁰¹ (in Macedonia known as *bondruk*¹⁰²) and is close to what we know in German as *Fachwerk* or in French as *colombage*. The oldest testimonies of this Roman-Balkan-Ottoman building type in Turkey have been found to exist starting in the 17th century (Günay 1998: 16). An example is the Sofa Kosku building in the Topkapi Palace in Istanbul (Ahunbay 2000). According to historical reports for Istanbul in the 16th century, Hatzitrifon (2016: 11) mentions simple, one-storey houses and representative buildings made of wood besides other materials like stone. In addition, paintings may point towards the use of simple, one-storey buildings in Istanbul and Anatolia during the 16th century, and a common development of the multi-storey type in the 17th century (ibid.). The

101 Cf. Langenbach 2002b: 3. The Turkish term depends on the filling: *himiş* for a filling with masonry, *bağdadi* for a filling with bulk material (*vrac* in French) and *dizeme* when filled with wood (*rondins* in French) (Caimi 2006: 499). According to Poletti (2013: 114), the kind of infill changes the behaviour of the wall, ranging from flexural to shear predominance.

102 Cf. Gramatikov 2000: 1.



Fig. 4.7 Safranbolu, Turkey. View over the mostly two- or three-storey *himiş* constructions of the city.



Fig. 4.8 Ankara, Turkey. *Himiş* structure on top of a solid ground floor.

oldest remaining buildings in Kastoria in Greece from the 18th century follow a similar typology with stone walls in the lower level and the upper level constructed with wood (Hatzitrifon 2016: 13).

The vertical structural division is a feature of Balkan-Ottoman buildings from the 17th century onwards. In the first half of the 17th century, not only the ground floor, but also three facades of the upper floors were erected in stone and do not project beyond the ground floor (Günay 1998: 72). The ground floor was mostly made of rubble stone, with dressed stones rarely used. Today and since at least the 17th/18th century, this type of solid construction with a half-timbered upper floor can be found all over the Balkans from Albania in the west and Romania in the north, via Greece, North Africa in the south and Central Asia in the east (ibid. see Map 1). Syrian influence can be attributed with having a significant impact on the development of stone construction techniques (ibid. 19).¹⁰³

Moving eastwards into the Himalayas, half-timber frame constructions developed primarily in Kashmir. A dating of the origin of this tradition is difficult and we cannot exclude influence from western regions. An early development of timber-framed structures as we know from Europe under the Greek or the Romans is not evident in the Himalayas or the Indian subcontinent. A common use of structural timber started in Kashmir at least in the 12th century CE. King Jayasimha (1128–1140) allowed the citizens a free supply of forest wood, which increased the common use of timber for building construction, which peaked between 1420 and 1470 (Kachru, Thapalyal 1990: 103). Langenbach (2009: 5) mentions historical sources such as Kalhana in 1148 and Tímúr the Tátár in 1398 CE, both of whom refer to the large amount of timber constructions in Kashmir (after Elliot 1867). According to Langenbach, the two vernacular main building techniques in Kashmir, *dhajji-dewari* and the *taq*, may have evolved much later at the beginning of the 19th century (Langenbach 2015: 84). This seems to be a late dating, in particular for the use of *taq*, for which earlier use cannot be excluded (see below in parts 1.3 and 4 of this Chapter).

103 At this point we need to emphasise that we have to differentiate between a standardised building type, which may span over a transnational area and local variations, for instance, due to particular local material resources and climate conditions. For example, the type of timber for Ottoman buildings is addressed to the respective local availability: chestnut at the Black Sea, oak and yellow fir in Western and Northern Anatolia, and cedar, cypress and juniper in Mediterranean areas up to the Taurus Mountains (Günay 1998: 30). The widespread use of wood shingles for roofing is determined by the availability of wood (ibid.).

1.2 Bracing of solid walls

Structures found in Orchomenos in Greece, which were dated c. 3000 BCE, show a succession of different types of walls made either round or oval in their ground plan (Rider 1965: 45). These wall shapes oppose an early use of timber-lacing at this time in this region. Throughout Minoan era, timber structural systems were continuously used for about 1,300 years (Tsakanika-Theohari 2009: 129). In different levels of the walls, unworked timber trunks or branches were laid as reinforcement transversally and longitudinally into the wall. This technique was developed during the Minoan era with vertical timber components (ibid. 130, 131).

The bracing of solid stone walls is traditionally made with timber lacing,¹⁰⁴ and in many cases ring beams are used. A kind of timber lacing is the use of a ‘ladder’-like timber construction placed on the wall at a certain height, e.g. on top of each floor, but also placed within a storey. It is composed of a pair of runner beams facing the inner and outer surface of the wall. They are connected by wooden cross-pieces, which resemble a ladder (in the following also called “‘ladder’-like timber lacing”). Ring beams in general work only in a force-fitting manner, in particular at the corner joints. The efficiency of the ring beam is substantially increased if it is not only linear along the wall, but covering the whole area on top of the wall. This may be one reason for the development of the ‘ladder’-like timber lacing. Moreover, it facilitates the connection of the solid wall portion with the floor beams on top.

Traditionally, the wooden joints were made as pure wooden constructions, e.g. with pegs and lap joints. Early examples of timber lacing may date back to 9,000 years ago in Anatolia¹⁰⁵ (Hughes 2000a). In Akrotiri of Santorin (c. 1500 BCE), an early type of a wooden timber lacing was found (Touliatos 1996: 78–81). Buildings each with two to three-storeys were mainly made of rubble stone, in which horizontal timber lacing made of tree branches with cross-pieces on top had been placed as a kind of ‘ladder’-like construction (Vintzileou 2011: 169). We can describe this construction as an early form of timber lacing. However, as shown by Vintzileou (2011: 172), several buildings had the horizontal lacing connected to a vertical timber structure and by that formed a framework construction for the reinforcement of stone walls.

Julius Caesar mentions the “Gallic wall”, wherein straight beams were placed (with a length of about 12 m) lengthwise connected at a distance of about 60 cm. Distance between the beams was about the same and the beams were held in position by a load of stones on top. Advantages of this technique are its strength as a defensive construction and fire safety resulting from the high content of stone. (The Gallic Wars; pictures of reconstruction see Caimi (2006), after G.A. Rondelet (1832) in Barucci (1990)).

The use of timber in combination with solid structures such as walls and domes is reported from the Roman and Byzantine period. During this time, timber belts were used at the bases of domes for stabilisation during earthquakes (Gavrilović et al. 2003: 64). For the Byzantine era, different structures with timber reinforcement have been found (Vintzileou 2011: 172). In this context,

104 Timber lacing is a horizontal bracing of solid walls (made of, e.g. stone or clay) with wooden elements, beams or scantling, also seen with logs.

105 Following Hughes (2000a) where no further source for this dating is given.



Fig. 4.9 Baldan Bereveen Khiid. Mongolia. Vertical and horizontal timber lacing in a solid wall.



Fig. 4.10 Kashmir. India. *Dhajji dewari* (1) and *taq* (2) constructions along the banks of the Jhelum River.

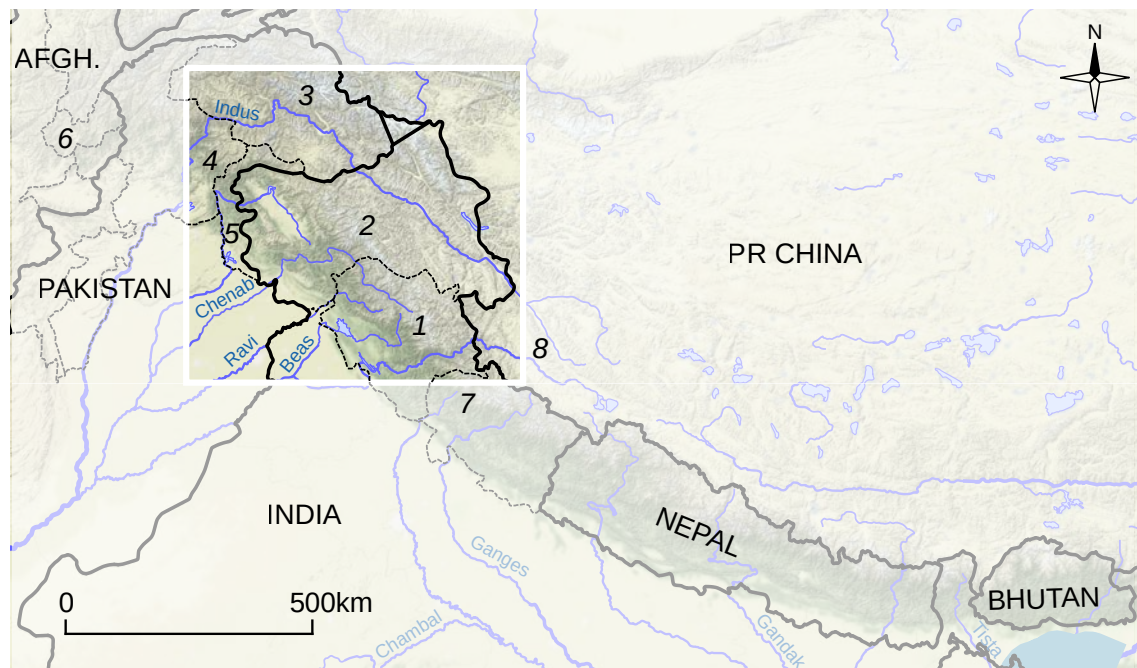
the term *imandosis*¹⁰⁶ (*imantodi* after Hatzitrifon 2016: 20), deriving from the Greek language, is used. According to two dictionaries – one from the 9th century and the other from the 10th century – the term *imandosis* is defined as a tying system, i.e. to tie timber components inside masonry construction, arches and vaults using diagonal timber bracing (ibid. 173, 174). An early example of timber lacing is known from Khorezm in Central Asia and dates back to the 8th century CE (Günay 1998: 32, after Yazicioğlu-Mustafa 1982: 37–38)¹⁰⁷. In the Greek, Balkan and Ottoman constructions, since at least the 18th century, the use of timber lacing is reported for solid ground floors made of stone.

Moving eastwards into the Himalayas, early dating for the use of timber lacing is given by Darragon (2015: 42). She specifically refers to one 12-cornered tower dating to the 4th century CE. It is located in the higher reaches of the Nyangchu River of present day Gyamda (Tib. Rgya mda') County in East Tibet. Another early East Tibetan example is found in the chamber of the burial mound M-3 at the burial ground in Reshui. Here, walls in the east and west chambers were made of stone using a kind of 'ladder'-like timber lacing dating between the 7th and 9th century CE (SAM 2004: 63). We can also mention Mongolian sites to show the far-reaching use of timber lacing in solid structures, e.g. at the Baldan Bereeven Monastery in the east of Mongolia (48°12'8.78"N, 109°26'20.41"E), where the use of timber lacing in combination with vertical timber bracing in an earth structure has been observed (Fig. 4.9).

Timber lacing in solid walls is traditionally used worldwide in many regions. This building technique is spread throughout Europe along the Mediterranean region, the Balkans, Greece across Turkey (here known with the term *hatil*, cf. Langenbach 2002b: 3), North Africa, Syria or Jordania (e.g. used along the inner surface of well-dressed stone walls of Qasr el-Bint in Petra), the mountainous region of Iran (e.g. used in the adobe brick walls of Abyaneh; alt. 2,230 m, 33°35'9.92"N, 51°35'29.99"E), North Pakistan (here known by the Pashto term *bhatar*, cf. Dipasquale, Mecca 2015: 85), Kashmir (here known by the term *taq*) (Fig. 4.10), along the Himalayan region into East Tibet and Mongolia.

106 Hatzitrifon (2016: 20) mentions the incorporation of Greek terms into Turkish and also the replacement thereof by Turkish terms. This includes a Greek term for "timber ladder-type stretching bars in stone walls" as *μάντωδι*.

107 Günay mentions in his book the place as Harzem. Mrs. Zeynep Ahunbay was so kind as to verify Harzem as Khorezm in Central Asia in an e-mail on Oct. 13th, 2016.



Map 4.1 Core region and extended core region.

GIS data based map: Jakob Gredler. Final graphics: author. Map based on data from Vector data (VD) and Basemaps (BM). Citations of VD and BM also see: Chapter IX, list of illustrations.

- 1 = Himachal Pradesh;
- 2 = Jammu and Kashmir;
- 3 = Gilgit-Baltistan;
- 4 = Khyber Pakhtunkhwa;
- 5 = Azad Jammu and Kashmir;
- 6 = Nuristan;
- 7 = Uttarakhand;
- 8 = Ngari.

1.3 Composite constructions in the Himalayan region

The core region of further investigation is located in the Himalayas in the states of Jammu and Kashmir, and Himachal Pradesh. The expanded core region extends into the adjacent region of North Pakistan, which is included in this study because of essential comparison features, although it is already part of the Karakoram region (Map 4.1). In the core region, we find distinct traditions of composite constructions. In this section, the relevant structures are shortly presented. The composite constructions of the core region are covered in greater detail in the following parts of this chapter. The mentioned constructions represent commonly occurring composite techniques, which should not be understood as exclusively the only types of constructions in these regions. Furthermore, different variations of the mentioned composite techniques are treated below.

1.3.1 Core regions Himachal Pradesh, Jammu and Kashmir and North Pakistan

The majority of the population in Himachal Pradesh belongs to the *Khash*, whose settlement in the Indo-Gangetic plains dates back to the time before the *Aryans* (Handa 2008b: 137). For the high quality, wood-stone-composite multi-storey construction, the *Khash*¹⁰⁸ are considered predominant, in particular for the use of the *kath-kuni* composite technique (explanation of the technique below). Before using this composite technique, *Khash* buildings had mainly been made of wood (Handa 2006: 49). Other major population groups in Jammu and Kashmir, and Himachal Pradesh are the *Gujjar* (mainly building with clay) and the *Gaddi*, the latter having settled in the Indian mainland since the early Middle Ages (Handa 2008b: 137). The *Gaddi* use the *farque* composite construction technique for their buildings (ibid. 140; explanation of the *farque* technique below in part 4 of this chapter). Both *Gaddi* and *Khash* constructions are also found with a cantilevered upper floor.

In the Transhimalayan part of Himachal Pradesh (Upper Kinnaur, Lahaul and Spiti; detailed map of Kinnaur see Map 4.7), we find stone and earth buildings with a relatively small content of wood, primarily used as timber lacing. In some areas in Himachal Pradesh, in particular in some parts of the districts Chamba, Shimla, Kullu and Kinnaur, dry stone walls (not as composite) are common due to the availability of river stones and a local scarcity of wood (cf. Sood et al. 2013), although app. one third of Himachal Pradesh is forested (see Map 4.5).

In Ladakh (located in Jammu and Kashmir), we primarily find clay and stone structures. Different techniques for using ‘simple’ timber lacing or ‘ladder’-like ring beams are known. From Ladakh to North Pakistan, the design changes with a significantly higher content of wood. In North Pakistan, we find composite constructions such as *bhatar*, and *cator and cribbage*, the latter being from a construction-typological point of view related to the *kath-kuni* construction in Himachal Pradesh.¹⁰⁹

From Ladakh to Kashmir, a substantial change of structures is obvious. On the one hand, we find solid constructions with ‘ladder’-like timber constructions (in Kashmir known as *taq*), similar to the *hatil* in Turkey; on the other hand, we find half-timbered buildings (in Kashmir known as *dhajji-dewari*), similar to the *himiş* in Turkey. Concerning strong similarities between construction techniques used in Kashmir and in Turkey, we cannot exclude mutual influences or even a primary influence, as already mentioned, between Kashmir and its western regions. The ‘ladder’-like development, which we find in Kashmir with *taq*, is also evident in Himachal Pradesh and Uttarakhand, and further east just scattered, rarely as a main building type and often reduced to ‘simple’ timber lacing without the use of pairs of runner beams. The Ottoman-Kashmir half-timber type (*dhajji-dewari*) with diagonal components finds its core area in the Himalayas in Kashmir with some remains of *dhajji-dewari* in Himachal Pradesh and the *rabsey* in Bhutan.

108 Negi Loktus (2015: 361) gives a vague hypothesis of a possible link between the ‘*Khash*’ and the Tibetan designation of Kashmiri people as ‘*Khashe*’.

109 For further explanations of the mentioned techniques see below in part 4 of this chapter.

1.3.2 Himalayan regions outside the core region



Fig. 4.11 West Bhutan. Located close to Paro along the road to the Tagtshang Monastery. Traditional *rabsey* construction. Photo: Roland Meingast 2016.



Fig. 4.12 Tawang. Arunachal Pradesh. Stone, clay and bamboo mats used side by side.



Fig. 4.13 Rumtek. Sikkim. Monks' residences close to the monastery. The building type is locally referred to *Bhotia* people.

In Bhutan we find varying altitude-differentiated thatched bamboo houses in the south, rammed earth in the west and stone architecture in the east. Stone buildings are made with rubble stone in a random bond. Timber lacing is rather uncommon. Wood is primarily used for the projecting upper storeys, the so-called “*rabsey*” (Fig. 4.11). They are connected to solid subconstructions made of rammed earth or stone. The supporting beams are placed on projecting wooden brackets. The *rabsey* construction is a wooden framework infilled with wattle and daub or wooden panels (cf. Potocnik 2007). A stone building tradition continues in the east of Bhutan in Arunachal Pradesh in Tawang and Bomdilla, where besides solid stone structures we find ‘simple’ timber frame buildings with walls of bamboo mats (Fig. 4.12). Their frequency increases towards Assam.

To the west of Bhutan in Bengal in Kalimpong and the surrounding area as well as in Sikkim, different cultural influences meet. In this region we find solid constructions, mainly of stone, e.g. at religious Tibetan Buddhist structures. Attributed to the ethnic group of the *Bhutia* is a type of building with a ground floor used for storage and made of well-dressed stones, and an upper floor made of wattle and daub as a living floor. An example is the monk's accommodation beside the Rumtek Monastery (Fig. 4.13). Similarly, another example is the nun accommodation near the Ralang Monastery, in which even the upper floor was partially built in stone, and open wall sections were closed with wattle and daub. Traditional architecture of the *Lepcha*, found in Bhutan, Sikkim and West Bengal in the area of Kalimpong, is a stilt construction on stone bases. The ground floor is open, and the upper living floor is closed with wattle and daub panels, similar to *Bhutia* houses.



Fig. 4.14 Lhasa. Tibet. Traditional technique of stone laying shown at the Shide Lhakhang.

In the timberless West and Upper Tibet regions, stone and earth buildings are prevalent. A variety of different stone bonds were used. The ruins of the ancient monastery of Chekha (Tib. Chad kha) in Central Tibet are an example of the diversity (cf. pictures in Feiglstorfer 2015: 77–81). The ruins of the Shide Lhakhang in Lhasa show typical banded stone masonry (ibid. 82–83). This technique uses large (mostly dressed) stones on the outer and inner surfaces of the walls placed side by side in a row in clay mortar (Fig. 4.14). Cavities between the large stones are filled with smaller stones. At certain vertical distances, cross-stones connect the outer and inner wall shell. The reduction of the cavities to a minimum increases the friction between the stones and by that the ability of distributing pressure within the wall. The use of two shells of stone with a vertical infill layer and the type of layering of the stones ensure flexibility in the wall in the case of structural movements.

The outer surfaces of the walls are inclined, whereby the amount of building material is reduced towards the top, which also reduces the labour force required to lift the stones. Furthermore, the mass of the wall is reduced in the upper part, which is positive in the case of structural movements. The inclination of the wall shifts the centre of gravity of the wall to the inside, which in the case of movement makes outward tilting more difficult. These stone structures are entirely without wood. In contrast, in East Tibet wood is much more common, primarily for timber lacing in stone walls with clay mortar, for timber frames, or for log buildings (Ryser 1997: 54).



Fig. 4.15 Kathmandu Valley. Nepal.
1 = Wooden wedges as a traditional technique to stabilise walls.
2 = Wooden components destroyed during the earthquake in 2015.
Photo: Christof Ziegert.

In Nepal, at Newar structures in the Kathmandu Valley, in many cases the outer walls of a house are made of fired bricks, while the interior structure is divided by timber frames (Tavares et al. 2014: 15). In the case of structural movements, ceiling beams are chocked with wooden wedges (Nep. *chokus*; cf. Bonapace, Sestini 2003: 66; Fig. 4.15). These wedges secure against slipping out of the hole in the wall. In prestigious buildings, ceiling beams are often placed relatively close to each other (with a distance of app. the width of one beam), whereby a bracing along the floor surface is increased (cf. Feiglstorfer 2011b: 130). In Nepal, timber lacing and ring beams are known by tradition, however, they seem to have a minor role in Newar vernacular buildings. Section drawings of the Basantpur Tower (from 1770 CE; Le Port 1991: 103–105) show a vertical and horizontal timber lacing, a characteristic not present in many other buildings of this form. A *Kashia* house in Nepal does not differ much from a *Khash* House in Himachal Pradesh or Uttarakhand (Handa 2008b: 140). In western Nepal, the use of timber lacing in stone buildings is common. It follows a type also known from East Tibet (Ryser 1997: 54, after Kleinert 1983: 19). *Khash* people, who still live in Jumla District in Nepal, may have brought composite building techniques to Nepal.

1.4. Diffusion of composite constructions

In addition to local developments, specific types of construction were spread over long distances. The channels of dissemination of composite constructions, in particular half-timber and timber-laced walls that are commonly used over a wide region stretching from the Balkans towards Kashmir, are difficult to determine and can here only be called hypothetical. Even more so, we find similarities in the materials and techniques used, and this may point towards a common development or mutual influences. In addition to the mentioned types of construction, numerous others, which we have yet to consider, exist in the discussed regions, including monolithic (non-composite) types of construction. The diffusion of techniques can be linked to different parameters such as trade, war or peoples' relocation. Local resources, environmental conditions and building traditions are opposed to imported expertise.

Based on the aforementioned historical markers of half-timbered buildings, early roots in a Greek-Roman-Balkan-Ottoman cultural zone can be seen, with diffusion over the European and Ottoman regions to Kashmir. At this point, strong constructive similarities between Kashmir construction and technical developments to the West can be drawn, such as a particular type of half-timber construction and methods of infill, the vertical separation between a solid ground floor and light-weight upper storey or the cantilevered half-timber storeys. Towards the Far East, presently no direct influence can be stated. Central Chinese timber frame constructions show individual features and point towards a cultural development of its own.

The use of timber lacing in solid buildings in general has a much earlier development than the framework tradition, and its diffusion is considerably more extensive. Timber lacing belongs to a type of construction that spread not only through knowledge transfer, but may have developed as it was locally adapted to specific technical requirements. Again, a certain unifying characteristic between the ‘ladder’-like timber lacing in Kashmir and Western cultures (e.g. Balkans or Turkey) becomes obvious.

The dissemination of knowledge was supported by imperial political structures and ethnic-religious affiliation. The construction of defence structures, for example, was concerned with continuous technical progress (see “Gallic Wall” described afore) as well as the construction of buildings with a claim to represent a higher social status, as related to rulers or religious communities. Belonging to certain population groups and religions may also contribute to such widespread dissemination. A diffusion of certain constructive features of identity by Muslims in the Late Middle Ages can be suspected.

The dissemination process is complex and cannot be reduced simply to a religion as a priority transporter of knowledge. For example, we find constructive parallels to Islamic North Pakistan in Hindu dominated Himachal Pradesh. According to a hypothesis by Handa (2001: 97), no structural temple existed in the Western Himalayan region up until the 7th century, except possibly several Deva Temples in Kullu. For the Śakti Devī Temple (late 7th/early 8th century) in Himachal Pradesh, construction is described as “made by the usual timber-bonding method that combines layers of stone with a framework of wood” and points towards the use of a *kath-kuni* or a similar building technique (Bernier 1989: 38). The Buddhist temple of Ribba built in the 9th/early 10th century (Klimburg-Salter 2002: 21; Luczanits 1996: 71) follows a type of construction similar to the *cator and cribbage* technique found in North Pakistan; the same can be said for the Hinduistic Mirkulā Devī Temple in Udaipur in Himachal Pradesh built in the 11th century (acc. to Handa (2006: 180) in the 8th century). The local non-Muslim population of *Khash* primarily propagated the *kath-kuni* technique (as it is known in Himachal Pradesh).¹¹⁰

The Islamisation of Kashmir, which peaked in the 13th to 15th centuries, started in the 11th century during the Lohara-Dynasty. In the 11th century, Turkish influence in Kashmir may have existed. Tunga, who led the war under the Kashmiri ruler Saṃgrāmarāja (1003–1028 CE), was defeated in 1013 by Turkish troops (Handa 2006: 47). This is evidence of contacts between Kashmir

110 In Uttarakhand, the *Khashia* could not evolve as had been the case in the rest of the Western Himalayas, which lead to a neglect of the development of wooden architecture (Handa 2006: 47). For further explanations of the techniques mentioned see below in part 4 of this chapter.

and western territories. During the foundation of Chamba (c. 1025 CE), a mixture of Pratihāra Renewal (10th to 12th century) and the Kashmiri style is evident in artistic products (Bernier 1997: 132).

The conquest of Chamba by King Lalitāditya (ruled 724–760 CE) after the reign of Chamba's King Meruvarman (680–700 CE, Singh 1999: 74) probably extended influence to southern Lahaul, Kullu and Kangra by rulers of Kashmir's Karkoṭa Dynasty (Bernier 1997: 132; cf. Handa 2001: 104). Muslim rulers followed this dynasty. Because of the increase of the dominance of Muslim culture in Kashmir, Hindu stone carvers had to leave to the Hindu kingdom of Chamba, resulting in a lack of carvers in Kashmir (Handa 2006: 97). Under Sultan Zain-ul-Abidin (1420–1470 CE), wooden architecture flourished in Kashmir (Handa 2001: 107). Handa (2006: 26) points towards political and socio-economic factors in Kashmir during the 14th century as influencing those of Himachal Pradesh and Uttarakhand. Specifically, the *kath-kuni* technique was of more strength for defence, and displaced the earlier full-wooden structures. Additionally, an over-exploitation of deodar wood may have caused restrictions to be put into place by the local rulers regarding cutting of deodar trees (ibid.).

At this point of research, we cannot state a primary Kashmir and / or Muslim influence on the development of the *kath-kuni* technique in Himachal Pradesh. As shown in the following, the *kath-kuni* technique seems to be a logical continuation in the development of timber lacing in solid walls in Himachal Pradesh. This seems to differ from the *dhajji-dewari* technique, which has its eastern limit of extensive influence in the Himalayas in Kashmir.

Important for diffusion is also the willingness of the ruling class to accept new influences. Langenbach (2002b: 3) hypothesises that Nepal remained a protected kingdom isolated from cultural influences from the Ottoman Empire (or earlier Muslim craft traditions, AN), and thus a diffusion of the 'ladder'-like timber lacing was excluded from Nepal. However, we need to consider that Nepal was known for its exchange of various goods and craftspeople already in the imperial period in Central Tibet in the 7th century. Literature sources for Nepal between the 8th and 12th century are very limited. At least in the late 10th/early 11th century, we know that craftspeople from Nepal were in high demand in the Western Himalayas and must have been in contact with craftspeople from Kashmir. Thus at this early time an exchange of the latest technical standards in Kashmir must have existed in Nepal. One of the earliest strong earthquakes reported in Nepal occurred in 1255 CE (cf. Pradhan 2000), and the occurrence of earlier earthquakes is likely. The questions still remain of why 'ladder'-like timber lacing was not introduced to a much higher degree into vernacular Newar architecture, and why a technique using wedges at the ends of the floor beams to stabilise the walls in case of structural movements was preferred.¹¹¹

For Western Gujarat in the Khuch area, where a seismic building culture is also absent, Langenbach (2002b: 3) argues that the Moguls' influence was too minimal for this sizable Hindu region. In Ahmedabad in Central Gujarat, in contrast, where a timber-composite tradition is existent the period of Islamisation was in parallel to the Ottoman Empire, facilitating cultural exchange.

111 Research conducted after the Nepal earthquake in 2015 reported that wedges and wooden components were strongly weathered and had lost their static strength (Telephone conference in spring 2016 with Christoph Ziegert, who conducted a post-earthquake survey). This may have supported the collapse of many historical Newar structures.



Fig. 4.16 Mandriza, Bulgaria. Adobe brick walls with timber lacing and a projecting upper floor.



Fig. 4.17 Mandriza. Adobe brick walls with 'ladder'-like timber lacing.

1.5 Relation between diffusion of composite constructions and seismic culture

Sensitivity of building traditions to foreign influence is well expressed by a Bulgarian example from the Ottoman period: Mandriza, a village in the far east of Bulgaria (alt. 81 m; 41°23'30.32"N, 26° 7'59.58"E) located close to the Greek and Turkish borders, gives evidence of a mixture of different building traditions. During the Ottoman rule, Albanian shepherds from the south-east of Albania founded this village, following an adobe brick culture (Figs. 4.16, 4.17).¹¹² Until the 1970s, they were silk farmers, and during its economical peak, the village had about 3,000 inhabitants. Today, it is nearly abandoned. Surrounding villages like Dolno Lukovo follow a widespread Bulgarian tradition of building with rubble stone in a random bond with 'ladder'-like timber lacing (Figs. 4.18, 4.19). Interior walls were made as timber frame constructions with wattle and daub infill. In Mandriza, in contrast, which is said to be the only Albanian village in Bulgaria, buildings are made of adobe bricks – surrounded by villages following stone architecture. This means that the Albanian settlers may have brought their building traditions with them. However, what remains the same in the neighbourhood is the use of timber lacings, which obviously follows a local building tradition. Several of the lacings were made like 'ladders', as found in the

¹¹² Personal information given by Hristo Peev in Mandriza in December 2014. The following data were collected by the author during field research:

Ad Mandriza (an adobe village): In earlier days, a centre for education on silk production was situated in Bursa; old buildings were erected in app. the 17th century, new buildings around 1850 CE; the width of adobe walls is app. 64 cm; the brick size is about 29 x 14.5 x 7 cm; the width of the brick bond is either 2 x 29 cm or 4 x 14.5 cm, with a bed joint of 2.5 cm; the use of ring beams as timber lacing is common; timber lacings are app. 8 x 8 cm in profile; the common length of houses along the road is app. 8 m to 9 m; during earthquakes, buildings survived without significant damage; houses were built in cooperation of all village members; nails were forged in the village.

Ad Dolno Lukovo (a stone village): Stone walls are made as double shell constructions with well-dressed outer faces using smaller rubble stones as filling material; stones were chiselled out of big boulders; the wall thickness is app. 50 cm; about three 'ladder'-like timber lacings are laid within the height of each floor; walls are straight with well-dressed corner stones; oak wood is used as structural timber; during earthquakes a few buildings showed cracks, most survived without any damage; the tradition of making stone constructions ended with the beginning of the socialist era changing to fired bricks.

Villages towards the north between Mandriza and Ivanova: The villages contain remaining stone and adobe buildings. Some of the stone buildings show timber lacings, others are built without.



Fig. 4.18 Dolno Lukovo. Bulgaria. Stone walls with timber lacing.



Fig. 4.19 Dolno Lukovo. Corner half lap joints.

neighbouring stone constructions; others were made of ‘simple’ ring beams with just one runner beam. Mandriza is a good example of both the assimilation of a foreign building tradition and the use of proved local techniques in wall stabilisation. This example is strongly related to the matter of timber lacing in regard to structural movements, which have become a part of the traditional knowledge on building technique in particular regions. In context with earthquake endangered regions, this technical evolution has become part of a seismic culture.

In addition to historical references to the correlation of influences concerning either the diffusion or the independent local development of techniques in different places, particular types of construction may help to find consistencies. The global field of vernacular development appears extremely diverse. Considering the aforementioned region spanning from the Balkans to the Himalayas, clear technical measures are present for the strengthening of buildings in the case of structural movements. Structural movements can result from ground settlement and earthquakes, the latter being much more extensive over wide areas. Globally, some regions have been more affected by earthquakes due to their tectonic preconditions. Damages are an essential parameter for the development of buildings. In particular, people have learned and developed from the effects of earthquakes.

The development of a seismic culture in affected areas and of related local building traditions is likely. Regarding the aforementioned Balkan-Ottoman-Kashmir-Himalayan zone, connecting principles of techniques used in a seismic culture along the west-east zone from the Balkans to the Himalayas become obvious. Several striking coherences are mentioned at this point: The fact that composite structures have been deliberately applied to counter earthquakes is shown in the following two examples: 1) After the city of Lefkas in Greece was destroyed in 1825, the British, who occupied the island (1810–1864), introduced new regulations with timber framed constructions, which today are still in common use (Touliatos 1996: 78–81). 2) Another example is the *Construção Pombalina* (after the Marquis of Pombal) in Portugal. Knowledge of the development of a timber frame construction was collected from the surviving buildings of the 1755 earthquake, and new building rules including a framework construction were established and followed for about eighty years after the earthquake.¹¹³

¹¹³ During the mid 19th century, these constructions were progressively abandoned and a simple type of this building technique (known as *gaioleiros*) developed (Simões et al. 2012).

Earthquakes pose a widespread threat to buildings. Today, earthquake zones are determined over the globe and divided by earthquake intensities. The map “Earthquake danger zones around the world”¹¹⁴ includes all earthquakes measuring 6.0 and more on the Richter scale over the past 40 years. The affected regions are mostly located in areas of plate tectonic activity. Looking at the further region adjacent to the Himalayas in a Eurasian context, a zone of strong activity becomes evident (after Richter ≥ 6.0) from west to east, and from Italy across the Balkans (to Romania in the north; cf. Hărmănescu, Georgescu 2015), Greece, Turkey, Iran, Afghanistan, Pakistan, Himalaya and adjacent regions.

This zone corresponds approximately to the main distribution area of composite structures, i.e. solid walls with timber lacing. Half-timbered structures, however, show a different main distribution area, namely across a large part of Europe towards Kashmir. In Kashmir and North Pakistan, we find a focal point of different composite techniques: on the one hand, half-timbered buildings, on the other hand, solid constructions with timber lacing. In further parts of the Western Himalayas (e.g. Himachal Pradesh), the half-timbered building tradition is no longer being practised. With the introduction of the *cator and cribbage* technique, North Pakistan and the Western Himalayas show a cultivation of a technical development of a solid wall composite technique with an extremely high content of timber. In some rural areas, these traditions are still alive.

The Himalayan fold mountains are the largest and youngest mountain range. They developed from the collision of the Indian and Eurasian plates. These activities are still in progress. The “Seismic Hazard Maps of the World”¹¹⁵ shows the peak ground acceleration (PGA) that a site can expect during the next 50 years with ten percent probability. On the 5-point upward rising scale of the “Seismic Hazard Maps”, the Himalayas are marked with level 4. The high risk of earthquakes in the Himalayas and historical disasters must have been a major reason for the development of certain composite constructions.

Historical sources on Himalayan earthquakes in the 18th century and earlier are scarce. According to Bilham et al. (2001: 1442; adjusted by the author according to Sood et al. 2013), great earthquakes occurred in 1255 (Nepal)¹¹⁶, 1555 (Kashmir), the 16th century CE (Kashmir), 1720 (Kumaon), 1803 (Garhwal; it caused great damage between Delhi and Lucknow), 1833 (Nepal), 1855 (Srinagar), 1897 (Bhutan), 1905 (Kangra), 1934 (Nepal-Bihar), 1950 (Assam), 1974 (Pattan), 1975 (Kinnaur and Spiti; it caused damage (e.g.) in the villages of Nako, Shelkhar and Chango), 1981 (Karakoram, Darel, Tangir, Khanbari Valleys), 1991 (Uttarkashi), 1999 (Chamoli in Gharwal region), 2005 (Muzzafarabad in Kashmir), and 2015 (Nepal).

114 Map: *Earthquake danger zones around the world*: <http://www.cbc.ca/news2/interactives/world-quakes>, access: 05/2016.

115 Seismic Hazard Maps of the World: <http://geology.about.com/od/seishazardmaps/ss/World-Seismic-Hazard-Maps.htm#step15>, access: 05/2016.

116 This seismic activity is reported according to the Gopalraj Bamsabali (a fifteenth century chronology) and caused the collapse of temples and the death of one third of the population (Pradhan 2000).

Certain features such as the use of locally available materials, simple floor plans, small window openings or the use of pure wooden joints are generally part of vernacular architecture and do not necessarily point towards characteristics of a seismic culture. There are some technical features that can be an indication of additional seismic measures, and which may also show up in particular details of construction. Ortega et al. (2015) mention some characteristics of vernacular seismic-resistant constructions like elevation configuration, use of timber elements, connection between structural elements, stabilisation of floors and roofs, and reinforcement of the openings. Some of these characteristics are explained in the following in relation to the Himalayan regions.

1.5.1 Quality of the ground

Within an earthquake zone, the consistency of the ground is striking for its behaviour during vibrations. It is not an anthropogenic feature, like the following described technical aspects of seismic culture, but a crucial natural circumstance, on which culture concerning developments are based.

During an earthquake, due to a sudden displacement, the ground accelerates, and shear waves (S-waves) and primary waves (P-waves) are produced (Hettler 2000: 407). This happens along the surface and underground, and is followed by accelerating foundations and constructions (Gasparini 2000: 5). How vibrations during an earthquake are absorbed depends on the quality of the ground, which is an essential criterion for the impact of an earthquake on a building. A soft, sandy ground can be regarded as particularly critical. It can lead to vibration amplification, liquefaction or sudden subsiding (Adam, Paulmichl 2010: 67). Excessive vibrations significantly change the behaviour of a soft ground. Its properties are similar to liquefaction (Tabet 2016: 4).

The ground directly influences the building's foundation, which in turn has to work as a shear component. In order to form a rigid foundation plate, a bedrock is suitable as a stiff base. Solid floors have a positive impact on the resilience of a building against earthquake forces. They increase the range of the excitation frequency and divide the energy released on several frequencies. In a reverse sense, this effect could be observed in the 1985 earthquake in Mexico City. The soft ground contributes to a filtering of vibrations and results in an amplification of a smaller frequency range. (Interview with Adam in 2004)

In South America and, indeed, in Kashmir, we find a soft ground, as opposed to rocky mountain ground (cf. Langenbach 2005: 15). Schick (1997: 64–66) also mentions the ground as an important parameter in the examination of earthquake resistance. Specifically, in regard to earthquakes, alluvial ground is ideal for settlement, and uncompressed mixtures of sand and clay problematic. In the Himalayas, as an example, in particular in the Tibetan cultural areas, many of the settlements have been founded on alluvial fans.

1.5.2 Structural timber elements

As seen from the previously given overview of composite constructions in the Himalayas, we are basically concerned with two types: 1) solid walls with timber lacing, and 2) half-timber frame constructions. The wood in both applications is characterised by properties such as tensile

strength or resistance against flexure and torsion. Such attributes are in contrast to some of the poor qualities of pure solid wall structures without timber lacing.

Timber elements generally behave elastically in a linear direction under alternating loads (Ceccotti, Thelandersson 2000: 3). This is in consideration of failures due to natural defects like knots and also of dissipation energy in areas of the timber components that are perpendicularly compressed (ibid.). According to Cokcan (2001: 53), during an earthquake we find a concentration of tensions along the corners.

At flexible vernacular constructions, the natural frequency may be higher than the stimulating frequency; however, having both equal to each other can be crucially influential. (Schick 1997: 64–66) Soft structures may be forced to take over natural frequency, while rigid constructions such as earth buildings are not endangered by this effect, as they shake rather quickly and do not show such clear deformations. Since the direction of acceleration is random, they have to be strengthened properly. (Gasparini 2000: 5) “Strength and rigidity are less effective in ordinary and unregulated construction than is flexibility, ductile behaviour, and cumulative non-destructive damping” (Langenbach 2002b: 9). Regarding weak half-timber frame constructions without rigid components, Langenbach (ibid. 5) differentiates between strength and lateral capacity, and takes note of their ability to withstand lateral forces for a longer period of time without collapsing (Langenbach 2000: 15). The strong bond between solid structure and timber would suggest using “membrane” instead of “frame” (Langenbach 2015: 87).

Over the course of history, the use of timber constructions has proven to be a common measure in earthquake prone zones. As an example, in the Marmara earthquake in 1999, timber elements in buildings performed positively (Gülhan, Özyörük 2000). In addition, some negative aspects go along with the use of timber. The higher the content of timber, the more forest land is required and the higher is the risk of fire and weathering. Half-timbered houses are found in areas with relatively high resources of timber¹¹⁷ and not in arid zones. Timber lacing in solid structures, however, is also found in arid zones, e.g. in Ladakh.

Half-timbered structures are made as a kind of stabilising and flexible cache. Their connection to supporting constructions such as plinths or solid walls also remains flexible. To achieve a box-like structure, floors strengthen the horizontal surface areas, and diagonal bracings and infills strengthen vertical surface areas. Timber lacings in solid walls, in contrast, are held in position by the load of the wall on top, and wall and lacing stabilise each other.

1.5.3 Solid walls and timber lacing

One of the essential static tasks of a ‘ladder’-like timber lacing (known as *taq*, *bhatar*, or *cheol*)¹¹⁸ is its performance as a ring beam, i.e. a kind of belt to hold the construction together in the case of structural movements (Fig. 4.20). Ring beams have to be joined at their corners. Further, as an advantage of ‘ladder’-like *taq* constructions, this joint may be connected at each corner at both

117 Traditions of timber lacing are not dependent on a particular altitude, much more on the availability of timber. We also find a timber lacing culture at low altitudes close to sea level, as examples from the Balkans show.

118 The wooden framework is in Himachal Pradesh also known as *chzalairi* or *patari* (Handa 2008b: 144).

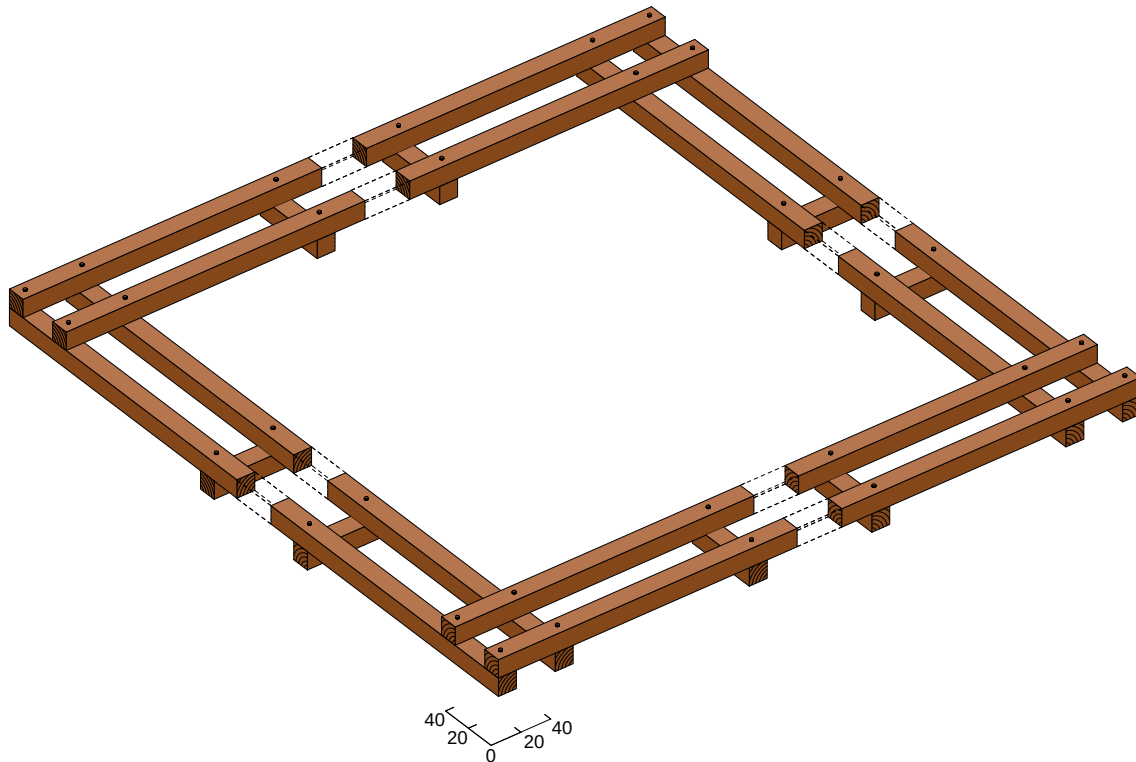


Fig. 4.20 System of ring beams.

CAD: Martin Pospichal. Details provided by the author.

facing runner beams of the 'ladder'. It does not act only linearly, but over the whole corner area. Specifically, in the case of a 40 cm strong wall, there is an area of app. 0.16 m² at each corner. An advantage of timber runners is the additional and by that increasing ductility that augments the capacity to absorb energy and increase earthquake resistance (Langenbach 1989; referring to Gosain, Arya 1967: 29).

In general, foundations, walls, ceilings and roofs are as much as possible designed as shear components.¹¹⁹ In the case of an earthquake, this box-like structure supports the stabilisation of the walls in position. This method requires an appropriate structural connection of the floors with the support wall and a stability of the walls on each floor. The floor beams at each floor are connected to the ring beams and by that form a reinforced horizontal shear component. For a stable structure, it is important to ensure that floor beams, roof beams, and ring beams are firmly bonded with each other to absorb the shear forces of the floor and roof in conjunction with the walls. This rigid diaphragm allows the distribution of loads to relatively rigid vertical elements on the basis that the relative rigidity of the vertical and horizontal elements correlate with each other (Ambrose, Vergun 1999: 63).

¹¹⁹ For floor beams in Newar structures, which are often laid rather close to each other, the single parts of the floor or flat roof form a two-dimensional shear component for strengthening the whole structure.

During an earthquake, the vibration frequencies of the roof and the walls are different (cf. Minke 2001). This means that, in the case of a non-flexible joint between roof and walls, additional force is placed on the walls. Their connection should be of such strength that the risk of the walls drifting outwards and causing a collapse of the roof onto the inhabitants is reduced.¹²⁰ This depends on a proper structural connection of the floor and roof beams with a ring beam. A ring beam is a proper support for the floor and roof beams. For the *kath-kuni*¹²¹ technique in Himachal Pradesh or the *cator and cribbage* technique in North Pakistan, roof beams are integrated into the wall structure and connected to the ring beams. For the *taq* system in Kashmir, floor beams are placed between a double layer of runner beams. Similar is the *dhajji-dewari* construction in Kashmir and the *himiş* construction in Turkey. For several examples, the floor beams are sandwiched between two runner beams facing the outside of the facade. These sandwich techniques support the stabilisation of the floor beams in position.

In the case of movements within solid structures, an important aspect for keeping the construction in position is the friction between timber elements and the wall, and the denticulation of these two constructive elements (Gasparini 2000: 2, 3). At various examples in the Himalayas, as shown below, timber lacing was placed in dry stone walls without the use of mortar. According to Minke (2001: 35), it is recommended to cover ring beams, which are best located centrally over the wall, with app. 2 cm of mortar having good adhesion values. In the case of ‘ladder’-like timber lacings, which are kept in position by the load of the wall on top, this method seems to not have been of striking relevance in vernacular Himalayan examples.

As we know from ‘simple’ building structures in Ladakh, in the case of solid earth and stone structures, floor beams are laid into a wall niche and not fixed on a ring beam. In some cases within the niche, beams are placed on a supporting stone. One method to reduce the possibility of slipping out of the wall during an earthquake is to let the beams protrude outside of the wall. Also in this case, the beams remain slidable. This method brings us to the structural influence of protruding components such as verandas or upper storeys, as we find them in the Ottoman architecture, in Kashmir, in Himachal Pradesh, in Gujarat and in Bhutan. In contrast to the mentioned technique, by placing floor and roof beams without using ring beams, protruding constructions are commonly connected to ring beams. These protruding components press onto the structure below and support stabilisation (Langenbach 2002b: 3). An observation made after the earthquake in 2001 in Gujarat was that the buildings with balconies were more resistant to earthquakes (Langenbach 2002a: 120). This may explain the advantage of beams that extend through the rubble stone walls against joists, which terminate in pockets (ibid.).

Ring beams in stone structures are a common feature throughout the Himalayas. To keep a theoretical box-like structure, the horizontal timber lacing is usually mounted over the entire height

120 During an earthquake in Upper Kinnaur and Spiti in 1975, strong damage was caused to residential and religious buildings, including the temple in Nako and structures in Shelkhar and Chango. As locally reported, at the monastery of Shelkhar, due to the drifting outwards of walls, several monks were sepulchered and trapped below the collapsing roof.

121 *Kath-kuni* (for further explanation see Handa 2006: 102): *Kunā* meaning “corner” and *kāth* meaning “wood”; translated as “forming corners of the square-cut wooden sections” (ibid.) or meaning that the corners were all made of wood.

of the building at similar vertical intervals so that the mentioned belt-effect is active not only on top of the structure, but across the structure. In case of an adobe brick structure (e.g. in Tibet or Ladakh) or a half-timber structure (e.g. in Bhutan or Turkey) on top of a building, the most upper part of the solid structure below is separated from the following upper structure by a ring beam. In contrast, within 'simple' adobe brick structures in Ladakh, the use of ring beams is not as common as at stone structures.¹²² In the aforementioned case of floor beams, which are not connected to a ring beam, in the case of an earthquake, the single beams do not give the needed stabilisation over the floor surface area. On the contrary, they increase the mass¹²³ by acting as point loads on the wall construction, resulting in increased vibration of the wall (Interview with Adam in 2004).

For that purpose, in the Tibetan cultural zone, the introduction of a tapering of the outside of walls may have been a result of development. Their load decreases from bottom to top, and by that reduces the load vibrating in the upper section of the building. By shifting the centre of gravity towards the interior due to tapering, the chance of collapse towards the outside is reduced. This tapering also provides improved rigidity in the corners. If the wall were made with the full wall thickness upwards, this would not only reduce the geometric rigidity, but also increase the mass of the wall and thus lower the natural frequency of the wall. These tapering walls also increase the horizontal rigidity, which is a decisive factor for the establishment of an earthquake-resistant building. (Interview with Adam in 2004) For early West Tibetan religious adobe brick structures, wall thickness reaches up to 1.3 m with wall inclinations deriving up to 2°. ¹²⁴ In general, for prestigious structures, the thickness is rather high. In contrast, for 'simple' vernacular two-storey structures, the thickness of the wall is mostly the length of one brick and tapering is not possible. Interior walls are often made as light-weight constructions, e.g. as timber frame constructions with wattle and daub infill. They are not primarily acting to transfer load like shear walls, but "as energy dissipaters and sway dampers" (Langenbach 2000: 19).

A development in the Tibetan cultural zone, which ignores the aforementioned importance of strengthening corners, are the open corners at rammed earth constructions. At several rammed earth constructions in Spiti and in Central Tibet, rammed earth walls that are part of a simple rectangular ground plan are just 'leaned' towards each other in the corners without any further joint, and by that a gap is left over the whole height of the wall. It remains unclear whether this method is thought to create separation joints. In this case, the mentioned advantages given by the tapering of the wall become evident by pressing the walls together in the corners. In the case that the flat roof collapses, its stabilising load is missing and the walls may collapse easily (see collapsed walls at the Chakyung Babsa Tower in Chekha; cf. Feiglstorfer 2015: 74).

122 In the Tibetan cultural zone, at adobe brick structures with high social status, such as the main temples at Nako, Tabo and Khorchag, timber lacing is used in the walls. Many of the investigated 'simple' vernacular adobe structures have rather thin walls with the length of a brick as thickness and even no space for timber lacing.

123 The weight of a 20 cm thick flat earth roof is app. 400 kg/m². Problematic for the structure during an earthquake is the high mass on top of the building, which results from a continuous addition of earth for the renovation of a roof without exchanging layers.

124 Wall inclinations of the monastery of Nyarma (earliest parts from 996 CE) were presented by the author at the TERRA 2016 conference in Lyon.

1.5.4 Elevation configuration

Another aspect of vernacular buildings in earthquake zones is their vertical segmentation between a solid lower part (higher mass) and a lighter and more detailed upper part (lower mass). Thus, the centre of gravity is lowered (cf. Dipasquale, Mecca: 2015). Already at the Minoan house, which was made of several storeys, a division of the lower part made of stones and the upper part made of adobe bricks is reported (Rider 1965: 142, 143). In several early cases – e.g. at Ottoman houses before the 17th century or at early West Tibetan temples – a single-storey structure was common, while at later multi-storey structures, we find the load of the used materials often reduced towards the top of the building.

Also in multi-storey buildings¹²⁵ from the Balkans to the Himalayas, the lower floor is usually built with the largest mass, in most cases as stone masonry. Such a change between lower and upper floors is also found at timber-laced structures in Kashmir (see Bhushan 2016: 55) or in Himachal Pradesh (see Dave et al. 2013: 34ff.). In most of these regions, the solid ground floor is preferably built of stone. The lacing is an essential technical marker within this seismic cultural region from the Balkans to the Himalayas. In the case that the solid walls are built of rammed earth, as we can find in Tibet or Spiti, such timber reinforcement is not common.

The upper floors of the Ottoman house are built as half-timber structures. Also in Kashmir or Himachal Pradesh, in many cases, timber frame and timber-laced constructions, respectively, are placed on top of a solid basement. According to particular building traditions, the floors on top of the solid (plinth) structure are built with lighter and handier materials. On the one hand, this reduces the load of the building from bottom to top and facilitates the transport of the material to the upper floors. On the other hand, in the case of earthquakes, the upward reduction of the mass has a positive effect on the vibration behaviour of the wall. Also, at many structures in Himachal Pradesh, the *kath-kuni* construction was placed on top of one or more storeys made of stone (ibid.). In the Tibetan cultural zone, it is common to place adobe walls on top of solid walls made of stone or rammed earth. In Bhutan, the wooden *rabsey* is set on a solid substructure, also either made of stone or rammed earth. Besides the structure, where a *dhajji-dewari* construction is placed on top of a solid plinth, several *dhajji-dewari* buildings in Kashmir are raised as half-timber structures over the full height of the building. In the case of *taq* constructions, if bigger openings are introduced, they are usually placed in the upper floors. In strong contrast to the examples using stone for the plinth, in North Pakistan, e.g. at the tower of the Altit Fort or at the Baltit Fort, where the *cator and cribbage* technique is applied, the lower part of the construction is made with a much higher content of timber than the upper part.

1.5.5 Material and joints

The use of proper materials and joints is not primarily a statement of a seismic culture, but for vernacular architecture in general. Their efficiency has to be understood as part of an earthquake-proof structure. The quality of the building material – brittle like mineral-based materials or flexible like timber – influences behaviour during an earthquake. Weak mortar (lime or clay mortar)

125 This change between solid lower and light upper constructions is related to a change between winter and summer places within residential buildings, as we know this, for example, from Safranbolu houses (cf. Bammer 1980: 49).

is essential for the transmission of forces into the whole structure (Langenbach 2000:8). For his observations of the architecture of the Mirkulā Devī Temple at Udaipur in Himachal Pradesh, Nocci (1994: 101, fn. 8) mentions the use of clay mortar and points out its low binding power in the case of an earthquake.

For stone walls, for example as observed at the Old Monastery in Chekha in Central Tibet, clay mortar was used. Neve (1913: 38) talks about the use of clay instead of mortar for traditional Kashmir buildings to enable elastic bonding. With an increasing rigidity of a structure, the necessity for a stronger avoidance of fracture rises (Langenbach 1989: 11). At flexible traditional structures, the rigidity of joints is limited. Minke's objection is the often-used low quality of clay mortar. He argues that the typical diagonal cracks result from the use of a poor mortar (Minke 2001: 13). This would be the case when a clay with too low a binding power, e.g. when containing not enough clay minerals, is used. At various Himalayan examples, simple dry stone walls were erected and no mortar seems to have been used. According to Dave et al. (2013: 73), this has been the case at *kath-kuni* constructions in Kinnaur.

Shaking during an earthquake affects the junctions between materials to a certain degree of deformation, followed by a collapse. The vibration period of structures increases with the slenderness of a structure, and the rigidity becomes more important (Cokcan 2001: 47). In particular, constructive joints in the upper storeys are more stressed due to higher shear forces, and the lower weight of wooden ceilings keeps the horizontal shear low (ibid.). The absorption of tensile forces by wooden joints is of crucial relevance. To fulfill this requirement, traditional techniques for joining wooden components were introduced – for ring beams, e.g. the use of wooden pegs in combination with halving lap joints, dovetail or mortise, and tenon joints. Since they weaken with age, they have to be maintained and, if necessary, replaced after a certain period.

One possibility of stabilisation would be the use of anchoring devices such as brackets. Such brackets are inserted at the outer wall through the ends of the protruding beam. In this way, brackets serve as a tie rod and make a firm connection between the roof and the outer wall. This construction technique can be found in several earth building cultures, for example in the mountainous regions of Iran in Abyaneh, in Himachal Pradesh in the Upper Temple at Nako, in the Skurbuchan Temple in Ladakh (Nako and Skurbuchan see below) or at the castle-temple of Shani Maharaj at Kharshali in Uttarakhand (cf. Handa 2008b: Fig. 35).

1.5.6 Wall openings

The methods used for fixing window frames within masonry walls may point towards awareness of seismicity; more so, the way of fixing may be such an indication. Concerning structural movements, each opening is a weak spot, and cracks in a wall often start in the corners of openings. Horizontal components of window frames often project deep into the adjoining brick wall. They allow an efficient interlocking of the window member with the surrounding masonry, and prevent cracks in the corners of the openings in case of movements. Inserting a wooden lintel, which protrudes into the adjacent wall, reduces the transmission of forces in the wall along the edges of the masonry wall opening. Examples of big-sized window frames with horizontal wooden components in the lintel and parapet area developed during the Newar period in Nepal.



Fig. 4.21 Gondhla. Lahaul. Placing wooden window frames in a stone construction with 'ladder'-like timber lacing.

This type of window construction is widely used and we find it in some Western Himalayan buildings, for example, in the tower of Gondhla in Lahaul, which was built with timber-laced stone walls as opposed to Newar brick walls (Fig. 4.21). Another possibility to reduce cracks in walls along openings is to reduce the size and amount of openings. As an example, early West Tibetan religious structures had only one storey and one door opening, no windows. Openings in solid walls at vernacular structures are in general small, which makes the rooms rather dark. In contrast, openings in half-timber frame structures can be designed larger without interfering with the static system.

1.6 Discussion

The Western Himalayas can be regarded as a “transition” zone of different vernacular building techniques. A significant proportion assumes composite constructions, in particular combinations of stone / clay and wood, and timber frames with different kinds of infill material. In principle, we have to distinguish between timber frame constructions and solid walls with timber lacing. These two basic types show different distribution areas and historical developments. Their development can geographically only be assessed approximately and they are subject to different local and regional adaptations. Local adjustments are found, for example, in the choice of locally available raw materials. Regional common terms show the embedding of certain techniques in the respective architecture.

Timber frames already appear as an early development among the Hittites, Greeks and Romans. Wide dissemination took place in Europe, and Asia Minor to Kashmir in the Western Himalayas. The development of solid walls with timber lacing is more difficult to grasp. Again, early discoveries were made in Greece and in Central Asia. The distribution is significantly over a wide area. It is found in various forms over the entire Himalayas – from the Western Himalayas to East Tibet. Timber lacing can be as simple as a crack stopper not being joined at the corners of the building, or technically more elaborated as ring beams – either with just one facing runner beam or as a

‘ladder’-like ring beam. The latter describes a technique found over a wide area from the Balkans into the Himalayas. Dominant distribution areas are in the regions of the Balkans, Turkey, Iran, Kashmir, the Western Himalayas and North Pakistan, including Himachal Pradesh in northern India.

The change from single-storey buildings to several storeys is connected to particular technical developments, for example, the differentiation between a massive lower building zone and a timber frame structure in the upper zone. Early examples among the Hittites or Romans show similarities to ‘ladder’-like ring beams.

Cultural influence by certain ethnic groups including the acceptance of wood as a construction material and its release by a ruling elite for general use have a significant impact on the spread of timber building techniques. The dissemination is a combination of imported and local traditional knowledge, as the Albanian influence in Mandriza shows. Why certain techniques, such as the use of timber lacing, despite high earthquake hazard, are not rooted in the vernacular architectural Newar culture remains unclear.

From the Himalayas in the east to the Mediterranean area in the west, there are wide regions exposed to strong seismic activity. Certain extensive constructive developments point to the development of a seismic culture. Techniques that have also been applied in the Western Himalayas are the vertical layout of buildings with a solid lower level and light-weight upper level, reinforcement via timber lacing and ring beams, and integration of floor beams into the wall construction to avoid a drifting outwards of the wall or to withstand tension, shear and torsional forces by appropriate materials and compounds.

2. THE IMPORTANCE OF MATERIAL DIVERSITY

Several parameters, such as topography and morphology, ethnic-cultural aspects, and environment and raw material resources, are strongly involved in the process of determining the vernacular features of a given building. One of the most essential factors is the dependence on local availability of certain materials. In this part (4.2), general aspects of the importance of material diversity and its impact on processes of vernacular architecture, including some Himalayan specifications, will be discussed.

Vernacular architecture in general originates locally and within a certain reachable distance from raw material sources, such as timber, stones, and clay. Considering the available range of materials, constructions are adjusted according to particular local living conditions, like climate, protection against enemies, soil characteristics, earthquakes, and fire or flood protection. Rural architecture in the Himalayas, in particular in remote areas, is still based on the most essential needs, resulting in rather simple and functional construction techniques. The core matter for dimensioning the thickness of walls, as an example, is primarily static strength, while heat insulation is subordinate (cf. Künzel 2014: 27). Means of heating are dependent on the heating and cooling phases that result from the thermal conductivity of the used constructions (ibid. 41, 42).

Local material resources are processed in a most efficient way, and they are collected from close distances. Ideally, clay is available from one's own land, stones also may originate from one's own land or a particular quarry in the close vicinity, lime or gypsum originate from the mountains, and certain organic materials like timber or grass also from places nearby. In Central Tibet the saying *sana dona* (Tib. *sa sna rdo na*) reduces material diversity into two words, and can be translated with "different kinds of earth and different kinds of stones", with *sana* (Tib. *sa sna*) meaning "different kinds of earth" and *dona* (Tib. *rdo sna*) meaning "different kinds of stones". This saying points towards a traditional variety of building materials and an awareness of material diversity. For each type of stone, one has to know the right place to collect, also to purchase, and to trade it. This ability involves detailed understanding of local structures in all their facets, be it economical, social, technical, etc. If not, building may become more expensive, there may be a misuse of the proper technique necessary to process local materials, or building may not be adequate for a particular social status. In this context, a free interpretation may read *sana dona* as expression of a basic understanding of the correlation between the availability of local resources and an ecological sustainability. Economic conditions may be valid within a certain community – be it a neighbourhood, a settlement or particular personal relationships – close to what we understand as "local". In general, regarding a relation between ecological conditions and social organisation, these relations may not be comparable over certain regions (Eriksen 2001: 193).

In traditional belief, materials may be more than simply functional goods. They can be classified as male and female, which we know from different kinds of *arga* or bricks.¹²⁶ Furthermore, they may also be respected in a religious context. The Buddhist worship of a *shukpa* tree, which provides a high-quality structural timber, is one example within the Tibetan culture. The term

126 Personal information on "male and female" bricks given by Tashi Tsering at the IATS conference in Vancouver in 2010.

for the Himalayan cedar (*Cedrus deodara*), which is locally known as *deodar*, derives from the Sanskrit term *devadāru*, meaning “wood of gods”. Such connotations of materials connect them with a certain awareness and respect. The professional processing of particular materials is connected to a particular social status. In Tibetan tradition, the carpenter, for example, belongs to the highest-ranked craft while the blacksmith to the lowest. Not only building material but the whole building process is part of religious life. In Buddhist regions like Tibet, Bhutan or Ladakh as well as in Hindu dominated regions like Himachal Pradesh, a building process takes place under the protection of a local deity.

Not using material that originates from nearby would probably point towards the use of a material in a decorative, technical or functional relation to represent a higher social status. An example of a decorative reason would be the use of particular mineral colours for mural paintings, for example, that have to be brought from other countries like India, Nepal, Tibet or Bhutan. An example of a technical functional aspect would be the use of *arga* stone instead of a commonly used flat earth roof construction. The use of *arga* as is the case in Ladakh and Tibet means heavier transport over longer distances and a more complicated process in quarrying this material than simply digging for earth. The gain for this higher effort is longer durability of the roof related to a higher social status (cf. Lehner 2009: 83). This basic precondition for the use of locally available raw material – which is inseparably connected with perpetuating of particular traditions – interferes with the need to overcome uneconomically long distances with high loads. In the context of representing a higher social status, increased effort in organising building material across longer distances would mean a differentiation between those of a common or lower social status and those of a higher social class. In earlier days, *arga* was – and even in remote Himalayan areas still is – either transported on the backs of carriers or with the help of animals. Long-distance transport to Ladakh and Tibet of *arga* stones and proper high quality timber, such as cedar, was primarily conducted by yaks. In the case of buildings representing a higher social status, such as monasteries, higher requirements in the quality of building material increased the length of transport distance. Having the financial means to afford such transport was beyond the means of a simple farmer, who was dependent on nearby resources of building material. In breaking the forces of dependence on local products and customers, a further step is the use of motor ability going hand in hand with the easier availability of goods from an external market (cf. Feiglstorfer 2012a: 3). Thus, reliance on locally available building material was reduced. In this regard, motorised transport assistance facilitated a termination of the concept of pre-modernity¹²⁷.

An early example from the late 10th century CE in Ladakh of acting economically is provided by one of the three earliest monasteries of West Tibet located in Nyarma in Ladakh. In the course of a study at the IAG / BOKU it was proven that the clay used for the entire construction of the monastery was collected nearby, even for a building of such high social status. With the thus obtained clay, bricks were produced with the minimum amount of additives possible. The material was even ideal for use as a plaster ground layer. At this example, only the upper plaster layer was either sieved or desludged. Both methods do not need any addition of a second material, only the

127 The delimitation itself of ‘modern’ and ‘premodern’ according to the *Querelle des Anciens et des Modernes* (1687) is still related to ancient times, while in later use, since the second half of the 19th century, the term *modern* has started to be commonly used in Europe (Barnard, Spencer 1996: 377).

separation of fine from coarse material. With this seemingly simple approach, a rather economic and material-efficient procedure was possible. Further, a rather high knowledge of clay within an economical as well as ecological context becomes obvious.

This interrelation between local material resources and applied techniques marks the kind of construction used and the choice of material within composite constructions. There are several parameters that define the availability of certain natural materials, like altitude and climate as well as vegetation and geological zones, which are up to a certain point interrelated with each other. These generalising statements are explained in detail in part 3 of this chapter, and the effects of changes of these parameters on the particular local material composition are analysed in part 4 of this chapter.

Workers are in a vernacular context predominantly relatives, neighbours and as much as possible people out of the local context. In a modernised context they become predominantly paid workers from outside the vernacular community. It is relevant if a personal relationship exists between workers and house owners in that they may see their personal effort to produce a high-quality product as an honour. In a vernacular community, local builders with specific knowledge and interest in certain techniques, such as stone cutting, masonry or carpentry, and also people with a related profession share their skills with relatives, friends and those related to a certain local community. In remote Himalayan areas, people have to cooperate on the building site, and this is only possible at specific times in the year, since many of the labourers are primarily farmers. Their year is structured by the seasons and related social events. For example, for a traditional earth roof of a residential building in Himachal Pradesh we can find up to twenty people on the roof preparing insulation or thereafter compressing the clay, similar to the ramming of walls.

In the case of brick laying, an effort depends on whether the bricks are fired or sunburned. Firing of bricks is related to a high-energy input and much higher costs than using adobe bricks. The latter have to be prepared quite early within a year, as soon as the earth is no longer frozen, so that they can dry and be ready for processing in another season within the same year. In Tibet, construction of a residential house in general does not take longer than two seasons (Alexander 2011: 70). The system of seasonal construction work influences the private sector but also public construction work, for instance, at monasteries. Again, in the Himalayas, traditional work at monasteries is (or in Tibet was) executed by either monks, persons directly related to the monastery, locals with a certain duty towards the monastery or by paid external workers. Workers were commonly recruited from the rural area.

The survival of knowledge of traditional techniques also depends on their complexity. To keep with the example of making a rammed earth wall or an *arga* roof, the need exists for someone who has knowledge of the individual working steps, their duration, their need in human and material resources, and specific technical features. At least one person, for example, the supervisor, has to be aware of all these facets of construction. However, some of the work itself can be conducted by labourers with no specific knowledge or education. In Tibet for the case of repairing an *arga* roof, the process has to be conducted in several steps guided by at least one supervisor, who precisely knows the individual working steps.

While ramming a roof requires no special training, specific knowledge is essential for the work of a carpenter or mason. The quality of work is not dependent only on having a good supervisor but on the skill of the single worker. Today in Ladakh or Spiti, skilled stone carvers are locals but also workers from Kashmir or Nepal. Another recent example of employing workers from outside the village community concerns the renovation of the village temple of Lalung (alt. 3,650 m) in Spiti in 2006. Here construction of a flat roof is a tradition related to a shortage of timber in this region. Contrary to tradition, a sloping roof was installed on the former flat roof by carpenters originating not from the village but from outside Spiti. For such specific crafts, the limits of neighbourly help are evident.

With the use of particular materials and related building techniques, a specific demand for labourers follows. Depending on the complexity of the work, it can either be conducted by lay- or semi-skilled workers or just by skilled workers. Knowledge is passed on from one generation to the next, within a master-apprentice-relation or within a specific group of workers in a kind of craft guild. Crafts are not necessarily inherited, as shown by the example of Könchog Tsering, a clay sculptor in Lhasa, who the author visited in December 2015 (see Chapter II). As a young man, Könchog Tsering worked as a house and furniture painter. About 30 years ago, he followed his passion and was trained in clay modelling by a master in Lhasa. In his case he did not follow a family tradition. Up until 1959, besides the clergy and aristocracy, sub-categories of commoners can be mentioned according to their social rank. A differentiation of these categories correlates with freedom of movement, ownership of land, economic status and a specifically regulated duty to pay taxes. Among these, we find a guild of artisans similar to a social group of its own, which formed under the Fifth Dalai Lama's government in the 17th century (Ronge 1978: 86, 102). This Tibetan guild included a builders' community called *doshing zokhang* (Tib. *rdo shing bzo khang*) or *doshing chipa* (Tib. *rdo shing spyi pa*), which before 1959 had included up to 500 regular members and more, if required (Alexander 2011: 62). In major Tibetan monasteries, this guild was employed to engage in the maintenance, repair and restoration work of major monasteries. This guild also included experts responsible for plaster and clay, and the *shepön* (Tib. *zhal dpon*, "leader of the flooring"), which included female members. In this community of masons, the *shepön* had the lowest social status, contrary to the carpenters who had the highest. Living and working as an artisan in Lhasa required joining of a guild (ibid. 62, 63).

In Himachal Pradesh, building works, like the erection of a new house, are conducted within customary community participation (locally known as *kewar* or *saret*) (Handa 2008b: 138). Related customs are different in the case that someone within the community is not able to conduct a specific task. At the *Gaddi* in Himachal Pradesh, for example, a carpenter is a skilled person by choice, not by compulsion or inheritance (ibid. 138); this is contrary to the *Gujjars*, who do not accept anyone from outside kith and kin as part of customary community participation (ibid. 150).

Primarily in the so-called "Western world", the loss of building traditions has already strongly progressed. In most of the rest of the world, tendencies are orientated towards that loss. Today, as a result of naturally defined forces, the following of traditions has changed into a voluntary decision. Modern building materials are advertised with a longevity and less time resources of individuals for maintenance. In rural areas, building with 'modern' materials generates a lack of skilled workers with knowledge of certain traditionally predetermined qualities. This change towards the 'modern era' has even reached remote places in the Himalayas.

With the neglect of certain natural material resources and the loss of related traditions, evidence of their existence is disappearing. Earlier clay pits in large settlements, for example, in Leh in Ladakh, are reported to have been built over and are no longer accessible. This results in either accepting building material of lower quality or investing in higher quality with higher costs for a longer distance of transport. With opening of the market and the need for innovations, renunciation of local resources is a way to keep pace or dominate a market. As comparison, in the Western sphere during the 18th and 19th century, continental and American traders started to look for new manufacturing methods, with Great Britain as the first industrialised power (Jeremy 1991: 2). Decisions for development changed from a local level towards a state level. Technologies were imported, transformed and modified by cultural features (ibid. 1991: 3).¹²⁸ Governmental building structures installed by the British in Indian Himalayan settlements in Himachal Pradesh, for example in Shimla or in Kaza (the latter located in Spiti), stick out with corrugated iron roofs or massive stone walls erected against local building traditions. Within this process, external influences become a driving force for further changes of the ‘local’, which is – regarding building traditions – dwindling over time.

On the Himalayan plateau, over the centuries the availability of wood has decreased and this point needs to be considered during research on historical structures. It should not be excluded that centuries ago the use of timber was much more common in the Himalayas than it is the case today. Scientific reports state that the aridity within Central Tibet is primarily caused by deforestation and high-quality timber such as cedar was much more easily available in earlier days. Recent research shows that “the present high mountain deserts of southern Tibet are the result of deforestation due to centuries of woodcutting, use of incense, and grazing”¹²⁹ (Miehe et al. 2003). Previously, around 3,000 years ago, the Muktinath Valley in Mustang, as an example, was much more densely settled with a higher number of livestock. This may have resulted in an over-exploitation of the land (Kriechbaum 2002: 82). Examinations of the vegetation have shown that the vegetation cover of the whole valley was strongly changed by human activities (ibid. 81) and resources of structural timber may have continuously decreased.

2.1 Discussion

Vernacular is a social concept tightly related to local conditions of raw material resources. Diversity of local building materials and expertise in processing is a crucial factor for keeping a vernacular system alive. In Central Tibet, the saying *sana dona* points towards this material diversity of different kinds of stones and clay, their different qualities and different ways of processing. In this context, diversity of raw materials becomes essential with their use. For the maintenance of diversity, certain preconditions need to be held in balance. To keep the use of local materials economic and ecological, availability must be secured within a certain distance. This fact determines the means of transportation. Materials for a representative purpose for a wealthy society are not

128 A further development that diverges inevitably from traditional local standards is based on a technology transfer, which may explain further dynamics in import and transformation of technologies. Jeremy (1991: 4) mentions the following parameters: Vehicles of transfer, networks of access to the originating economy, information goals of acquirers, methods of information collection, and speed of transfer of a given technology.

129 Sir Charles Bell (1924: 16) reports a traditional saying that in earlier times there were much more cypress trees in Tibet.

bound in the same way to local availability, justifying transport over a longer distance.

Substitution of local materials for products from external markets influences the vernacular system, possibly irreversibly. Transmission of knowledge of materials is primarily given by oral and inherited means. Work is basically conducted by the house owners and the local community. A distinction is to be made between crafts capable of being conducted by semi-skilled labourers, and those requiring a specifically trained skill. This difference influences the complexity in transmission of certain skills. In vernacular systems, only in particular cases and communities are specialists brought into the local community from outside. In the Himalayas, dependent on cultural and in particular religious affiliation, materials are connoted with a certain meaning beyond their simple functional use. This fact integrates them into customs of a village community.

Composite constructions, which follow a particular content of raw materials, for instance, stone, clay or wood, are based on material diversity and sensitive to changes in the local availability of raw material components. In the following parts 3 and 4 of Chapter IV, this matter leads us from material diversity towards diversity of constructions.

3. ENVIRONMENTAL ASPECTS: CLIMATE AND RAW MATERIAL

Building traditions follow particular cultural patterns and are subject to change over time (see *Preliminaries*). On the one hand, changes may be regarded as culturally determined, and traditions may remain the same, change or vanish due to a variety of reasons. On the other hand, variations may result from certain local preconditions. Thus, mentioned here are naturally given aspects,¹³⁰ which in general are fixed and change only over a rather long time span (climate, vegetation, geology, etc.). Such change (e.g. precipitation or availability of natural resources) may induce a change of building traditions.

Environmental, socio-cultural and socio-economic are described as the three main attributes of sustainable architecture (Guillaud et al. 2014: 6). Vernacular architecture in general follows these aspects. Specifically, environmental preconditions and their impact on Himalayan composite constructions are treated in the following.

Inhabitants of former times did not have knowledge of statics calculations, e.g. concerning seismic motions or statics and static collaterals. The high durability of the building materials used shows that they understood the qualities of regionally available building material and were well aware of their constructive use. This also points towards an awareness of earthquake-resistant structures. Historical structures were not built on the basis of a unified building codex, but followed knowledge transmitted over generations and which grew empirically through experience.¹³¹ Posing the question for the use of particular constructions is based on the existence of knowledge related to environment-behaviour interaction (Rapoport 1990: 245). People are not settled in a particular influencing environment; they instead search for the proper environment (ibid. 246).

In the Himalayas, we find great diversity in different naturally given preconditions and related building traditions. Within several field studies in the Himalayas, a coherent picture of existing building traditions was gained. We can distinguish between a generalised and a detailed categorisation of features of vernacular architecture. With the general categorisation we can refer to general features of construction, such as the use of particular raw materials related to particular altitudes over a wide region, for example, the Himalayas in general. This approach is rather inaccurate. With detailed categorisation, in addition to the assignment of particular features of construction to a certain altitude, it is possible to relate specific constructions and related variations to a particular local influence. This approach considers local variations and is essential for the following study.

130 Sanders (1990: 44) mentions in his study on “behavioural conventions and archaeology” seven factors that shape a house: climate, topography, available materials, level of technology, available economic resources, function, and cultural conventions. According to his categorisation three of these factors, namely climate, topography and raw materials, are fixed influences and naturally determined (ibid. 1990: 45).

131 These traditional and commonly accepted practices stand in contrast to today’s building codes. In a Kashmir context there are four essential aspects mentioned by Langenbach (1989: 10): 1) small strength of the mortar; 2) no bonding between infill walls and piers; 3) weak bond between the wythes of the masonry in the walls; and 4) frequent (historical) use of heavy sod roofs.



Map 4.2 Elevation within the core region.

GIS data based map drawn by: Jakob Gredler. Final graphics: author. Map based on Vector data (VD) and SRTM digital elevation data (SR) adapted from Jarvis et al. 2008. Citations of VD and SR also see: Chapter IX, list of illustrations.

The present study concerns primarily composite constructions with wooden components in the Western Himalayas. In the field of structural engineering, a composite construction is given when two different materials (in the particular case of this contribution i.e. clay and / or stone and wood) are bound together in such a way that they ‘collaborate’ as a single structure. This includes, e.g. framework constructions or solid walls with timber lacing, i.e. materials that work as a constructive unit. At least two materials have to be bound to gain a new unified structural unit and in doing so the materials support each other, for instance, concerning their energy effort in processing or their physical or mechanical properties, like insulation, thermal storage, water repellence etc.

Composite constructions are a synergy of several materials. This may be a solid wall construction as a combination of different components, e.g. a stone wall, a brick wall or a rammed earth wall, all of which in this study are combined with wooden lacing; in this study it may also be a skeleton construction of wood with infills of clay, bricks or stone. The way of combining materials and the proportional distribution of each material component depends on particular technical parameters.

The Himalayas have to be mentioned as having a great variety of different building traditions. A large number of these traditions are still practised and include a great variety of composite constructions. Various forms of timber lacing were treated in the literature, e.g. Randolph Langenbach covered various regions such as Pakistan and India, in particular Kashmir, and Turkey (see <http://www.conservationtech.com>), and Richard Hughes focused on vernacular architecture in Pakistan (see Hughes 2000a, 2005, 2007) or Turkey (see Hughes 2000b). For the Indian Himalayas, Neil Howard (1989) looked at fortress architecture in Ladakh, and O.C. Handa (2001) examined particular local constructions in the Western Himalayas. One of the main criteria for a continuous change of resources is a changing altitude, correlating with changes in temperature and precipitation. These are some of the crucial parameters for technical building decisions. They are in direct relation to local availability of particular raw materials, and availability changes with increasing altitudes (Map 4.2). Composite constructions in the Western Himalayas are found in mountainous areas within a certain altitude range. Related areas reach from lower altitudes of app. 1,585 m in Srinagar up to altitudes of app. 3,600 m in Ladakh. This study concerns environmental influences primarily within these app. 2,000 metres difference of altitude.

For the reason that early structures provide a good picture of later developments, such early structures are emphasised. Several of the representative objects of research are religious structures. They represent a hierarchically high social status within the related local community, were maintained with most care, and erected with building techniques following a high technical standard. Of relevance in this study are local technical authenticities, which in some examples still remain as local traditions or have either vanished or changed over centuries, e.g. were replaced by modern structures. The names of the builders of vernacular architecture are in many cases not known.¹³² Material resources exert influence on the design of a building. The final design decision is not solely material, but culturally related. Certain timber-laced techniques show both local affiliation and an integration into a wider typological context. Finding an origin of timber lacing traditions seems to be difficult, but looking for early technical developments may help to understand historical and in particular function-based developments.

¹³² Basically, we are talking about architecture without architects following Rudofsky’s (1993) core message, with patterns of construction as communal achievement, related to a particular region. For a further discourse on vernacular architecture, see above under *Preliminaries*.

3.1 Research question and method

What influence has the changing altitude in the Western Himalayas in correlation with environmental influences on the technical development of traditional composite wall constructions? Traditional composite wall constructions and their material components will be examined according to altitude-related environmental parameters.

3.2 Research area

A core region of this examination within the Western Himalayas stretches from Ladakh (which is located in the province Jammu and Kashmir) in the north and the districts Chamba, Lahaul & Spiti, and Kinnaur (which are located in the province Himachal Pradesh) in the south. Comparative examples from the mountainous Pakistan provinces Gilgit-Baltistan, Khyber Pakhtunkhwa and Azad Jammu and Kashmir are given (see Map 4.1).

3.3 Natural preconditions related to altitude

Regarding environmental changes due to changing altitude, both temperature and precipitation are of central importance for vernacular building traditions. Temperatures may influence the thickness of walls. Wall structures affect the heat insulation and the dispersion of humidity in a fluid or gaseous aggregate phase inside the wall structure as well as inside the building. Persistent humidity negatively affects the construction. At cold temperatures, water that has frozen within the construction may lead towards the effect of congelifraction and by that open cracks for further water intrusion. Persistent moisture penetration of wooden parts of the building may result in rotting. Precipitation concerns primarily the protection of the surface to make the wall repellent against or closed off from water intrusion. Making a stone plinth up to a certain height above ground level is the most common method to break the capillary moisture rising from the ground below. Aside from the wall construction, the roof is primarily affected by precipitation, and using a pitched roof instead of a flat roof can roughly be ascribed to different influences like rain or snow or the changing amount of precipitation in higher altitudes and less forested areas.

Another vulnerability of constructions is caused by water along the outer surface of the wall, in particular when using wooden components. This problem is evident in the framework or in timber-laced buildings, where the wooden components are often visible along the outer surface of the wall. Plastering of the whole wall can easily result in cracks in the plaster in the area covering the junction between the wood and other material components. In a traditional way, the use of vegetable or animal fibres helps to reduce or even to avoid cracks. Different methods in using such fibres are shown with techniques of processing clay for sculptures (see Chapter II). As soon as a crack occurs, humidity is able to enter the construction. In the case of frost, a congelifraction can result with the crack eventually enlarging and causing weakening of the particular wall structure. In the case of plaster avoidance, as is the case at many vernacular structures, the circulation of air, water and damp within the construction is not impeded and the chance of quicker drying of the infiltrated humidity is given. Avoidance of plastering outer wall surfaces can be found in many vernacular structures all over the Himalayas. The adobe brick temples of Tabo can be mentioned as early examples. The foundation of the earliest core of this monastery dates back to 996 CE. In pictures published by Romi Khosla in the course of a conservation project by the ASI

(Khosla 1979: pictures 42–45), we can see the documentation of their unplastered state before plastering. In arid zones rainfall may also be strong, but not of such a duration that the saturation of the unfired bricks leads to the danger of a loss of stability of the construction. This changes with an increase of the duration of rainfall in that stability would be negatively affected. The strong rainfalls in August 2010 in Ladakh and Spiti showed the dramatic effects of a climatic change with long lasting precipitation on adobe constructions.

The primary function of exterior walls of vernacular structures in the Himalayas is related to stability. This concerns carrying both a static load (e.g. a roof) and a dynamic load (e.g. by ground settlement or earthquakes). Within traditional village life, the insulation of stone, wood and earth walls of vernacular structures is not of striking relevance for the inhabitants since most activities during the day happen outside the building, and heating is reduced, primarily to the preparation of food. Clothing and not buildings is the main heat regulator. In a traditional Himalayan house, the intermittent way of heating results in dependence on the heating and cooling phases from the thermal conductivity of the used constructions (cf. Künzle 2014: 41, 42).

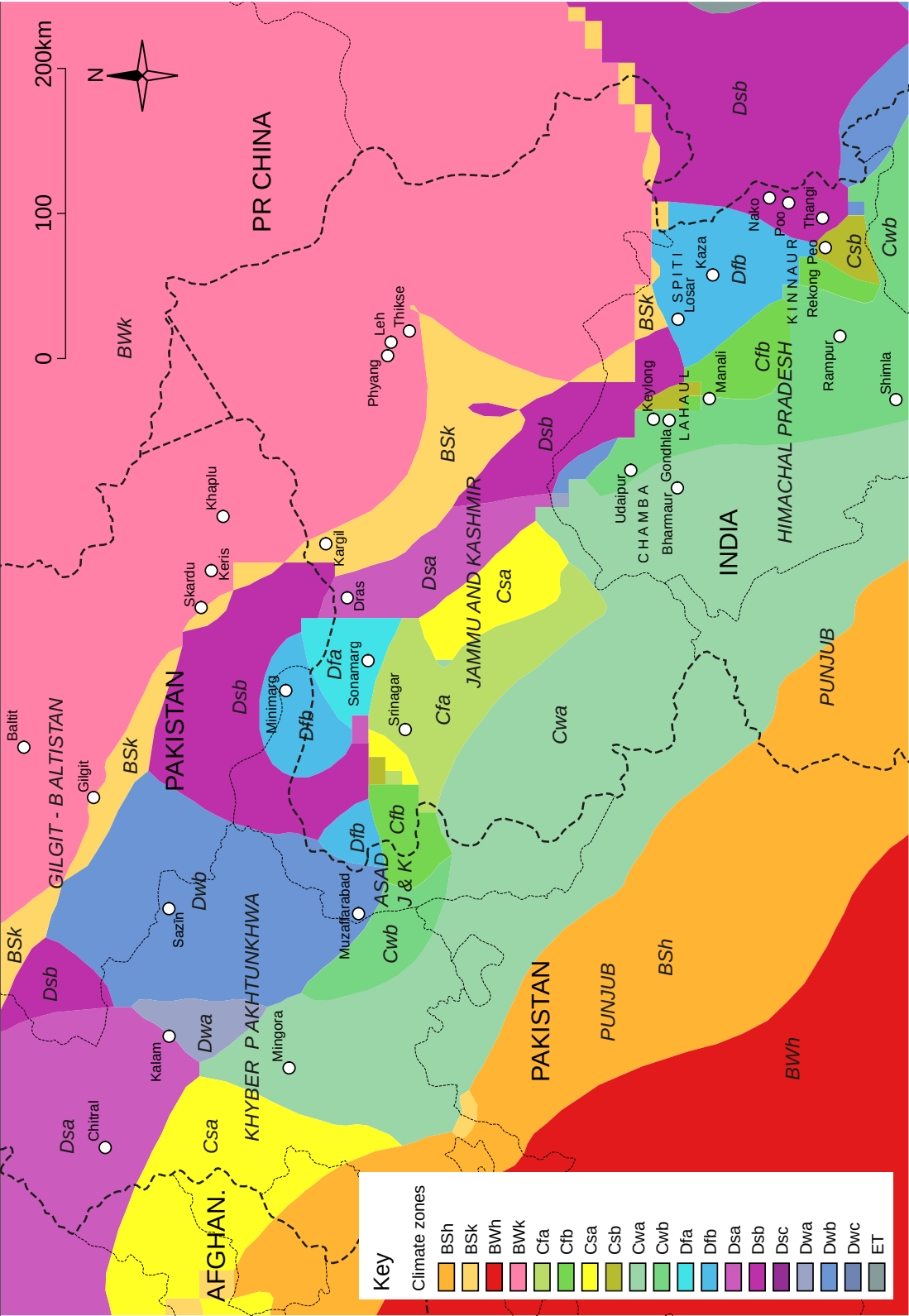
The thermal conductivity (measured in W/mK) of building materials and the degree of moisture penetration are essential parameters for the insulating effect of building components. Compared with mineral building materials such as clay or stone, wood has a relatively low thermal conductivity. The content of wood at composite constructions is rather low, and an increasing content of wooden elements increases the heat insulation of the wall but also the amount of joint gaps to adjoining wall materials. Insulation with clay is worse than with wood, but still more efficient than with stone. In the case of rain, the insulation is strongly reduced due to temperature transmission supported by sorption. An unplastered wall, for example, may contribute to a quicker removal of water stored inside the wall compared to a plastered wall.

Before analysing single structures, temperature and precipitation are to be summed for the research areas. This step supports getting insight into the dependence of a particular type of building technique on environmental conditions and the local availability of particular raw materials. Vegetation is mainly influenced by changing temperatures and precipitation. The particular type of locally available clay is also influenced, for example, by wind or water erosion. Available species of stone are primarily related to geological factors.

3.4 Western Himalayan climate in general

Himalayan altitudes of the core region of this study (mountainous regions of Jammu and Kashmir, and Himachal Pradesh) range between app. 1,800 m and 3,600 m. Climate plays a crucial role in the availability of specific raw materials for building purpose, in particular, timber, stone and clay. The climate diversity of the Himalayas, which act as climate barriers, reflects the variety of natural building resources in this region. In the following, an overview is given of the different climate types in the core region. Table 4.2, which contains altitudes and climate data, is shown in the Appendix of Chapter IV. According to a detailed global climate classification by Köppen-Geiger (WMKG), the present area of study within the Western Himalayas will be classified according to Peel et al. (2007)¹³³.

133 Cf. map by Peel et al. 2007. Online: <http://people.eng.unimelb.edu.au/mpeel/koppen.html>, access: 05/2016.



Map 4.3 Climate classification.
GIS data based map drawn by: Jakob Gredler. Final graphics: author. Map based on Vector data (VD) and Climate map (CM) adapted from Peel et al. 2007. Citations of VD and CM also see: Chapter IX, list of illustrations.

Of the five climate types given by Peel et al. (2007), three stretch over the Western Himalayas: arid [B], temperate [C] and cold [D]. The orientation of the different climate types in the Western Himalayas follows the orientation of the topography from north-west to south-east. The north-eastern region with Ladakh is assigned to the arid zone [B]. The cold zone [D] continues to the west, stretching from Chitral in North Pakistan in the north to Moorang in Kinnaur in the south. Further west the temperate zone [C] continues from Nuristan in Afghanistan in the north to Uttarakhand in the south. These three climate types are subdivided into several categories, as described in the following from north-east to south-west (Map 4.3). Abbreviations for climate types are given in square brackets according to Peel et al. (2007).

3.4.1 Arid climates [B]

- Arid, desert, cold [BWk]: This climate type stretches over Ladakh (Leh) to the north into North Pakistan (Khaplu).
- Arid, steppe, cold [BSk]: This climate type stretches from Skardu to the south towards Kargil located in Ladakh, Karsha and the Markha Valley in Zangskar, and ends at the north of Spiti.

3.4.2 Cold climates [D]

- Cold, dry and hot summers [Dsa]: This climate type stretches from west of Kalam (located in Khyber Pakhtunkhwa) to the west via Chitral into eastern Afghanistan. A second zone of this climate type stretches from Dras (located in Ladakh) to the northern border of the Chamba District.
- Cold, dry winters and warm summers [Dwb]: This climate type stretches from Muzaffarabad (located in Kashmir) in the south towards Gilgit (located in Gilgit-Baltistan) in the north-east and Kalam (located in Khyber Pakhtunkhwa) in the north-west.
- Cold, dry and warm summers [Dsb]: This climate type stretches west of Skardu (located in Gilgit-Baltistan) and west of Kargil (located in Ladakh) and is westwards connected to the climate type [Dwb]. A second zone with this climate type is located further south, stretching from Upper Kinnaur south via Lipa, Spillo and Thangi to Charang.
- Cold, without dry season, warm summers [Dfb] or hot summers [Dfa]: Both climate types are partially surrounded in the north by climate type [Dsb]. Climate type [Dfb] is found in the area to the south surrounding Minimarg in Kashmir, and climate type [Dfa] is described by the area surrounding Sonamarg in Kashmir. Further south, climate type [Dfb] stretches from Losar to Kaza in Spiti towards Poo and further south to Asrang in Kinnaur.

3.4.3 Temperate climate [C]

- Temperate, dry winters, warm summer [Cwb]: This climate type stretches over most of the eastern part of Himachal Pradesh from Udaipur (located in Chamba) in the north to Keylong (located in Lahaul) in the south-east and to the south to Manali, Shimla and further on to Uttarakhand. To the west, the climate type [Cwb] is flanked by the large climate type [Cwa] and along its east flank smaller climate types are embedded, in particular the climate types [Cfb] and [Csb].
- Temperate, without dry season, warm summers [Cfb]: This climate type stretches from Manali in the west over a large part of Kullu in the east.
- Temperate, dry and warm summers [Csb]: This climate type is attributed to a region in Kinnaur, which stretches from Kalpa to Sangla.

- Temperate, dry winters, hot summers [Cwa]: This climate type stretches over the largest region within the area of study, from Mingora (located in Khyber Pakhtunkhwa) in a southern direction via Jammu to the west of Shimla. Another climate type [Cfa] is embedded along the north-eastern part of climate type [Cwa].
- Temperate, without a dry season, hot summers [Cfa]: This climate type includes Srinagar and the Kashmir Valley.

3.5 Climate in the areas of study:

Jammu and Kashmir, Himachal Pradesh, North Pakistan, Central and West Tibet

When not further mentioned, the summary follows the data given in Table 4.3 in the Appendix of Chapter IV according to *Climate data for cities worldwide* according to Köppen and Geiger (in the following briefly mentioned as “CD”). Altitudes are given in metres. The given data are based on an annual average, and maximum and minimum peaks in temperature may differ from the given average data. In an architectural context, precipitation stresses the need for the proper protection of roofs and walls regarding water ingress into the construction. In the case of snowfall, besides water ingress as a result of melting, the increasing weight from snowfall is of particular relevance. A high difference between daily minimum and maximum temperatures will strain the ability of materials to increase or decrease their volumes. In this relation, cracks become an important matter of construction. Varying conditions influence local techniques of construction. Altitudes above sea level are given in metres [m]. The altitude data of Köppen and Geiger (CD) are compared with and, if necessary, adjusted to the data given in Google Earth.

3.5.1 Jammu and Kashmir

Ladakh

In Ladakh, minimal precipitation over the year is the norm. The data for Leh (alt. 3,520 m), Phyang (alt. 3,510 m) and Thikse (alt. 3,250 m) are similar. Low temperature is on average app. -9°C, and the difference between minimum and maximum temperature goes up to app. 26°C, which is comparatively high. Precipitation increases in the west towards Kargil (alt. 2,700 m). This is visible by the increase of vegetation. (CD) Over the course of a single year, there is more snowfall (maximum app. 15 cm) than rain (Cunningham 2005: 179). In Dras (west of Kargil), strong snowfall may start in November (ibid. 180). In Leh, rainfall is limited to short showers usually between July and September. In Kargil, in summer, there are just a few days with rainfall and lots of snow in winter. (Negi 1998: 68)

Srinagar

A strong change occurs from Ladakh towards Srinagar in Kashmir (alt. 1,590 m). Precipitation occurs throughout the entire year, and even in the driest month it is still relatively high. Annual precipitation is about twice as high as in Kargil (alt. 2,700 m) and six times as high as in Leh or Phyang. Also in winter precipitation is rather high. Temperatures go down to around 0°C. (CD) Precipitation is higher in winter than in summer (Negi 1998: 69). Summers in Kashmir Valley are temperate with severe winters (GSI 2012b: 2).

3.5.2 Himachal Pradesh

Lahaul

In Lahaul (Keylong, alt. 3,100 m; Gondhla, alt. 3,170 m; Udaipur, alt. 2,650 m), the amount of precipitation is much higher compared to the data given for Leh and Phyang, but still rather low. Precipitation is higher in summer than in winter. While maximum temperature in Lahaul is similar to Leh and Phyang, the minimum temperature is higher (CD), and in Keylong it may severely drop below the freezing point (Negi 1998: 70). Snow may fall already in October (Cunningham 2005: 180). Snowfall is much stronger than in Spiti (see below) (Bajpai 1987: 5).

Spiti and Upper Kinnaur

In Spiti (Kaza, alt. 3,660 m), annual precipitation is lower than in Lahaul, but still higher compared to Leh or Phyang. Climate in Upper Kinnaur (Nako, alt. 3,630 m) is similar to the climate of Kaza. Precipitation is still higher in summer than in winter. (CD) The biggest amount of snow is mentioned with a height of app. 75 cm. The season for snow is between November and February (Cunningham 2005: 181). For Spiti, Verma (1997: 13) reports heavy downpours, e.g. in September 1988 with 140 mm, in July 1989 with 110 mm and in August 1990 with 100 mm, and that snow may remain on the surface until April.

Middle and Lower Kinnaur

In Middle and Lower Kinnaur (Spillo, alt. 2,400 m; Rekonig Peo, alt. 2,420 m; Kalpa, alt. 2,760 m), annual precipitation is similar to Lahaul (Keylong, alt. 3,100 m), and temperatures in winter drop to close to 0°C. From Upper Kinnaur to Middle Kinnaur, winter instead of summer is the season with the most precipitation. (CD)

Shimla District

In Shimla District (Rampur, alt. 960 m), precipitation clearly increases compared to Kinnaur. From Kinnaur to Middle Kinnaur, summer instead of winter is the season with the most precipitation. (CD) In Shimla (alt. 2,100 m), frost is frequent in winter, while in summer temperatures rise to app. 20°C (Negi 1998: 70).

Kullu

Further north towards Kullu (Manali, alt. 2,000 m), annual precipitation is nearly double compared to Rampur and twenty times more compared to Leh. The average minimum temperature ranges around 0°C. The North Indian districts Lahaul, Spiti, Upper Kinnaur and Ladakh have less precipitation and are on average colder, while towards Chamba (Bharmaur, alt. 2,170 m), precipitation and temperature are rather similar. (CD) Winter in Manali can be severe (Negi 1998: 70). Kullu is located at a frontier of two climatic zones, i.e. the south zone with monsoons and the continental zone with a cycle of seasons (Postel et al. 1985: 287).

Chamba

In Chamba (Purthi, alt. 2,460 m; Bharmaur, alt. 2,170 m; Chamba, alt. 950 m), the climate is similar to regions west of Kinnaur with less precipitation in winter compared to summer. This changes again further north in Lahaul. In Purthi, precipitation occurs throughout the whole year. (CD) In the upper valleys of the Chandra and Bhaga Rivers, during the season from app. the end of the year until May, a small amount of snow may be experienced (Bajpai 1987: 5).

3.5.3 North Pakistan

Gilgit-Baltistan

In the province of Gilgit-Baltistan, a climate with low precipitation throughout the year is prevalent (CD). Altitudes of the observed areas range between 1,470 m in Gilgit and 2,430 m in Baltit. (CD) In Baltit (alt. 2,430 m), Skardu (alt. 2,250 m), Keris (alt. 2,310 m) and Khaplu (alt. 2,600 m), temperatures range between -9°C and 23°C. The difference between minimum and maximum temperature is up to app. 30°C. Annual precipitation is about twice as high as in Ladakh (see Leh and Phyang). Minimum temperatures are similar to Ladakh (see Leh and Phyang), while in comparison maximum temperatures are higher. The highest precipitation occurs in the warm season. In Gilgit (alt. 1,470 m), which is about 1,000 m lower than, e.g. Baltit, it is much warmer, while precipitation remains similar. (CD) As reported by Hughes (2005: 22), in Hunza rainfall can be quite intense and damaging, but not frequent.

Khyber Pakhtunkhwa

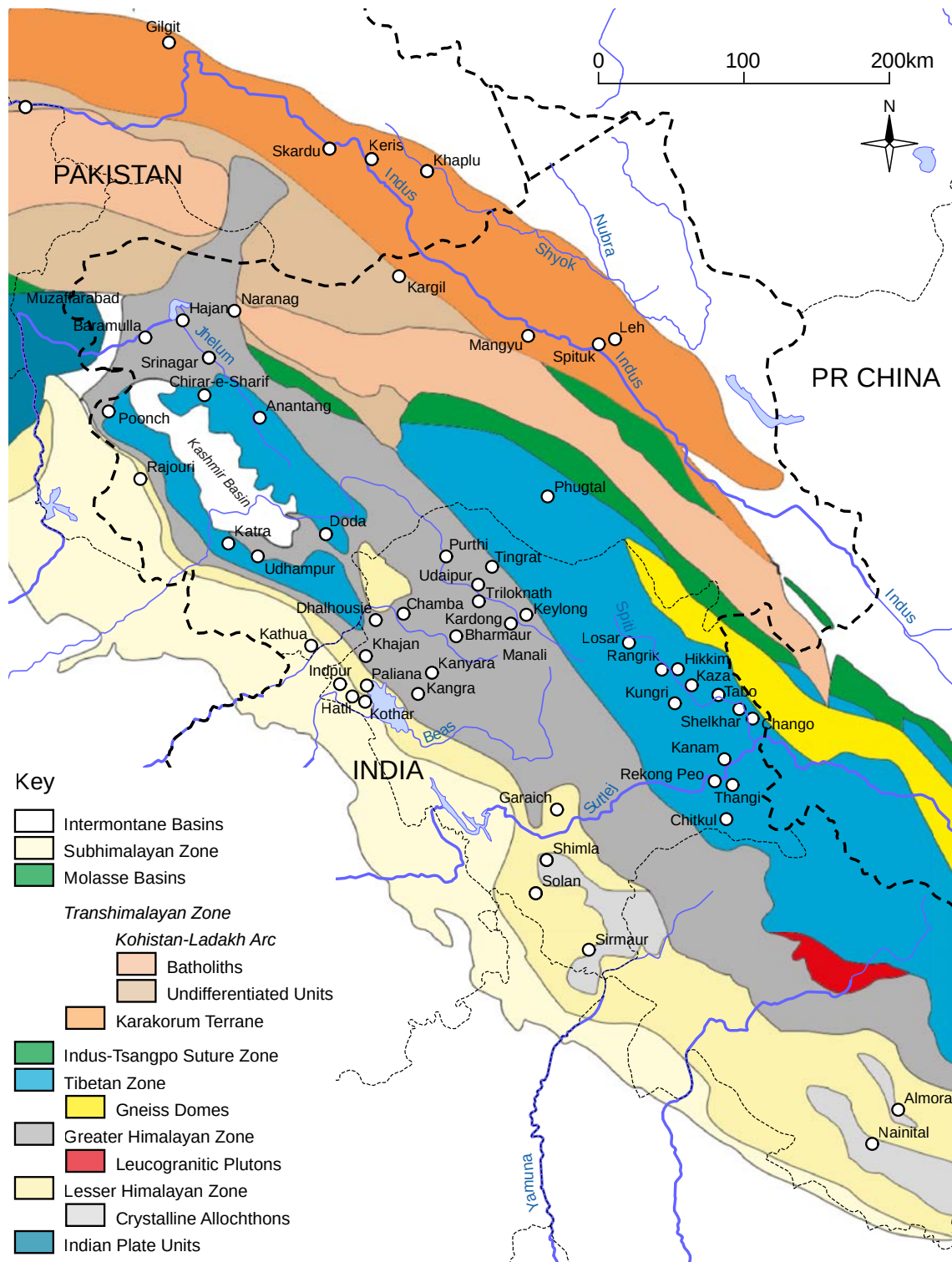
Further west in the province of Khyber Pakhtunkhwa, we also find low precipitation over the course of the year. In Sazīn (alt. 1,000 m), which is app. 470 m below the altitude of Gilgit, maximum temperature is similar, but low temperatures are in comparison higher and not below 0°C. Annual precipitation is about three times as high. At Kalam (alt. 2,000 m), which is app. 250 m lower than Skardu, we find a similar relation with minimum temperature ranging above 0°C. In Kalam, the climate is moderate, but warm. Precipitation is observed throughout the year, with even the driest month experiencing high precipitation. (CD)

3.5.4 Central and West Tibet

In comparison with Tibetan climate conditions, Lhasa (alt. 3,660 m) has an annual precipitation of app. four times of Leh or Phyang. Maximum temperatures are about similar to those of Leh, but minimum temperatures are higher than those of Ladakh. The difference between minimum and maximum temperature is app. 18°C, which is lower than the data given for Ladakh. Purang (alt. 3,890 m) in West Tibet has higher precipitation and lower temperatures compared to Lhasa. The climate in Purang is moderate and cold. The amount of precipitation in winter is higher compared to summer. (CD)

3.6 Raw material for building purpose

Raw material resources strongly relate to climatic conditions and altitudes. For vernacular architecture in general, nearby materials with a short distance of transport – if necessary with animals – are chosen. The choice of building materials and of appropriate methods of processing depend on social status, which is expressed by increased effort and by increasing the final building quality. The following data on wood, earth and stone are summarised for the research area to provide possible interrelations between climate and material resources, and the development of building techniques.



Map 4.4 Tectonic map of the core region.

GIS data based map by: Jakob Gredler. Final graphics: author. Map based on Vector data (VD) and Tectonic map (TM) adapted from Hodges 2000: 239. Citations of VD and TM also see: Chapter IX, list of illustrations.

According to Gansser (1964), the Himalayas can be divided into the following geological belts: Transhimalaya, Higher Himalaya, Lower Himalaya and Siwalik Himalaya. Following a categorisation after Negi (1998: 106), we can reduce this division into three belts, correlating with a biophysical graduation between these belts (Handa 2008b: 130). Map 4.4 is based on a tectonic map published by Hodges (2000: 329). The Geological Survey of India published the following categorisation (2012b: 2, 3).

Shiwalik or Sub- or Outer Himalaya: 600 m to 1,200 m; “structural and denudational hills separated by sub-latitudinal flat bottomed valleys” (cf. GSI 2012b).

- Lower or Lesser Himalaya: also “structural and denudational hills”, but higher elevations from 3,500 m to 5,000 m (ibid. 2).
- Greater or Higher or Main Himalaya: heights exceeding 6,000 m; rising steeper than the Lesser Himalaya; located above snowline except for deep ravines (cf. GSI 2012b: 2).
- Trans- or Tibetan or Tethyan Himalaya: Zangskar and Karakorum Range; Ladakh Range between Indus and Shyok Rivers up to 6,529 m; Indus Valley as erosional and depositional terraces, flood plains, palaeolake and aeolian surfaces located between Ladakh and Zangskar with a valley floor between 3,195 m and 3,395 m at Upshi and the Shyok Valley between Ladakh and Karakorum (cf. GSI 2012b: 2, 3).

3.6.1 Methods of processing raw material for vernacular structures

Today, in remote Himalayan areas, logs are still sawn by hand with a bucksaw (Ger. *Rahmensäge*). This tool needs two workers who alternately pulling the saw. One method in Ladakh involves the log being stabilised in a vertical, slightly inclining position while (as shown in the picture) the two workers – husband and wife – sit opposite each other (Fig. 4.22). Another method is the use of a two-men crosscut saw as found in Tawang in Arunachal Pradesh, where the log is kept in a horizontal position and two male workers stand above each other (Fig. 4.23). In both cases, the log is cut at the same time into several boards in a longitudinal direction. An early method of processing the surface of a board, e.g. for historical ceiling boards in Nako in Upper Kinnaur, involved use of an adze. The planks and beams are straight and cut very precisely,¹³⁴ requiring a high processing effort. Thus cutting is done only to meet real needs. In ‘simple’ building structures beams can be found uncut and in some cases even unpeeled (cf. Feiglstorfer 2012a).

Figures opposite page:

Fig. 4.22 (Top, left) Kaza. Ladakh. Buck saw.

Fig. 4.23 (Top, right) Tawang. Arunachal Pradesh. Two-men crosscut saw used in a vertical position.

Fig. 4.24 (Centre, left) Nyarma. Ladakh. Mould for producing sun-dried adobe bricks.

Fig. 4.25 (Centre, right) Sangnam. Spiti Valley. Wooden shuttering for rammed earth walls made on top of a stone basement.

Fig. 4.26 (Bottom, left) Central Tibet. Close to the Chekha Monastery. Villages along the river show a dominance of rounded river stones, which are used for house constructions.

Fig. 4.27 (Bottom, right) Gondhla. Lahaul. Stone carver using hammer and chisel.

¹³⁴ The early history of the use of a handsaw made of bronze in East Asia goes back to the Zhou Dynasty (1122/1045–770 BCE), while the use of a bucksaw started in the Song Dynasty (960–1279 CE) (cf. Li Zhen 2004).



Adobe bricks are usually processed in bottomless moulds (just with four sides) (Fig. 4.24). Sieving is conducted with metal sieves. A traditional method is the use of sieves made of fibres or the use of textiles to gain fine engobe for slurries used for upper layers of wall surfaces. The method of desludging may have also been used (Feiglstorfer 2019: 48ff.). For rammed earth walls, shuttering made of boards or wattled willow mats are commonly used (Fig. 4.25). Mortar is applied by hand. Fired bricks are of negligible importance in the research area except for Srinagar, where a particular small brick size, the so-called “*maharaji*” brick, was produced. In the Srinagar District, plentiful wood resources allow for the firing of kilns.

Boulders are either collected when loose – e.g. as rounded river stones (Fig. 4.26), which are from a static point of view less appropriate than quarried angular-shaped stones – or they are quarried with simple tools, such as a pickaxe, iron hammer, wedge or crowbar (Atkinson 2002: 267). For a random stone wall, the effort to dress the stones is less than in the case of ashlars (square hewn blocks), which are often used as corner stones or for lined stone walls (Fig. 4.27). Different qualities of processing can be distinguished, e.g. a simple dressing as widely used in Lahaul or more sophisticated methods for processing of rectangular hewn blocks. An example of the latter is the Bhīmā Kālī Temple in Sarahan in Himachal Pradesh. The kind of stone plays an essential role in the effort and labour costs. We may differentiate between random stone walls and banded masonry, with or without the use of mortar. The term “banded masonry” follows Howard’s description (Howard 1989: 218) with a first layer of large stones followed by a second layer for filling the gaps and for levelling of the next layer of large stones. Alexander (2011: 35) calls this texture a “galleted rubble texture”.

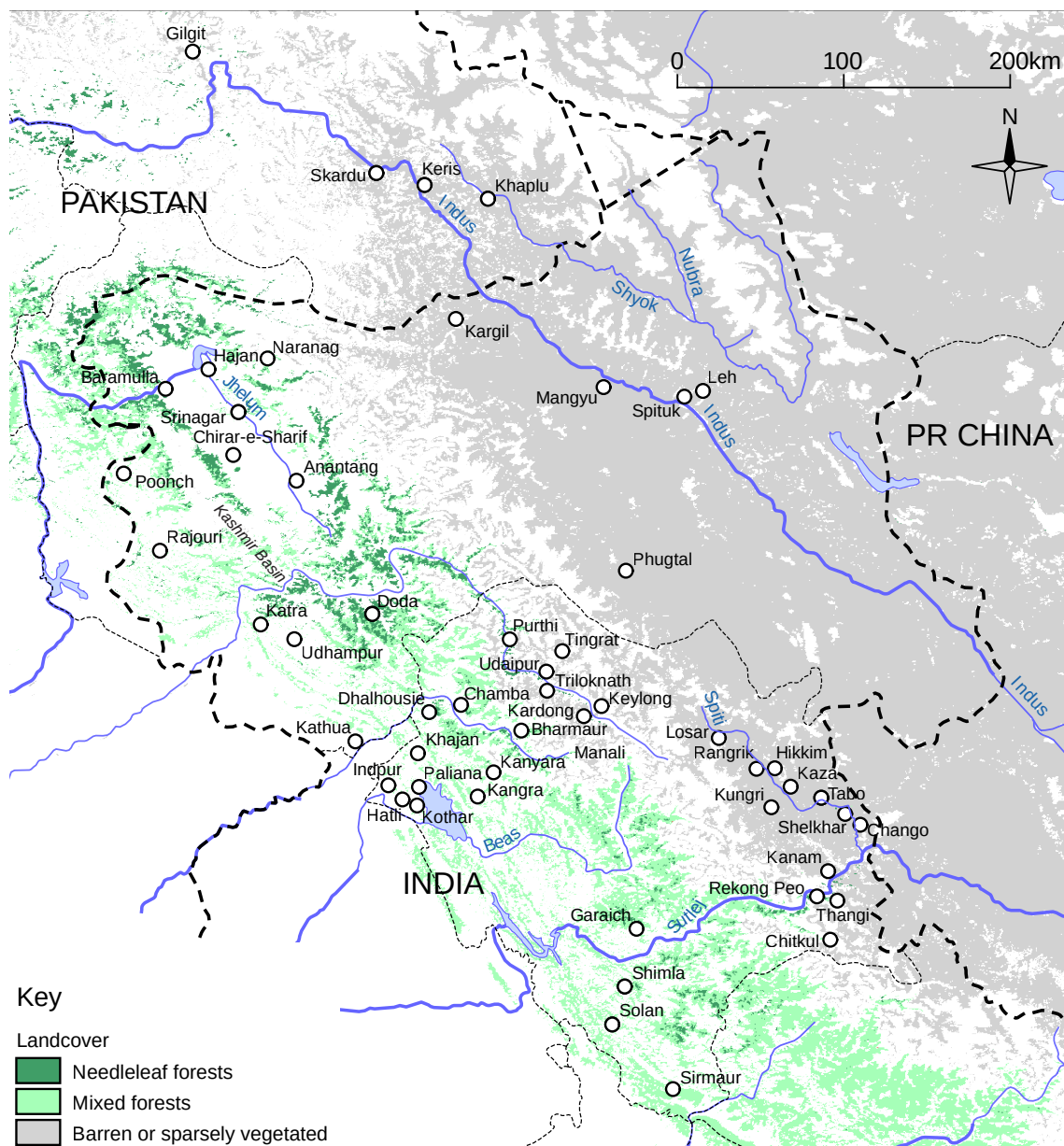
3.6.2 Timber

Regions like Chamba, Kashmir or Kinnaur are well known for a long tradition in wood carving and carpentry. The availability of appropriate timber is an essential precondition. One parameter for the availability of wood is the tree line. In arid zones, trees are primarily available in river valleys as groups. All the highest records for treelines in High Asia above 4,850 m consist of *Juniperus* species (Farjon 2005: 170). Found even at 4,900 metres in south-eastern Tibet, the highest tree species known in the Himalayas in general is *Juniperus tibetica* (Miehe et al. 2007: 169). In the following, the most common types of trees used for structural timber in the Western Himalayas are matched with altitude related climate features (Map 4.5). Given in italics are the local names of trees as collected in the field and adjusted with literature. The local terms may vary between different places. For a comprehensive summary of further local terms, compare Gamble (1984).

3.6.2.a Jammu and Kashmir

Ladakh

- In higher altitudes with less precipitation than we can find in Ladakh, Lahaul, Spiti, or Upper Kinnaur, i.e. all areas at an altitude of app. 3,100 m and above, willow, poplar, *takpa* (*Betula utilis*; Hindi *bhujpatra*; “white Himalayan birch”) and *shukpa* (*Juniperus macropoda* or *Juniperus excelsa*; in Himachal Pradesh known as *lewar* or *shur*, Handa 2006: 42; “Himalayan pencil cedar”) are commonly used for construction. Throughout the Himalayas, *takpa* is known for its bark, which is used for flat roof insulation between the wooden subconstruction and the



Map 4.5 Forest landcover.

GIS data based map: Jakob Gredler. Final graphics: author. Map based on Vector data (VD) and MODIS Land Cover (LC) according to Friedl, Sulla-Menashe (2015). Citations of VD and LC also see: Chapter IX, list of illustrations.

earth layer on top (cf. Feiglstorfer 2019: 145ff.). Due to its elasticity, its branches are also known for their use for bridges made of twigs. *Takpa* rarely grows below 3,050 m (Gamble 1984: 668). Birch forests are found at altitudes between 200 m and 2,000 m, a precondition, which is not dependent on monsoon rains, but on the amount of water occurring during the snowmelt (Holzner, Kriechbaum 1998: 63). According to Negi (1998: 193), it is associated with the category of sub-alpine forest.

- *Shukpa* is known as a hard wood used for carving, and it is preferably used for religious structures. Its needles are collected and used as incense. Since forest decimation in the past has greatly impacted this wood, cutting is currently prohibited, and in some areas such as in Lahaul, even the collecting of its needles is not allowed. According to Negi (1998: 193, 212), *shukpa* is found in the dry zone of the Higher Himalaya and the Transhimalaya between 2,700 m and 4,300 m. It is reported to have a height of up to 21 m and a girth of up to 6 m (Gamble 1984: 699).
- For 'simple' vernacular structures, poplar with its long and straight growth is commonly used. *Yarpa* (*Populus balsamifera*) and *makkal* (*Populus nigra*; according to Handa 2006: 42 locally also known as *yarpa*) are mentioned as common at high altitudes. Gamble (1984: 691, 692) describes the *yarpa* as available between 2,450 m and 4,250 m in arid zones of the Himalayas. He describes the *makkal* as present only in a cultivated form and with growth at altitudes up to 3,800 m. As a further species of poplar, Gamble mentions *hodung* (*Populus euphratica*). This species is found at high altitudes up to 4,100 m, like in Ladakh (ibid. 691). It is common in Nubra along the Shyok River, and grows in pure sand (Brandis, Stewart 1874: 474, 475). The *safedar* (*Populus alba*) grows wild and is cultivated at an altitude between 1,200 m and 3,650 m with a height up to 12 m and a girth up to 2 m (ibid. 473). Willow is commonly used for wattled objects. Handa (2006: 42) also mentions the *Salix alba* ("white willow", see Gamble 1984: 687), locally known in Himachal Pradesh as *chung*. Besides the above mentioned locally available species of wood, for elite building constructions *devdar* is brought from lower elevated regions in Kashmir or Himachal Pradesh.

Kashmir

- Kashmir is a centre for wooden architecture and arts. In Kashmir along the rivers Vitasta and Jhelum, pine forests are predominant (Kachru, Thapalyal 1990: 103). *Kail* (*Pinus wallichiana* or *Pinus excelsa*; "blue pine") is commonly used for constructions in Kashmir and Punjab (Gamble 1984: 704). For its use for planking, doors, windows or furniture, it is said to be superior to the deodar, since *kail* is not brittle, contains no oil and is free of scent (ibid. 705). Deodar is strongly present in Kashmir (ibid. 710). Throughout the Himalayas, it was commonly used for religious buildings. In Kashmir, besides various other examples, it was used for the Nund Rishi Mosque in Chirar-e-Sharif (Kachru, Thapalyal 1990: 109). In western regions such as Jammu and Kashmir and Himachal Pradesh, deodar grows within a wide altitude range between app. 1,370 and 3,350 m (Handa 2008b: 136). In the area of Jammu and an adjoining part of western Himachal Pradesh, there are sub-tropical semi-desert forests, inter alia, containing *shisham* (*Dalbergia sissoo*) (Negi 1988: 191). At lower altitudes, insects endanger wooden building structures. In the lower areas of the Jammu-Kangra region, for example, termites are a problem (Handa 2008b: 164).

3.6.2.b Himachal Pradesh

Lahaul and Kullu

- Lahaul differs from the southern district of Kullu due to a smaller variety of species of trees. *Shukpa* can be found here (Sudershan Vashishtha 2003: 186) and was in former times used for processing house beams (Gamble 1984: 699). Small groves of *takpa* are common.
- The *devdar* (*Cedrus deodara*, “deodar”) is one of the main timbers for construction in Lahaul and Kullu and, according to Gamble (1984: 710), the most important and valuable timber in the whole of North India. It grows, e.g. at higher altitudes along the Chandra, Bhaga, Ravi, Beas, Sutlej, Yamuna and Ganges Valleys (Handa 2008b: 136). According to Negi (1998: 203, 211), in the Western Himalayas deodar is associated with the categories of Himalayan moist deodar forest between 1,700 m and 2,500 m and the dry deodar forest between 2,000 m and 3,200 m. During British rule, *deodar* was an important good for export from Kullu (Minhas 1998: 131). It grows with a height of up to 45 m and a girth from 2 m to 13 m (Gamble 1984: 712). The deodar can be found in Jammu and Kashmir via Uttarakhand to Nepal (Handa 2008b: 130).
- In Lahaul, two species of poplar are predominant: *yarpa* and *makkal*. *Yarpa* grows high and straight. The *makkal* is often cut, making it look smaller and broader (correspondence with Tsering Dorje 2005). In lower regions towards Kullu *kail*, walnut and spruce fir can be found. Walnut trees grow, e.g. in the area of Gondhla (Postel et al. 1985: 291), located about 7 km south of Keylong.
- The *kail* is associated with the categories of the Himalayan moist temperate forest, which is found between 1,500 m and 3,300 m. The Himalayan dry temperate forest and *kail* forests can be found in the moist temperate zone above 2,100 m and 2,500 m (Negi 1998: 192, 193), inter alia, in Kashmir, Punjab, Chamba, Dalhousie, Shimla and Kinnaur (cf. Negi 1998: 209). The *kail* is superior to the *chir* (both belonging to the family of the *Pinus*) and reaches a height of up to 45 m and a girth of up to 3.5 m (Gamble 1984: 704, 705).

Spiti

- For Spiti, Verma (1997: 9, 10) mentions northern slopes as the location of *takpa* growth, and moist irrigated locations for willow and poplar. In the temple of Lalung in Spiti (12th century CE; Luczanits 2004: 106), primarily two different types of wood were used, i.e. *devdar* and *shukpa*. *Devdar* was used for the ground floor and contains the earliest structure from the 12th century. For this prestigious structure, this points towards an import of deodar wood from lower areas of Himachal Pradesh. Today, the nearest place for Spiti to collect deodar is Mandi (150 km) or Rampur (100 km) (correspondence with Dechen Lundup in 2015). *Shukpa* was used in the temple of Lalung for the upper floor. This floor was added in the 20th century and is most likely of local origin. The use of different kinds of wood within one building is found not only in Spiti, but is in general rather common in the region.

Kinnaur

- In Kinnaur, *shukpa* was commonly used for religious structures (Gamble 1984: 699). Species of poplar (e.g. *safedar*) and willow (e.g. *malchang*, *Salix daphnoides*; in arid zones of the Himalayas growing up to 4,500 m) are found here (Royle 1979: 344). In Lahaul, willow is rarely used as wood for construction, but is utilised more commonly in Kinnaur, Spiti, Zangskar and Ladakh (Interview with Tsering Dorje in 2005).

- According to local information, *devdar* is the wood used in the temples of Nako (in Kinnaur also known as *kelmang*; Handa 2006: 24). Deodar forests are still widespread in Kinnaur, where wood, also known as *kelo* or *diar*, from these forests is the main timber for construction (Dave 2013: 13). It grows, for example, in the Sutlej Valley. Deodar is considered sacred (cf. Handa 2006, Belz 2012: 64) as expressed by its name *devdar* (on the terminology of *devdar* see part 2 of Chapter IV).
- Another wood used for construction in Kinnaur is *kail* (Gamble 1984: 705). Today, for constructions in Nako, the primarily used wood comes from the *kail* tree (Tib. *gsom shing*) from the Ropa Valley and Rekong Peo, the latter of which is at a lower altitude in Kinnaur and further south from Nako. Together with the *devdar*, the *kail* is the most commonly used tree for building construction (Dave 2013: 69). Deodar is a very durable wood and used for various purposes in architecture. Due to the release of oil, it is not suitable for polishing and painting (ibid. 69).
- *Spun* or *tosh* (*Abies pindrow*, “silver fir”) is used for making wooden shingles and grows at altitudes of up to 3,000 m with a height of up to 42 m and a diameter of up to 76 cm (Gamble 1984: 719, 720). The *thelu* (*Juniperus communis*), which grows between 2,750 m and 3,350 m, is found in Kinnaur (Gamble 1984: 697, 698). In Kinnaur, *chīr* (*Pinus roxburghii*) is available up to app. 2,000 m (Negi 1998: 252; Interview with Tsering Dorje in 2005). Besides its use for structural purposes, it is known for the extraction of resin. It is resinous and highly inflammable, thus it is not popularly used as structural timber (Handa 2008b: 132). Brandis and Stewart (1874: 506, 507) mention extensive use of *chīr* wood in the hills for buildings and add that in Kumaon, roof timbering takes a period of two generations.
- Oak is known as a good firing wood (Belz 2012: 64), in addition to its use for structural purpose. Oak trees are associated with the category of temperate forests (Negi 1998: 192–203). In Kinnaur, the *bān* (*Quercus leucotricophora* or *Quercus incana*, “oak”) appears between 900 m and 2,400 m. It is known as hard wood, but “liable to warp and decompose on exposure to wet.” During the British rule in India, the British used oak beams and rafters in their residences. (Indus Publishing (ed.), *Gazetteer of the Kangra District* 1994: 28). Another species of oak is the *mohru* (*Quercus dilatata*), which grows between 1,800 m and 2,700 m. Contrary to the *bān* tree, it prefers moist forests (Gamble 1984: 673). Other trees used for building purposes are the *akhrot* (*Juglans regia*; “walnut”), which grows between 900 m and 3,000 m (ibid. 663), and the *parong* (*Acer oblongum*, “Himalayan maple”), which grows between 600 m and 1,800 m (ibid. 199).

Chamba

- In the Chamba District settlements of Chhatrari, Bharmaur, Tisa, and Chamba Town, the presence of highly experienced carpenters (Hindi *badhai*) is widely known (Bharti 2001: 177). In Chamba District, close to Kangra District, one of the main tree species is *chīr* (*Pinus roxburghii*). The area close to Dalhousie is associated with the *bān* tree, and the main species used for structural timber are *kail* and *deodar*. According to Bharti (2001: 185, 186), deodar is the main timber for construction in Chamba (ibid. 177). In the Ravi Valley, for example, pine trees are common, also towards Udaipur and Triloknath (Postel et al. 1985: 291).

Kangra

- In the *Gazetteer of the Kangra District* (1994), a relation between species and altitude is mentioned. Trees grow predominantly along the northern slopes of hill ranges (ibid. 26). Most

common is the *chīr*, which grows under different climate conditions at altitudes between 500 m and 2,100 m. Its wood is hard. It grows straight and reaches a height of up to 10 m with planks that have a width of up to 60 cm. Above Dharamsala, we find the *rai* (*Picea smithiana*, “Himalayan spruce”). Here altitude reaches between 2,400 m and 3,200 m. Wood from this altitude is mentioned as inferior to the wood of the *chīr*; and is used only for the construction of shingles. (ibid. 27) Lower regions of Kangra are much richer in wood, e.g. in *toon* (Gamble 1984: 157).

- Montane sub-tropical forests are situated between 500 m and 1,500 m with hot summers of up to 40°C (Negi 1988: 191). Negi describes the *sāl* (*Shorea robusta*) as dominant in the Shiwalik and Himalayan foothills. It grows to a length of 35 m or even higher (ibid. 194). It is one of the most commonly used types of wood in Northern India. For example, it is employed as piles, beams, planks or bridge rails. Its height reaches app. 45 m and its girth is app. 2.4 m. (Gamble 1984: 78) Its quality as structural timber is below the deodar, but due to availability and affordability, it is often preferred to deodar (Handa 2008b: 132).
- The *shisham* is preferably used for carpentry. It is spread throughout the whole district, and was reserved for the British during their reign. It is also known as durable, and used for construction, furniture, carvings and boats (Gamble 1984: 247). Its height is reported to be up to 18 m and its girth is up to 3 m (ibid. 248).

Uttarakhand

- In areas west of the Yamuna in Himachal Pradesh and in parts of Uttarakhand, the *toon* (*Toona ciliata* or *Cedrela toona*; “red cedar”) is commonly used, e.g. as beams. In addition to *deodar* and *chīr*, it is also used for making planks (Handa 2008b: 148). *Toon* is durable and grows up to 1,200 m. It is also used for furniture, door panels and carvings (Gamble 1984: 157).

3.6.2.c North Pakistan

Gilgit-Baltistan and Kyber Pakhtunkhwa

- In a description given by Hunzai and Beg (2005: 54), elaborate decorative timber work is mentioned for Baltistan, using local walnut, mulberry, juniper, cedar, apricot and poplar wood. For Kyber Pakhtunkhwa (the former North Western Frontier), Schacher (1998: 3) mentions cedar (*deodar* in Urdu and Pashto), blue pine (*pavich* in Urdu; *biar* in Pashto) and Himalayan poplar in northern areas as the types of wood used for beams. In the Karakorum region, pine, walnut, mulberry and apricot are commonly used for structural elements. In Hunza and Baltistan, juniper is in high demand for beams in the *cator* and *cribbage* construction (Hughes 2007: 109).

3.6.3 Stone

According to Map 4.4 showing the tectonic structure of the Western Himalayas within the core region of this study, an allocation primarily to four different tectonic zones becomes evident. North Pakistan and Ladakh in the area between Leh and Gilgit are located in the Karakorum Terrane, which belongs to the Transhimalayan zone. The area from Zangskar via eastern Lahaul and Spiti to Kinnaur belongs to the Tibetan zone, while the area of western Himachal Pradesh (Chamba and Kangra) belongs to the Greater Himalaya. The area between Srinagar and Udhampur belongs to the Kashmir Basin, which is surrounded by the Tibetan zone.

- In many parts of the Western Himalayas, a proper stone building material is available (Atkinson 1993: 296). Among these are granite, gneiss, volcanic rock, sandstone, limestone, dolomite,

shale, schist, slate, siltstone, quartzite and various conglomerates. The quality for building purposes between the stones varies, and in certain cases stones must be transported over long distances to ensure a certain quality. Transport to remote places is still conducted by pack animals. Today, stone is free when it can be quarried from one's own land (Belz 2012: 159).

- According to Atkinson (1993: 207, 208), in the sub-Himalayan zone, sediments are predominant, while in the Lesser Himalaya, crystalline rocks (gneiss and granite) are prevalent, and in the Tibetan zone, highly fossiliferous sediments such as limestone are reported.
- Stones with a content of mica (such as gneiss) are preferred for building purposes, since these are easier to cut. From stone sculptures produced in North India, we know of the origin of the material that is of interest as building material. In the Gandhara period, mainly carbonaceous chloritoid phyllite and chlorite schist were used, while in the Gupta period metasiltstone was preferred and in the Gujara-Pratihara period chlorite-quartz-mica schist was commonly used (Satish 2003: 288). During all periods, sandstone (e.g. from Himachal Pradesh) was used and in a later phase also metasiltstone, limestone, or chlorite schist from Almora (ibid.). Sandstone in particular is widely available in the Central Himalayan region (Handa 2008b: 137).
- Stones for building purpose of different qualities are found all over Jammu and Kashmir, and Himachal Pradesh. Certain types of stones are known as predominant in various regions. In the following, an overview will be given of structural stones and related geology in Himachal Pradesh, and Jammu and Kashmir in order to determine further relations between locally available raw materials and local building techniques.

3.6.3.a Stones commonly used as building material

Slates

- Over the Western Himalayas, several deposits of slates are commonly known and used as building material. The use of schist as roof material is locally associated with a particular social status. In various regions with high precipitation, slates are predominantly used as roof covering and for paving. The use of slates as roofing material increases from the cold climate zone [B] towards the temperate climate zone [D] (for climate data see Map 4.3)
- In Jammu and Kashmir, slates used for roofing are quarried in the Chhonthash area in Leh District and in the districts Udampur-Rajouri-Poonch (GSI 2012b: 42).
- In Himachal Pradesh, slates of a high quality for building purpose originate from the Dhauladhar Range between Kangra and Chamba. Slate is also quarried in the Shimla region. It is of lesser quality to that found in the Chamba District. (Cunningham 2005: 229) Further slate belts in Himachal Pradesh exist in the Kangra District (GSI 2012a: 36–37; in Kangra near Kanyara, see Burrard, Hayden 1908: 265) and in the area to the south-east of Himachal Pradesh in Garhwal (GH 1993: 296). In Garhwal, high-quality slates are reported (ibid.).

Gypsum and limestone

- In Jammu and Kashmir, gypsum is available in the districts of Baramulla, Kargil and Doda.
- In Himachal Pradesh, gypsum is available at deposits in the districts of Kinnaur, Lahaul and Spiti, Sirmaur, and Solan. (GSI 2012a: 25ff.; GSI 2012b: 34ff.) In Spiti, gypsum is found in the Gyundi sub-valley and in an area near Losar (Verma 1997: 9).
- In Jammu and Kashmir, limestone is available in the districts of Anantnag, Baramulla, Srinagar, Kargil, Leh, Doda, Kathua, Udampur, Rajouri, and Poonch (GSI 2012a: 25ff.;

GSI 2012b: 34ff.). In Himachal Pradesh, limestone is available as deposits in the districts of Bilaspur, Chamba, Kangra, Kinnaur, Kullu, Mandi, Shimla, Sirmaur and Solan (ibid.). Also for Garhwal, gypsum deposits and the manufacturing of limestone are reported (GH 1993: 294, 295; Verma 1997: 8).

3.6.3.b Stones following a geographical order

Jammu and Kashmir

- In the Jammu-Kangra region, many of the buildings are made of sandstone (Handa 2008b: 126), which is a commonly used building stone in the Shiwalik Himalaya in Jammu and Kashmir. However, in the Lesser Himalaya, limestone, slates, shales and schists can be found (Negi 1998: 105–111). As building material in Jammu and Kashmir, inter alia, granite is used in the Panjal Trap, sandstone is common in the Murrees, marble is used in the region of Jammu, and limestone is prevalent in the Kashmir Valley (GSI 2012b: 29). From Kashmir towards Kaghan Valley in North Pakistan, gneiss is reported, though this resource is extinct at the Zoji La. From here to Tibet, limestone and schists are prevalent. (GH 1993: 151) In the Transhimalayan Zangskar crystalline formation gneiss and granite can be found (Negi 1998: 112). In Ladakh – which is part of the Transhimalayan zone, separating it from Jammu and Kashmir (GSI 2012b: 1) – a large variety of stones exists, inter alia, granite (e.g. along the southern slope of the Karakorum), gneiss, schist, shale, limestone (marble in Kupwara and Leh District; GSI 2012b: 40), volcanic stones (e.g. in the areas of Shyok or Dras), conglomerates, and fine sediments (e.g. in the Indus Flysch zone; cf. Negi 1998). According to the Geological Survey of India, local building materials in Ladakh include, inter alia, volcanic stones, limestone and granite (GSI 2012b: 29). Deposits of *arga* stone (highly carbonatic) are known in Mangyu and Phugtal (cf. Feiglstorfer 2016, 2019).

Himachal Pradesh

- Geology in Spiti (part of the Transhimalayan zone) is similar to the geology of north-eastern Kullu, but differs from the rest of Kullu. It contains marine deposits, shale, limestone, Giumal sandstone (Sudershan Vashishtha 2003: 255, 257), and conglomerates (Atkinson 1993: 207, 208). Most of Lahaul is made up of metamorphic and crystalline rocks. Just a small part close to the crossing of the Bhaga and Chandra Rivers consists of volcanic rocks. (Sudershan Vashishtha 2003: 185) In Kullu, crystalline stones (granite, gneiss, schist) and unfossiliferous rocks are available. Further south, unfossiliferous sedimentary rocks stretch from Chamba via Kangra and Shimla Hills to Garhwal. These consist of limestones, slates, quartzites and conglomerates. (ibid. 9) For Garhwal, close to Almora, fine-grained quartzites and mica schist are present, and at Nainital limestone and clay schist are reported as well as gneiss, sandstone and chlorite-schist (GH 1993: 296). For Kinnaur, Handa (2008b: 137) mentions the availability of high-quality structural sandstone. In the Sangla Valley, slates, quartz schists, phyllite, garnetiferous schists, quartzite and lenticular limestone are reported (Devi et al. 2014: 740).

North Pakistan

- In North Pakistan, the use of granodiorites and gneiss is common, along with slate, marble or basalt (Hughes 2007: 108). Atkinson (1993: 207, 208) mentions a preferred use of limestone for Chitral and Afghanistan.

West and Central Tibet

- In West Tibet, Atkinson (1993: 207, 208) reports limestone in Ngari and volcanic stone in the area of Lake Manasarowar. Deposits of *arga* stone (see Chapter II) are known in the Purang region. In Central Tibet, granite, slate, schist and quartz stones are commonly used for construction (Alexander 2011: 35). From Central Tibet to the source of the rivers Indus and Sutlej, granite, schist, mica-schist, gneiss and beds of highly crystalline limestone are stated (GH 1993: 152). Deposits of *arga* (highly carbonatic) are known in the region of Leh and the surrounding area (Feiglstorfer 2019: 139ff.).

3.6.4 Clay

In Himachal Pradesh, and Jammu and Kashmir, clay is traditionally used for a variety of construction and crafts purposes. Places related to clay examination within this study are given in Map 4.6. Table 4.1 and Table 4.2 contain clay samples, which are mentioned in the text. The samples with a sample number were examined at the IAG / BOKU. Data on grain size distribution and bulk and clay mineral analysis are given in Table 4.4, Table 4.5 and Table 4.6 in the Appendix of Chapter IV. Various types of clay for different use were examined by the author:

Walls:	rammed earth walls wattle and daub walls bricks (primarily adobe; rarely fired) clay mortar and clay plaster
Roofs / floors:	flat and rarely pitched earth roofs rammed earth floors
Other use:	clay stoves clay sculptures pottery ware painting

In order to change the binding behaviour of clay, different additives are traditionally known in the Himalayas (*ibid.*). These include anorganic additives, e.g. lime or sand, and organic additives, e.g. fibres, needles from trees, straw, pieces of twigs, salt, gum, rice starch, or the juice of apricots. In Ladakh, Chamba and Kinnaur, apricots are locally known as *chulli*. The *chulli* (*Prunus armeniaca*) grows at altitudes between app. 1,200 m and 3,000 m (cf. Kureel et al. 2007: 2). In general, clay is processed in a moistened state and has to dry after being processed. Usually local clay that has been sourced nearby is used. Only for a particular purpose, e.g. clays for waterproofing of a roof, does transport over longer distances occur. Whether clay is used at all for building purposes generally depends on environmental conditions such as local availability, the quality of the raw material, and climate conditions, e.g. the amount and strength of precipitation.

Clay of different qualities for building purposes is found all over Jammu and Kashmir, and Himachal Pradesh. Certain types of clays are known by local terms, and these terms may point towards their place of origin, or specific properties and purpose. In the following, an overview is given of clay deposits in Himachal Pradesh, and Jammu and Kashmir so as to find further relations to other locally available raw materials and building techniques. Samples of clay were collected in Himachal Pradesh, and Jammu and Kashmir. Results of these examinations – conducted at the IAG / BOKU – are presented below.¹³⁵

135 See Appendix of Chapter IV for grain size classes and results of bulk and clay mineral analysis.



Map 4.6 The map shows sampling points of clay samples and settlements related to part 3.6.3 (“Stone”) and part 3.6.4 (“Clay”) of Chapter IV.

GIS data based map: Jakob Gredler. Final graphics: author. Map based on Vector data (VD). Citations of VD also see: Chapter IX, list of illustrations.

Table 4.1 List of clay samples

Sample no.	Place	State	Origin	Use	Local name
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Chamba

8506	Purthi	HP	clay pit	roof, plaster	<i>sho</i>
8510	Purthi	HP	clay pit	field clay	<i>kit-jan</i>
8528	Purthi	HP	clay pit	whitewash	
	Purthi	HP	clay pit	whitewash	<i>makol</i>
	Purthi	HP	clay pit	whitewash	<i>golu</i>
	Purthi	HP	clay pit		<i>kosti (also losti)</i>

Kinnaur

8467	Ribba	HP	clay pit	roof, plaster	
8493	Ribba	HP	clay pit	painting	
8492	Chulling	HP	old house	interior plaster	
8511	Thangi	HP	clay pit	roof, plaster	<i>cham</i>
8518	Thangi	HP	stable	roof	
8529	Thangi	HP	entrance gate	plaster	
8513	Moorang	HP	clay pit	exterior plaster	<i>chit</i>
		HP	clay pit	roof	<i>kum-mating</i>
	Shelkhar	HP	clay pit	roof, plaster	<i>tua</i>

Spiti

6041	Tabo	HP	old house	interior plaster	
6053	Tabo	HP	old house	brick	
	Tabo	HP	clay pit	brick, rammed earth, roof	<i>duksa</i>
	Tabo	HP	clay pit	rammed earth, roof, plaster	<i>shaksa</i>
	Tabo	HP	clay pit	painting	<i>tsak</i>
6048	Sangnam	HP	residential building	roof	
6049	Kungri	HP	old house	roof	
6050	Dhankhar	HP	old house	roof	
8507	Rangrik	HP	old house	exterior plaster	
8515	Rangrik	HP	old house	rammed earth	
8512	Lalung	HP	clay pit	mortar, plaster	
8527	Hikkim	HP	ruins of an old house	adobe brick	
8530	Hikkim	HP	ruins of an old house	interior plaster	

Table 4.2 List of clay samples

Sample no.	Place	State	Origin	Use	Local name
Lahaul					
8480	Keylong	HP	clay pit	building purpose	<i>sakalak</i>
6057	Keylong	HP	old house	brick	
8478	Tingrat	HP	clay pit	roof, plaster	<i>talba</i>
Kashmir					
11755	Srinagar	J&K	Jalali Haweli	interior plaster	
11916	Srinagar	J&K	Jalali Haweli	mortar, roof	
11757	Naranag	J&K	stable	flat roof, brick, plaster	
Ladakh					
	Spituk	J&K	clay pit	roof, plaster	<i>markalak</i>
	Basgo	J&K	clay pit	roof, plaster	<i>dzasa</i>
	Basgo	J&K	clay pit	roof, floor, brick, plaster	<i>thetsa</i>
	Likir, Ne	J&K	clay pit	stove	<i>thabsa</i>
North Pakistan					
	Hunza	Gilgit-B.	clay pit	roof, floor	<i>damul</i>
West Tibet					
	Khorchag	Ngari	clay pit	roof, plaster	<i>narkalak</i>

3.6.4.a Jammu and Kashmir

Kashmir

- In the Srinagar District in Karewas in Kashmir Valley, and also at Wuyan and near Hajan Har, deposits of clays, used for cement manufacturing, are reported (GSI 2012b: 29ff.). During field research, samples were collected at Srinagar (samples 11755 and 11916) and Naranag (sample 11757).
- Sample 11755 from Srinagar is an interior plaster (5cm)¹³⁶ from the Jalali Haweli and was given to the author by the owner. This plaster contains 62.8% silt, 34.9% clay and hardly any-coarser grains.
- Sample 11916 was also collected from the Jalali Haweli in Srinagar, but this clay is used for mortar and the flat roof covered by a gable roof. The grain size distribution of these two materials is rather similar. Since the technical standard of this building is high and may be counted as a residential elite structure, the materials used can be expected to follow a high technical standard. From the roof material we know that it was not sieved and that it is locally available with this fine consistency. Both samples show a content of smectite as swellable clay mineral.
- Sample 11757 from Naranag in Kashmir, which is located about 30 km north of Srinagar, originates from a flat roof of a stable used by nomads during summer. This clay is locally universally used, inter alia, for bricks and plaster. It is coarser than the afore-mentioned material used at the Jalali Haweli and contains no swellable clay minerals. All samples taken in Kashmir, similar to Spiti, show a content of calcite.
- In the Udhampur District, clay shale bands in rocks close to Katra-Reasi and Tikri have been identified. This clay is used for the manufacturing of Portland cement. In Jammu District in the Bameal-Dhun sector, clay for a refractory use is known, but due to a high content of Fe_2O_3 , it is unsuitable for the ceramic industry (GSI 2012b: 29ff.).

Ladakh

- In Ladakh, white bentonitic lacustrine clays at Lamayuru and Spituk are locally known as *markalak* (Feiglstorfer 2019: 199ff.). Further locally available types of clay, such as *dzasa* or *thetsa*, and their use for plaster, roofs, bricks, stoves or pottery are discussed in Chapter III. A geological profile was conducted when carrying out pollen analysis from a 23 m core dating from about 30,000 to 9,000 BCE at the Tso Kar in Rupshu in Changtang at about 4,572 m (cf. Bhattacharyya 1989: 28, 29). Seventeen different layers are reported within these 23 m, primarily showing sediments with a content of varying types of clay (ibid.).
- East of the Jammu-Kangra region, *chik* clay (red-ochre clay) is known for its structural qualities for building purposes (Handa 2008b: 169). In Uttarbaini in Jammu District, deposits of bentonite are reported (GSI 2012b: 28).

136 The interior plaster is applied in three layers all using the same red clay: The 1st layer is clay mixed with grass growing at the lake close to the building (known as *kalrun*); the 2nd layer is clay mixed with paddy straw; the 3rd layer is clay applied after drying of the 2nd layer and mixed with *kalrun*; finally finished with a trowel. The exterior plaster (app. 3 cm) is a clay mortar mixed with lime without grass. In side rooms the plaster is made with two layers: The 1st layer is app. 1 cm with mixed straw; the 2nd layer (very fine) is app. 1 cm mixed with paddy straw.

3.6.4.b Himachal Pradesh

Chamba

- In Chamba, a particular white clay is known as *makol* or *golu*, and a red clay is referred to as *losti* (Handa 2005: 61; Handa 2008b: 176). Handa (2008b: 169) reports the use of *makol* or *golu* (a white clay) for whitewashing. *Makol* or *golu* is mixed with salt and gum or *pitchh* (rice starch) after having been dissolved in water. For traditional paint, *geru* (Eng. *raddle*) is dissolved in water. Next, a coat of mustard oil is added to the exterior, or oil of the seeds of *chulli* or *sahare* (apricots) is applied to the interior (ibid.). Red-coloured clay is used for painting, similar to ochre. During field research the author collected clay samples in Chamba, inter alia, in Purthi.
- Sample 8506 from Purthi is a red clay, sample 8510 is a grey clay, and sample 8528 is a white clay, the latter of which is used for whitewashing. The red clay (sample 8506) was collected at a clay pit along the road. Its local designation is *sho* (spoken: *shau*). It is used as a roof layer with a thickness of app. 30 cm. For plaster it is mixed with cow dung and needles of the *kail* tree. It is applied with a thickness of app. 5 cm to 8 cm. The material contains 27.6% of gravel and sand and a rather high amount of silt with 51.9% and a median of 17 μm .
- Sample 8510 from Purthi is a grey clay that was also collected along the road. Its local designation is *kit-jan*. It is a material, which is also collected from the fields and rarely used as building material. This clay is much coarser than the *sho* clay, in particular due to a higher content of gravel.
- Sample 8513 from Purthi is a white clay also collected along the road. It is mixed with water and used for whitewashing on interior and exterior walls. This clay is even coarser than the *kit-jan* clay and has to be sieved before processing.
- In Purthi, having all locally known types of clay available along the road points towards short distances of transport and central availability of the material. The bulk mineral analysis of the Chamba samples shows, inter alia, mica, quartz and plagioclase. In general, these samples are rather poor in swellable clay minerals and show a high content of illite and partially also of chlorite. The content of kaolinite is present only as traces.

Middle Kinnaur

- In Middle Kinnaur at Kanam, a peach-coloured clay, known as *kum mating* or *kum pating*, is placed at roof constructions on the birch bark, preferably used for waterproofing of roofs (Negi Loktus 2015: 324). East of Lipa, also in Middle Kinnaur, deposits of kaolin clay are reported (GSI 2012a: 21ff.). Samples were collected at Ribba (samples 8467 and 8493), at Thangi (samples 8511, 8518 and 8529), at Moorang (sample 8513) and at Chulling (sample 8492).
- Sample 8467 from Ribba was taken from a clay pit in the village close to the Ribba Temple. It is locally known as a good building material used as plaster or for the roof. Its grain size distribution is similar to the *sho* clay from Purthi, which was also used as plaster and roof clay.
- Sample 8493 from Ribba was taken from a clay pit in the village close to the Ribba Temple. It is used for plaster and particularly for wall painting. For further building purpose, it is considered too weak. With a median of 5 μm , it is much finer than sample 8467 from Ribba.
- Sample 8511 from Thangi is a red clay collected from a local clay pit. Its local designation is *cham*. It is mixed with the needles of the *chilgoza* pine tree (*Pinus gerardiana*) or with chopped chaff and used as plaster. A better quality is obtained when mixed with cow dung.

- Sample 8518 from Thangi originates from the roof of an app. 80 years old collapsed stable. It was placed and compressed on top of the birch bark. The raw material was sieved up to app. 2 cm grain size, as explained by the owner of the stable.
- Sample 8529 from Thangi originates from the wall of the entrance gate to the village. The grain size distribution and also the clay mineral properties are very similar to sample 8518.
- Sample 8513 from Moorang is taken from a clay pit and has to be sieved before use. Its local designation is *chit*. It is locally described as clay with good quality for application of an upper plaster layer. It colours the wall white and thereafter there is no need for further whitewashing.

Upper Kinnaur

- In Upper Kinnaur, lacustrine clays are found at Shelkhar and Chango (GSI 2012a: 21ff.). The local designation is *tua*, and it is used for flat roofs and plaster (cf. Gruber 2011; cf. Feiglstorfer 2019: 139ff.). The fine *tua* clay from Shelkhar, which is used for plaster and roofs, is mixed with a dark, coarse clay to create a mixture locally described as “hard as concrete” and which is used for rammed earth walls. The *tua* clay alone is too fine for ramming. In the Spiti area, ramming is a widespread traditional building technique.
- In Chulling (Upper Kinnaur), sample 8492, which is a part of the interior plaster of an old village house, fits in the mineral range of clays from Kinnaur. At 44%, its grain size distribution has a rather high content of silt compared to a content of just 5.6% of clay.
- The bulk mineral analyses of the samples of Kinnaur show values similar to those from Chamba, inter alia, with a content of mica, quartz and plagioclase. Except for sample 8493, no swellable clay minerals could be found.

Spiti

- In Spiti, deposits of lacustrine clay at Kioto and Atargoo are reported (GSI 2012a: 21ff.). In Tabo and its surroundings, several other types of clay are known, e.g. *duksa*, *shaksa* or *tsak* (Dechen Lundup 2015).
- Earth floors are made of *shaksa*, which is covered with a liquid paste and then burnished. This liquid paste consists of *duksa* mixed with water and cow dung. Bricks are also made with *duksa* without mixing any further clay or additives. For a rammed earth wall, *shaksa* and *duksa* are mixed. For the roof, first a layer of *duksa* (also known as *shodam*) is covered with *shaksa* and then again covered with *duksa*, which is burnished with a mixture of *duksa* and cow dung. Plaster on rammed earth walls is made of sieved *shaksa* to create a sand-powder-like material, which is then mixed with straw. The *tsak* is reported as a clay used for painting. It is collected from Pin Valley or Lidang Village¹³⁷, the first being at a distance of 30 km from Tabo.
- During field research, samples were collected in Spiti and Lahaul (for these samples, see Appendix of Chapter IV). Sample 8515 is debris which originates from a damaged part of a wall of an old village house in Rangrik, which is located close to Kaza. It is an example of clay used for rammed earth. For a clay used for rammed earth, a median of 35 μm is rather fine and the content of clay relatively high. In fact, the content equals the grain size distribution of the exterior plaster (sample 8507). Thus we can suspect that a similar raw material was used for plastering and ramming.
- The clay used for adobe bricks at an old house at Tabo (see sample 6053, i.e. debris from the floor along the wall) has a rather coarse median of 260 μm . Compared to this adobe brick sample, the interior plaster used on this brick, as described with sample 6041, has a very small

¹³⁷ The village of Lidang has yet not been clearly localised and will be part of future research.

median of 3 μm . A comparison of their bulk and clay mineral properties shows strong similarities. Regarding the grain size distribution, the plaster may be the sieved portion of sample 6053.

- Sample 8512 from Lalung in Spiti was collected from a local clay pit and is locally described as universally used clay, used for plaster, mortar and ramming. For plaster, sieving thereof is necessary. The contents of clay and silt are similar to the clays used in Rangrik for ramming and plastering. Only the content of gravel is higher.
- Roof clays from Spiti originate from damaged parts of a ten-year-old residential building in Sangnam (sample 6048), of an old house in Kungri (sample 6049) and an old house in Dhankar (sample 6050). The grain size distribution of these three examples shows similarities, in particular, the sand, silt and gravel fractions. The content of gravel and sand is rather high. The content of clay ranges between 13.4% and 19.2%, and the medians range between 65 μm and 150 μm . These results point towards a similar base material used for the roofs between Sangnam and Dhankar. The content of silt is between 23.4% and 33.8%, and the content of clay is between 13.4% and 19.2%. These similarities point towards the use of locally available clay without mixing, since the content of gravel is still between 18.4% and 26.4%.
- Another comparison is made between samples 8527 (adobe brick) and 8530 (interior plaster) from the ruins of an old house in Hikkim in Spiti. At 30 μm , the median is the same and the content of clay and silt is rather similar. The difference is in the gravel and sand fractions. In the brick, with 19.5% a much higher content of gravel is available compared to 5.7% in the interior plaster, while in the interior plaster the content of sand is higher. According to the grain size distribution, the base material for bricks and plaster seems to be similar, but for the use as plaster it was sieved. The clay used for the bricks shows a rather similar grain size distribution compared to the clay used for rammed earth at Rangrik (sample 8515). The bulk mineral analysis is basically similar to those shown for Chamba and Kinnaur, but in contrast, calcite is a content of all samples in Spiti, which is missing in the samples of Chamba and Kinnaur.

Lahaul

- From Lahaul, sample 8480 is clay from a pit commonly used for building purpose. Its local designation is *sakalak*. With a content of 31.2% of gravel and 4.4% of clay, it is a rather coarse material.
- Sample 6057, which originates from a damaged adobe brick in a wall of an old house in Keylong, shows a different grain size distribution and seems to be a sieved *sakalak* clay, as emphasised by the similar bulk and clay mineral properties. The bulk mineral analysis with the higher content of plagioclase and a lower content of calcite shows more similarities to samples taken in Chamba or Kinnaur than those taken in Spiti.
- Sample 8478 from Tingrat was taken from a clay pit in the village. Its local designation is *talba*. Its grain size distribution is similar to sample 8467 from Ribba, and is also used as clay for plaster and roofs. This sample shows, in contrast to the other samples from this region, a 14Å vermiculite and a smaller content of illite.

Kangra

- In Kangra District, deposits of clay are reported: yellow-coloured clay west of Shahpur; light grey clay in the Middle and Upper Shiwaliks at Khajan, Indpur, Paliana, Kothar (a composition of montmorillonite, kaolin, quartz, carbonates, and Fe-oxides), and Hatli (GSI 2012a: 21ff.).

Kullu

- In Kullu District, kaolin clay near Bathua used for whitewashing is reported. In Mandi District, a variety of deposits, which are commonly used for plastering and whitewashing, is reported; clays from Garaich and Negi Nal are suitable for the manufacturing of stoneware. In Shimla District north of Shimla, clay is found and used for the manufacturing of bricks, tiles and pottery. In Sirmaur District, a variety of deposits of varied lacustrine clay is reported and commonly used for making bricks. Some clay pockets contain a kaolin clay and also clay that is sticky when wet and powdered when dry. (GSI 2012a: 21ff.)

*3.6.4.c North Pakistan**Hunza and Karakorum region*

- In Hunza in North Pakistan, a fine grained lacustrine clay, known as *damul*, is used for waterproofing of flat roofs and compacted floors (Hughes 2007: 109). Clay in the Karakorum region, used for adobe bricks, is characterised by a high content of silt, sand, quartz, biotite mica and a lack of clay minerals (ibid.).

3.7 Discussion

The orientation of the mountains from north-west to south-east influences the orientation of the climate zones. Arid, cold and temperate zones follow this pattern in elongated bands. A change from zone to zone correlates with a change of altitudes. This influences the vegetation zones and the availability of particular trees. In turn, these factors influence architectural developments, which are dependent on the orientation of these zones.

In the arid zone, precipitation is rather low, while in the cold zone we can distinguish between dry and humid regions. Further, in the temperate zone, precipitation also changes between dry and rather humid areas. This goes hand in hand with the development from the flat earth roof towards the pitched roof covered with wood or stone. This change also follows a north-east to south-west direction within the temperate zone and in the area, where the cold zone [D] changes into a temperate zone [C] (see Map 4.3). This goes hand in hand with the development of a high culture of wooden architecture in the north-west to south-east stretching zone from North Pakistan via Kashmir, Chamba, and Kinnaur into Uttarakhand. This zoning also describes the direction of the increase of structural timber in composite constructions from the north-east towards the south-east and may be mentioned as a prime reason for certain material changes within traditional buildings.

The above given association of trees with particular regions and altitudes shows a relation with a change of the tree population and of a local availability of species of trees. This becomes mainly the case in sparsely wooded higher altitudes. The given tree species are those, which are commonly used for constructions. For elite structures, wood is brought from outside a given region with a high effort of transport.

The historical use of various species of trees differs partially from present use. Primarily, hard wood, which grew straight and long, was used, while today poplar and willow have become predominant over mountainous regions from Baltistan over Ladakh, Lahaul and Upper Kinnaur. The high availability of structural timber may have supported its intense use, particularly in Kashmir

and Himachal Pradesh, where, from a historical point of view, use was supported by the agreement of the regional ruler.

Today, large forest areas still exist in Himachal Pradesh. Of a total area of 14,353 km² for Himachal Pradesh, 811 km² are covered by different species of deodar, 809 km² by *kail*, 1,436 km² by *chīr*, 1,343 km² by fir spruce, 183 km² by *sāl* and 540 km² by *bān* (GSI 2012a: 38). About one third of the whole area of Himachal Pradesh is covered with forest – mostly mixed forests and a small amount of needleleaf forests. This is contrary, e.g. to Ladakh, where in higher arid regions only groups of trees exist.

Most populated are valleys connected to a water supply and timber resources. Stones may be collected along riverbeds. A structurally good stone has to be quarried and is in general not rounded, as stones found in rivers would be. Structural stone is found all over the Western Himalayas in different qualities. In some areas of the Western Himalayan region and up to the Yamuna eastwards in Uttarakhand – areas with a strong population of deodar trees – a good structural stone is rare (Handa 2006: 26). In settlements, where material of particular good quality is quarried in the close vicinity, such as slates in Bharmaur, its popularity in vernacular use is obvious. At such places, thick and large pieces of slate can be found stapled by the villagers along the road or at building sites. The availability of slate in the area close to Leh did not change the vernacular flat roof tradition, since the timber resources for roof timbering to carry heavy slates are too scarce. For wall structures, e.g. for religious structures or fortress structures, inter alia, stones were used for solid walls.

The general content of mica, which we can refer to in the examined clay samples (see Appendix of Chapter IV), may support a favourite use of stone due to its easier cutting. The use of timber implicates, on the one hand, knowledge of movements within building structures and, on the other hand, a possible support of structures made of stone. It may also correlate with the need for a strengthening of the mica-laden stone in solid walls (Handa 2008b: 136). In lower regions, the increase of termites is an indicator for less use of wood and a preference for stone.

For commonly known clays, their location along routes of transport is evident and points towards an economical and collective use. A short distance of transport is in general an important condition for the use of particular clay. On the other hand, clays such as the *tsak*, which is used in Tabo in Spiti for painting, is collected at places, which are located a longer distance away, similar to limestone, which often has to be collected at mountainous sites.

Making of fired bricks depends much on the availability of proper clay, in addition to the availability of wood or peat for firing. According to reports by the Geological Survey of India (GSI 2012a,b), deposits of fireable clay for the ceramic industry are found in Jammu or in the Shimla District.

The samples from Spiti and Kashmir point towards a carbonatic mineral geology in these regions, which influences the properties of the clay. Also the low content of swellable clay minerals – except for lacustrine clays – in the clays over the Western Himalayas determines a technically possible range of application. Rather coarse material in Spiti containing calcite and no swellable minerals shows its proper use for rammed earth. An economic approach makes it necessary to use

the same base material for ramming, bricks and also for plaster. The availability of different kinds of clay, e.g. as shown for Tabo, made possible the development of different mixtures customised to particular needs. The use of organic additives shows the deep understanding and high development of locally available material resources. These developments have to be regarded from a local point of view and may change in detail from village to village. The use of local terms for clays points towards their use as rooted in traditional knowledge.

At the high altitudes of Ladakh, an earth building tradition still exists. Connected to the minimal resources of wood, this region shows a weathering of the soil of a characteristic that differs from forested areas. In the high-altitude arid zone, transport by glaciers, rivers and wind indicates the given properties of the clays and the availability of some very fine and silty lacustrine clays (cf. Feiglstorfer 2019: 24ff.).

4. ASPECTS OF CONSTRUCTION

The present research focuses on indigenous building traditions, whose building material qualities are primarily dependent on local material resources. Application of particular materials follows environmental preconditions, such as climate and local raw material resources, while processing is strongly related to cultural parameters. In the case of changing raw material resources, local techniques were adjusted.

If possible, solid walls were reinforced with timber lacing to make them more stable. Different methods of strengthening solid constructions with wood as a flexible additive were developed as composite constructions. Stone, clay and wood were optimised for mutual support. The different environmental parameters for stone, clay and wood in accordance with climate conditions imply a large variety of different local reactions, which are an essential part of defining local identity. A peculiarity in the Western Himalayas is the large variety of different local traditions based on a large variety of different natural preconditions and cultural influences. The aim of this last part of Chapter IV is to delve deeper into different local variations in order to get closer to an understanding of regional changes.

In regions with less timber resources, the method of construction was adjusted. Adjusting is not to be mainly understood as simply adding or omitting wood but rather creating a homogenous construction that fulfils particular architectural needs. At higher altitudes, the use of clay or stone or both in combination with a less content of wood is obvious, while in lower and more wooded areas with higher precipitation, the content of timber in constructions increases. Regarding these naturally predefined circumstances, we can state a detailed hypothesis for the predominance of raw material resources in predefining local building techniques. The way of processing and assembling the raw material in contrast is dominated by local cultural traditions. In this respect, this study involves two basic aspects, i.e. natural environmental preconditions, which are more or less fixed, and local material-cultural traditions, which are adaptable.

Over the last decades, due to continuous changes of and additions to constructions, at a single site different techniques of constructions may have been introduced. Continuous transformations of

techniques are found all over the Himalayas. The ruins of the Old Monastery of Chekha in Charado (Tib. Chad kha in Bya ra mdo) in Central Tibet are a Central Tibetan example of such a mixture of different technical applications at one site. The monastery was founded by the Kadampa master Ja Chekhapa Yeshe Dorje (Tib. Bya 'Chad kha pa Ye shes rdo rje; 1101–1175) in 1164 CE.¹³⁸ Different methods of existing wall constructions situated beside each other indicate different ages of the single constructions. Constructions range from pure rammed earth, adobe bricks as single and double-shell constructions, stone walls with flat stones and a rather thin layer of clay mortar, and dry stone walls without mortar (cf. Feiglstorfer 2015: 74).

Starting at high altitudes and continuously descending within the given research area, locally predominant wall constructions are categorised and juxtaposed. The chosen examples give evidence only in a qualitative, but not in a quantitative context. Except for the region of Gilgit-Baltistan, the examined regions have been visited several times for field research in the years between 2001 and 2015. The remaining witnesses of early constructions clearly show local knowledge of a differentiation between various technical methods in using timber. Several of the given examples are elite structures such as fortresses, *shikari*-towers, religious buildings (Buddhist and Hindu temples and mosques), shrines or palaces. Examples for Himachal Pradesh may date back more than 1,000 years. The given examples, which have been well maintained over centuries, provide an idea of developments in structural engineering in the Himalayan Middle Ages, and leave space for hypothesising on indigenous developments and historical technology transfer. An interest of the builders of elite structures must have been the production of a long lasting shell to protect, e.g. precious religious goods, like wall paintings or sculptures, and to represent a particular social status. Techniques and materials of high quality were adjusted to local possibilities.

Climate data in the following analysis are given according to *Climate data for cities worldwide* according to Köppen and Geiger¹³⁹. Basic data for the regional availability correlate with previously given analysis. The single regions (Ladakh, North Pakistan, Kashmir, Himachal Pradesh) are analysed in the given sequence (Map 4.7).

138 Available at: http://www.oeaw.ac.at/tibetantumulustradition/sites_by_id/0104/

139 See part 3 of this Chapter and Table 4.3 in the Appendix of Chapter IV.



Map 4.7 Sites related to part 4 of Chapter IV “Aspects of Construction”.
 GIS data based map: Jakob Gredler. Final graphics: author. Map based on Vector data (VD).
 Citations of VD also see: Chapter IX, list of illustrations.



4.1 Ladakh

This part concerns composite wall constructions containing wood in the province of Ladakh with a closer look at the vernacular architecture in the Indus Valley.

As given in the table with climate data (see Table 4.3 in the Appendix of Chapter IV), the altitude of settlements along the Indus Valley changes from around 3,520 m at Leh, Phyang and Thikse, and decreases by app. 800 m to Kargil with an altitude of app. 2,700 m to the Pakistan border. The average annual temperature in Leh, Phyang and Thikse ranges from 4.7°C to 6.8°C. This is comparable to Spiti, which is located at a similar altitude. Temperatures increase towards Kargil by app. 2°C to 4°C. Compared to North Pakistan, temperatures are close to those in Kargil. In Leh, the difference between annual minimum and maximum temperature is 26°C, which is relatively high. In Kargil, the temperature is even higher at 32°C. The resulting stretching of material is a factor to be considered in regard to combinations of different materials within a composite construction. Annual precipitation increases in Leh at around 100 mm, and moving towards Kargil, precipitation is about three times higher. Towards North Pakistan, it increases slightly compared to Leh. Snowfall can already start in October and last until April. Snowfall has also been recorded at passes during the summer months. Extreme temperature may decrease below -40°C and increase above 30°C. Traditional architecture is not prepared for strong rainfall such as occurred in 2010. At this time small creeks became powerful streams that swept away trees and rocks, forming damaging mud slides.

Correlating with the given climate data, the timber population for building constructions in Ladakh is low compared to the environmental conditions of the adjoining territories Khyber Pakhtunkhwa, Lahaul and Kashmir (see Map 4.5). These conditions are reflected in the vernacular architecture of Ladakh. In recent constructions similar to traditional building techniques, adobe bricks were primarily used; the use of timber was widely neglected. In contrast, regarding historical composite wall constructions, the use of timber was widely known, as shown in the following research on historical structures.

The traditional roof construction in Ladakh is a flat roof made of clay on an organic layer. In arid zones the flat roof is the predominant roof form. The upper and heavy constructive layer is in most cases a compressed earth construction, which is typically constructed using several layers of a different homogeneity. The upper layer is the water-bearing layer, which is prepared according to particular local methods (see material analysis in Chapter III). In various areas of the Himalayas, some types of clay used for the upper layers are easily repaired, for example, with a silty clay known as *markalak*. If this is not the case, at least the upper layer has to be replaced after several years as soon as the roof starts to leak. At this point, a concern is the possibility of overstraining the timber subconstruction in the case that the old soaked clay is not exchanged, but instead new heavy material is loaded on top. In several cases, damage to the subconstruction was found and attributed to this kind of continuous overloading.

4.1.1 'Simple' timber lacing (horizontal timber straps along wall faces)

This technique uses the timbers as scantling placed on stone or brick walls, horizontally running along the facade. No cross-pieces are evident. Wooden lacing is in general made of cut wooden

beams. Their use in an uncut form or even with bark would not enable the necessary friction resistance between the wood and the adjoining stone or brick.

With this kind of construction, the adobe bricks are the primary load-bearing part and not the wooden component, as would be the case with a much higher content of wood. A reason for the use of the ‘simple’ timber lacing is its impact as a crack stopper.¹⁴⁰ In the case of static movements within the wall, either by wall settings or due to earthquakes, these inlays avoid cracks crossing along the whole height of the wall and destruction of the wall. In the case of using a ‘ladder’-like system as shown with the following technique, a drifting apart of the wall can also be avoided.

There are two ways to use this kind of ‘simple’ timber lacing: (a) as a simple inlay or (b) as a ring beam.

a) Single beams are laid, and the lacing does not work as a ring beam (Fig. 4.28). It acts as a crack stopper and as a levelling layer for the following top row of bricks or stones. As a levelling layer it also impedes a collapse of the masonry. In this function, it is commonly used in plinths of stone walls and in adobe brick walls.

b) The lacing as a ring beam needs a connection between the single runner beams along the facade, at the corners, for example, by using wooden pegs (Fig. 4.29). Effects of external forces due to earthquakes or uneven subsidings of walls and also internal forces due to the wall’s dead load related to its height are reduced. The wooden inlays also act as a reducer of the buckling length along the height of the wall. It stabilises the whole structure and not just the single wall. Drifting inwards is prevented by the existence of floor and roof constructions acting as stabilising plates. Such ring beams may be erected on the floor level and combined with the floor beams to avoid a drifting outwards of parts of walls.

Howard (1989: 221) differs the size of the used timbers for fortress constructions according to their use: for a banded texture timber, width is up to 25 cm, and for a random texture wall, width is app. 10 cm. His description that adjacent timbers may be simply butted together or joined by halving joints, which are sometimes dowel pegged, points towards the timbers’ use as ‘simple’ lacings without a primary static function as ring beams. An early example of this technique is described with mixed-stone masonry with timber lacing at the tower of Hankar in Zangskar dating to the 12th/13th century (Devers, Vernier 2011: 85).

4.1.2 ‘Ladder’-like timber lacing

This technique consists of runner beams placed in pairs along the in- and outside faces of a wall (see Fig. 4.20). They are connected by cross-pieces and stabilised by the masonry on top (Langenbach 2010: 2). It is similar to the system known as *taq* in Kashmir. The Kashmir version in contrast shows a ‘ladder’ consisting of two facing beams above each other with the floor beams in-between. The technique commonly used in Ladakh shows a ‘ladder’ with only one facing beam along the facade.

¹⁴⁰ We often find such crack stoppers above wall openings to strengthen wall corners. Crack stoppers consist of runner beams along the surface of a wall. This prevents cracks disseminating over a wider area of the wall.

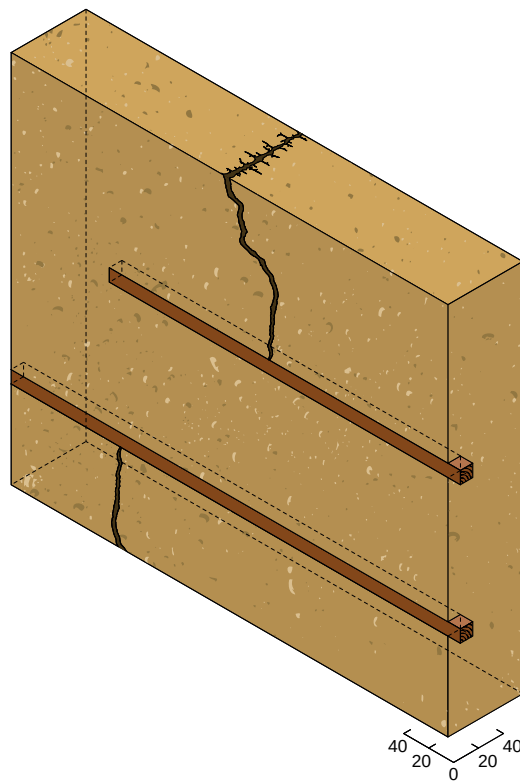


Fig. 4.28 System of 'simple' timber lacing acting as a crack stopper.
CAD: Martin Pospichal.
Details provided by the author.

Generally, the heads of the cross-pieces and the exterior beams running along the facade are visible from outside the building. 'Ladder'-like constructions connected with the floor beams mark the position of the storeys, as long as they are not covered along the facades. In most cases the runner beams are scantlings, while the cross-beams may also be round in shape. In addition to the beams' function as crack stoppers and levelling support for the following row of bricks or stones, two crossing 'ladders' may easily be closed at the building's corners and act as a ring beam. Since the timber lacing covers the whole width of the wall, it is more efficient as a stabiliser than 'simple' timber lacings (as mentioned above).

4.1.3 Wattle and daub

Apart from timber lacing constructions, Ladakh is home to other composite techniques that use wood. Wattled mats are widely used and often made of willow branches. A traditional use of such mats is as shuttering for rammed earth walls, as shown in a picture by Khosla (1979: Fig. 179) from Padum in Zangskar. In an interview in 2005 with Mr. Wangchuk in Leh, he mentioned the uppermost storey of the Sumtseg in Alchi (c. 11th century CE) having been built as a wattle and daub construction (Interview with Mr. Wangchuk in November 2005). He supposed that such a lighter weight construction technique was chosen because of the reduction of the load on top of the two storeys and also the reduced effort needed for lifting the material.

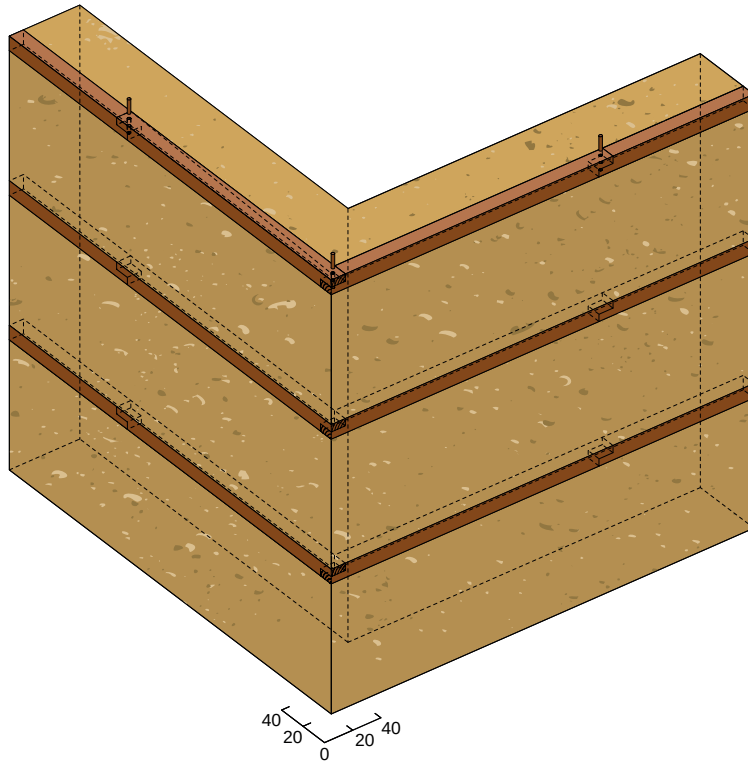


Fig. 4.29 System of 'simple' timber lacing acting as a crack stopper.
CAD: Martin Pospichal.
Details provided by the author.

4.1.4 Bracing of rammed earth lintels

Another composite technique using wood is known by its use as tensile reinforcement of rammed earth lintels (Fig. 4.30). During field survey at an entrance to the central tower of the fortress in Saspol (for further description of this fortress, see Howard 1989: 282ff.), Sonam Wangchuk pointed towards the existence of bendable and elastic twigs (Interview with Sonam Wangchuk in August 2011). Before ramming, these twigs were laid into the clay. This technique is also known for recent rammed earth constructions, in particular at the corners and along the edges of the rammed layer.

4.1.5 Investigated objects

Nyarma, Temple VIa

Alt. 3,264; 34° 2'21.64"N, 77°41'3.37"E. Up until now, this building has not been dated (Fig. 4.31). It may date back to the end of the first millennium if erected together with the main temple. Along the eastern adobe brick wall, a notch for the former position of a timber lacing was found. The thickness of the wall is app. 115 cm (cf. Feiglstorfer 2011: 8, 28).



Fig. 4.30 (Left) Saspol. Ladakh. Rammed earth lintel of an entrance gate of the fortress reinforced with twigs.

Fig. 4.31 (Right) Nyarma. Ladakh. Structure in front of the *tsuglagkhang* with notches of former timber lacing.

Leh, Old Town

Alt. 3,520 m; 34°9'54.25"N, 77°35'9.20"E. Houses in the Old Town of Leh, located at the foot of the palace (foundation date around 1600 CE), are built of stone and clay using different composite techniques, including components of timber lacing. Several of the housing structures in the old town of Leh show different techniques within one and the same structure.

In a facade as shown on Fig. 4.32, the use of 'simple' timber lacings connected to each other by halved joints is evident (Figs. 4.33, 4.34). This example shows the effect of timber lacings as crack stoppers. Below the upper storey, several cracks end at the lacing. The ring beam is laid between a stone basement and an adobe brick wall on top. Lintels project a long distance into the laterally adjoining stone wall. Thereby, they act as crack stoppers, in particular in the corners of the window openings. The banded stone walls are made with clay mortar. Using stone for the plinth results in a higher strength thereof compared to adobe bricks. The latter, in contrast, are of less weight and easier to carry on top.

Wanla, Fortress tower

Alt. 3,175 m; 34°14'58.71"N, 76°49'50.02"E. As an example, on top of the ridge where the temple is situated, a tower-shaped building of three storeys made of stone faces north-west. It may be dated to the 11th century (Howard 1989: 260). Along its plinth on the north-west side, a kind of retaining wall with a 'simple' timber lacing was used. In this case, the primary function of the wood is to hold the front wall together and to avoid lateral outside drift.

Leh Palace

Alt. 3,540 m; 34°9'57.52"N, 77°35'11.69"E. Along the southern front of the palace of Leh, we can observe six storeys (Jest, Sanday 1983: 8). The front wall tapers from a width of app. 1.75 m at the base to app. 0.5 m at its top. For the walls in the lower storeys, granite stone was



Fig. 4.32 (Left) Leh. Stone wall in the Old Town topped with an earth wall, both using timber lacing as crack stopper.



Fig. 4.33 (Top) Leh. Old Town. Corner half lap joint.

Fig. 4.34 (Below) Leh. Halving joint.



used and adobe bricks for the upper storeys. For the lower levels in a vertical distance of app. 3 m, 'ladder'-like timber lacing made of *shukpa* was introduced and connected through the wall with round cross-pieces. (ibid.)

Basgo, Serzang Lhakhang

Alt. 3,270 m; 34°13'25.59"N, 77°16'33.92"E. The stone basement of the Serzang Lhakhang in Basgo has a height of app. 2 m at the south wall and carries an adobe brick wall on top. Two 'ladder'-like constructions are introduced within the stone basement and two further within the adobe brick wall. Most of the cross-pieces are round-shaped. They are not related to the position of a floor. The width of the wall is app. 67 cm. Howard (1989: 234) associates this temple with the reign of King Dragpa Bum (Tib. Grags pa bum). Bellini (2014: 226) gives the time of his reign as roughly 1450–1490.

Timogang, Maitreya Lhakhang and palace

Alt. 3,350 m; 34°19'38.55"N, 76°59'29.35"E. The Maitreya Lhakhang and the opposite located palace which are both close to the fortress of Timogang, were built with a similar 'ladder'-like timber lacing technique as we can find in the Serzang Lhakhang in Basgo. Both structures are dated to the same building period (Howard 1989: 254). The Serzang Lhakhang in Basgo, the Maitreya Lhakhang and the palace, which in Timogang were built with random texture and clay mortared stone (ibid).

Spituk Monastery

Alt. 3,240 m; 34°7'31.62"N, 77°31'36.17"E. Along parts of the facades of the monastery in Spituk, similar 'ladder'-like lacings with round cross-pieces were used. The monastery was rebuilt in the second half of the 15th century during the reign of King Dragpa Bum (Bellini 2014: 226). In contrast to the main building, the *gönkhang* ("protectors' chapel"), which is much smaller, does not show any timber lacing. The walls are built with a high random stone plinth and an adobe brick wall on top. Along the south facade of the main monastery, the stone plinth reaches partially up to the level of the ground floor, which is up to app. 2 m above ground. The walls of the three storeys on top are made with adobe bricks. In each floor a timber lacing was introduced. The lacing supports the floor beams, which project over the front of the facade. A lacing was introduced as a flexible partition layer between the stone basement and the adobe wall on its top.

Phyang Monastery

Alt. 3,590 m; 34°11'11.53"N, 77°29'21.53"E. The walls of the main building of the Phyang Monastery (founded in the 16th century) show a plinth going up to the second floor. They are made of random stone with mortar. The two upper storeys on top of the stone plinth are made of adobe bricks (Figs. 4.35, 4.36). Similar to the given example of Spituk, the 'ladder'-like lacings are at floor level. The wall thickness along the west facade is app 73 cm on the 2nd floor. Stone walls on the ground level reach up to 150 cm. In some of the cross-pieces, a notch is cut to improve their connection with the front facing beams. Halving lap joints connect them.

Skurbuchan Khar

Alt. 2,960 m; 34°26'4.50"N, 76°42'26.40"E. In front of the rammed earth defence tower, an extension towards the Indus River was built with random stone walls. Their round shape points to them being brought from the riverbed below. The rounding of the stones reduces the stability of the bond. A part of the front of the whole structure was made with angular rubble stone. Each of the single horizontal sections of the stone walls was individually made with 'ladder'-like timber lacings (Fig. 4.37). Between these wall sections, the single lacings are not connected to each other. At the corners the lacings were connected with corner half lap joints. Round cross-pieces hold the facing runner beams in position by applying two different methods. One method is to use a lap joint, similar to what is seen in Phyang. The other method is to fix the cross-piece with wall brackets (shear keys) – a kind of wooden nail (or stick). In the latter case, with some examples the cross-piece was laid into a notch in the upper surface of the front beam, possibly to keep the level for the stone wall above in one line (Figs. 4.38, 4.39). The width of the rammed earth entrance wall leading to the temple is 72 cm, and the width of the entrance wall made of stone and leading to the ante-chamber is 94 cm.

Saspol Monastery

Alt. 3,110 m; 34°14'46.19"N, 77°10'0.81"E. Along the outer face of the rear wall of the tower-like part of the Saspol Monastery, the use of 'ladder'-like timber lacing is evident. Due to an uneven and whitewashed surface it is not easy to detect. It shows fewer cross-pieces than the previously mentioned examples.



Fig. 4.35 Phyang. Two storeys with stone walls topped with two storeys of adobe brick walls. Timber lacing at floor level carries the floor beams. Along the facade runner beams are connected to halving joints.



Fig. 4.36 Phyang. Floor beams are connected to the runner beams by lap joints.



Fig. 4.37 (Top) Skurbuchan Khar. Timber lacing in the lower stone part of the wall.

Fig. 4.38 (Bottom, left) Skurbuchan Khar. Corner half lap joint.

Fig. 4.39 (Bottom, right) Skurbuchan Khar. Wall bracket (shear keys).

Chigtan Castle

Alt. 3,290 m; 34°27'28.84"N, 76°31'10.12"E. The castle dating back to possibly the 16th/17th century, shows several stages and techniques of construction (cf. Khan et al. 2014: 254ff.). Two of these techniques show different ways of using timber in composite constructions: (a) situated in the core of the castle with closely-laid timbers and (b) situated with timbers laid at a greater distance from each other. According to Khan et al. (2014: 266), the latter (i.e. construction b) chronologically follows the first mentioned wall construction (a). Francke (1994: Plates XLIIa and XLIIIa) shows the position and also a detail of the closely-laid stone-timber construction (a), while parts of the latter construction (b) still partially exist (Fig. 4.40).

Construction (a):

The closely-laid timber construction shows traces of a building tradition using more wood, a technique that is common in wooded zones. This points towards a higher availability of wood. Using 'ladder'-like timber lacing with round cross-pieces connected using lap joints is widely known for Ladakh constructions (see above). In this regard, the structure within the castle of Chigtan follows a similar pattern with a difference being that the timbers were laid at a much closer vertical distance to each other (based on proportions in the picture, the distance between the timbers can roughly be estimated between 30 cm to 40 cm). The stones show a well-dressed outer surface. They are relatively flat and long and in this aspect similar to the timber-laced outer walls of Chigtan Castle (see construction b; Fig. 4.41). They are laid in a thick mortar bed. This technique increases the stability of the stone construction and together with the closely laid timbers, the builders' intention of giving the inner core of the castle a superior strength becomes evident. Easily cutting the stone into this flat shape is enabled by its mineralogical composition.

What this construction has primarily in common with vernacular composite constructions in the northern adjoining region of Gilgit-Baltistan (see below) is the increased use of wood, but not necessarily the technique itself, as mentioned in Khan et al. (2014: 264). Examples like the Kharmag Castle¹⁴¹ follow a *cator and cribbage* technique, which is common in the region of Baltistan (see below), and similar to the techniques applied at the fortresses of Baltit or Shigar. They seem basically to be a different type of construction technique, as is the case in the closely-laid composite construction (a) in Chigtan. As far as can be seen in Francke's detailed photograph of a piece of the facade of this building, there is no evidence of a *cribbage* structure and the facing beams are simply resting on the stone walls. A tapering of this wall, according to Tibetan building tradition, cannot be excluded.

Construction (b):

Parts of the outer walls of the castle are still standing in-between a big amount of rubble from collapsed walls (Figs. 4.41, 4.42). At the time of visit in 2011, it was possible to enter the western part of the fortress for observations. Some of the free standing walls are still of a height of more than 6 m, of which the upper part of app. 2 m to 3 m is made of adobe bricks placed on the stone wall below. Parts of these free standing stone walls continue downwards as retaining walls. The total height (= plinth and retaining wall together) rises up to app. 10 m above the rubble-covered ground. From downhill, when approximating the castle, these walls impressively rise against the sky.

141 Compare photographs at <http://www.tibet-encyclopaedia.de>, access: 05/2016.

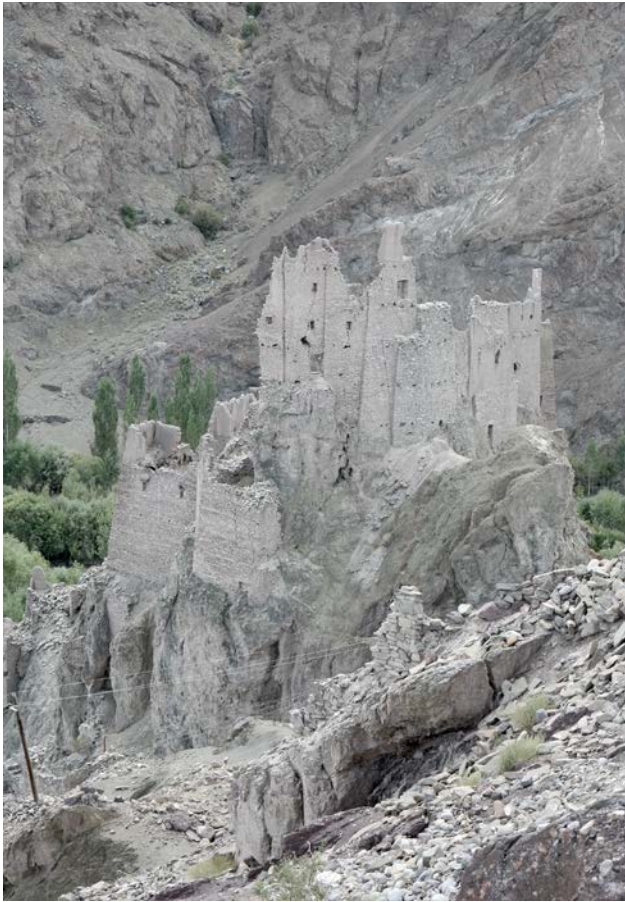


Fig. 4.40 Chigtan. Fortress made of rubble stone.



Fig. 4.41 Chigtan. Fortress. The stones are relatively flat. Corner half lap joint.



Fig. 4.42 Chigtan. Fortress. Timbers are laid on a plane stone level and covered by one layer of flat stones. Surrounding stones are pressed to the timber using a clay mortar.

Some of these walls show a tapering that we know from Tibetan structures. ‘Ladder’-like timber lacing can still be found along the western and southern flanks of the castle, though less along the eastern flank. The construction of the walls is a random double-shell stone structure with an inner core filled with rubble. Some of the stones are rather flat and of a kind we may also find in a wall structure (a). Particularly the stones, which are on top or below bordering the timber lacing, are relatively long and well-processed. The stones are laid in a mortar bed. The lacings are connected with halving lap joints. The round cross-pieces are connected with lap joints similar to the ones found at the closely laid timber wall structure (a). In both structures, they are also laid rather tightly to each other (at structure (b) with a distance of app. 60 cm to 80 cm). Wall thickness ranges between app. 40 cm and 60 cm. For small wall openings, lintels are made of stone, and for longer lintels wood is used.

Chigtan Monastery

Fragments of several adobe brick walls of the former Chigtan Monastery are located in today’s village of Sgang, which is in the close vicinity of the castle of Chigtan, located in a plain area (Figs. 4.43, 4.44). Francke (1994: Plate XLII) shows the Chigtan Monastery in a photograph, and it resembles in shape, topography and mountain rocks in the background the ruins, which the author found in the village of Sgang (local pronunciation).¹⁴² Francke (1994: 100) states the temple’s size to be 14 x 15 paces (app. 10.7 x 11.4 m)¹⁴³ with a height of 24 ft (app. 7.3 m). The interior size of the measured temple is (after conversion into paces) 13 paces (9.9 m) x 16.6 paces (12.7 m), which does not prove identicalness with the taken measurements. The entrance porch is of a lower height than the temple chamber.

From the point of construction, this temple – in particular remains of its best-preserved wall (see Fig. 4.44) – is of importance for further observations. It shows a timber-laced structure in an adobe wall of a width of app. 86 cm. This equals the length of two bricks (brick size 43 x 29 x 11 cm) (Figs. 4.45, 4.46). The wall’s facade is divided into three sections by the horizontally running lacings’ positions. Today, no timber remains and only the notches of the former runner beams are left. The wall is vertically straight and shows no tapering. A kind of double-shell construction with infill of pieces of clay and small stones resembles a technique known from the temples of Nyarma¹⁴⁴ and also from Ladakh stone constructions. Regarding the ‘ladder’-like timber lacing and the unusually thin West Tibetan adobe brick wall – which is also much more similar to stone constructions – structural similarities to the stone walls found at Chigtan Castle can be hypothetically stated (see Chigtan Castle construction b). Francke (1994: 100) dates this temple hypothetically to the Kadampa period in the 11th century CE, i.e. at least 500 to 600 years earlier than the construction of the castle of Chigtan. The transfer of particular techniques from stone to earth constructions regarding wall thickness and the use of timber lacing is known from other examples in cultural transfer zones (e.g. see afore-given explanations for Mandriza in Bulgaria in the context of a transfer zone). Concerning the walls of the Chigtan Temple, the basic features can be found at various early West Tibetan religious structures, but certain influences point towards an adaption of techniques, which may derive from this and / or adjoining regions possibly up to about 900 years ago.

142 Brick bonds of early temples in Ladakh were shown on a poster presented by the author at the TERRA 2008 conference in Bamako.

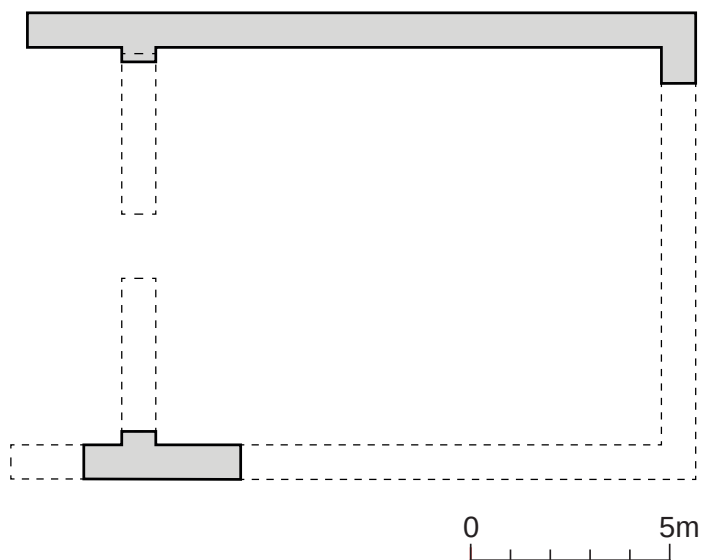
143 The conversion from paces into metres was made using the factor 0.75. This remains hypothetical since for this measurement given by Francke, his definition of paces remains unclear.

144 Methods of construction were presented by the author at the TERRA 2016 conference in Lyon.



Fig. 4.43 Chigtan (Sgang). View from the south onto the ruins of a temple with notches of former timber lacing.

Fig. 4.44 Chigtan (Sgang). Ground plan.



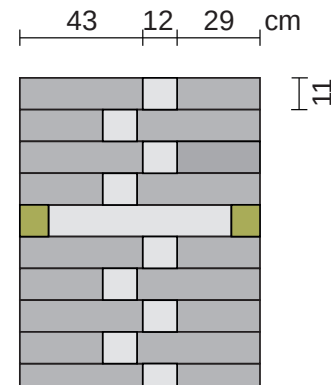


Fig. 4.45 Chigtan (Sgang) (Left). View from the former verandah onto the interior surface of a wall.

Fig. 4.46 Chigtan (Sgang) (Right). Double-leaf wall filled with clay mortar.

4.2 North Pakistan and Nuristan

This part concerns composite wall constructions containing wood in the province Gilgit-Baltistan with a closer look at the vernacular architecture in the valleys of Hunza and Indus and in the province Khyber Pakthunkhwa, with a closer look into the Swat Valley. The province of Nuristan, which is located in eastern Afghanistan, is mentioned as a comparison. In 2006, the author conducted field research in the valleys of Swat and Kunar. For data on the architecture in Gilgit-Baltistan and Nuristan, the author is dependent on literature sources and personal information.

As given in the table with climate data, the altitude of settlements along the valleys Indus and Hunza (e.g. Baltit with an altitude of 2,430 m) is roughly 1,000 m below settled areas in Central Ladakh. The altitude of Kalam, with an altitude of 2,000 m, is even 1,400 m lower. From Kalam to the south in the direction of the Swat Valley towards Mingora (alt. 930 m), altitude decreases rapidly. At app. 4°C, the average annual temperature in Gilgit-Baltistan is above the comparable data of Leh, while at Kalam, the difference to Leh is already app. 8°C. Annual precipitation is higher in the Indus and Hunza Valleys compared to Leh, while the precipitation in Kalam is more than four times compared to Baltit or Khaplu. Compared to Leh, maximum temperatures are higher in the Indus and Hunza Valleys in Pakistan. These differences between Baltistan and Ladakh become much smaller when compared with western parts of Ladakh, i.e. in the area of Kargil (alt. 2,700 m). The climate conditions in the valleys Hunza, Indus and Swat may explain the higher population of timber as compared to most places in Ladakh. This fact implicates a higher amount of wood used in building constructions, and by that a different development of building techniques. Concerning a regional type of roof construction, a flat roof is the traditional roof in Gilgit-Baltistan and Khyber Pakthunkhwa, and also further west in Nuristan.

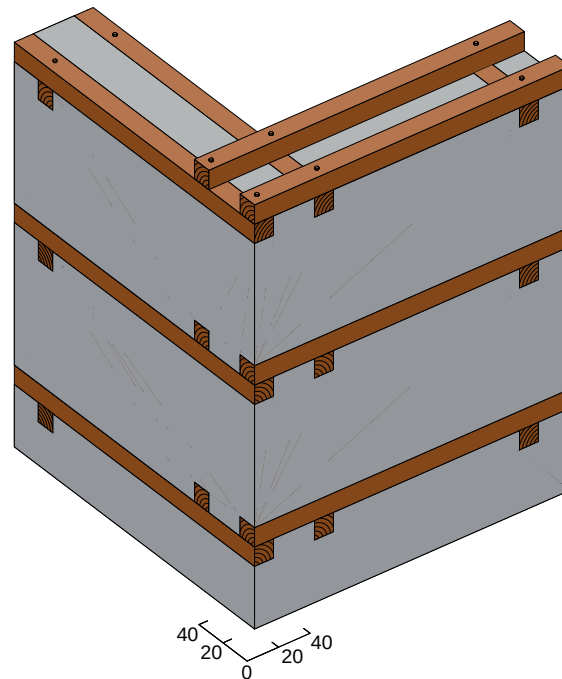


Fig. 4.47 System of a *bhatar* construction.
CAD: Martin Pospichal. Details provided by the author.

4.2.1 *Bhatar*

At the *bhatar* construction, the ‘ladder’-like timber lacing is not only at floor level, but at a certain distance along the whole height of the wall (Fig. 4.47). The vertical distance between the timber lacings ranges between 30 cm and 60 cm. Beams are in profile between 10 x 10 cm and 12 x 12 cm, and the facing runner beams are connected with cross-pieces every 90 cm to 150 cm (Schacher 1998: 3). Stone structures are made with or without mortar. Cross-pieces are in general placed below the runner beams (*ibid.*). In contrast to the *cator* and *cribbage* technique (see below), the vertical ‘column’-like timber-stone structures (*cribbage*) are missing and just the *cator*-construction remains. Vertical timber elements are also not used. Commonly used timbers include deodar, blue pine and, at higher altitudes, also poplar (*ibid.*).

In Kalam and the surrounding area, the main construction of vernacular buildings is the ‘ladder’-like timber lacing in combination with stone walls (Fig. 4.48). This technique is locally known as *bhatar*¹⁴⁵ and is similar to the ‘ladder’-like construction at floor level. In Indian Kashmir, this technique is known as *taq*, in Turkey as *hatil* or *dugmeli* (Schacher 1998: 2; Hughes 2000b; Langenbach 2007), and in the Greek Middle Ages as *imantodi*. In North Pakistan, it is commonly used between Chitral in the west to Besham in the east, in Nuristan and in the northern provinces of Pakistan (Schacher 1998: 2). In Keshtagrom in Nuristan, Edelberg (1984: 6) shows examples of

¹⁴⁵ Schacher (1998: 2) describes the *bhatar*, on the one hand, as wooden laths reinforcing a stone wall and, on the other hand, as the whole construction, which includes this kind of timber lacing.



Fig. 4.48 Kalam, North Pakistan. *Bhatar* construction.

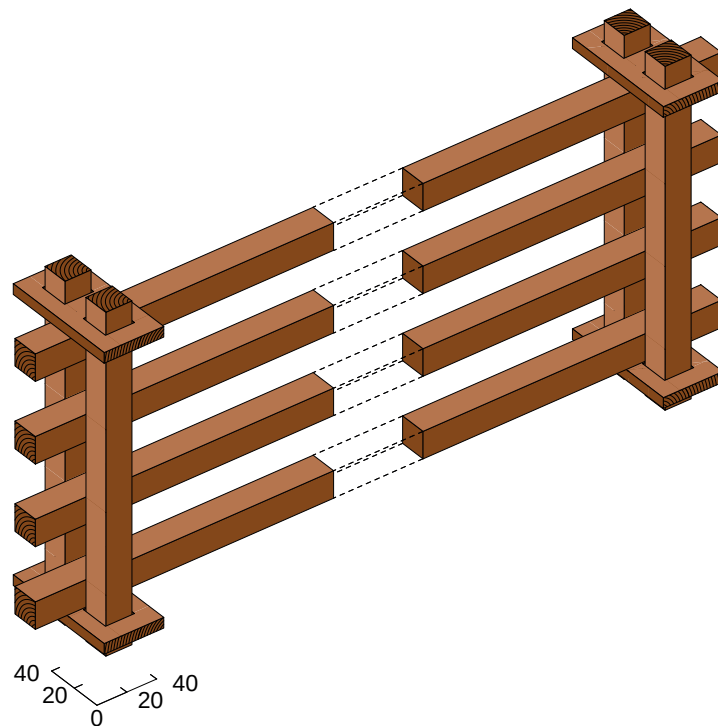


Fig. 4.49 Nuristan, Afghanistan. System of a *pik'ū* construction.

CAD: Martin Pospichal. Details provided by the author, according to a picture given in Edelberg 1984.

‘ladder’-like constructions with about two layers of stones above the runner beams notched at the corners. The stones are described as being rendered with clay, while the runner beams (Kt. *makř’ik*) are placed without such a rendering.

A common tradition for making walls is mentioned with the *pik’ū* (Wg.) construction (Fig. 4.49). The *pik’ū* or *pik’ū-nakur’ä* construction resembles the *bhatar* construction as it also changes layerwise between wooden runner beams and stone-clay infill. However, striking differences do exist: The layers of timber runners (Wg. *ban-ē*) are not laid as pairs but rather as single beams and are kept in position by vertical poles (Wg. *pik’ū*) at the inside and outside of the walls. These poles pass through wooden clamps (Wg. *nakur’ä*) that protrude from the wall both inside and outside. (cf. Edelberg 1984: 4ff.) Such poles are rarely used in Himachal Pradesh, while in Uttarakhand they appear as wall brackets or shear keys to stabilise walls.

4.2.2 *Cator and cribbage*

A traditional technique in this region is the combination of the ‘ladder’-like timber lacing (known as *cator*) as the horizontal component – as mentioned for structures in Ladakh – with a stone-filled timber column-like system (*cribbage*) as the vertical component (Fig. 4.50). In the ground plan, square-shaped column-like components (known as *cribbage*¹⁴⁶) are made by piling up logs two by two, with each layer rotated by 90°. For Ladakh, the use of the *cribbage* technique is not common and no historical data exists showing its use. Hughes (2000a) mentions its common use between Nuristan and Baltistan; this system was already used in Mohenjodaro (app. 3,500 BCE), in Roman and Medieval London for quay construction, and at the Baltit Fort already app. 800 years ago (ibid.).

The combination of the *cribbage* construction with the *cator* construction changes the static role of the wood. In the simple *cator* system – as described afore for Ladakh – the wooden components are integrated into the solid wall construction, which may be of stones or adobe bricks. In this case, the solid wall component (stone or brick) is the prime carrier of the load and we can still talk of a solid wall construction. In contrast, the *cator and cribbage* technique as described for North Pakistan is from a static point of view closer to a wooden skeleton construction. This is emphasised by the fact that parts of this construction, in particular the *cribbage* components, may be erected as ‘simple’ wooden constructions first and filled with stones in a later phase.

The solid component of this construction is primarily stone. Fired bricks would be too energy-intensive and, from a static point of view, would mean no improvement. On the other hand, adobe bricks are not common, possibly due to the unsuitable properties of local clay (see aforementioned material resources). The strength of adobe bricks in general is lower than stone, which may result in cracks due to tensions in the wooden part of the construction. In particular, strength for adobe bricks is low against shear forces and tensile loads.

In a drawing, Hughes (2000a: Fig. 1) shows standards for the *cator and cribbage* construction, where the *cribbage* columns are set at a distance of app. 2 m to 4 m from each other. This refers to the available average length of structural timber. The runner beams (*cator*) are placed with a

146 Hughes (2007: 102) describes *cribbage* as a “vertical timber box frame”.

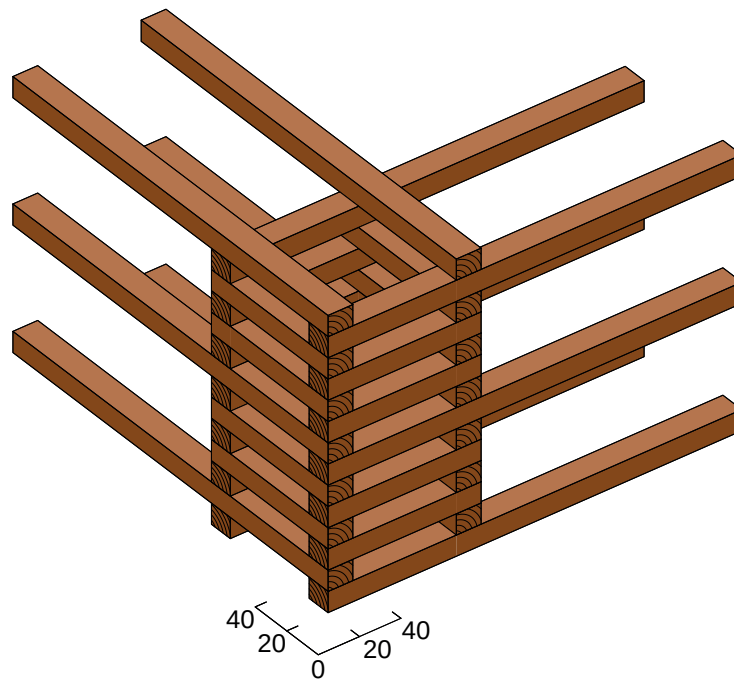


Fig. 4.50 System of a *cator and cribbage* construction.
CAD: Martin Pospichal. Details provided by the author.

vertical distance of max. app. 1 m from each other. They are connected with each other at the corners by wooden pegs. Timbers are in profile 5 cm to 12 cm square. Timber length is not always jointed or nailed together. To reach a better quality, runner beams are tied together through the wall thickness with cross-pieces at 1 m to 4 m intervals.

This technique enables rather slim and high wall proportions, as is seen at the facade of the Baltit Fort, which is just app. 40 cm thick, but 10 m high (Hughes 2007: 112). Historical monuments of these regions, as shown in photographs by Dani (1989), are mainly built with the *cator and cribbage* system. This concerns forts and palaces (*khars*), mosques (*masjids*) and tombs of saints (*astanas*); the artistic style related to this construction is locally known as *thatar*¹⁴⁷ (Klimburg 2007: 151). For an additional strengthening of the corners in the *cribbage* system, wooden boards were introduced between two rows of *cator* beams covering the end of the wall (cf. Dani 1989: Plate Xa, Tower of Dost Mohammad in Tangir Valley). This technique is also practiced in Himachal Pradesh, e.g. in Chamba and Middle Kinnaur (see Fig. 4.79).

147 The North Pakistan term *thatar* is used in Chamba (as *thathar*) to describe the single horizontal pieces used in the *farque* construction (cf. Handa 2008b: 101).

4.3 Kashmir

This chapter concerns composite wall constructions containing wood in Kashmir. In 2006 and 2011, the author conducted field research in Srinagar and surrounding areas. The altitude of Srinagar is about 1,585 m, which is roughly 2,000 m below settled areas in Ladakh, 1,000 m below settled areas in Chamba and Baltit, and 500 m below Kalam.

At 13.6°C, the average annual temperature in Srinagar is, besides Chamba Town, the highest within the reached North Indian settlements. It is about 8°C higher compared to Leh and similar to Kinnaur and Chamba. At 23.1°C, the maximum temperature is, besides Chamba Town, the highest within the researched North Indian settlements, while the difference between annual maximum and minimum temperature is 23.1°C, which is the highest after the Ladakh region. This high difference means a particular high stress of the building material over the seasons of a year, resulting in the need of flexible behaviour. The climate conditions in the Kashmir Valley may explain the relatively high population of timber. This fact implicates a higher amount of wood used in building constructions compared to higher altitudes and regions with less tree population. Such conditions support the development of some particular building techniques. Low temperatures around 0°C in winter may bring big amounts of snow.

A pitched roof is the traditional roof construction in Srinagar and the hilly surrounding region. At a few historical building sites in the Srinagar region, we find a mixture of sloping and green roofs. The *khanqah* in Pampur (alt. 1,620 m; app. 10 km south-east of Srinagar) or the Madeen Saheb (15th century CE, INTACH 2010b: 480) located near Nowshohar are good examples, and from a constructive point of view related to what we find at the Sumtseg in Alchi located in Ladakh at an altitude of 3,020 m. This is one of the few examples in Ladakh influenced by Kashmir in regard to art history and building structure. In a picture by Kak, the *khanqah* in Pampur is shown with a sloping grass roof (Kak 1933: Plate XLVI). In the meantime, it has been changed to a tin roof.

The sophisticated roof timbering shows a construction typical for many of the mosques in Kashmir and North Pakistan. The part of the roof next to the eave is made with a gentle slope in a single- or multi-tiered pyramidal shape (Kash. *chaar baam*). The central part of the roof is a steep sloping spire. A small open pavillon (Kash. *brangh*) is often integrated between the spire and the *chaar baam* (Fig. 4.51). Similar types of roofs with a central steep sloping portion on top of an open roof pavillon and covered with wooden shingles are also found at Buddhist structures, e.g. in Middle Kinnaur, specifically in Ropa, Sunnam or Karla.

In Srinagar, a particular composite building culture developed with buildings of a common height of up to three and four storeys. Srinagar appears as a kind of transition zone of different building techniques with light-weight as well as solid structures, and those resulting from a combination. As a light-weight construction, the *dhajji-dewari* is predominant; as solid structures the *taq* is predominant and the *cator and cribbage* construction frequently used. All these constructions are closely related to the availability of structural timber. The *dhajji-dewari* is widely used over Kashmir (in India and Pakistan as well), while further north in North Pakistan and in Himachal Pradesh, we find it occasionally. In Chamba, which is close to Kashmir, the *dhajji-dewari* is still more prevalent than in the districts of Shimla or Kinnaur. *Cator and cribbage* constructions are



Fig. 4.51 View over the city of Srinagar. In the centre of the picture, four pyramidal-shaped roofs (*chaar baam*) are visible.

widely used in Kashmir, North Pakistan and Himachal Pradesh. *Bhatar* constructions are widely known in the Himalayas. Historical monuments are mainly from the last two centuries, in particular *taq* constructions, although some historical monuments can also be mentioned for the 13th/14th century. In particular, some historical *cator* and *cribbage* constructions reach back to this period.

4.3.1 *Taq*

It is a 'ladder'-like timber lacing similar to the *bhatar* in Pakistan or the *hatil* in Turkey (Fig. 4.52). The 'ladders' are primarily laid on floor level and connected to the floor beams to strengthen the wall against lateral forces (cf. Langenbach 1989). Together, *taq* and floor beams form a horizontal rigid membrane (Fig. 4.53). Floor beams are in most cases visible from the outside. 'Ladder'-like timber lacings (in Kashmir known as *ker*, Langenbach 2009: 8; in Himachal Pradesh as *cheol*) act as ring beams and are joined at the corners. The lacing is not vertically connected. The runner beams are app. 10 cm to 15 cm square (ibid. 5). The *taq* may also be introduced in the wall between the floors for additional strengthening (as it is common with *bhatar* constructions). The runner beams are stabilised by the load on top, a technique as already described by Julius Caesar for the Gallic walls (see part 1 of this Chapter). Besides the timber's use as a reinforcing component, the *taq* also describes a modularity alternating between masonry piers (*tshun*, 45 cm to 60 cm) and window bays (*taqshe*, 90 cm to 120 cm) (ibid. 8). The amount of bays is used to describe a building's size (ibid. Forward). The rhythmical change between masonry piers and window bays is also known from Turkish buildings, for example, from Safranbolu (cf. figure in Caimi 2006: 465). In Srinagar, some of the buildings are vertically divided into a solid masonry part with timber lacing in the lower part of the building and a *dhajji-dewari* construction on top. The cross-pieces within the 'ladders' are preferably below the runner beams, and in earlier days



Fig. 4.52 Kashmir, India. *Taq* constructions along the banks of the Jhelum River.

notches instead of nails were preferred.¹⁴⁸ An early example for the use of a *taq* construction in Srinagar is the Syed Shah Niamatullah Qadri's Shrine (13th/14th century CE, INTACH 2010a: 55, 306), though the majority of historical monuments using *taq* are not older than the 19th century, as described by Langenbach (2015: 84).

In Srinagar, fired bricks are commonly used for wall constructions. A special size for fired bricks was used in Kashmir in the 19th and 20th century, and relates to the Maharaja of Dogra (Langenbach 2009: 8). These bricks are known as *maharaji* bricks (Kash. *maharaji seer*) and had already been used at earlier structures such as the Syed Shah Niamatullah Qadri's Shrine (13th/14th century CE, INTACH 2010a: 306) or the Aastan-i-Syed Mohammad Hussain Baladur (14th century CE, *ibid.* 188). They were placed as a protecting cover in front of adobe bricks (*khaam seer*) (*ibid.* 8). They are also known as Lachania bricks with a size of 23 x 10 x 2.5 cm (Interview with Saleem Beg in 2011). Lachan¹⁴⁹, which is located south of Srinagar, is where the clay for the bricks was collected and where the bricks were fired. Their low height means various advantages such as a higher brick stability and a bigger amount of flexible joints between the bricks. The bricks were modelled by hand and fired at a rather high heat (Seminar held by Langenbach in 2008). In the city museum of Safranbolu in January 2012, two traditionally used bricks were exhibited – one as an adobe brick with a size of app. 30 x 14 x 7 cm and one as a fired brick of app. 20 x 10 x 5 cm. The size of the fired brick shows close similarity to the *maharaji seer*. For solid walls, besides bricks also stones are used, in particular in the countryside, as seen at local houses in Naranag, north of Srinagar.

¹⁴⁸ Information given at a seminar held by Randolph Langenbach, 22/09 to 26/09/2008 in Brescia, Italy (see under "Correspondence and Interviews").

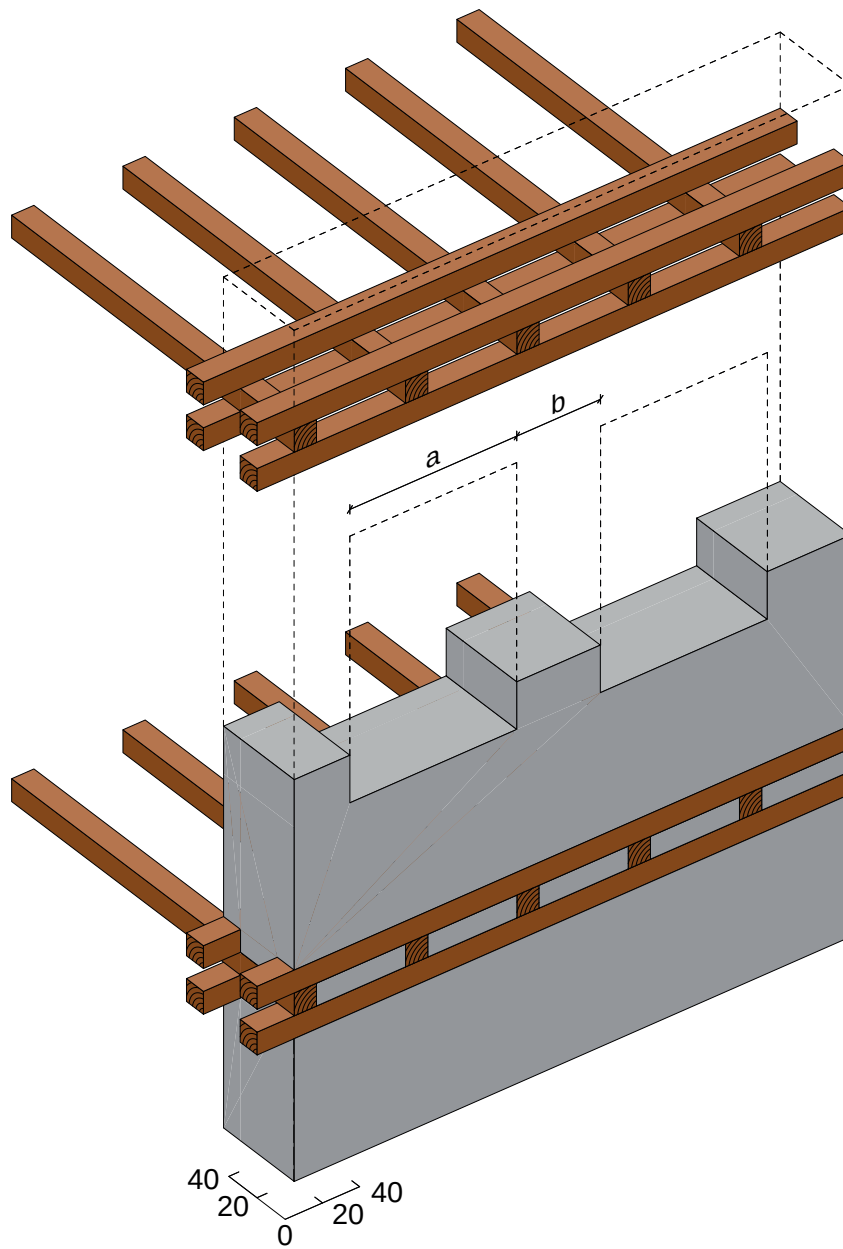


Fig. 4.53 System of a *taq* construction. $a = taqshe$, $b = tshun$, both based on proportions given in Langenbach 2009: 8. CAD: Martin Pospichal.

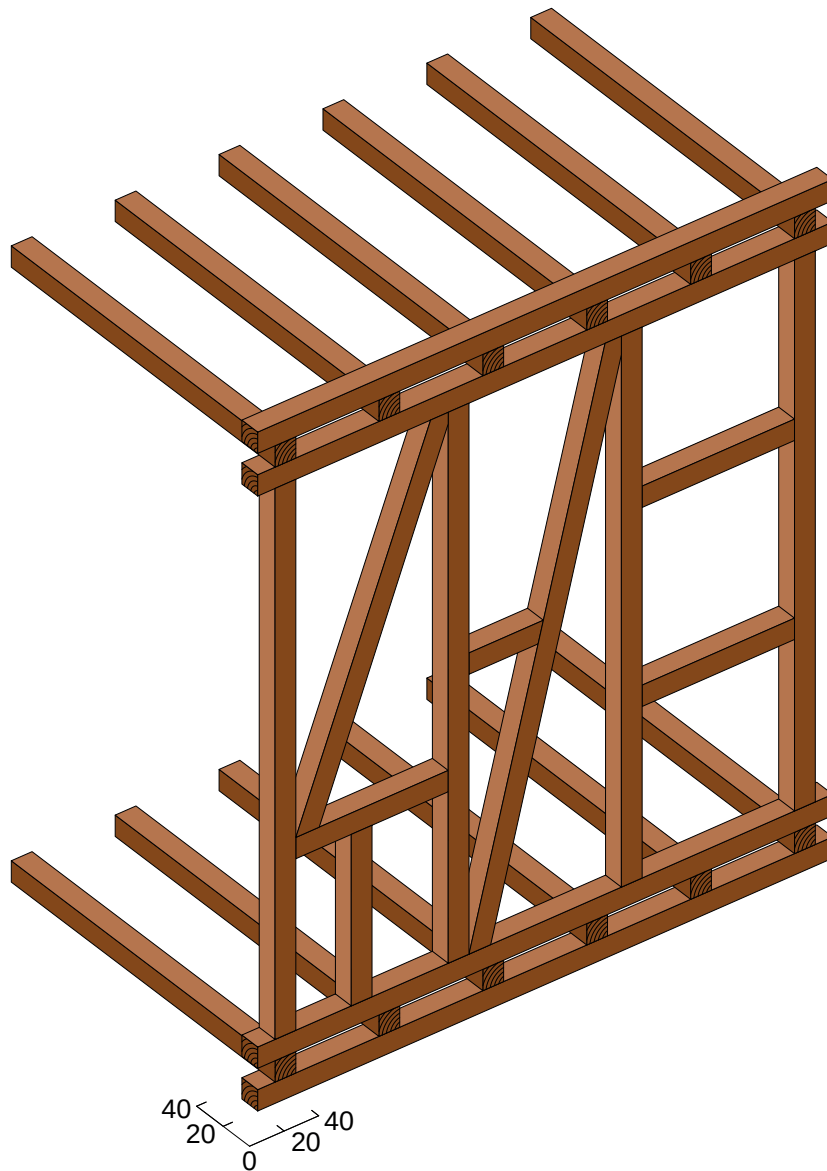


Fig. 4.54 System of a *dhajji-dewari* construction. Compare a structural model given in Langenbach 2009: 17. CAD: Martin Pospichal.

4.3.2 *Dhajji-dewari*

The term *dhajji-dewari* deriving from the Persian meaning “patchwork quilt wall” (Schacher, Quaisar 2009: iii) is a half timber frame construction, which may either rise over the whole height of a building or be placed on top of solid walls (Fig. 4.54). Kashmir (in India and Pakistan as well) is one of the main regions of dissemination of this technique. Commonly used timbers are blue pine, deodar and *chīr* pine (Arup 2011: 10). The timber frame consists of vertical and horizontal members. Within the facade – except at its corners – the vertical members do not necessarily have to be placed above each other. The frames are divided for later wall openings and are commonly

filled with adobe or fired bricks having a wall thickness of app. 12 cm to 14 cm, which remains unplastered (Seminar held by Langenbach in 2008). The frames may be subdivided by several horizontal wooden members over one storey. In many cases, but not in general, diagonal members are introduced. In villages the use of wooden boards instead of square timber elements is common and the frames are divided into smaller frames with stone infill. Also among Turkish half-timber frame structures (*himiş*), we find many examples without diagonal bracing.

Dhajji-dewari walls are independent structures for each floor. The floor beams are clamped (pressed together) between the upper runner beam of the lower part of the wall (i.e. the storey below) and the lower runner beam of the upper part of the wall (i.e. the storey on top). Further, the parts of the wall are connected to each other in a 'cage'-like manner. Floor beams remain in general visible along the front and rear facade. In the case of structural movements, the single storeys of *dhajji-dewari* move partially independently from each other. The high amount of joints increases a structure's flexibility.

4.3.3 *Cator and cribbage*

In Kashmir, several *cator and cribbage* constructions follow the type as described for North Pakistan. The *khanqah* in Pampur is one of the impressive examples in Kashmir (Figs. 4.55, 4.56). It was built with deodar wood. The wood construction remained widely open, and only at some parts it was filled with stones. Big parts of the load-bearing walls of this *khanqah* are built without stone infill and show the statical independence of the timber structure in this construction. Several examples show the early development of this technique in Srinagar. Among them are the 14th century examples like the Aastan-i-Syed Mohammad Hussain Baladur, the Kanqah-i-Muallah (INTACH 2010a: 366) or the Ratqail Mosque (INTACH 2010b: 805).

Another representative example in Srinagar is the Khanqah-i-Naqshbandi built app. in the 17th century (INTACH 2010a: 205) (Fig. 4.57). The wall thickness is app. 90 cm. The runner beams made of deodar are app. 12 x 16 cm (W/H), and the bricks used in the exterior wall are of a size 17 x 13 x 3 cm (L/W/H) following in height a *maharaji* brick size. The width between the *cator* ranges between 50 cm and 160 cm, with the latter larger width used for window openings. The interspaces along the facade between the wooden components are filled with small-sized bricks (Fig. 4.58). The construction at the corners shows that the position of the runner beams is around the whole building kept at the same level (Fig. 4.59) and not displaced with the height of one beam at each corner, as known from North Pakistan *dhajji-dewari* buildings.

4.4 Eastern Lahaul, Spiti, Upper Kinnaur and northern region of Middle Kinnaur

This chapter concerns composite wall constructions in Himachal Pradesh in the east part of the province Lahaul (village of Keylong, alt. 3,100 m) and Spiti (village of Kaza, alt. 3,660 m and Tabo, alt. 3,285 m), in Upper Kinnaur (villages of Nako, alt. 3,630 m and Chulling, alt. 3,200 m) and in Ropa Division as a northern region of Middle Kinnaur (village Ropa, alt. 3,030 m). Altitude ranges between 3,030 m and 3,660 m and separates this region of study from the following lower altitude region of Middle Kinnaur.

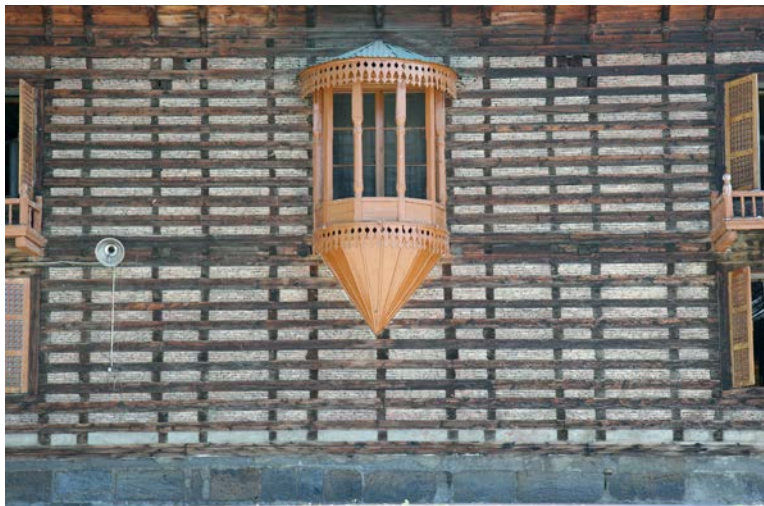


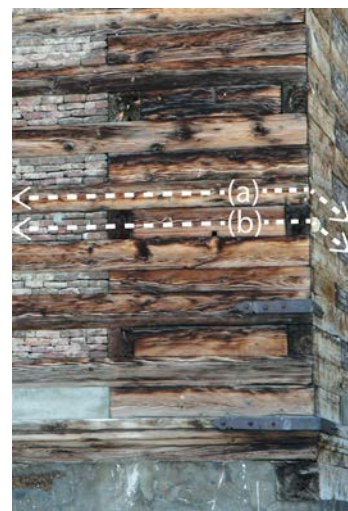
Fig. 4.55 (Top, left) Pampur. Kashmir. Prayer room of the *khanqah*.

Fig. 4.56 (Top, right) Pampur. Kashmir. Open and filled spaces between the cross-pieces.

Fig. 4.57 (Centre, left) Srinagar. Khanqah-i-Naqshbandi.

Fig. 4.58 (Centre, right) Srinagar. Khanqah-i-Muallah. Small bricks are used to fill the holes between the cross-beams.

Fig. 4.59 (Bottom) Srinagar. Khanqah-i-Naqshbandi. Corner construction: Runner beams (a) and layers of brick infill (b) are layerwise alternately kept on the same level around the whole building.



4.4.1 Eastern Lahaul

Regarding climate data of Keylong in Lahaul, Kaza in Spiti and Nako in Upper Kinnaur, we find close similarities between Spiti and Upper Kinnaur. At app. 5.2°C, the annual temperature is similar to Leh, whereas the annual precipitation in Spiti and Upper Kinnaur is much higher compared to Leh and similar to Kalam in the Swat Valley. At app. 19.5°C, the difference between minimum and maximum temperatures during one year is much lower than in Leh with 26°C or Gilgit-Baltistan with between 27°C (Baltit) and 30.6°C (Khaplu), and similar to Kalam with 22.6°C. Keylong (alt. 3,100 m) and its surrounding, like Gondhla (alt. 3,170 m), show a slightly higher average annual temperature and precipitation compared to Spiti and Upper Kinnaur. Snowfall during winter can be strong, in particular in the southern regions of Lahaul.

From Ladakh (Leh, alt. 3,520 m) towards Lahaul (Keylong, alt. 3,100 m) as well as from Zangskar (Padum, alt. 3,570 m) towards the Chenab Valley in the south, we observe a move from predominant earth constructions towards stone and earth constructions as well as a higher content of wooden components. Forestration is higher than in Ladakh, in particular in the foothills of this area of study between Lahaul and Middle Kinnaur. In the west in the areas of western Lahaul and towards Kullu and in the east towards Middle Kinnaur, the availability of timber increases. These areas seem to be a transition zone towards stone constructions with an increased content of wooden components. The transition between such zones is gradual and not precisely defined. In general we find regionally determined types of construction with local variations. The stone walls in general are plastered at the inside and in several cases also outside.

The traditional roof construction around Keylong, Spiti and Upper Kinnaur is a flat roof covered with clay, often placed on a layer of birch bark. Exceptions exist, for example, the fortress tower of Gondhla, which is today covered with a slightly inclined roof of stone slates, or the temple of Guru Ganthal, which had a sloping wooden roof in earlier days similar to what we find at wooden temples in Chamba District or at the Hadimba Temple in Manali in Kullu (see Khosla 1979: 92).

4.4.1.a Investigated objects in Eastern Lahaul

Gondhla, Fortress tower

Alt. 3,180 m; 32°30'29.38"N, 77°1'33.76"E. Located about 15 km south of Keylong in Gondhla in the Chandra Valley, it is an eight-storey high fortress tower formerly belonging to the Thakurs (Fig. 4.60). It was founded in app. 1700 CE (cf. Handa 2008a) as a royal residence and watch tower with a shrine upstairs (Bernier 1989: 82).

It is a construction made with rather flat stones in-between a 'ladder'-like construction without the use of vertical wooden elements. This construction is known as *dhol-maide*. Parts of the facade between the *cheol* (which is a local term for the runner beams) still bear plaster. The brown wooden lacings and the bright appearing plaster show a relatively conspicuous linear pattern. The flat stones are an additional factor in stabilising the wall. The stones are set in a clay mortar (ibid. 1989: 82).

In Himachal Pradesh, most fortress towers are placed on a high plinth reinforced with a *dhol-maide* construction (e.g. the fortress tower in Labrang, see below), and the walls in the upper



Fig. 4.60 Gondhla. Lahaul.
Fortress tower.

part typically continue as *kath-kuni* constructions (in Kinnaur also known as *doriyā*¹⁵⁰, Handa 2008b: 145).¹⁵¹ The fortress tower in Gondhla diverges from this typology, since its plinth is rather low and the whole construction follows the *dhol-maide* type. Handa (2001: 184) describes roughly between one and one-and-a half metres of wall thickness for fortress towers. Towers in general may raise up to 45 metres, as shown with the five-storeys-high tower at Chaini (31°37'38.79"N, 77°21'29.60"E), c. 17th/18th century CE (Handa 2001: 188).

In the case of Chaini, the high plinth is made as a *dhol-maide* construction with a height of 15 m (Handa 2008b: 75). The fortress tower in Gondhla, in contrast, does not follow this pattern, since it rises over its full height with a *dhol-maide* construction.

Johling Temple

Johling is a small village located on the left banks of the Bhaga River before reaching Keylong. At this temple, which dates back to the early West Tibetan period (11th century, Luczanits 2004: 68), the walls are rubble stone constructions. Here it is possible to find a few wooden lacings, in particular fixing one corner, but a ring beam was not used. Some of the beams show slits, which points towards their former use within another construction or at another position within this temple. Two runner beams are connected at the corner by a half lap joint.¹⁵²

¹⁵⁰ According to Dave et al. (2013: 67), different other local terms for the *kath-kuni* technique are known: *katth ki kanni* in Sarahan region or *kashth kona* at other places.

¹⁵¹ At the *kath-kuni* construction, as described for the Koti Banal architecture in Uttarakhand, the timber structure was built first and thereafter filled with stones (Rautela, Joshi 2008: 476).

¹⁵² Presented by the author at a lecture at the Vienna University of Technology in January 2011 on "Constructive



Fig. 4.61 Taryul. Lahaul.
Village houses built with stone.

Gumrang Temple

Alt. 3,300 m; 32°34'13.82"N, 77°2'49.59"E. Gumrang is a small village located on the right banks of the Bhaga River before reaching Keylong. At least the lower portion of this temple's walls was made of stones. The upper portion was difficult to investigate due to its irregularly thick plaster and changes due to a possible former repair. The wall thickness of the stone wall is app. 38 cm and was covered by a concrete wall of a similar thickness. No wooden lacing could be found. Around 1973 an avalanche destroyed the early temple of Gumrang (Luczanits 1994: 84) and a new temple was erected. This temple shows the erection of a later concrete wall around the original wall.¹⁵³

Taryul, village houses

Alt. 3,450 m; 32°34'10.69"N, 77°3'45.32"E. Taryul is a small village on the right banks of the Bhaga River above the village of Satingri on the way to Keylong. In this village the walls are traditionally made of stone with wooden 'ladder'-like timber lacing. The thickness of these walls ranges around 45 cm. Recent structures in this village were erected with stone walls without timber lacing, which compared to early structures shows a change towards reducing timber (Fig. 4.61). Khosla (1979: 118) states that clay mortar was not used for the traditional timber-bonded walls since the shear compression held the stones in place. However, for new stone walls, clay mortar is used for levelling instead of timbers. In this village some of the upper walls – most probably for economic reasons and to reduce the load onto the walls below – wattle and daub walls were erected. Wattle constructions are primarily made of willow twigs and plastered at the outside and inside.

Traditions in the Western Himalayas". Analysis of the walls of this temple is based on pictures from the Western Himalaya Archive Vienna. Online: <https://whav.aussereurop.univie.ac.at/ic/4610/#page=1>, access: 06/2016.

¹⁵³ In order to strengthen the original stone structure, a second wall was partially erected in front of the original wall and strengthened with columns of steel concrete.

4.4.2 Spiti

The altitude increases from Lahaul towards the south-east in Spiti. Here, e.g. at the villages Losar and Hansa (alt. 4,000 m) and Kaza (alt. 3,660 m), one enters a traditionally predominated rammed earth region, which also includes adobe brick structures. As described by Khosla (1979: 120), a method of making window and door holes is first to ram the walls without openings, but with the door and window frames already placed in the correct position. After the ramming is finished, the openings are gouged out. At several structures, such as the ruins of the Hikkim Monastery, rammed earth walls and adobe walls were erected beside each other, both on stone plinths.

For rammed earth constructions, saw wood to produce boards for the scaffolding is needed. This need is specific in arid zones, where timber in general is scarce. In this case, wattled mats made of branches – similar to what is used for wattle and daub constructions – were used as shuttering in earlier days (cf. Khosla 1979: Fig. 179). The rods to produce such mats must be flexible and are made primarily from the twigs of the willow tree. The walls of some of the rammed earth buildings follow the method of tapering the outer surface of the wall by reducing its thickness from a thicker base towards a thinner top and reducing the load of the wall towards its top. For the erection of a tapering rammed earth wall, towards the wall's top, the distance between the scaffolding boards is reduced layer by layer. The height determined of the shuttering boards in Dhankar and Sangnam was on average 60 cm.

Besides a predominance of rammed earth constructions as a local tradition, as is the case in the Spiti Valley or the Pin Valley, adobe brick buildings are also present. In this regard we state a relative predominance that may continuously change or has been changed, and we are certainly not talking of an exclusive and pure rammed earth region.

4.4.2.a Investigated objects

Even today, the method of ramming walls is common, as can be observed in Dhankar or Tabo village. Common wall thickness, as observed in Tabo, Dhankar and Sangnam ranges between 35 cm and 45 cm. Besides residential buildings, religious structures were also rammed. Only the very early temples of the West Tibetan empire were exclusively made of adobe bricks. Two structures are given as examples for a later development of an extensive rammed earth building culture: the village temple in Rangrik (appr. data: alt. 3,685 m; 32°15'20.22"N, 78° 1'28.23"E) and a ruined monastery in Hikkim (appr. data: alt. 4,400 m; 32°14'48.01"N, 78° 5'45.47"E).

Rangrik Temple

In Rangrik Village the Old Temple was built as a rammed earth construction. It follows the design concept of a centralised Buddhist temple with an internal circumambulation corridor (Figs. 4.62, 4.63). The rammed earth walls are plastered. As shown with an old village house, the same raw material was used for the rammed earth and for the plaster (see before). The thickness of the rammed earth walls is app. 50 cm.

Hikkim Monastery

At the Hikkim Monastery, of which only remains of walls exist, rammed earth walls were erected along with adobe brick walls at the first floor level. Walls were plastered. Similar to

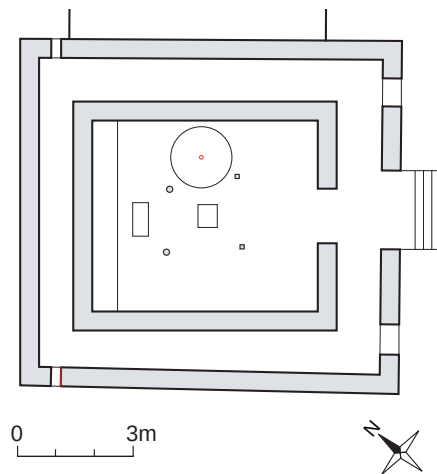


Fig. 4.62 Rangrik. Spiti. Ground plan.



Fig. 4.63 Rangrik. Spiti. Temple walls made of rammed earth.

the results of the material analysis for the old house in Rangrik – as shown with an old house in the surrounding of Hikkim for ramming, brick making and plastering the same raw material was used. Wall thickness of rammed earth walls ranges between app. 40 cm and 50 cm.

Tabo Monastery

Alt. 3,285 m; 32°5'37.27"N, 78°23'2.04"E. Founded in 996 AD, the monastery of Tabo is the oldest known religious architectural structure in Spiti. It was built with adobe bricks. Its walls (thickness at the main temple app. 120 cm) were kept unplastered for nearly 1000 years until renovation work in the 1970s.¹⁵⁴ Still, many of the wall paintings on the interior wall surfaces are well preserved. Photographs of the unplastered walls published by Khosla (1979) show no wooden inlays. On the other hand, according to reports (cf. Luczanits 2004: 263), wooden planks of a thickness of 8 cm to 10 cm were inserted into the adobe brick walls with a vertical distance of app. 1.5 cm to 2 m.¹⁵⁵ The description points towards the existence of timber lacing within the adobe wall structure, and draws a picture of a far uncommon construction in Spiti.

4.4.3 Upper Kinnaur (Hangrang Division) and Middle Kinnaur (Ropa Division)

In Kinnaur in pre-colonial times, under the earlier ancient kingdom of Bashahr, near total control of the forests belonged to the villages (Belz 2012: 64; cf. Bajpai 1981; cf. Cranney 2001). Concerning building material features, Upper Kinnaur is more related to the Spiti and Lahaul region than to the southern regions of Kinnaur. This district is divided into Upper, Middle and

154 A paper titled "Tabo Tsuglagkhang – various aspects of integrative conservation" was presented by the author at an international seminar in January 2014 in Krakow.

155 Since the inner surface of the walls is plastered and mostly painted, the use of timber lacing could only be reconstructed with the help of conservation reports.

Lower Kinnaur, which are again subdivided into the following regional divisions:¹⁵⁶

- Upper Kinnaur: Poo-Namgia, Hangrang
- Middle Kinnaur: Baspa, Sairag and across, Jangram, Upper Tukpa, Sumcho, Ropa
- Lower Kinnaur: Atharabees, Pandrabis-Bhaba, Pagramang-Rajgram

Upper Kinnaur and Ropa, which is the northern division of Middle Kinnaur, are located to the east and south of Spiti. In this northern part of Kinnaur (located at an altitude of 3,000 m and above), the tradition of building with stones is present, similar to Lahaul, but with an even less content of timber. Due to these features, Upper Kinnaur and the northern region of Middle Kinnaur are close to each other and differ from constructions further south. This may be explained by changes in geological characteristics and timber resources. Since river stones were also used for construction, a general tendency towards the use of stones is indicated. The region of Upper Kinnaur shows less precipitation and much lower temperatures, as is the case in lower areas of Middle Kinnaur.

From Upper Kinnaur southwards (towards Middle and Lower Kinnaur) and to the west and south of Lahaul, a change towards an increased use of stone becomes evident. In contrast, Spiti shows an exception with a preference for earth constructions. On the other hand, the amount of wood used for buildings increases in these directions and is used in different composite ways, primarily together with stone. In transitional zones being home of establishments of different building techniques, like in Hangrang in Upper Kinnaur, in Ropa in the northern part of Middle Kinnaur, or in Lahaul, we find pure stone constructions as a traditional way of building. There is a change from Upper Kinnaur to Middle Kinnaur from solid structures of stone and clay towards the use of *dhol-maide* constructions (cf. Handa 2001: 108f.), which resembles the *bhatar* construction in North Pakistan.

A main feature of this construction is the still high amount of stones used in relation to the whole construction as well as the technique of stone laying and the absence of vertical wooden structural wall components. Stone is still not just an infill, but the primary load-bearing material, although the timber components take over important static features of the construction.

4.4.3.a Investigated objects

Nako, village buildings

The village houses of Nako are in most cases either pure stone constructions of quarried stone, or the ground floor is stone and the upper floor constructed of adobe bricks. The use of wooden bracings is uncommon.

Nako, temple compound

Alt. 3,628 m; 31°52'53.88"N, 78°37'33.80"E. Contrary to the stone building tradition of the village houses, the four temples of the temple compound are all built with adobe bricks. The two earliest temples of this compound are the Lotsāba Temple, which is dated to the first decades of the 12th century, and the Upper Temple, which at the earliest is dated to the middle of the 12th century (Luczanits 2004: 84, 88). The thickness of the walls of these two temples is app. 80 cm. At some parts of the facade of these two temples, 'simple' timber lacings, but no



Fig. 4.64 Nako. Wooden bracket.

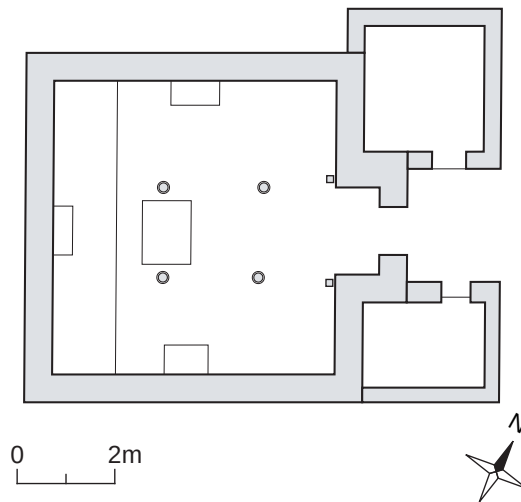


Fig. 4.65 Chulling. Temple. Ground plan.

‘ladder’-like construction could be traced. At the northern corner of the Upper Temple (front left corner with view towards the temple), a wooden bracket was used to keep the lacing in position (Fig. 4.64). The random stone structures with the use of a ‘simple’ timber lacing resemble stone constructions, for example, in Lahaul as found at the Johling Temple. In general, this approach seems to be related primarily to a stone building tradition. The use of clay as a building material within a region, which is today shaped by a stone building culture, may either refer to a change of a building tradition in the past or to the establishment of a doctrinal ideology, by which the use of adobe bricks may have been favoured for early West Tibetan structures (see 4.4.3.b below).

Chulling Temple

Alt. 3,200 m. The village-temple in Chulling in Hangrang is made as a random stone structure similar to the temples in Johling with no wooden lacing found (Fig. 4.65). At the example of Chulling in Upper Kinnaur, the stones used have a rounded shape, probably from the river nearby, while at the Johling example, quarry stones were used. At both constructions no mortar was found between the stones.¹⁵⁷ The technique of using round-shaped stones correlates with the simplicity of the geometry of the ground plan.

156 The partition of Kinnaur into three internal regions, Upper, Middle and Lower Kinnaur, follows the systematisation given by Sanan and Swadi 1998:18–20, 107, 108.

157 Presented by the author at a lecture at the Vienna University of Technology in January 2011 on “Constructive Traditions in the Western Himalayas”.

Ropa, Lotsāba Temple

Alt. 3,030 m; 31°47'47.59"N, 78°25'15.69"E. In the case of the Lotsāba Temple in Ropa (Figs. 4.66, 4.67; 10th or 11th century CE, Luczanits 2004: 62), the 'simple' timber lacing as found in the temples of Nako changes into a 'ladder'-like construction known as "*dhol-maide*"¹⁵⁸. App. 15 km further west from Chulling and about 140 m below the Lotsāba Temple of Ropa, a change in construction occurs, similar to what was observed for the change from Lahaul towards western and southern located lower areas. The mentioned construction in Ropa, which is still primarily a solid structure with wooden lacing, already shows a clear tendency towards the increasing use of timber and a related increasing share of wooden components in the construction. Wooden components exist not only as reduced to 'simple' timber lacing, as we know from the temples of Nako, but as successively approaching a distinct structural and load bearing body.

The stone wall of this *dhol-maide* construction with a width of app. 70 cm is built in vertical segments, with each segment having a height of about 50 cm to 90 cm. To hold the runner beams in position, wooden cross-pieces are alternately placed below and on top of the runner beams with a horizontal distance of about 1.5 m to 2 m. This technique increases the stabilising efficiency of the *dhol-maide*. The method of joining runner beams and cross-pieces varies locally and even among single objects within the same village.

In order to reconstruct the process of construction, the first layer of cross-pieces is laid across the wall with a certain protrusion that is to be later used to fix the beams with a lap joint to the runner beams. The space between the cross-pieces is filled with stones. After bringing the runner beams into position on top of the first layer of cross-pieces, the space between the runner beams is filled with stones. Thereafter, the second layer of cross-pieces is placed on top of the runner beams, again with a certain protrusion, and joined to them with lap joints. The horizontal position of this second layers of cross-pieces is between the cross-pieces of the first layer.

In the case of Ropa, the profile of these cross-pieces is rectangular. As shown at examples in Ladakh (see above), the wooden cross-pieces may also be round, pointing towards a simpler version with less availability of cutting timber. However, in regard to the static system, they show a similar function. The runner beams are always cut and treated carefully regarding size, dimension and straight growth.

In the case that the wall is longer than the average length of beams – which in the Himalayan zone is about four metres – the beams have to be joined. In the case of Ropa, this joining was conducted by half lap joints. Also at the *cator and cribbage* structures as shown by Hughes (2000a: Fig. 1) or at the *kath-kuni* structures as shown by Rautela and Joshi (2008: 477), maximum length is given with four metres. Special care is given to the corners with larger stones used along the wall. At the corners the crossing 'ladders' are supported by a piece of a beam of a length slightly more than the width of the wall. This corner piece keeps the top beams in a levelled position.

158 The system of a *dhol-maide* (= *bhatar*) construction is depicted in Fig. 4.47.



Fig. 4.66 Ropa. Lotsāba Lhakhang. South-east corner.

Dhol-maide construction. The detail shows a strengthening of the corners by supporting the *cheol* (1) with wooden beams (2).

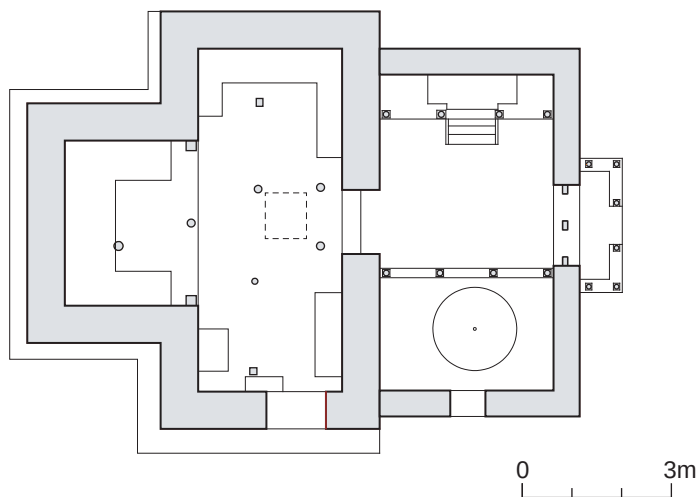


Fig. 4.67 Ropa. Lotsāba Lhakhang. Ground plan.

The stone wall of the *dhol-maide* construction traditionally remains unplastered. In the case of the Ropa Temple, even after app. 900 years, precipitation is not to such an extent that the wooden construction is rotting. Since the outer walls are plastered only inside, the unplastered facade supports air circulation within the walls and drains water inside the walls to the outside. Further, dampness is easily moved from the inside towards the outside due to the open construction caused by a plurality of gaps between the stones.

Compared to solid and plastered walls, at timber frame buildings the amount of building moisture is quite minimal and the drying time short (cf. Künzle 2014: 31). A similar idea may be behind keeping the outside walls unplastered. Clay mortar as it is used at the Ropa Temple is in general permeable to water vapour. Air circulation by openings and air leakiness of the walls support the drying process. A quickly drying wall is necessary so as to not affect the plaster and the wall paintings on the inner surfaces of the wall.

4.4.3.b Construction of early West Tibetan monasteries for comparison

Since with early Buddhist temples in Tabo and Nako a close relation to early West Tibetan structures is given, before moving further to southern regions in Kinnaur, the significance of adobe bricks for the earliest West Tibetan monasteries is discussed (see Map 1.2 in Chapter I). This concerns the following monasteries: Nyarma in Ladakh (alt. 3,264 m; 34°2'21.96"N, 77°41'2.27"E), Tabo in Spiti (alt. 3,285 m; 32°5'37.19"N, 78°22'55.43"E), Nako in Upper Kinnaur (alt. 3,628 m; 31°52'53.88"N, 78°37'33.80"E), Tholing in West Tibet (alt. 3,730 m; 31°28'59.51"N, 79°47'50.31"E) and Khorchag in Purang in Tibet (3,721 m; 30°11'47.28"N, 81°16'4.66"E). From Kinnaur along the Sutlej towards the east into Ngari (West Tibet), we find the early historical West Tibetan centre of Tholing. Here the altitude increases and an arid zone is present. Further, in an easterly direction into Purang, we find Khorchag (app. 3,730 m), another early West Tibetan centre. The whole area shows a predominance of earth construction. Today, clay is the predominant building material. These monastic centres are located at an altitude between 3,264 m and 3,730 m. In Purang, the annual average precipitation is slightly higher compared to Spiti and Upper Kinnaur, while the annual average temperature is similar. Due to the influence of the monsoon, precipitation in this area is much higher than in Leh.

At several of these sites, we find the original constructions of the early religious structures embedded in an environment of different technical developments:

- Today, Nyarma (main temple founded in 996 CE) is embedded in a region of adobe tradition, though the fortress erected on top of a rock in the north of the monastery compound and also some *stupas* within the compound show the remains of a stone building tradition. All five temples of the monastery were erected with adobe bricks and just one wall shows a notch in the wall, which may point to a former timber lacing (see Fig. 4.31).
- In the case of Tabo Monastery (main temple founded in 996 CE), all temples were built with adobe bricks within a region partially dominated by rammed earth constructions. According to renovation reports, timber lacing was used (Luczanits 2004: 263).
- Today, moving further east from Tabo towards Nako in Upper Kinnaur, stone constructions are predominant within the village. Contrary to current local tradition, all temples within the temple compound were not erected in stone but rather in adobe with partial wooden bracing using lap joints and wooden pegs.
- Further east, the cores of the main temples of the monasteries of Tholing and Khorchag in West Tibet (main temples founded in 996 CE) show an adobe brick construction. Khorchag is located close to the Nepalese border in the east of the Western Himalayas with closer access to timber. Today, villagers report of former transports of wood from Nepal up into the arid zone of Purang. At Nyarma, Tabo, Nako and Tholing, access to timber in surrounding regions means a high effort of transport.
- In the Khorchag Monastery, the central core of the two temples, Lhakhang Chenmo and Jokhang, was erected with adobe bricks, while later additions were built as rammed earth walls on the ground floor. These rammed earth walls were again topped with adobe bricks to reduce the load of the wall and minimise transport effort of building material onto the upper floor. In this temple, adobe bricks with wooden bracing are found at the rear side of the Maitreya Lhakhang – the earliest part of the monastery (cf. Feiglstorfer 2017a). According to written sources, the decision to extend the monastery with rammed earth constructions may have resulted from flooding, which endangered the monastery, particularly its sacred core (ibid.). Reasons for a traditional use of rammed earth versus adobe

bricks are potentially various, such as the availability of the proper clay for adobe bricks, the need for a defensive structure against enemies, flooding as a natural catastrophe or quick processing of the clay without a preceding time-consuming drying process. The need for a certain form of representation could also have been a reason for the decision in the choice between rammed earth and adobe bricks. A rammed earth construction has a dominant and fortress-like appearance, in particular with tapering walls.

- The selection of one of the two building methods (rammed earth or adobe bricks) is related to the availability of a proper quality of clay.¹⁵⁹ In the case of the availability of coarse clay with a content of just a few clay minerals as binders, the material is appropriate for the use of rammed earth constructions. In the opposite case, where finer material with a higher content of clay minerals is available, the production of adobe bricks would be a consequence. Also the content of calcite reduces the strength of the clay, which is the case, for example, in the regionally available clay in Spiti (see Table 4.5 in the Appendix of Chapter IV).

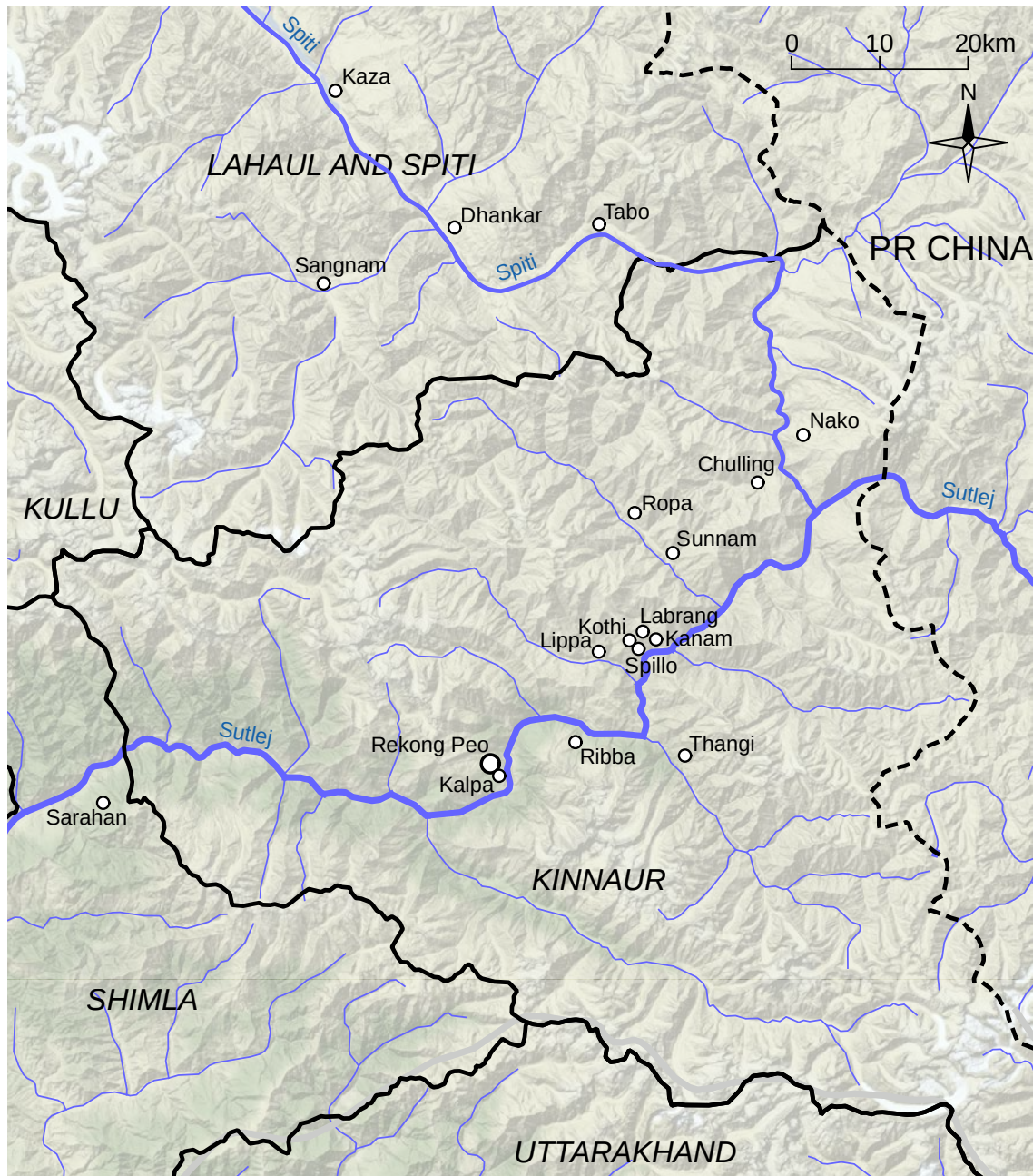
It becomes obvious that over the distance of about 500 km, main temples of early monasteries of the West Tibetan kingdom under Lama Yeshe Ö (late 10th century CE), namely Nyarma, Khorchag, Tholing and Tabo, were all built with adobe bricks – partially contradicting earlier or later regional developments. This seems not to have been a coincidence, but was most probably part of a general concept also concerning layout and construction of the main temples of these compounds. The layout of the temples is related to a geometrical and proportional pattern. For the precise realisation of such concepts, adobe bricks seem to be an appropriate building material. The use of adobe bricks was also appropriate for keeping a certain accurate precision in building right angles, and in keeping the walls straight and of a relatively consistent thickness, i.e. with a thickness reaching up to 130 cm (for example, at Temple II in Nyarma; cf. Feiglstorfer 2011b).

4.4.4 Middle Kinnaur (Sairag, Jangram, Upper Tukpa, Sumcho)

Districts/regions:	Places:
· Sairag and across	Rekong Peo (alt. 2,420 m), Kalpa (alt. 2,760 m), Kothi (alt. 2,450 m)
· Jangram	Lippa (alt. 2,700 m)
· Upper Tukpa	Ribba (alt. 2,720 m), Thangi (alt. 2,820 m)
· Sumcho	Labrang (alt. 3,000 m), Kanam (alt. 2,800 m), Spillo (alt. 2,400 m), Karla (alt. 2,780 m)

From Nako in Upper Kinnaur towards Middle Kinnaur in the south and along the Sutlej towards Shimla District, the altitude decreases continuously (Map 4.8), correlating with an increase in the use of timber. In Nako in Upper Kinnaur compared to Spillo in Middle Kinnaur, the average annual temperature decreases from 12.2°C to 4.8°C in Nako. Also annual precipitation increases, and the difference between minimum and maximum temperature decreases. The amount of snow is higher than in Upper Kinnaur. Towards Rampur (alt. 970 m), these differences obviously increase.

¹⁵⁹ Important factors for easy availability are criteria like less effort in digging and short ways of transport.



Map 4.8 Sites related to Kinnaur and Spiti.

GIS data based map: Jakob Gredler. Final graphics: author. Map based on data from Vector data (VD) and Basemaps (BM). Citations of VD and BM also see: Chapter IX, list of illustrations.

A traditional roof construction in Middle Kinnaur is a flat roof covered with clay, often on a layer of birch bark (Fig. 4.68). Several residential and also temple structures, e.g. around Rekong Peo or the temples of Kothi, have slate roofs (Fig. 4.69), and a few buildings, like the central temple of the monastery in Labrang or a roof over the central *stupa* of a *stupa* ensemble in Karla, are covered with a steep roof with wooden slats (Fig. 4.70). As an example, the sixth floor of the fortress tower at Labrang was covered with a pitched wooden roof, before the top floor was removed, and the fifth floor was covered with a flat roof (Negi Loktus 2015: 318).

The Bhīmā Kālī Temple in Sarahan in Shimla District follows a similar slate covered roof pattern. With a decreasing altitude towards lower regions of Rampur and increasing precipitation, the traditional sloping roofs become more common. Using wood for covering the most holy part of a shrine or temple is said to be an old tradition (Handa 2001: 111). This may be the reason that, for example, in Middle Kinnaur, such wooden roof coverings appear in regions, where slate is commonly used to cover inclining roofs. According to Belz (2012: 164, 167), in Kinnaur slate has been used as a roofing material since the 1920s, and even more commonly starting in the 1930s after flat roofs, as the ancient roof type, were partially replaced by pitched wooden slats.

4.4.4.a From *dhol-maide* to *kath-kuni*

Moving further south in Middle Kinnaur along the Sutlej Valley, the amount of timber within stone-timber composite constructions increases and the structural timber elements become statically more relevant as autonomous constructions within the whole composite compound. The timber components are not just reduced to wooden horizontal layers, as we know from a *dhol-maide* construction, but increasingly more wooden components are introduced primarily at the corners. For the *kath-kuni* technique, beams are placed within a smaller vertical distance (in general the height of one beam) to each other (Fig. 4.71). The wooden framework (known as *cheol*) is either filled with stone or rubble masonry. *Kath-kuni* refers to all the corners made of wood (Handa 2001: 108). This meaning points to a change from the ‘simple’ timber lacing via the *dhol-maide* construction towards the *kath-kuni* construction. Within these gradual variation from ‘simple’ lacing towards the *kath-kuni* composite system, stone takes over the position of an infill material. An important factor of stone infill is the stabilisation of the whole construction in that the stone keeps the timber components in position. Their mass is a factor for the stabilisation of the elastic timber construction. Equally tight placing of stones and timber decreases the possibility of later movement of parts of the construction, and keeps the construction flexible in the case of structural movements, caused, for example, by earthquakes.

The resulting construction equals the *cator* and *cribbage* technique as already described for North Pakistan. An average length of residential *kath-kuni* structures ranges between 4 m and 8 m (Dave et al. 2013: 75), which is similar to the average length given for runner beams at *cator* and *cribbage* constructions (cf. Hughes 2000a). The average width of *kath-kuni* walls ranges between 50 cm and 60 cm (Dave et al. 2013: 75). The layer of stone is locally known as *mait* (Handa 2008b: 145). Fixing the runner beams with cross-pieces, which is known as being dove-tailed,¹⁶⁰ is an option to keep the beams in position (Thakur 1996: 30; Handa 2001:108). The horizontal timber components of the *cator* in many cases remain unplastered and give the wall a horizontally striped appearance.

160 Local term for cross braces or dove tail is *maanvi* (Dave et al. 2013: 73).



Fig. 4.68 (Top) Labrang. Middle Kinnaur. View over the flat roofs.

Fig. 4.69 (Bottom, left) Kalpa. Middle Kinnaur. Slate covered roof.

Fig. 4.70 (Bottom, right) Karla. Middle Kinnaur. Wooden slat covered roof.



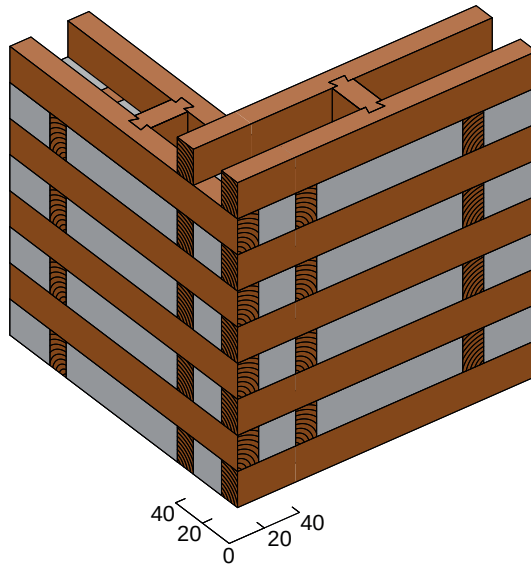


Fig. 4.71 System of a *kath-kuni* construction.

CAD: Martin Pospichal. Acc. to: Handa 2001: 109. Details provided by the author.

4.4.4.b Farque

For the vertical 'column'-like members of the *cribbage*, either squared timber or thick planks are piled upon each other, with each layer rotated by 90° (Fig. 4.72). In Chamba, this technique is known as *farque* (Handa 2001: 108). The single wooden pieces, which are laid as facing pairs at each layer, are known as *thathar* (Handa 2008b: 101). This technique can also be found in Kinnaur as a subordinate type of construction.

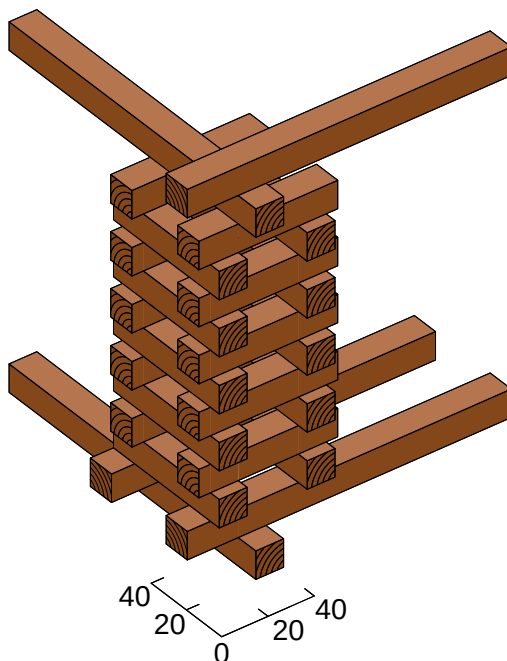


Fig. 4.72 System of a *farque* construction.

CAD: Martin Pospichal. Details provided by the author.

4.4.4.c *Dhajji-dewari*

Another technique, which is compared to *kath-kuni* rarely used in Kinnaur, is the so-called “*dhajji-dewari*” (see Fig. 4.54). This technique is mainly found in Kashmir or North Pakistan, though several examples can also be found in Himachal Pradesh, e.g. in Kanam in Kinnaur. In Kinnaur, this technique plays a subordinate role. The type of *dhajji-dewari* wall as it is shown in Kanam (see Fig. 4.86) consists of a wooden frame structure (foundation beam, roof beam, square-shaped pillars) divided into smaller frames by horizontal boards and diagonally placed boards. The amount of wood is high, but the dimension of the single wooden pieces is small.

4.4.4.d *Observed objects in Middle Kinnaur*

Karla, village

Alt. 2,780 m; 31°39'57.62"N, 78°26'4.26"E. Karla is a small village located north of Spillo. Several examples show the diversity of constructions to be found in this village. Close to the village temple, there is a *stupa* group covered by a roof supported by pillars, which follow a *kath-kuni* technique. At the front the supporting construction is made with pillars following the *farque* technique, but without stone infill. This example shows the timber construction as the primary load-bearing component of a *farque* construction (Fig. 4.73). The stone walls of the village temple in Karla follow the *kath-kuni* technique (Fig. 4.74). An old decayed house beside the temple shows a similar construction technique, but the content of timber is reduced to a *dhhol-maide* construction (Fig. 4.75). In the latter example, two different techniques (*kath-kuni* and *dhhol-maide*) are located beside each other.

Labrang, Fortress tower

Alt. 2,865 m; 31°40'44.45"N, 78°26'26.45"E. Labrang is a village close to Spillo located opposite to the village Kanam (Fig. 4.76). Its monastery is located at a higher altitude of app. 3,000 m. The village stretches downwards below the monastery to an altitude of app. 2,830 m. A fortress tower is located in the south-western section of the village. Since Capt. Gerard did not mention this fort after his stay at Kanam and Labrang in 1818, its existence at this early time is doubtful (Negi Loktus 2015: 312). Above the third *cheol* located in the plinth, the tower raises with a *kath-kuni* construction (Fig. 4.77). The beams of the *kath-kuni* portion of the tower are of a height of two layers of stone. The wooden structure of each facade is formed by layerwise piling up runner beams and cross-pieces and interlacing the runner beams at the corners. Structurally, this arrangement forms a column-like reinforcement at each facade's corners (1) and centre (2) (see numbers given in Fig. 4.77), the latter dividing each facade into two symmetrical parts. Each of these two symmetrical parts is structurally again divided into two parts by the placement of wooden cross-pieces between the runner beams (see number 3 in Fig. 4.77). Since the cross-pieces are not connected by lap joints it can be assumed that they are fixed with wooden pegs (locally known as *kadil*, Dave et al. 2013: 75) to the facing beams. The basement of this five-storey tower, which had six storeys in earlier days (Negi Loktus 2015: 317), is a *dhhol-maide* construction (Fig. 4.78). The heads of the outside facing runner beams of some *cheol* of the *dhhol-maide* construction decoratively protrude from the wall (number 1 in Fig. 4.78). *Cheol* meeting at one corner are vertically offset to each other. Following this offset, cross-pieces are located either below or on top of the runner beam (number 2 in Fig. 4.78). The stones are in general rather flat and carefully dressed. The corner stones are bigger in size. The height of the beams equals the height of two to four layers of stone.



Fig. 4.73 Karla.
Farque construction.



Fig. 4.74 Karla.
In the picture left:
kath-kuni construction (1).



Fig. 4.75 Karla.
In the picture left:
dhol-maide construction (1).
In the picture right (in ruins):
kath-kuni construction (2).



Fig. 4.76 (Top, left) Labrang. Fortress tower.

Fig. 4.77 (Top, right) Labrang. Fortress tower.

Kath-kuni construction.

1, 2 = Groups of runner beams and cross-pieces;

3 = Single cross-pieces.

Fig. 4.78 (Bottom, left) Labrang. Fortress tower.

Dhol-maide construction.

Fig. 4.79 (Bottom, right) Labrang. Village house.

End of a *kath-kuni* wall.



Labrang, village and Old Monastery

Village houses (alt. 2,830 m to 3,020 m) show stone walls of the two types as already described for the Karla Temple (see Figs. 4.74, 4.75) – one type defined by the *kath-kuni* technique and the other by the *dhol-maide* technique. The stones are dressed, but not as precisely as shown at the Labrang Fortress tower, underlining a particular status of the given workmanship. One example shows beams equalling the height of two layers of stone. Ends of open walls are covered with panels (or beams), which are reminiscent of a *farque* construction (Fig. 4.79). Parts of the Old Monastery also follow this technique, though thick layers of whitewash and plaster make it hard to make definite statements about the technique used. This type of *kath-kuni* with rather high beams used as cross-pieces and for the closing of wall fronts is common at various other places, for example at Lippa, which is located app. 5 km west of Spillo.

Thangi, village and temple compound

Alt. 2,755 m; 31°33'16.70"N, 78°28'45.84"E. Thangi is a village located on the right banks of the Tedong Valley, which is a side valley of the Sutlej Valley, app. 12 km south of Spillo. Already the entrance gate to the village follows a timber lacing tradition. It is a kind of *dhol-maide* construction with wooden boards closing the open facing ends of the wall between the single *cheol*, similar to the construction from Labrang in Fig. 4.79 but using well-dressed stones. The wall thickness was measured with 41 cm. At 11 x 13 cm (W/H), the timbers are app. square with a vertical distance of 35 cm to 40 cm from each other.

The solid core of village houses (Fig. 4.80) as well as the way the window frames were mounted is close to the technique and precision used at the Labrang Fortress tower. The height of the beams equals the height of several (often two) stone layers (see number 1 in Fig. 4.80). For closing the *cheol* at the corners, various methods were developed: One method that can be found at simple village residential buildings or stables, was already shown for Labrang in Fig. 4.79 by using high wooden boards or beams of the length of the wall thickness. Another method found at *kath-kuni* structures is that the runner beams within the *cheol*, which face inwards, are not of full height filling the vertical interspace between the runner beams (see number 2 in Fig. 4.80). Some of these lower beams are covered with one layer of stones or are laid on top of a layer of stones so as to save wood. Another method is to close the end of a *cheol* with a beam placed between the two runner beams (see number 1 in Fig. 4.81). In this case stones are not visible at the *cheol's* end.

At the temples of Thangi, several layers of stone fill the vertical space between the *cheol* (Fig. 4.82). Since this space is too high to be filled by one beam, a further supporting piece of wood was introduced below each corner crossing of two *cheol* (number 1 in Fig. 4.82). The wall thickness is app. 47 cm. The runner beams are up to 18 cm in height, and the vertical distance between them is also app. 47 cm.

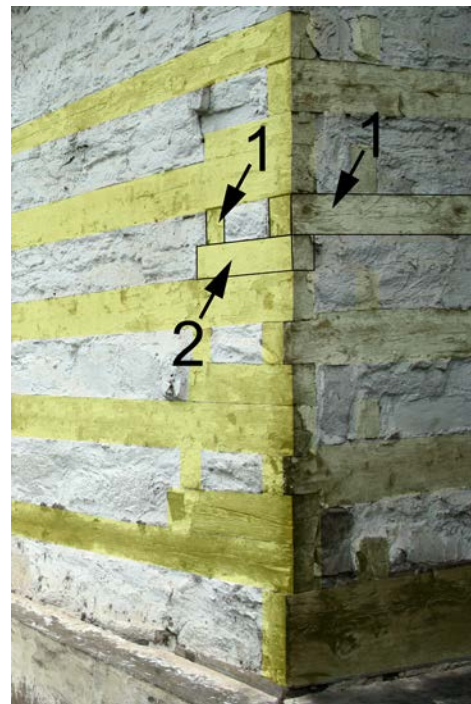
Columns to hold the roof of stables are made as *farque* constructions, not filled with stones, similar as shown at Karla in Fig. 4.73.



Fig. 4.80 (Top) Thangi. Middle Kinnaur. Verandas attached to the *kath-kuni* core of the building.

Fig. 4.81 (Bottom, left) Thangi. A beam fills the interspace between the runner beams.

Fig. 4.82 (Bottom, right) Thangi. Supporting piece (1) of wood below each corner crossing of two *cheol* (2).



4.4.4.e *Koti banal (Uttarakhand) for comparison*

With a height of up to five storeys, structures in the Yamuna Valley in the Rajgarhi region of Uttarkashi show similarities in shape and building techniques to structures found in several villages of Kinnaur, e.g. in Thangi. As reported by Handa (2008a: 81), in most of the regions of Uttarakhand, the *kath-kuni* wall type is notably uncommon. This type of construction in this region may refer back to app. 1,000 years ago (Rautela, Joshi 2008; Rautela et al. 2008). In Thangi, some parts within one construction may show the use of clay mortar, while other parts appear dry-packed. For this technique at Koti banal (as an example besides other places like Dakhiyatgaon, Guna or Dharali), the use of a paste made of pulses (lentils) as mortar is reported (Rautela et al. 2008). At residential structures in Thangi, wall thickness is between app. 40 cm to 50 cm. Koti banal structures have a wall thickness of app. 50 cm to 60 cm (ibid.). At these structures, a difference to the *kath-kuni* in Kinnaur is the use of wall brackets (also known as shear keys). For a Koti banal construction, the use of lap and nailed joints is documented (Rautela, Joshi 2008: 478).

Kanam, village and temples

Alt. 2,680 m to 2,840 m; 31°40'33.32"N, 78°27'8.93"E. Compared to Labrang, a bigger variety of techniques was found in Kanam. Early residential structures (*khyum*) built of wood and stone go back more than 250 years (ibid. 45, 323). The following examples show a variety of different constructions in this village.

Kath-kuni and *dhol-maide* are commonly used in Kanam. The Palden Lhundup Gephel Monastery (locally known as “Khache Lhakhang”) is situated within a courtyard surrounded by a timber-laced structure, where the vertical interspace between the *cheol* is raised by one or more additional wooden cross-pieces placed at the corners and with a length of the thickness of the wall (number 1 in Fig. 4.83). This method of closing the corner with wooden beams is also shown with an example of a residential structure (Fig. 4.84). At the Kangyur Lhakhang, a *dhol-maide* construction was erected with runner beams of a vertical distance of 80 cm without closing the corners with wooden elements (Fig. 4.85). The wooden cross-pieces (round and square-shaped) were connected with lap joints and alternatingly laid below and on top of the facing beams (number 1 in Fig. 4.85).

A small residential structure was attached to the Kangyur Lhakhang (Fig. 4.86). Walls were built with the *dhaji-dewari* technique on a stone plinth of a height of app. 80 cm above ground level. Wooden pillars were placed at a distance of app. 80 cm on a foundation beam with a beam on top to carry the roof. Each field between these pillars was vertically divided into three smaller fields by horizontal boards, which were fixed with notches in the pillars. In these rectangular frames, two crosswise placed boards diagonally fit into each other. The space in-between the boards is filled with dressed stones and clay mortar. The space between the pillars is partially also used to integrate door and window frames. From a static point of view, the crosswise position of the boards in-between horizontal and vertical elements strengthens the wall against horizontal forces as a kind of ‘wind bracing’. The horizontal timbers keep the construction from falling apart. The *dhaji-dewari* construction can be categorised as ‘restrained’ masonry, pointing to the use of a soft mortar (cf. Langenbach 1989: 24, fn. 22). Wood and stone structures are in general multi-storey with a maximum of three storeys (Negi Loktus 2015: 323).



Fig. 4.83 (Top) Kanam, Middle Kinnaur. Palden Lhundup Gephel Monastery.

Fig. 4.84 (Bottom, left) Kanam, Village house. Timber-laced structure with corners strengthened by additional wooden beams.

Fig. 4.85 (Bottom, right) Kanam, Kangyur Lhakhang. *Dhol-maide* construction.

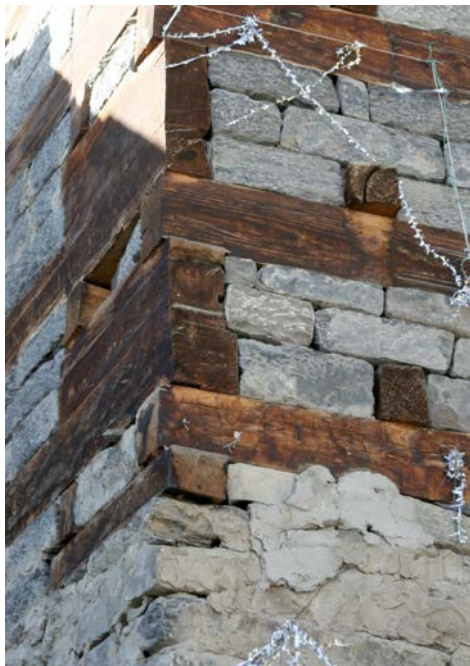




Fig. 4.86 (Left) Kanam. *Dhajji-dewari* structure attached to the Kangyur Lhakhang.

Fig. 4.87 (Right) Kalpa. *Dhajji-dewari* structure on the upper floor of a village house. See arrow.

Kalpa

Alt. 2,760 m; 31°31'53.00"N, 78°15'7.49"E. Kalpa is a hamlet in the close vicinity of Rekong Peo. *Kath-kuni* constructions are traditionally predominant. Some walls are made as *dhajji-dewari*, e.g. as lighter constructions on the second floor of a residential building (Fig. 4.87). The use of *dhajji-dewari* in Kinnaur is in general subordinate to *kath-kuni* constructions. However, for several buildings this technique was also used in this district – similar to the Shimla District located further west, for example, in Sainj according to a drawing given in Dave et al. (2013: 132).

At the ruin of a residential structure, which was made as a *kath-kuni* construction, facing beams (11–14 x 16 cm; W/H) with a height of two layers of stone were documented (Figs. 4.88, 4.89, 4.90). The width of a wall is between 38 cm and 42 cm. The filling between the beams is rubble stone, and ends with a dressed stone.

Ribba Lotsāba Lhakhang (*Translator's Temple*)

Alt. 2,720 m; 31°34'42.27"N, 78°21'21.06"E. Ribba is a small village on top of the hill along the left bank of the Sutlej River. The Lotsāba Lhakhang was located in a small forest glade with a good view upstream into the river valley. Its foundation can be dated back to the 9th/early 10th century (cf. Klimburg-Salter 2002: 21; Luczanits 1996: 71). In 2006, the author documented the structure of this temple. Unfortunately, it burned down later in the same year. It showed a type of *kath-kuni* construction in a decorative manner – contrary to the commonly simple structural appearance of a *kath-kuni* construction – by using beams protruding from the outer surface of the wall and painting their front black; the rest of the facade was painted white. Just the pillars, window facings and window frames were kept red. A thick layer of whitewash covered the whole facade, while the inside was plastered (Fig. 4.91).



Fig. 4.88 Kalpa. Ruin of a *kath-kuni* village house.



Fig. 4.89 Kalpa. Interior of the *kath-kuni* wall between the runner beams is filled with rubble stone.



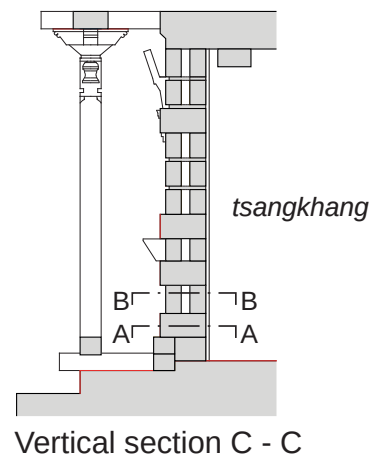
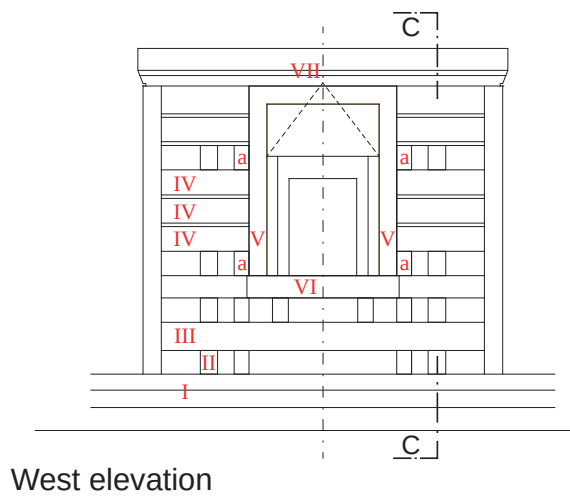
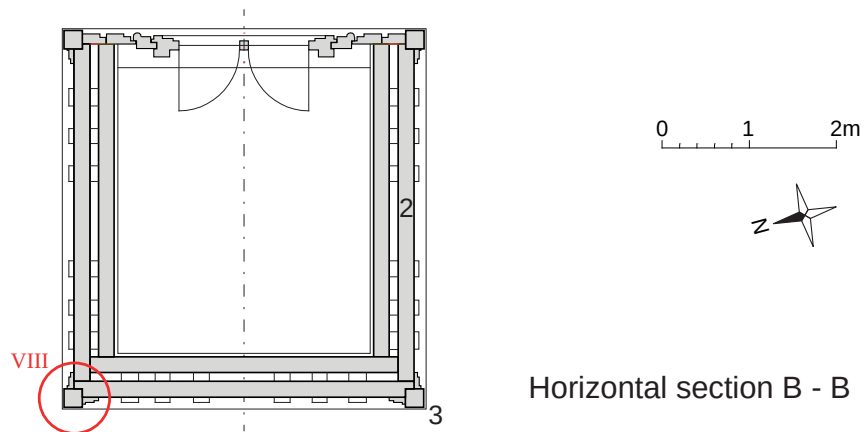
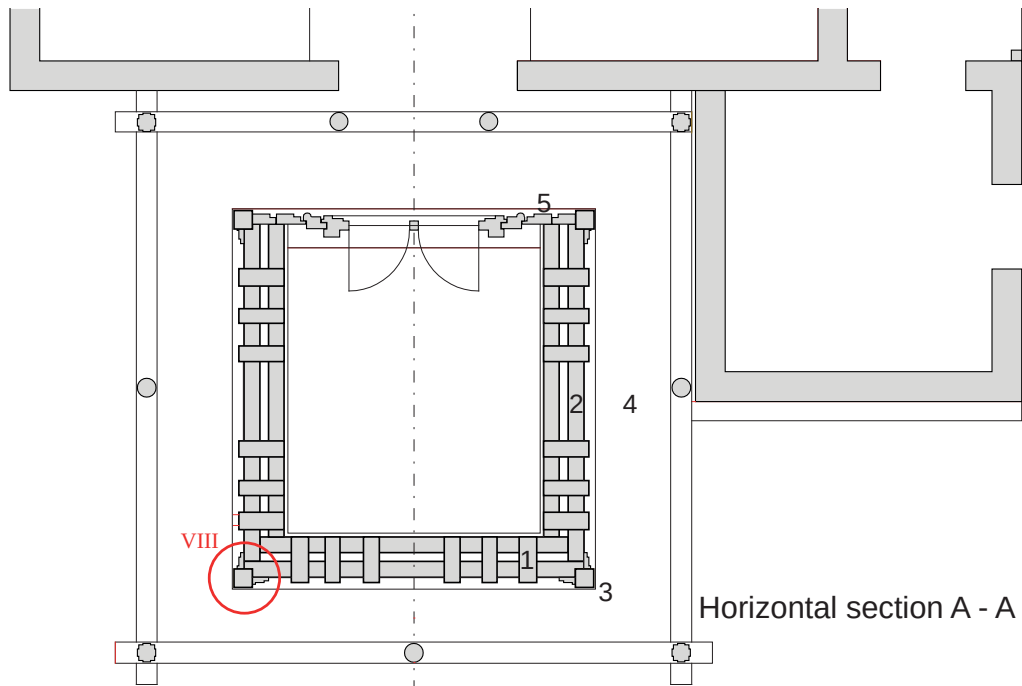
Fig. 4.90 Kalpa. Connection of the floor beams to the *kath-kuni* wall structure.



Fig. 4.91 Ribba. Middle Kinnaur. North facade.

The door entrance was a wooden panel construction. The ground plan of the *garbhagrha* was app. square with an interior length of the rear wall of 295 cm and an exterior length of app. 390 cm. The wall thickness was app. 47 cm (measured without protrusion of the cross-pieces). The height of the wall measured at its outside app. 4 m (rear wall), at its inside app. 355 cm (Fig. 4.92). Reconstructing the process of construction (from bottom to top), *cheol* were put in position as a plinth layer (see number (I) in the West elevation of Fig. 4.92). In the next layer, cross-pieces (II), which protrude from the outer surface of the wall, were placed on top of the *cheol* and were flush mounted to the inside for later interior plastering. The interspace between these cross-pieces, probably filled with wood, was plastered and whitewashed. A pair of outwardly and inwardly facing runner beams (III) was again laid on top of this layer of cross-pieces, and so on. After the third layer of cross-pieces, the following three layers of runner beams (IV) show carved ornaments. The carved window frame (V) was made as part of the wall construction and fixed between cross-pieces (a) and the heads of runner beams (IV). The window frame at its bottom was connected to the window board (VI). At its top, the window frame was connected to a carved beam, which acted as lintel (VII). The gap between the runner beams at the corner junctions was covered by a corner pillar and adjoining wooden pilaster strips (see number (VIII) in horizontal sections A-A and B-B in Fig. 4.92).

The *kath-kuni* construction at Ribba used timber to a high extent. The roof at the time of survey was a flat roof construction with a covering metal sheet tent roof. Its wooden subconstruction pointed towards a former wooden tent construction, hypothetically covered with wooden shingles as is traditionally common in this region, compared, for example, with the temples in Sunnam or Karla.



4.5 Shimla District (Rampur Division)

Sarahan, Bhīmā Kālī Temple

Alt. 2,170 m; 31°30'37.18"N, 77°47'43.15"E. Sarahan is a village embedded in deodar forests. The stones within the *kath-kuni* structure are well dressed. Like in the fortress tower of Labrang (see Fig. 4.77), the high precision of construction has to be emphasised and points towards a way of representing elite status. The front of the stones is precisely flush mounted with the timber construction. As visible at the ends of the *cheol*, the interspace between the runner beams is filled with two further beams – similar to constructions at Thangi (see Fig. 4.81) or at Labrang (see Fig. 4.77). Thus, in a front view there are visible four beams laid beside each other and no further filling material. Lap joints connecting runner beams overlap app. 40 cm.

4.6 Kullu, western Lahaul and Chamba

This part concerns composite wall constructions in the districts Kullu (village of Manali, alt. 1,950 m), western Lahaul (village of Udaipur, alt. 2,650 m) and Chamba (village of Purthi, alt. 2,460 m; Chamba Town, alt. 950 m). The elevation difference ranges at app. 1,700 m and separates this region into different zones regarding availability of particular types of timber and climate conditions. Kangra towards the south continues at low altitude, while towards Zangskar in the north and Lahaul in the east, altitudes increase.

Regarding climate data, Manali in Kullu compared to Spillo in Kinnaur (alt. 2,400 m) shows a higher annual average temperature (15.1°C versus 12.2°C) and about 2.5 times the amount of annual precipitation (1,972 mm versus 710 mm). At 379 mm, the difference between minimum and maximum precipitation during one year in Manali is relatively high compared to the surrounding places: Udaipur in Lahaul with 122 mm, Spillo in Kinnaur with 89 mm and Purthi in Chamba with 157 mm. Places within Chamba District like Chamba Town and Bharmour show higher differences, with 454 mm and 588 mm, respectively. In the whole region, snowfall can be strong. The difference in the annual average temperature between Manali in Kullu and Udaipur in Lahaul with 9.4°C is wider than compared to Spillo in Kinnaur. On the other hand, at 1,057 mm, the difference concerning the annual precipitation in Udaipur is less compared to Purthi and Chamba Town in Chamba District, and Bharmour and Manali in Kullu. Comparing Udaipur in Lahaul and Purthi in Chamba, at app. 2°C the annual average temperature in Udaipur is slightly less and the

Fig. 4.92 Ribba. (Opposite page) Lotsāba Lhakhang. *Kath-kuni* construction.

Top: Horizontal section A-A with a new structure attached to the east.

Centre: Horizontal section B-B.

Bottom left: West elevation.

Bottom right: Vertical section of the west wall.

1 = Cross-piece;

2 = Runner beam;

3 = Corner pillar;

4 = Circumambulation path along the surrounding platform;

5 = Carved door panel.

annual precipitation at 1,299 mm in Purthi slightly higher. A comparison between the annual precipitation in Keylong in eastern Lahaul and Udaipur in western Lahaul shows an increase towards the west, which continues into Chamba District. Due to low altitude, places in Chamba District, like Chamba Town and Bharmour, are warmer with an average annual temperature of 20.7°C in Chamba Town and 15.1°C in Bharmaur. At Purthi, which is located at a higher altitude than Chamba Town and Bharmour, annual precipitation decreases considerably. Of all the discussed places in this region, Chamba Town and Bharmour are hit most by monsoons during July with 480 mm and 609 mm, respectively. All the mentioned regions are forested (see Map 4.5).

Influences on roof constructions by the given climate conditions explain the use of pitched roofs primarily covered with slates in Chamba, Bharmaur and Manali. At higher altitudes, like at Purthi or Udaipur, a change towards flat earth roofs is evident. Exceptions are religious structures such as the Mirkulā Devī Temple in Udaipur or the Hadimba Temple in Manali, which are covered with wooden slats. Handa (2008b: 131) reports of places along the Chamba border on the Jammu and Kashmir side, which prefer flat roofs, although enough deodar would be available. According to Handa (2001: 130), gable roofs may have been a development from a flat roof around the 18th century, and he mentions the Devi-Kothi Temple in Chamba as the earliest example in this region (Handa 2001: 130).

4.6.1 Kullu District

4.6.1.a Investigated objects

Manali, village and Hadimba Temple

Alt. 2,060 m; 32°14'53.73"N, 77°10'50.84"E. Manali is located in the north of Kullu District close to the borders of Lahaul and Kangra. In Kullu *kath-kuni* constructions are common. An example outside of Manali is the castle in Naggar (cf. Bernier 1989: Plate 7). In some parts of Manali (for example, in Vashist and Old Manali) we still find different traditional composite constructions, such as *kath-kuni*, *dhol-maide* or wood frame constructions. In some cases buildings are attached to each other, leaving only a small gap in-between. A connection between two farm houses was simply made by completing the two walls adjoining each other using a *kath-kuni* construction for each of these. At some buildings, the horizontal brown beams between whitewashed filling material increasingly underline the linear structure of the building.

The Hadimba Temple (1553 CE, Handa 2001: 236) is not a *kath-kuni* structure as sometimes propagated, but rather a timber frame structure with wooden pillars and massive horizontal wooden beams in-between.¹⁶¹ On top of these horizontal beams, which are of the length of the interspace between two posts, wooden cross-pieces are placed, as we know from *cheol* constructions. The filling between the timber elements is either stone or fired brick, though this remains unclear due to the thick layer of whitewash.

161 Cf. pictures (VW02 27,3; VW02 27,4; VW09 1002,1639) in the Western Himalaya Archive Vienna. Online: <https://whav.aussereurop.univie.ac.at/ic/>, access: 06/2016.

4.6.2 Western Lahaul

4.6.2.a Investigated objects

Udaipur, Mirkulā Devī Temple

Alt. 2,658 m; 32°43'34.32"N, 76°39'44.26"E. Udaipur is a village located along the banks of the Chandrabhaga River. On three sides except along the entrance, the walls of the *garbhagrha* of the Mirkulā Devī Temple are made as a *kath-kuni* construction using deodar wood. The door entrance is a wooden panel construction. The ground plan of the *garbhagrha* is app. square with 317 x 306 cm. The interior length of the rear wall and of the lateral walls is 222 cm (Thakur 1996: 95) (Fig. 4.93). The wall thickness is app. 48 cm (similar to Ribba with 47 cm). The height of the wall measured at its outside is app. 257 cm, and at its inside app. 190 cm.

At the corners, wooden pillars are placed overlapping the wall by app. 6 cm (number 1 in Figs. 4.93 and 4.95). The ends of the beams facing one another disappear behind the corner pillars, similar to the Lotsāba Lhakhang in Ribba (see number 1 in Fig. 4.95 and number 3 in Fig. 4.92). The wall is horizontally divided by wooden cross-pieces, which protrude from the wall by app. 6 cm (number 2 in Fig. 4.94). The construction of the layers between the runner beams is hidden behind the wall plaster and the question for the type of building material of this layer remains open. The plaster was not whitewashed and maintains its natural brown colour.

A main difference to the commonly known *kath-kuni* constructions is the use of four corner pillars. These are placed in front of the ends of the outwardly facing runner beams (number 1 in Fig. 4.95), consequently hiding the runner beams' ends. Just beside this pillar the inwardly facing runner beam protrudes from the wall (see number 2 in Fig. 4.95). In comparison, in Ribba the end of the inwardly facing runner beam was covered by a carved blind-wood (compare number VIII in Fig. 4.92).

Since it was not possible to look into the wall construction, these evidences hypothesise, similarly to the wall construction of the Lotsāba Lhakhang in Ribba, that the width of the wall is shaped by the width of two runner beams placed beside each other – keeping the question open for the existence of a horizontal interspace between the runner beams and the type of infill material used for this hypothetical interspace.

This kind of combination of a *kath-kuni* structure and corner pillars shows traces of an early period in the use of the *kath-kuni* system and a possible former use of pillar-based constructions. Regarding the thickness of the walls, the use of corner pillars and of protruding cross-pieces, the building technique applied for making the walls at the Lotsāba Lhakhang in Ribba is close to the one at the Mirkulā Devī Temple. A striking difference between the Mirkulā Devī Temple in Udaipur and the Lotsāba Lhakhang in Ribba is that the builders paid obviously more attention to an artistic appearance of the outer surface at the Lotsāba Lhakhang by carving the outer surface of the runner beams. Conversely, the facade of the *garbhagrha* at Udaipur remains plain without any further decoration.

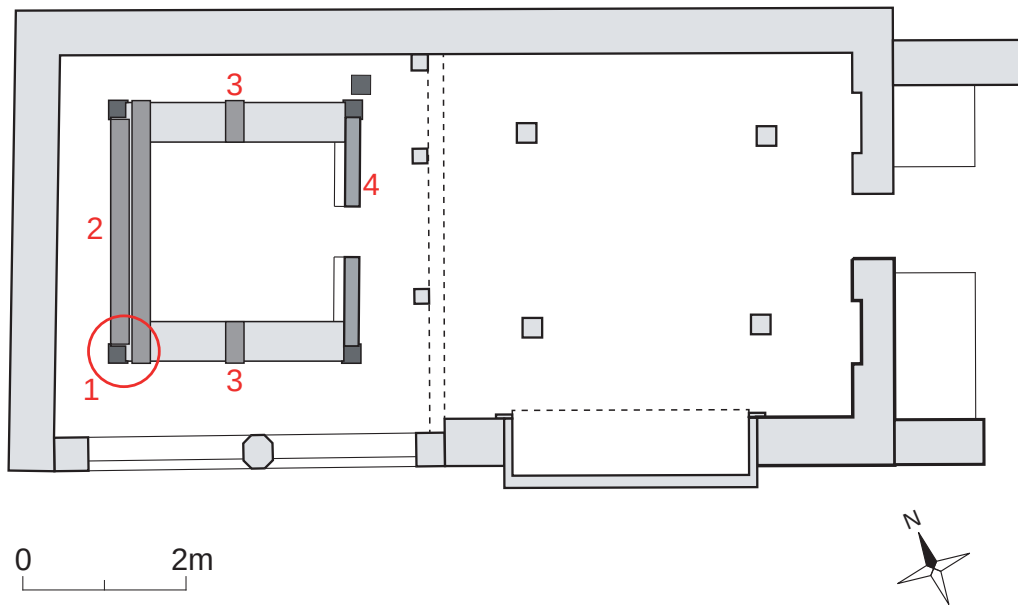


Fig. 4.93 (Top) Udaipur. Lahaul. Ground plan of the Mirkulā Devī Temple with corner pillars at the four corners of the *garbhagrha*. 1 = Corner pillar; 2 = Runner beams; 3 = Cross-beams; 4 = Wooden door panel.

Fig. 4.94 (Bottom, left) Udaipur. Mirkulā Devī Temple. Circumambulation corridor along a *kath-kuni* wall of the *garbhagrha* (on the left side of the picture).

Fig. 4.95 (Bottom, right) Udaipur. Mirkulā Devī Temple. Corner pillar at the southern corner of the *garbhagrha*.





Fig. 4.96 (Left) Purthi, Chamba. Combination of *dhol-maide* and *farque* technique.

Fig. 4.97 (Right) Purthi. Combination of *dhol-maide* and *farque* technique.

4.6.3 Chamba District

4.6.3.a Investigated objects

Purthi

Alt. 2,460 m; 32°54'54.58"N, 76°27'59.15"E. Purthi is a village located in the Chamba District on the route towards Jammu in the north. It is situated along a west-facing slope on the left banks of the Chenab River. At Purthi we find a variety of traditional building techniques. Some recent two-storey buildings were constructed purely with stone without any content of timber. *Dhajji-dewari* constructions show close similarities to those observed in the adjoining province Jammu and Kashmir, where this technique is commonly used. A variation of the *dhajji-dewari* construction as found in Purthi shows diagonally placed boards within a wooden frame, which spans over the whole height of a floor, being vertically divided into several smaller fields – similar to a *dhajji-dewari* construction as observed in Kanam in Fig. 4.86.

The *kath-kuni* technique is widely used. A particular type of a *kath-kuni* construction as found in Purthi shows a mixture of a *farque* construction and a *kath-kuni* construction, with every second or third wooden beam of the *farque* construction running along the whole facade (Figs. 4.96 and 4.97) – similar to the description of the *cator and cribbage* technique given by Hughes (2000a). In some cases the dimension of the single beams is relatively large, as shown in Fig. 4.96.

Ravi Valley

For the Ravi Valley, Postel et al. (1985: 298) describe a common method of construction using the *farque* technique at the corners in combination with *cheol*. Schist quarries in the close vicinity have a strong influence on the design of traditional architecture in Bharmour.¹⁶²

162 Particularly in the close vicinity to Bharmaur (see aforementioned), a schist quarry supplies the whole region with high-quality material.



Fig. 4.98 (Top) Bharmaur. Chamba. Corners made as *farque* construction and the wall in-between as *dhajji-dewari* construction.

Bharmaur

Alt. 2,170 m; 32°26'31.55"N, 76°32'15.96"E. Bharmaur is a village located about 28 km south-east of Purthi. Due to its position on a slope, it faces north into the Chenab Valley and west into the Ravi Valley. The village of Bharmaur shows a similar variety of building techniques, as is the case in Purthi. Some buildings show a combination of a *farque* construction at the corners of the building with the walls in-between made as *dhajji-dewari* constructions (Figs. 4.98 and 4.99). The *farque* technique seems to be more common in Chamba than in Lahaul, Kullu or Kinnaur. Several *dhajji-dewari* constructions follow the type as described at Purthi, with diagonally placed boards within a wooden frame, which spans over the whole height of a floor, being vertically divided into several smaller fields. Fig. 4.100 shows the use of a *farque* construction at the corners of a three-storey construction. At houses built adjacent to each other, the *farque* constructions are built close to each other but without any further structural connection.

Also in Bharmaur, *kath-kuni* is a commonly used building technique. The Lakṣaṇā Devī Temple at Bharmaur (c. 680 CE, Handa 2001: 136), whose *garbhagrha* measures 420 x 300 cm outside and 312 x 200 cm inside with a wall thickness of 80 cm to 85 cm (Thakur 1996: 90), is described as a clay-plastered timber-bonded structure (Handa 2001: 138, after: ASI report by Hargreaves 1929: 17). The mentioned wall thickness of 80 cm to 85 cm appears rather strong compared to an average wall thickness of *kath-kuni* constructions.

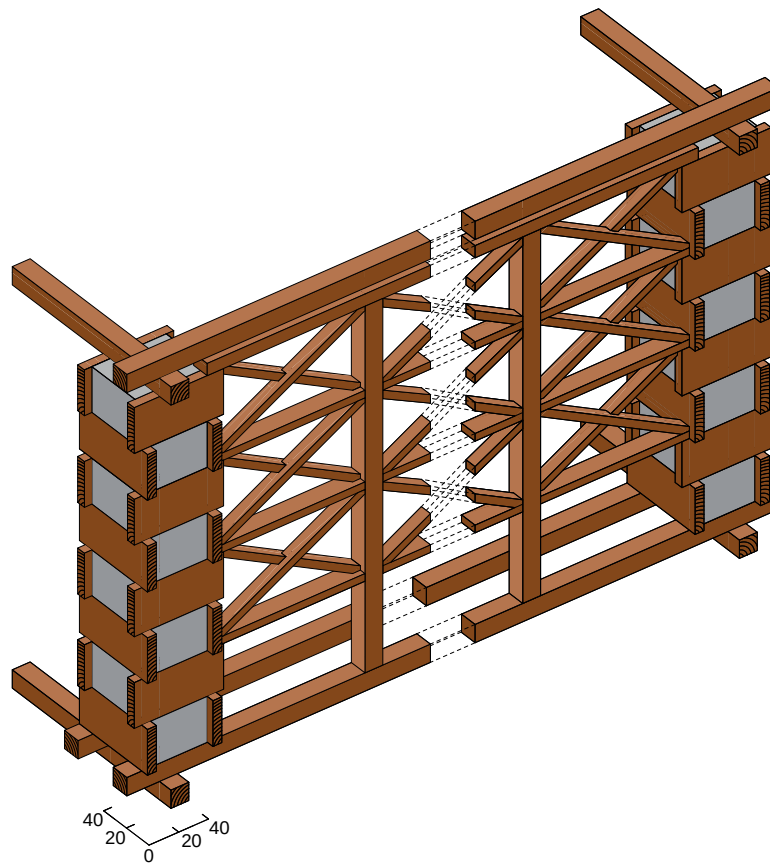


Fig. 4.99 (Below) Bharmaur. Combination of *farque* and *kath-kuni* construction.
CAD: Martin Pospichal. Details provided by the author.

Chhatrarhi

Alt. 1,825 m; 32°26'49.51"N, 76°22'31.10"E. The use of the *kath-kuni* technique at early wooden temples in Himachal Pradesh may point towards an early introduction or development of this technique, with the Śakti Devi Temple in Chhatrarhi in Chamba dating back to the late 7th/early 8th century (cf. Handa 2006: 90; Bernier 1989: 38). The dimensions of the ground plan of the *garbhagrha* with 314 x 342 cm inside and 438 x 480 cm outside are bigger than those measured at the Mirkulā Devī in Udaipur. Further, the thickness of the clay-plastered walls, which is between 60 cm and 65 cm (cf. Thakur 1996: 92), resembles a size of *kath-kuni* constructions, with a width of the infill space between the facing runner beams being larger than is the case at the Mirkulā Devī Temple in Udaipur or at the Lotsāba Lhakhang in Ribba (where the wall thicknesses are just 48 cm and 47 cm, respectively).



Fig. 4.100 Bharmaur. *Kath-kuni* construction.

4.7 Discussion

The investigation of local building techniques and their structural adaptation to local resources reveals striking facets in the development of building methods. Technical details, choice of materials, quality of workmanship and representation of a particular cultural identity are locally defined. On the one hand, the development and organisation of certain crafts and building techniques are influenced by local and regional parameters and need to be understood in a local context, and on the other hand, they need to be considered as part of a wider context, which even includes neighbouring regions and beyond.

Inter alia, climatic parameters are dependent on altitude, and the respective local material resources are an essential basis for certain technical developments. The availability of wood, stone and clay and the respective quality of the locally-available building materials allow a variety of material combinations and mixtures. The resulting developments in building techniques cannot be understood in a linear way, but as a complex interdependence between natural and cultural preconditions. For example, increasing availability of wood locally resulted in local building techniques going from a 'simple' timber lacing, not using 'ladder-like ring beams, to a *dhol-maide* construction to a *kath-kuni* construction – all three being distinct types of constructions requiring individually-adapted craft techniques.

The intent behind the use of composite constructions is to strengthen a particular structure based on the optimised use of local resources. This technical optimisation responds to specific needs, on the one hand, and is also the product of a trial-and-error approach that yields construction experience and leads to the avoidance of failure. Here, long-term experience with structural movement must have played an important role, and which has led to a common understanding regarding the choice of building techniques. Timber lacing in the walls, for example, is connected to the ceiling and roof system, and together they form a three-dimensional static concept. Spanning thousands and thousands of kilometres from the Mediterranean to the Himalayas along a seismically active zone, such composite constructions developed as culturally-interrelated building traditions. This kind of collective experience and the resulting structural interventions can be considered to be a 'seismic culture'.

Over time, traditional building techniques have been adapted and changed. Viewed over several centuries, a specific building technique cannot necessarily be attributed to an immutable local technique, since it may have changed in the course of time for various reasons. Stone, clay and wooden structures, and the different methods of processing and applying them are evidence of this continuous change in the context of local resources. The main temples of the early historical West Tibetan monasteries are an example of this. They were consistently built with adobe bricks, although the development of vernacular structures in the areas surrounding the monasteries shows the use of different building techniques, as we can see in Tabo in Spiti or in Khorchag in Purang. Early examples of structures give us an idea of traditions in a certain historical period and allow us to make hypotheses regarding possible developments. And similar to a particularly homogenous earth building tradition in early historical West Tibetan monasteries, a particularly homogenous

wood building tradition can be observed in early wooden temples in Himachal Pradesh, even though each wooden structure has its own local expression regarding the size and proportion of the individual construction components. As shown with the structures of early wooden temples in Chhatrarhi, Bharmaur, Udaipur and Ribba, the length of timber used for the garbhagrha ranges between 3 m and 4.8 m. The wall thickness ranges between 47 cm and 85 cm.

In the following list, construction data for early structures are juxtaposed, according to the sources given before:

Site	Temple	Max. length of runner beams	Wall thickness
Chhatrarhi	Śakti Devi Temple	480 cm	60 cm to 65 cm
Bharmaur	Lakṣaṇā Devī Temple	420 cm	80 cm to 85 cm ¹⁶³
Udaipur	Mirkulā Devī Temple	317 cm	48 cm
Ribba	Lotsāba Lhakhang	390 cm	47 cm

The local type of roof construction is an indicator of the interplay of environmental factors and material resources. At higher altitudes, the traditional roof is flat and made of clay or *arga*. By contrast, in Himachal Pradesh, at altitudes of about 2,800 m or less, this resulted by tradition in a preference for a pitched roof covered with stone slates, wooden shingles or wooden slats. However, this cannot be considered as a general rule because, for example, in North Pakistan, which borders Ladakh to the north or further west in Nuristan, an east Afghan province, which borders Pakistan, flat roofs are also commonly used at lower altitudes.

In the Western Himalayas, composite constructions were erected in addition to solid stone and earth constructions. For these, the content of wood changes according to local availability, climate conditions and altitude. Several basic types of construction can be observed for the Western Himalayas, being connoted with different local designations. In the following list, the different types of constructions are ranked according to an increasing content of wood.

1. 'Simple' timber lacing (which does not consist of a ladder-like pair of runner beams but only of single runner beams at each layer of timber lacing)
 - Type a. not acting as a ring beam
 - Type b. acting as a ring beam
2. Ladder-like timber lacing acting as a ring beam (local terms: *ker*, *cheol*)
 - Type a. with the vertical distance between the runner beams of a height of more than one beam ranging up to the height of one storey: using only horizontal wooden components (local terms: *bhatar*, *taq*, *dhol-maide*)
 - Type b. with the vertical distance between the runner beams equalling the height of one beam or a multiple of a beam's height: using horizontal wooden components combined with vertically-arranged wooden 'column-like' corner components (known as *cator* and *cribbage* or locally as *kath-kuni*)
3. Timber frame constructions (local terms: *dhajji-dewari*)

163 A value of 85 cm for the wall thickness, as given by Thakur (1996: 90) for the Lakṣaṇā Devī Temple, seems to be rather high for a timber construction, for example a *kath-kuni* construction, and its verification will be part of further research.

These different types of Western Himalayan constructions show a different content of wood; the amount of load-bearing components such as stone or clay changes. Within this study, in particular for Himachal Pradesh, the author observed that construction methods were adapted very sensitively to keep step with changes in topography, altitudes, and timber requirements. Regarding this step-like change from higher to lower altitudes, as a first step of transformation, solid stone and earth structures with a low content of wooden components become solid structures with an increased content of timber but still working with stone and clay as the primary load-bearing components. In the next topographical-change step, the content of wood increases by such an amount that the load-bearing wall components become free-standing timber skeleton structures with stone infill. The individual phases of structural change are depicted in Fig. 4.101.

The cator and cribbage constructions of *kanqahs* in Kashmir, for example, are referred to as “wooden structures” in a resource mapping conducted by INTACH (2010). This designation corresponds to their structural nature, since, from a static point of view, they act as freestanding wooden structures, in some cases even without a stone infill.

Today, in Ladakh, the use of timber lacing is rare, whereas for historical structures, it was more common. In early West Tibetan temples, the use of ‘simple’ timber lacing not acting as a ring beam can be traced back to as far back as the 10th century. Regarding the aforementioned examples of early timber lacing, the use of timber lacing acting as a ring beam was already common in Ladakh in the 15th/16th century, and if we look at the construction of the Chigtan Monastery, the use of the latter technique may even go back as far as the 11th century. The construction of the central part of the castle of Chigtan points towards this border region being a transition zone for the assemblage of different building techniques, ranging from a predominant arid zone with solid stone and earth constructions to constructions with a high content of timber.

Wall brackets (or shear keys) are traditional, and in some areas, like Uttarakhand, they are commonly used in vernacular architecture. To the north of Ladakh, close to Pakistan, the use of stone constructions and of solid construction-strengthening timber lacing increases. Crossing the northern border towards Pakistan, this feature exhibits a kind of regularity with local variations, stretching from the Pakistan-Indian border, following the Shyok River into the Skardu district, via the Gilgit district and further on to the west to the Swat Valley, the Chitral district and into Nuristan. Along this route the altitude decreases, the amount of forest area increases, and with this, the increased amount of timber used in solid wall constructions results in timber-rich techniques such as *cator* and *cribbage*. Along the whole route, stone (primarily quarried stone) is a prime building material.

Similar developments can be observed when crossing the Zoji la from Kargil towards the west and entering the Kashmir Valley. In Srinagar the predominant construction is already primarily a wooden construction with brick infill. Kashmir is another zone of transition and interface of different composite building techniques. Environmental conditions and raw material resources support the development of composite constructions based on wood. Using fired brick is also based on the availability of wood for firing and a suitable quality of clay. *We find cator and cribbage* constructions – similar to those in North Pakistan – dating back to at least the 13th century, and *taq* constructions (similar to *bhatar* in north-western Pakistan) dating back at least 200 years, although the latter were possibly even used much earlier, in the 13th/14th century.

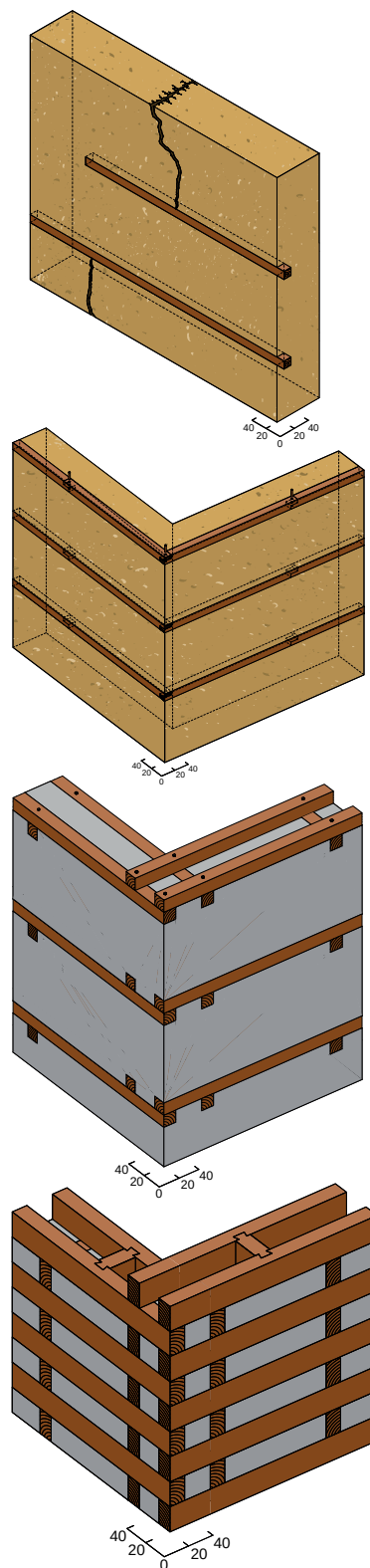


Fig. 4.101 Phases of structural change from solid clay and stone constructions (top) towards timber-based constructions (below). CAD: Martin Pospichal. Details provided by the author.

The ‘ladder-like timber lacing (*taq*)’ was optimised by modularly alternating between piers and bays within the wall construction. The introduction of fired bricks with a minimised height (similar to findings at Safranbolu in Turkey) allows us to formulate a hypothesis that the builders’ intent was to optimise the solid structures’ earthquake-resistance. *Dhajji-dewari* constructions are often found in Kashmir and can be found as subordinate techniques in surrounding regions such as Chamba, Shimla or Kinnaur. This type of construction is mainly related to a timber frame tradition which extends westwards from the Western Himalayas and continues towards Europe in different local constructive forms. For roof and wall constructions, we can also observe a focal point for various types developing alongside each other or even merging, as they do in Kashmir, for example, where we find earthen flat roofs, pitched roofs covering earthen flat roofs and pitched earthen roofs.

Himachal Pradesh offers a wide variety of facets of Western Himalayan developments in building techniques. At higher altitudes (including early evidence from the period of historical West Tibet in the late 10th century), reduced timber resources supported the development of solid structures made mainly of stone and clay. The availability of suitable raw material enabled this development. In this context, “suitable” in a vernacular context has to be understood to mean “available in the vicinity and capable of being quarried and processed in an energy-efficient manner”.

Structural changes from solid structures into wooden structures occur at higher altitudes, for example, between eastern Lahaul and Middle Kinnaur in the east of Himachal Pradesh, and Chamba and Kullu in the west. A transition zone from purely solid structures with a reduced content of timber towards timber-rich structures such as the *dhol-maide* can be found at an altitude of approx. 3,000 m. Examples of this transition zone are the tower at Gondhla, which is mainly a stone structure combined with the *dhol-maide* technique, the Old Temple of Ropa, which is one of the first villages reached when approaching Kinnaur from the north, where the *dhol-maide* building technique is commonly used, and the village of Labrang in Middle Kinnaur, where *dhol-maide* and *kath-kuni* constructions are found alongside each other.

Many of the traditional constructions – especially at altitudes of around 3,000 m and below – have not been plastered on the outside. One physical aspect of a faster humidity transport and a faster drying process within walls may explain the avoidance of plaster in regions with increasing rainfall below 3,000 m. In structures representing a particularly high social status, timber components were processed in a more elaborate manner. Highly-developed craftsmanship for a particularly well-processed design allows and emphasises this development, which we can observe in solid stone and clay structures as well as in wooden constructions.

With decreasing altitude, the content of wood in wall structures increases and changes from a *dhol-maide* into a *kath-kuni* construction with an increased amount of wood. A *kath-kuni* construction assembles features of a horizontal *dhol-maide* construction and a vertical *farque* construction. In Himachal Pradesh, *farque* constructions are found in Chamba and to a lesser extent also in Kinnaur. The use of the *kath-kuni* technique might date back to the 7th/8th century. Pillars at the corners of some of these early structures (e.g. in Udaipur or Ribba) may hypothetically point towards a more common earlier use of post and beam constructions.

Regarding constructions found within this study at altitudes above 2,000 m, altitude-dependant continuous technical modifications show the local adaptation of construction techniques to local building material resources and environmental conditions. Building cultural transition zones make these developments particularly evident. And tracing developments from higher to lower altitudes shows a smooth transition from solid earth and stone constructions to stone-wood dominated constructions. At higher elevations, we mainly find solid building structures, primarily earth and stone buildings with minimal wood content, but as wood availability continuously increases with the decrease in altitude, construction methods show an increasing proportion of wood – and not just simply more wood, but the timber construction techniques themselves change to adapt to the higher proportion of wood.