III. BRIDGES IN THE HIMALAYAS

Development of methods to cross rivers and gorges

Easily passable and unbroken link across the natural barrier are a basic condition for cultural and economic development. The people of the high mountains, like in the Alps as well as the Himalayas, had to overcome more torrential rivers and deep gorges than the people living in plains, where quite often simple fords across the rivers helped. Thus in the mountainous regions, people have to search for possibilities to overcome these obstacles. In the Himalayas and particularly Tibet, even the most difficult terrains are connected by continuous road networks and ingeniously built bridges even during the Middle Ages.

The methods to cross gorges and rivers in the Himalayas are extremely diverse and rich in variations. In the following, they are shown only briefly as it is necessary for the classification of Thangtong Gyalpo's work and the iron chain bridges. The chronology of the representation corresponds possibly to the technical degree of maturity, but does not follow a continuous development pattern, because even the oldest methods are applied differently on the regional level until today.

1. Ice and snow bridges
2. Rafts and inflated animal skins
3. Boats
4. Stone slab bridges
5. Girder bridges from round and squared timber trunks
6. Ropes made from plant fibres
7. Ropes made from yak skin
8. Single rope bridges
9. Bamboo arch bridges
10. Steel cable with hoops
11. Steel cables with rails
12. Wooden cantilever bridges
13. Iron chain suspension bridges
14. Suspension bridges

15. Bailey bridges
16. Concrete bridges
17. Concrete arch bridges
18. Steel truss bridges
19. Bridges, ferries and boats

Ice and snow bridges

Ice bridges and snow bridges along with frozen rivers permit unspectacular river crossings without large expenditures in the winter time. In the Zanskar valley (*Zangs dkar*) in the western Himalayas, the frozen river is used as a means to travel across and for travelling through the steep gorges in winter even today. Disadvantages consist in the fact that the shining ice is difficult to be walked upon for mounts and pack animals. Moreover, the 'bridges' can be used for only few months in a year.

Rafts and inflated animal skins

Smaller rafts of wood or bamboo and inflated animal skins can only be used to a limited extent, as they are applicable only in relatively calm water. The rafts were punted or pulled by ropes that were stretched across the rivers. In Bhutan, bamboo rafts, which can accommodate four to five people, are used in Manas, in the southern part of the country.[39] In Bhutan, rafts are also used if a corpse had to be transported across a river, since it was forbidden to transport deceased over a bridge in order not to offend the protective spirits. The author could observe in 1990 in Eastern Tibet a raft made from a rust of eight inflated pigskins. Moreover, in 1978 he also saw a Bhutanese who crossed the river recumbently paddling with hands and feet on an inflated yak skin in the Tang valley in Bumthang.

Boats

[39] Ura 2000, p.47.

Two kinds of boats are used for transporting goods and crossing rivers in Central Tibet since the Middle Ages. The first type consisted of light boats made from three yak skins stretched on wood, which could be carried on land. This boat can be carried comfortably upstream by a single person and has a carrying capacity of more than one ton on the water.

Since the 18th century (most probably from the 17th century), heavy wooden boats that were up to four metres wide and 20 metres long are to this day are ferried from Tsethang to Samye across the Yarlung Tsangpo river.

Stone slab bridges

The stone slab bridges were not common in the Himalayas up to the last century. Whatever the available material in the mountains allowed, natural slate plates or granite plates were moved with wooden roles to the creeks, and stable bridges were built. The spans were narrowly limited to a few metres. Accordingly, stone bridges in the Himalayas play a subordinate role.

Girder bridges from round and squared timber trunks

Despite their materials having had to be brought partially to the building site from afar girder bridges play a far more important role. For timber bridges, one stacked loose stone foundations up on both riverbanks and put over it several round or sharp-edged hewed trunks. Usually for this bridge, fir, spruce and pine trunks were used. With this kind of bridge, one reaches a span (with trunks that were long and thick) of more than twelve metres. Larger spans will fail because of the dead weight and the deflection of the trunks conditioned thereby or the transport possibilities of long and heavy wooden trunks. Because of the weight, only bridges with low spans could be provided with a layer from stone plates. The static system of these bridges is very simple, i.e. one girder on two props. All together, this simple system in many places attained durability, lasting many decades. In order to achieve larger spans, favourable conditions like suspending or overhanging rocks or recumbent rocks in the river were often used as natural stream pillars. In Bhutan, these bridges are built on a large scale even to this day along with the wooden cantilever bridges, which we will deal later.[40]

Single rope bridges

In travel reports of the past, the crossing of rivers by using ropes made from plant fibre are recorded with great respect. Fastened temporary ropes are used for the crossing of an expedition, but mostly, ropes are permanently fixed with stones. In the easiest case, a rope was stretched, where one had to 'work his way along'. Almost comfortably were two tense ropes with a ring. The traveller had to sit or kneel down in this hoop and then pull himself with both ropes (which also carry the ring) across the river or the gorge. In Bhutan, for spanning such a rope, it was knotted to a thin thread, which was then shot with an arrow across the river. The thinner thread or rope then pulled the heavy rope across the river.

[40] Gerner 1999, p.1411.

Fig. 21: Difficult gorge crossing on a single rope bridge. Source: Aris, 1982.

Captain Turner describes such a bridge between Murichom and Chukha in the valley of the Wang Chu in Bhutan:

> A very curious and simple bridge, for the accommodation of single passengers, communicated between this and the opposite mountain. It consisted of two large ropes made of twisted creepers, stretched parallel to each other, and encircled with a hoop. The traveller, who wishes to cross over from hence, has only to place himself between the ropes, and sit down on the hoop, seizing one rope in each hand, by means of which he slides himself along, and crosses an abyss on which I could not look without shuddering. Custom, however, has rendered it familiar, and easy to those who are in the practice of thus passing from one mountain to the other, as it saves them by this expedient, a laborious journey of several days.[41]

Ropes made from yak skin

[41] Turner 1800, p.54 and Ura 2000, p.48.

Father M. Huc saw on his trips to Tartary i.e. Tibet and China from 1840 to 1846 a bridge made from ropes, which were plaited out of yak skin leather. Huc comments:

> As we were passing the Ya-Loung-Kiang in a boat, a shepherd crossed the same river on a bridge merely composed of a thick rope of yak skin tightly stretched from one bank to the other. A solid strap to a moveable pulley on the rope suspended a sort of wooden stirrup. The shepherd had only to place himself backwards, under this strange bridge, with his feet on the stirrup, and hold on to the rope with both his hands; he then pulled the rope gently; the mere weight of his body made the pulley move, and he reached the other side in a very short time. These bridges are very common in Thibet, and are very convenient for crossing torrents and precipices; but one must be accustomed to them.[42]

Suspension bridges from plant fibres

In Bhutan as well as in Zanskar and Lahoul, elegant suspension bridges were built with a span reaching up to 40 metres. Karma Ura describes bridges of the semitropical areas of Bhutan made from reed and climbers, consisting of slope ropes and the walking layer fastened to it. The railing is made from twisted mats. The ropes are partially strengthened with wood and both supports were fastened with wooden constructions.[43]

Crook and Osmasten describe rope bridges from Zanskar:

> Suspension bridges are used on spans up to 60 metre in length, traditionally made of cables of twisted branchlets (Lonicera myrtillus, a kind of honeysuckle) or of stak.pa (Betula utilis, a birch). Since these bridges need renewing every three years or so, they are now being increasingly reinforced or replaced by steel cables. Normally these cannot

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[42] Huc 1856, p.572/573.
[43] Ura 2000, p.48.

> be crossed by animals. New and bigger bridges with wooden decking are being built in a few places (e. g. Padum).[44]

Similar rope bridges were built (and are still built occasionally) in South America. The immense road system of the Incas from the second half of 15th up to the beginning of the 16th century got by only with one system of bridges. The Incas had a similar 'bridge building program' like the ones to be found in the Himalayas: Stone bridges from big blocks, wooden cantilever bridges, hanging rope bridges, rope bridges with baskets but no iron chain bridges were constructed. The most interesting constructions are the suspension bridges made from dried grass.

In 1534, Pedro Sanches, the secretary of Pizarro observed the construction of such a rope bridge of the Incas. In 1870, there was a report about the Apurimac suspension bridge with approximately 45-metre span. Such constructions are to be observed until the end of 20th century.[45]

Weihreter reports about an outstanding suspension bridge near Schaor in Lahoul. It is regarded as among the biggest and best suspension bridges in the whole of the Himalayas. This fragile looking construction is only made out of the branches of the Killa-bush (tuzia remenodis). This bridge is produced of a thick rope twisted from branches used as a tread and two such ropes as handrails where three ropes are connected in such a way that also the handrails help with the carrying.[46]

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[44] Crook 1994, p.51.

[45] Zweitausendeins 2000, p.249 ff. "The seventy wonders of the ancient world. The great monuments and how they were built." Published by Thames and Hudson, London in 1999, German translation entitled "Die siebzig Weltwunder" published by Zweitausendeins, Frankfurt in 2000. The bridge of Apurimac, but also the so-called "hammock bridges", as it was recorded, e.g. by Alexander von Humboldt in 1802 in today's Ecuador, are often used in the whole bridge literature as examples.

[46] Weihreter 2001, p.33.

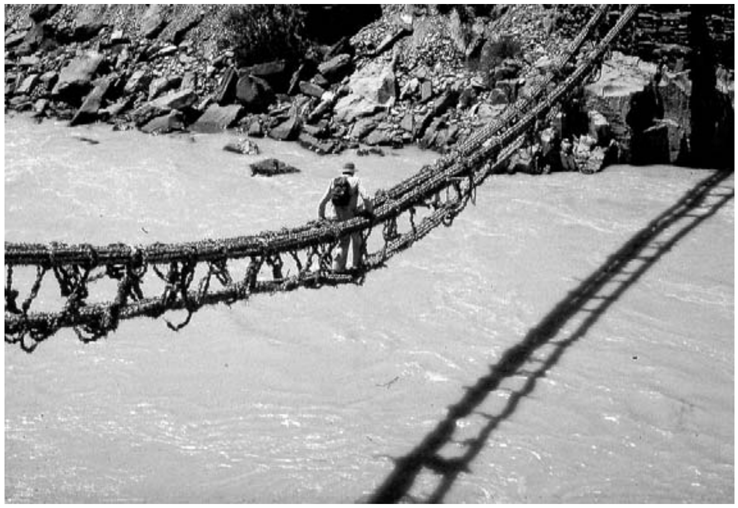

Fig. 22: The author in 1975, on a bridge made from willow tree branches in Ladakh.

During his travel from 1979 and 1980 in Zanskar, the author saw a bridges in use made from willow-tree branches. One such is the Zangla bridge across the Zanskar river and another is found across the Lingti Chhu at Char. These bridges had spans up to forty metres and are made of six to nine centimetre thick willow rope bundles with approximately fifteen centimetres in diameter. Together, these ropes were connected with thin pasture ropes again. Such bridges could be used by two to three people and swayed strongly in both directions. The packing animals could not use this bridge, but had to cross the rivers by swimming. The disadvantage of all rope bridges and bridges made from plant fibres lie in need for frequent repairs. This signifies a huge amount of work involved for the inhabitants of a village for many weeks. The bridge across the Zanskar river with its 40 metres of span was regarded as one of the longest spanned willow branch bridges.

Bamboo arch bridges

In the bamboo covered valleys of the southern and eastern Himalayas, arched bridges made from bamboos are still in use today. From a single bamboo pole to bundle of bamboo poles, one formed bows on which a light bridge rail with ropes from plant fibres was hung up. Blanche Christine Olschak reports about the English naturalist Joseph Dalton Hooker and his expeditions to Sikkim from 1848 to 1851: "Steadfast Hooker crossed the gorges of the rivers on slimy and swinging bamboo bridges." A detailed sketch of a bamboo bridge with approximately 30 metres of span is presented in the report.[47] In Bhutan, on the way upstream of the Paro Chhu towards Lingshi Dzong, the author could see a simple bamboo arch bridge in use as late as 1996.

Steel cables with hoops

Even in the 20th century, this method of crossing rivers and ravines was used in the Himalayas. A single wire rope is stretched over relatively light abutments and by means of a role with a bench one pulls oneself across the river. After some enhancements, a wooden box was hung up on two roles for a maximum of two people and one also had to pull oneself with the hands along the wire rope and in each case, the last quarter of the rope sagging required all power. Therefore, these 'transport boxes' were made even more comfortable, while they received a hauling cable with which one could pull the vehicle on the desired side, as well as be moved from the shore.

Weihreter in 1985 in the Western Himalaya could witness the transfer of a tensioning rope and calls the equipment 'Jhula'.[48]

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[47] Olschak 1965, p.66/67.
[48] Weihreter 2001, p.30.

Fig. 23: Crossing the Indus river with a hoop on a steel cable.

From 1976 to 1985, the author had to cross the Indus river in Ladakh (*La dvags*) several times, using such bridges. Similarly, Sven Hedin, while he was wandering through the Trans-Himalaya in 1906 and 1907, had numerous adventurous crossings of rivers and gorges by using this kind of bridges. About a Sutlej crossing, he writes:

> Deva Ram gives his sign, the rope carriage starts to glide; I float beyond the edge and now below me in the depth the greyish white waves of the river are rolling. An eternity passes. Why do I not already arrive over there, then? It is only 35 metres. Over there on the heights is my old Tibet. Down there in the levels is India. My caravan has been torn apart. I myself float between the sky and the murderous Satledch (Sutlej). I have investigated this river and have found its original spring. The discovery cost a sacrifice indeed. I had never had such respect before the immense majestic river like at this moment, and all at once I had understanding for the chörten-pyramids and stone marks of the Tibetans on shores and bridges, those calls for help against indomitable natural forces and those lithified prayers to relentless gods. My look falls on the white boiling gigantic kettle in the abyss down there. How splendid, how fascinatingly nice. The language owns no words for it; no master can paint this picture. The vertiginous bird's-eye view

> cannot be returned on the canvas. Only after a model one could make off a concept. Only listen to the concentrated rumbling of this water thunder which is renewed with every moment. It fills up the narrow stone gutter and I float in the midst of a chaos of sound waves which cross each other from all sides.
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> With every jerk that the drawing of the people causes, I swing, to and fro. Holla! Only two metres up to the edge of the stone dam. Marvellous land! If the cable has held so long, it will not exactly tear now with fateful crashing. Pull, only one more metre. With a cosy feeling of security I glide further on over the stone dam and in the twinkling of an eye. I am single for all gang and bonds![49]

Wooden cantilever bridges

Simple bended beams with a maximum of about 12 metres of span were not long enough for many broader rivers and gorges. First, one started to support the beam in bending from the riverbanks at an angle and then developed cantilever bridges with cantilevered tiers of beams from the river banks, which again supported up to 12 metre long single tense suspension beams. For the cantilever bridges, firm bridgeheads from stones and hardening tiers of wood were established. Then on the bridge height up to about five tiers of beams were piled on one another in each case, cantilevering from about 1.5 to 2.5 metres. The cantilever beams then carry the freely tensed middle section. The tiers of beams themselves are weighted with piled up stone tiers, so that they remain stable. Particularly, in the eastern Tibet, one will find reckless constructions of these cantilever bridges that are still in use today.

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[49] Hedin 1909, p.344.

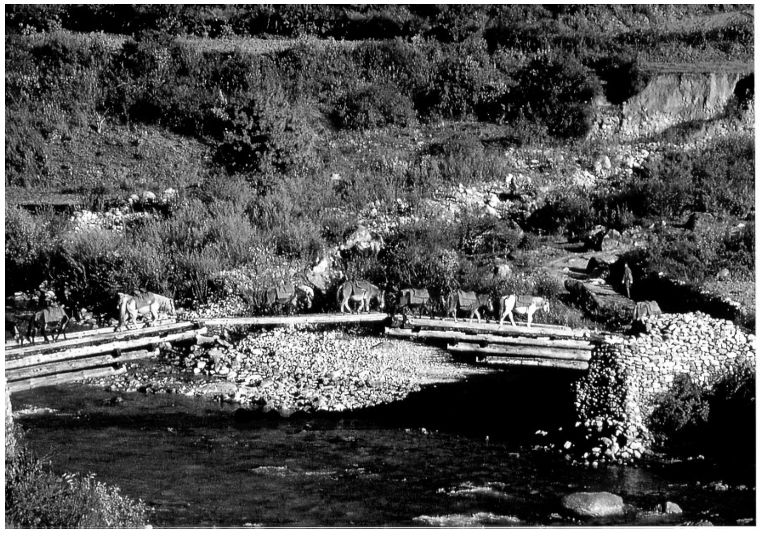

Fig. 24: Horse caravan on the former cantilever bridge across the Paro Chhu below Taktshang.

In Bhutan, they have received a special characteristic, where not only stone tiers were used as a weight to the tiers of beams, but also splendid bridge houses were built. The most significant of these bridges was the bridge below the Wangdi Phodrang Dzong, with a span of approximately 52 meters that stood from 1684 until it was washed away in 1968. These bridges provide their service in Bhutan to this day. One such bridge is built next to the vegetable market in Thimphu across the Thimphu Chhu in the year 2005 and another one is planned to connect the Punakha Dzong.[50]

[50] The cantilever bridge at the Punakha Dzong, the winter residence of the Je Khenpo, was destroyed by high water. However, the left bridge tower with the cantilever tiers of beams was preserved. An emergency bridge was first spanned at these cantilever beams as a light suspension bridge to the right riverbank. Later, only a few metres upstream, a cable rope suspension bridge with concrete pylons was erected. This is supposed to be substituted again

Iron chain suspension bridges

In the overall development of bridge building as well as forged suspension bridges, the earliest known iron chain bridge architect, Chakzampa Thangtong Gyalpo, play a significant role. Thangtong Gyalpo is supposed to have built 108 iron chain bridges in Tibet and Bhutan, in addition to a number of ferry boats, possibly between the year 1430 and 1464. Some of the iron chain bridges have survived to this day and have provided their services without repair or special care and without having shown signs of rust or corrosion. The remaining iron chain bridges by Thangtong Gyalpo or the vestiges of them that have survived to this day as well as a few drawings or the vestiges of abutments show that in Tibet and Bhutan at least two distinguishing constructions were carried out.

The type 1 bridge normally consists of two parallel spanned chains in between where the bridge rail, the walking layer was hung on to the ropes. Instead of a firm bridge rail, only bamboo mats were often inserted into the ropes. In some cases, such iron chain bridges were strengthened, while by height of the walking layer, two other chains were arranged. With the iron chain bridges existing even today, the 'railing chains' are provided with the chains with wires or wire meshes which carry the walking layer. Earlier, instead of the wires, one probably also used ropes from twisted willows or yak skins at the iron chain bridges.

The type 2 bridge, a stress ribbon bridge consists of several chains spanned side by side that directly carry the screed, the bridge rail, as well as additionally higher arranged chains at the side which served as a railing. The bridge existing today at Duksum in Eastern Bhutan and the bridge discovered by Samuel Turner in the 18th century close to Chukha and

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according to the plans of the Swiss engineer Fritz Baumgärtner by a wooden cantilever bridge.

drawn by James Basire and Samuel Davis belong to this kind. For this type, there is no evidence found by means of historical bridge descriptions or through other reports, which can be traced back to Thangtong Gyalpo. It is more likely that original iron chain bridges by Thangtong Gyalpo were extended with two or more chains.

A variation of type 1 bridge is the 'suspended' bridge. The bridge of Tholing in the former kingdom of Guge in Western Tibet shows a mixed construction in this respect, as it concerns one of the wooden cantilever bridge typical of the Himalayas, whose long span is supported by two spanned chains above it, as well as appropriately hung out chains.

Other mixed constructions are combined bridges, for example' wire ropes and willow ropes. Starting with father Grueber, almost all European travellers who used the iron chain bridges in Tibet and Bhutan were highly impressed by them.

In 1856, father Huc writes:

> Iron suspension bridges likewise are in use a lot, especially in the provinces of U (*dBus*) and Tsang (*gTsang*). To construct these (suspension bridges), as many iron anchors are attached on both sides of the river, as they have chains. Then the chains are stretched, and on top of the chain planks which are partially covered with a tier of earth are fastened. Because these bridges are especially loose (swing and sway) they are equipped with railings.[51]

In 1906, John Claude White informs about iron chain bridges in Bhutan,[52] and also from 1906 to 1907, Sven Hedin

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[51] Huc 1856, p.573/574.

[52] White reports about his trip through Bhutan in 1906 to the Royal Geographical Society in London on the 8 December, 1909. Among others, White mentions the good state of the cantilever bridges. However, it seemed to him that the suspension bridges had been given up.

mentions iron chain bridges in Tholing and Phuntsholing and, finally, Heinrich Harrer uses it in 1945 at Chung Riwoche on his way from India to Lhasa.

Suspension bridges

After steel cables were available at about the middle of the 20th century, ropes and rope bridges from plant fibres and chains were substituted increasingly by steel cables. This development first started in Nepal followed by Bhutan and Tibet. Especially, the iron chain bridges in Nepal were substituted with cable suspension bridges using the pylons and bridgeheads of the chain bridge. In the meantime, cable suspension bridges with spans of more than 250 metres and high pylons in form of steel truss constructions are no more a rarity in the Himalayas. In Bhutan alone, approximately 400 cable suspension bridges were said to be built.

Bailey bridges

Pioneer bridges from light steel truss parts that could be mounted without heavy hoists were likewise introduced to the Himalayas by Indian, Chinese and Nepalese military in the second half of the 20th century. These bridges, named after the British engineer Donald Coleman Bailey (1901-1985) spans to approximately 80 metres. This is achieved through building sets-like side by side stacks or on top of each other, sorting of light bridge building parts with about 1metre height and 3 metre long spans. These bridges are covered with wood and present one lane each; however, horses and mule caravans can well meet on the bridges.

Bridges like this were developed for military purposes. They are intended as temporary facilities. In many parts of the Himalayas, they have partially been used as stationary bridges for many decades. If a Bailey bridge is dismantled, its parts are reassembled in a new bridge. In 2003 at Khuruthang in Bhutan, the wide spanning Khuru Khuenphen Zam was erected from parts of other bridges. In addition, combinations of Bailey and steel cable suspension bridges have proved themselves. A similar one in Samtse was built in

1993, across the Daina Chhu with a span of 330 metres. For this a wide spanning Bailey bridge, rail with steel cables above high steel truss pylons was hung down.

Concrete bridges

Concrete bridges as single field bridges or multiple field bridges have removed Bailey-bridges in particular. The span from yoke to yoke can hardly reach 20 metres. These bridges also admit heavy driving traffic and are already partly two-lane. The bridges are either prefabricated or made out of concrete that is produced at the local spot. For the prefabrication, heavy transport vehicles and lifting devices are necessary.

Arch bridges

Arch bridges produced through concrete construction methods, with partly spectacular constructions have been introduced in the Himalayas in the second half of the 20th century. In the 50s and 60s, Chinese master builders began with wide-spanning concrete arches, e.g., with the Gangge Bridge across the Yarlung Tsangpo or the friendship bridge between Nepal and Tibet.

In Bhutan, with Swiss help, the concrete arch bridge across the Puna Tsang Chhu, also called Tsangmi Chhu, below Wangdi Phodrang was constructed during the last years of the 20th century. This bridge in particular has its development and history documented impressively. The first bridge, the Tsangmi Chakzam, an iron suspension bridge, was built by Thangtong Gyalpo after 1433. In 1684, it was replaced by a wooden cantilever bridge that spanned two times across a natural river pillar, the Tsangmi Zam. The larger bridge part had a span of 52 metres and the smaller one with a one sided cantilever a span of 24 metres. The bridge stood for centuries up to about 1915, when a mighty flood washed it away. A new wooden cantilever bridge with an identical construction like the old Tsangmi Zam was rebuilt immediately. In the meantime, a bamboo bridge was built as a temporary measure. In 1968, once gain the Tsangmi Zam fell victim to a flash flood. In the beginning of the 70s, it was substituted by a Bailey bridge. The Bailey bridge was once again replaced by a concrete arch bridge towards the turn of the millennium.

Steel truss bridges

As for the latest bridge development in the Himalayas, steel truss bridges are among the most popular. Steel truss bridges were built in Tibet, on the so-called south route from lake Manasarowar to the west. It is also popularly built in Nepal. Steel trusses have the special advantage that they can be prefabricated in relatively small and light units and be mounted on site with light lifting devices.

In Bhutan, Indian road builders first built steel truss bridges, like the one across the Paro Chhu between Paro and Chuzom. In cooperation between Bhutan and Japan, five steel truss bridges were built from 2002 to 2004, which were prefabricated in Japan, then shipped via Calcutta and finally mounted in a very short time. Largely, these bridges substituted the existing Bailey-bridges. In this way, the following bridges were established at the main artery road from the west to the east, which is the most important road connecting Western and Eastern Bhutan:

1. Waheyzam, Samtengang
2. Bjizam, Trongsa
3. Chamkharzam, Jakar
4. Kurizampa, Mongar

Yet another of this kind, a truss arch bridge with a 92-metre span is found across the Mangde Chhu in the south of Bhutan.

These bridges introduced a new era in the bridge technology of the Himalayas. They have span of more than 50 metres and are 7.5 metres wide, with two-lane traffic and the supporting steel constructions are maintenance free.

Bridges, ferries and boats made by Thangtong Gyalpo

Apart from the suspension bridges, Thangtong Gyalpo has also helped with the development of ferries and boats. In his biographies, Thangtong Gyalpo is often mentioned as Chakzampa, a suspension bridge builder, but he was also known as the constructor of ferries.[53] Continuous connecting lines as for the personality and the work of Thangtong Gyalpo can even be harder to draw. In Tibet, there are two kinds of ferries: One in the form of light yak skin boats called Kowa by the Tibetans, and heavy ferries of wood. The yak-skin boats are partially framed boats made from three complete and one divided yak's skin which can carry about one ton of load and which are to be found throughout Tibet. The wooden ferries are about four metres wide and up to 20 metres long with about a half a metre of draught. These ferries are only found at the Yarlung Tsangpo, for e.g., between Tsethang and Samye. Such ferries can transport up to 20 to 25 tons, including large herd of yaks, cows or horses, and even lorries.

At yak-skin boats, the triangular or semicircular with about 30 x 40 cm yak skin piece, which is sewed on the longer cross sides at the upper board between large yak skins, is called a 'head'. Diana Altner in her report "The Tibetan yak skin boat in the change of the time" writes:

> This skin piece symbolises the head of the holy Thangtong Gyalpo as well as those of the boat and should protect the passengers of the boat against demons and accidents. Today every Tibetan skin boat disposes this kind of "'head". On very old photos of former Tibet travellers, the "heads" of the boats are likewise recognizable. Unfortunately, the early wall paintings of skin boats give no explanation about the existence of these special sewed skin pieces. It remains unclear whether the so-called "head" of the boats was

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[53] Aris 1979, p.185. Aris writes: "... This interesting figure is not only remembered for his many iron chain suspension bridges and boat ferries, ..."

> originally used purely for practical reasons (to make the skin more imperishable from flaws by dividing the seam), or whether his origin can actually be related to Thangtong Gyalpo.[54]

Concerning the ferries in general, there is a clear reference to Thangtong Gyalpo. Probably, his most significant suspension bridge is 'Chakzam' (therefore, simply 'suspension bridge' without local epithet) which spans across the Yarlung Tsangpo, some distance above the confluence with the Kyi-chhu river at the holy mountain of Chu wo ri. Apart from the few distinct monasteries, there was once a monastery where the monks followed the tradition of Thangtong Gyalpo. This was also the seat of his incarnations and it was completely destroyed during the Cultural Revolution. Not only was the suspension bridge built for monastery, but it is also a facility for ferries.

Mc Govern comments on this in 1926:

> We had different animals brought with us and, hence, we could not use these boats (Kowa). For us a big, rectangular, wooden boat with a plane ground was prepared, which I believe, was the only one of its kind to be found in Tibet.[55]

Iron chain suspension bridges in the Himalayas

The literature attributes the construction of 108 suspension bridges and many ferries to Thangtong Gyalpo who is said to have built them with a principle motive of making the holy sites accessible to pilgrims. Out of 108, 100 are supposed to have been built in Tibet and the rest in Bhutan. The number 108 is a magic number, a lucky number, e.g., 108 plaits of the Tibetan women or 108 beads in the 'Tibetan rosary' (*phreng ba*) or 108 (9 x 12) columns that are manifested externally in the largest dukhang. Going by the biographical records, Thangtong Gyalpo, his followers and immediate

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[54] Altner 2005, p.36/37.
[55] Mc Govern 1926, p.203.

successors have built numerous suspension bridges in Tibet and Bhutan, and what seemed more reasonable, than to ascribe 108 'luck-bringing' bridges to the great master. Other authors mention 100 or 80 bridges of Thangtong Gyalpo, of which eight are across the Yarlung Tsangpo alone.

The fact that some chain bridges fell into the water at their original place or were dismantled and partly put together by using chains of different forerunner bridges to new bridges elsewhere, causes among other things, many difficulties at the identification and the assignment of the bridges. In this way, the iron chain bridge at Tashigang in Eastern Bhutan was destroyed in 1968 by floods and parts of those chains were reinstated in the bridge at the nearby Doksum. A part of the chains of this bridge was demolished again in 2005 and was integrated into a new iron chain bridge at Tamchog, which was chosen as the place for the building a new one at the special request of the royal family, as it is strongly associated with Thangtong Gyalpo. Although, the new bridge is planned for the site, however, it is very difficult to ascribe the chains to Thangtong Gyalpo owing to the above reason.

However, at least three facts help to assign iron chain bridges directly to the great master. They are biographical references to bridge buildings and places where Thangtong Gyalpo has worked; the form and arrangement of iron chain bridges; and, finally the form of the chain links or the blacksmith's technology.

Below is the list of iron chain bridges and their locations in Tibet, China, Bhutan and Nepal. Following this, existing bridges or bridge remnants are discussed followed by bridges which are mentioned in the literature, and finally data are presented to those bridges, where only the names are known. From the numerous reports on the bridges by travellers, researchers and adventurers, like Johannes Grueber and Samuel Turner up to Sven Hedin and Heinrich Harrer, only a few will be presented - as far as it seems necessary for the use of the technology, but also in as far as to elaborate on the impressions.

Tibet

In Tibet, at least six iron chain bridges or essential parts have survived to this day:

1. Chung Riwoche Chakzam
2. Phuntsholing Chakzam
3. Rinchen Chakzam
4. Tholing Chakzam
5. Riwoche Chakzam
6. Panding Chakzam

From two other significant bridges river pillars still exist.
1. Chakzam
2. Nyang Druka Chakzam

Finally, there are information available for the following bridges that were mostly sunk.
1. Rinchending Chakzam
2. Batang Chakzam
3. Sogchu Chakzam

Chung Riwoche Chakzam

Beside the 'Chakzam' at the Chuwo Ri mountain, the iron suspension bridge at the Kumbum in Chung Riwoche is one of the most significant creations of Thangtong Gyalpo. About 100 kilometres upstream from Lhatse and about 50 kilometres from Rinchen Ding, Thangtong Gyalpo's birthplace, the bridge straddles over the Yarlung Tsangpo. The bridge is located about 250 metres away from Thangtong Gyalpo's masterpiece, the Chung Riwoche Kumbum, which secured the access to the shrine for the pilgrims particularly during the time when the ferry traffic was not possible. In addition, the bridge safeguarded the transit on the big east-west connection in Tibet. Even today, the bridge from more technical side than aesthetic view proves to be an impressive work.

In only about 200 metres of distance downstream, a new cable suspension bridge that may be used by light vehicles was built in similar dimensions and in similar structure like the bridge of Thangtong Gyalpo.

Today Chung Riwoche and the bridge lie apart from the big traffic roads through Tibet and can be reached in a cumbersome journey from Lhatse even in about six to eight hours at favourable weather and road conditions.

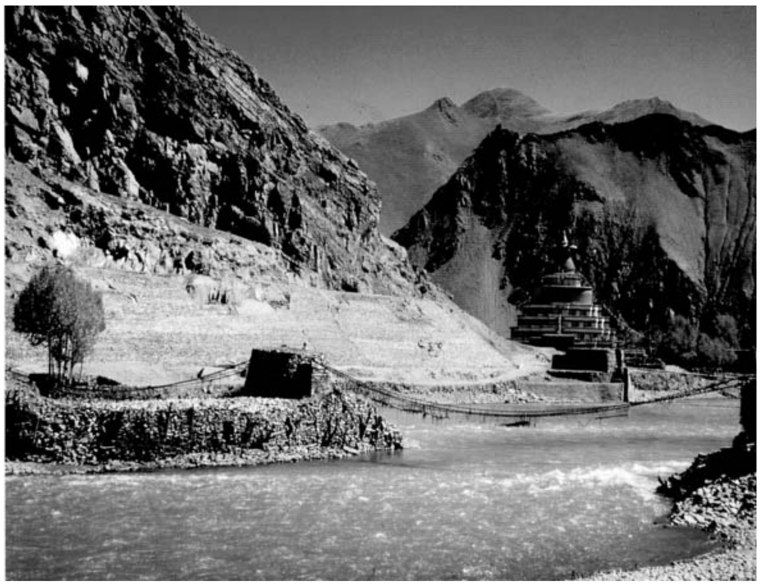

Fig. 25: The Chung Riwoche Chakzam in front with the Kumbum in the background.

Bridge technology

The bridge lies in a wide river valley, which does not support anchoring of chains in the rock, but had to be spanned across two land pillars, the bridgehead and the stream pillar. Because of the long span of the left bridge field, Thangtong Gyalpo used four chains in Chung Riwoche: Two chains with a little thicker chain links, which carry the walking layer directly and two chains possibly at the height of a handrail, which are connected to the lower chains by ropes and help with the carrying in this manner.

The stream pillar and both land pillars rise about six metres with a clear gradation of three metres of height above the normal water level. Stream pillars and land pillars consist of wackestone from the river that exist in large quantities at the site and are partly reinforced by strong wood. The stream pillar owns about 15-metre long breakwater and icebreaker upstream in the same construction like the pillar itself. The still original construction shows that one knew how to handle technically the floodwater strong, waves and even more so, the ice drifts of the stream current.

The dimensions of the bridge and chain links are:

- Span of the wide opening approximately 60 m
- Span of the shorter opening 35 m
- Chain links of the lower chains approximately 22 to 26 cm long, 7 to 8 cm wide
- Steel cross cut approximately 2 x 3 cm
- Chain links of the upper chains approximately 23 to 38 cm long, 7 to 8 cm wide
- Steel cross-cut approximately 2 x 2 cm

According to the biographical information, Thangtong Gyalpo built the bridge in 1436, i.e. after his first trip to Bhutan, from where he brought large quantity of iron to Tibet. In connection with the preparations for the construction of the Chung Riwoche Kumbum, Thangtong Gyalpo in 1448, even mentions about the advantages of bridge.[56] It is clearly mentioned in many sources, what importance it had for the

[56] To enforce the construction site desired by him, Thangtong Gyalpo in 1448 explained to the regional rulers the advantages of the construction site for the Chung Riwoche Kumbum, which was in immediate vicinity of the river crossing via the iron chain bridge built by him.

traffic in Tibet. It was obvious even in 1945, when Heinrich Harrer, after his escape with Peter Aufschnaiter from the English internment camp in India and on the way to Lhasa, writes:

> On the 2nd of December, 1945 Peter Aufschnaiter and I reached the big Tsangpo. Already days before worries tormented us as to how we could cross it. In Tschung Riwotsche (Chung Riwoche), as the place on the opposite riverbank was called, stood an enormous Stupa, as big as we knew it only of pictures from Gyantse. The Tsangpo was covered with gigantic ice floes and to swim through it was absolutely unthinkable, because of the strong current and cold. A nomad who noted our desperation pointed upstream where an iron chain bridge with two pillars spanned the stream. It was one of one hundred and eight iron bridges, that Thangdong Gyalpo built 500 years ago had forged.
>
> After we had unloaded our things, the yak went into the cold water without any hurry. The waves engulfed him, only his immense head protruded between the floes, the current grasped the obviously excellent swimmer and about one kilometre downstream he reached the other shore. Of course our minds at that time were thinking of other things, than to admire the brilliant construction of the bridge. We climbed on the raised bridge pillar and saw that there was no ground at all. One had to put the foot straight on strap and might not look down, so that to one did not become dizzy by the raving floes. I waited, until Aufschnaiter had reached the next bridge pillar, then the balancing act began. I carried the shivering dog under one arm, and with the other hand I had to hold on to compensate the swinging of the iron chain bridge. It was adventurous and the thought that I had to do it this way once again, disheartening. So that the fingers did not stick on the iron, we used socks as gloves. The bitter cold of twenty degrees minus gave us no end of trouble. We manoeuvred for hours and the day came to an end. However, we had overcome the big obstacle on the way to the north.[57]

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[57] Harrer 2005, pp.24-26.

In the year 2002, the bridge is still extant but was not passable anymore, because the cables to the connection of the chains and the walking layer were missing in each case on the last metres. The villagers explained to us that since the establishment of the new bridge, the old bridge was not maintained anymore. However, as it is associated with the Mahāsiddha, it is still revered highly: The numerous prayer flags like the dead black cat hung up nearby the bridgehead and the remains of a raven testify this fact. The black animals represent a defence symbol for the people and the bridge.

Phuntsholing Chakzam

The Puntsholing Chakzam (today Pinzoling) across the Yarlung Tsangpo is about 50 km downstream of Lhatse. The bridge served as an easy access to the Puntsholing monastery and even more to the huge Jonang Chörten, only about 1.5 hours of travel on foot from the bridge, but served also the holiday traffic to the north-south as well as to east-west direction.

The geographical situation of this bridge and the bridge building work is similar to Chung Riwoche, that Thangtong Gyalpo had two river pillars set up next to the banks, which almost stand dry at low water and another two pillars as bridgeheads on the banks in the distance of approximately 20 to 25 metres of the river pillars. The pillars, that are made from wackestones of the river and rise about nine metres above the water, are three times reinforced and protected well with wood. Since the crown of a pillar is worn out, it is easier to understand the construction well. Around a row of vertically placed wood, some rings of beams are carpentered that show a steady skeleton altogether. There are also timber joint plugs, mole plugs and leaves to be found. Despite the big span of the central field, only two chains are spanned here. In between the chains, which serve as handrails, ropes or, more recently cables, which carry the walking layer were and still are spanned. Because the stream pillars lie near the bank and are thereby are spanned less, the wave and ice rejecters are set up less strongly.

The dimensions of the bridge and chain links are as follows:

- Span of right bridgehead (1st stream pillar): 25 m
- Span of the central field: 76 m
- Span left bridgehead (2nd stream pillar): 20 m
- Chain links: approximately 25 cm to 28 cm long and 7 cm to 8 cm wide
- Steel crosscut: approximately 1.8 x 2.5 cm
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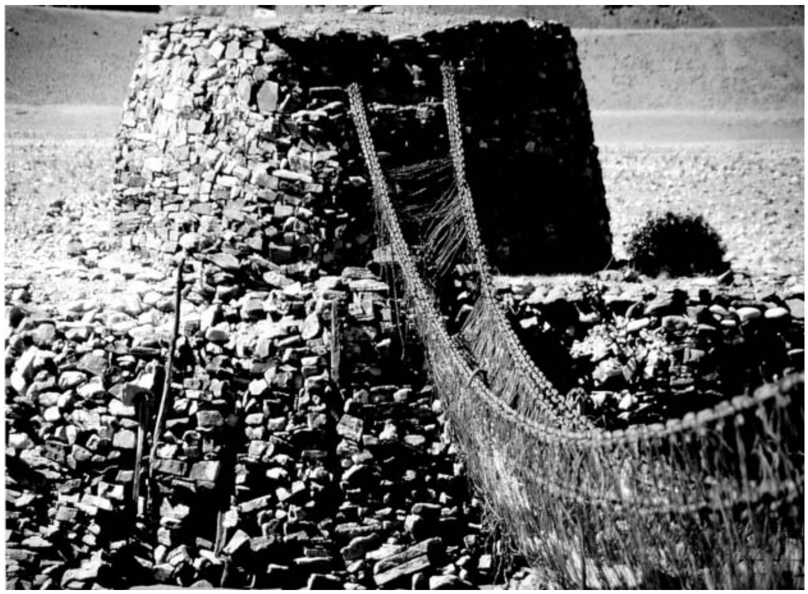

Fig. 26: The part of the Phuntsoling Chakzam across the Yarlung Tsangpo, which is still functioning.

The bridge was used until about 1904. In 1907, Sven Hedin reports in his book 'Transhimalaya':

> Almost immediately south of Tschagha, a village with a few stone houses in a grove of old willows, one can see the monastery and the Dsong (Dzong) of Pinsoling (Phuntsholing) on the right riverbank. The river is narrow and the banks full of round granite blocks of one metre in diameter; the necessary material to a bridge is available. On the banks two mighty stone pyramids and behind the two another two

> smaller ones are erected. Between those two thick chains are spanned that are prolonged up to the smaller pyramids and are fastened there once again. Between the chains, a network of ropes is spanned like a hammock on which one lays narrow planks; on these one walks and uses the chains as a railing. However, since three years the Pinsoling Bridge it is not used anymore; whoever wants to proceed to Pinsoling from Tschagha, must first go upstream to Ladse-dsong (Lhatse dzong) and then use the ferry there.[58]

During the last years of the 20th century, only a few metres from Phuntsholing a new suspension bridge was built upstream, which can also carry heavy traffic load. The bridge of Thangtong Gyalpo for some time must have still been used, because instead of the former ropes for the walking layer cables were arranged. With the first local perpetration by the author, the bridge was still passable. In 2001, it was no longer usable but still completely available. However, in 2002, the bridge stood only from the left bridgehead up to the first stream pillar, while the chains of the middle section and the right part lay in the floods of the Yarlung Tsangpo.

Rinchen Chakzam

On the edge of a wide valley, to the north of Lhasa where the rivers Rong Chhu, Talung Chhu and Miggi unite to the Kyichu river, another bridge attributed to Thangtong Gyalpo leads across the Kyichu. This iron chain bridge allowed among others, the access to the huge monasteries of Reting, Taglung and Drigung, but it is also important traffic wise, as well as strategically. Through this bridge, several caravan used to cross, in particular the north-south road from Sining and the Kokonor across the Tangla mountains, Reting, then via the Rinchen Chakzam, which for example, had already been used by father Johannes Grueber in the middle of the 17th century.

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[58] Hedin 1909. p.375/376.

The Chom Lhakhang, which has been restored in recent times, and a small settlement, the today's Lhundrub Xian, are located directly above the bridge. The bridge building place has a geomantic meaning concerning the related and consistently formed 'pyramid mountain'.

The four chains of the bridge from different construction phases spanned directly above the possibly head-high pylons on the riverbanks of the Kyichu.

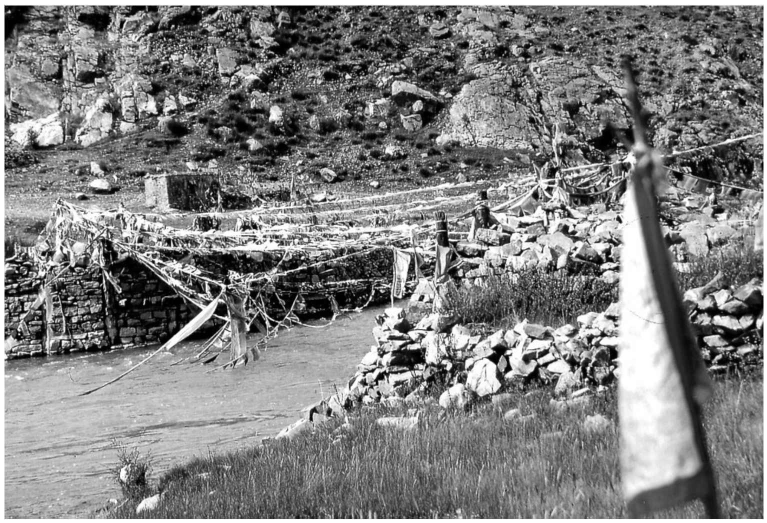

Fig. 27: The Rinchen Chagzam on the way the monastery of Reting and Lhasa, Tibet.

The dimensions of the bridge and chain links are:

- Span approximately 45m
- Chain links vary; they are approximately 30 to 40 cm long and 8 to 11 cm wide, where a single chain links with more than 50 cm of length occur.
- Steel cross cut approximately 1.8 x 2.0 cm to 1.8 x 2.8 cm.

Wolf Kahlen has, with the help of an indentation in a chain link identified the construction date to be 1442.[59] In another chain link, the name 'Rinchen Chakzam' is engraved and the term 'Rinchen' for 'great preciousness' must be seen in direct connection with the Mahāsiddha who has established the bridge.

In the third quarter of the 20th century, only a few metres farther downstream, a huge stone arch bridge, with double lanes for heavy traffic was built.

The numerous prayer flags at the chains and on the bridgeheads testify the high admiration, which people have for Thangtong Gyalpo. A dead black cat for the defence against evil of bridge and people is hung up at the chain links at the side of the village just before the investigation of the bridge by the author in 2004.

Tholing Chakzam

A combined bridge straddles a narrow gorge of the Sutlej only a few kilometres from Tholing. This bridge protected the access to the once important Western Tibetan kingdom of Guge with the monastic cities of Tholing and Tsaparang. The Sutlej river, with torrential flow and narrow gorge is practically not passable with ferries, and before iron chain bridges existed, had to be crossed on a so called 'single rope bridges' at other places, where one had to 'work his way along' or had to draw oneself to move in a ring or box. Several travellers report about the reckless enterprise of this suitable river crossing.

As the pack and riding animals also needed a bridge to cross the gorge and the torrential waters, another construction was chosen in Tholing. Initially a vertiginous wooden cantilever bridge was erected because of its bridgeheads that were

[59] Kahlen 1992. p.41/42.

'stuck' in the rocks. On top of the tiers of beams that are cantilevering far outside, bended beams that are as long superimpose the centre field. Because the span is too wide, this bridge could hardly carry itself. Therefore, high above the stonewall bridgeheads; two strong chains are hung to hold the wooden bridge.

Above the old bridge, the steel construction of the new iron truss bridge is visible.

Fig. 28: The combined cantilever and iron chain bridge on the way to Tholing.

Sven Hedin praised this bridge explicitly:

> The bridge of Totling (Tholing) is a good quality construction, and one can entrust the planks one's horses without slightest fears. The bridgeheads are built in form of short stone tunnels on the outlets of the rocks, maybe 12 metres above the water surfaces. Between the upper surfaces of the tunnel walls, two mighty iron chains are spanned from riverbank to riverbank; the wooden rail of the bridge is hanging in them. The whole construction is joined so firmly that the bridge does not even tremble noticeably under the weight of the horses. The chains

> also serve as railing, and my mould had no opportunity to try his luck with a new death jump.[60]

The suspension bridge of Tholing, better the cantilever bridge hung up by chains, is still standing. One must pay attention not to overlook it. Chinese engineers have erected a steel truss bridge for heavy load traffic, which lies slightly apart from it.

The dimensions of the old bridge and chain links are:

- Span approximately 30 m
- Chain links approximately 26 to 38 cm long and 7 to 8 cm wide
- Steel crosscut approximately 1.8 cm x 2.5 cm

Riwoche Chakzam

In the Eastern Tibetan Province of Kham, another suspension bridge is ascribed to Thangtong Gyalpo. The Riwoche Chakzam straddles the Chi Chu, a tributary of the Mekong, which is about 60 kilometres to the north of the provincial centre of Riwoche, near the village of Chakzamkha, called after the iron chain bridge. The bridge is constructed as a stress ribbon bridge possibly like the bridge in Chhuka, with five chains which had a width about 2.60 metres, which directly carry the bridge rail. Today the chains are connected among each other with cable.

Andreas Gruschke has accurately described this bridge:

> It has a span of about 40 metres and the chains are about 56 metres long, including its clamped support in the bridgeheads. Only one chain is supposed to stem from the original bridge, while the others arose with the repair and the rebuilding measures. The bridgeheads surmount the bridge

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[60] Hedin 1909, p.305. With the construction of a steel bridge, the suspension bridge was difficult to access and is now practically not walkable anymore.

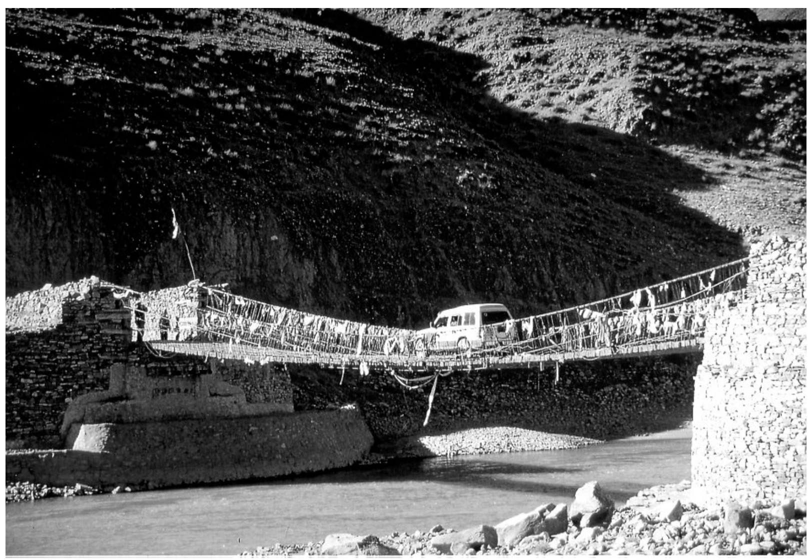
> rail by about 10 metres. The height of the bridge is about 7 metres above the water level gauge at normal water level.[61]

To start a small ferry service, the iron chain bridge was strengthened in the 19th century with a steel cable and the handrails.

The bridge was and still is an important limb of the caravan way from Lhasa and Central Tibet to the western part of the Chinese province of Szechuan.

The name of the province, Riwoche, as well as the monastic foundation in Derge, the successor of his school tradition, and not least indications to the death of Thangtong Gyalpo in Kham in Eastern Tibet, are enough clues that this bridge was originally constructed by Thangtong Gyalpo.

Panding Chakzam



[61] Gruschke 2004, p.157

Fig. 29: The Panding Chakzam strengthened with steel cables for modern traffic.

The suspension bridge at Panding across the Yarlung Tsangpo is approximately 40 metre wide is located about 65 kilometres upstream from Lhatse and 35 kilometres downstream from Chung Riwoche. The bridge is in close proximity to Thangtong Gyalpo's birthplace Rinchen Ding, which lies about three hours walk downstream. A 97-year-old Tibetan, Wangchuk from Panding recounted the fate of the bridge during the last about 100 years: Until 1994, the old suspension bridge stood with about six chains and a width of about 1.20 metres. This bridge, because of its width and planking stood relatively firm against the side wind and served for pack and riding animals. Chinese engineers altered the bridge in 1994, by widening it to 3.20 metres to make it passable for light vehicles. In addition to this modification, they strengthened the bridge with steel cables. Now the bridge has two mighty stonewall bridgeheads across which span the chains as well as the steel cables.

The dimensions of the bridge and chain links are:

- Span: 44 m
- Original width: 1.20 m and width since 1994: 3.20 m
- Chain at the top side of the river, chain links 30 to 41 cm long, 7 to 8 cm wide
- Steel cross cut approximately 2 x 2 cm
- Chain at the lower side of the river, chain links 26 to 31 cm long, 7 to 8 cm wide
- Steel cross- cut 2 x 2 cm

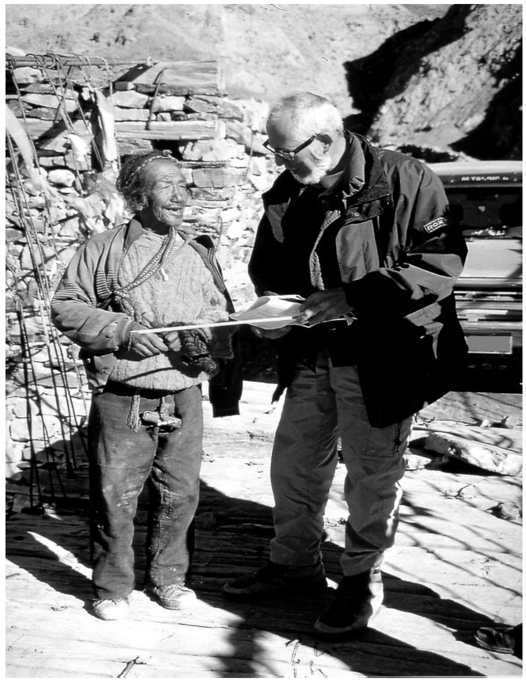


Fig. 30: The author interviewing a 97 year old Tibetan Wangchuk about the history of the Panding Chakzam.

Chakzam

Although Chinese engineers tore down this bridge during the construction of the new concrete bridge in about 1950, the 'Chakzam' now and then also called 'Chu Shur' or 'Chu Shul' Chakzam remains the most famous bridge building work by Thangtong Gyalpo. Only the southern stream pillar made from wackestone from the river still tells us about its significance as one of the oldest and probably farthest spanned iron chain bridges in the Himalayas. From the whole northern part of Tibet, including Lhasa, one reached Thangtong Gyalpo's main monastery at the southern Yarlung Tsangpo banks of Chuwo Ri via this iron chain bridge. Further, on, the north-south connection led to Bhutan, Sikkim, Nepal and India. Moreover, across this bridge, the way led from Lhasa to the big cities of Gyantse and Shigatse.

According to biographical information, Thangtong Gyalpo built this iron chain bridge in the male iron dog year, corresponding to 1430, before his visit and iron import from Bhutan. With the construction of this suspension bridge, even more legends and stories are attributed to him at other places. Before there was a bridge here, Thangtong Gyalpo wanted to cross the Tsangpo by a ferryboat at this place. Since he was looking like a beggar, the pugnacious ferryman hit Thangtong Gyalpo with the oar that led the Drubthop fall into water. Thangtong Gyalpo was so angry about the immorality and impudence of ferrymen in general, that he decided to build a bridge and save pilgrims and travellers from similar situation.

Another story recounts a practical side of Thangtong Gyalpo. For erecting the Chakzam as well as later bridges, he required money. In order to manage this, he created a musical play, searched seven especially pretty young girls as singers, let them perform the song play and earned a lot of success and high sums of money for his bridges: Ache Lhamo, the Tibetan opera was born. Tashi Tsering has precisely examined the activities of the Drubthop and has found the following passage in this regard:
The Biography of Dpal Lcags zam pa Thang stong rgyal po and brief account of the building of iron bridges by the 11th *Lcags zam grub thob sprul sku* says:

> In the 15th Century, in order to raise funds for building iron bridges across big rivers in Tibet which were difficult to cross, Thang stong rgyal po called together seven young daughters of a family known as Sbas sna in 'Phyongs rgyas. The seven sisters had beautiful figures, smiling faces, irresistibly attractive looks, the youthfulness of the full moon and melodious voices. The mere sight of them disturbed one's mental equilibrium. He taught them the steps and tunes etc., and with the achievements of the ancient forefathers as the theme of the performance, he introduced the tradition of *a lce lha mo*, comprising *Rngon pa, Rgya lu, Lha mo,* and the use of

> cymbals and drums, in all parts of Tibet. Hence Thang stong rgyal po is known as the founder of the *lha mo* tradition of the performing arts of Tibet. Not only does the folklore of Tibet describe Thang stong rgyal po as the lha mo tradition, but even today, when the lha mo artists stage performances, they always carry an image of Thang stong rgyal po with them. From this one can infer that Thang stong rgyal po founded the *lha mo* tradition of (the) performing art of Tibet.[62]

The Chakzam stood about 65 kilometres southwest from Lhasa, above the confluence of the Kyichu and the Yarlung Tsangpo. The northern bridgehead was located at the today's village of Chushul. At the southern bridgehead below the Chakzam or Chuwo Ri monastery, stood a big chörten**,** the so called Thangtong Kumbum, that had his statue and relics enshrined inside.

The bridge was erected in the design mostly chosen by Thangtong Gyalpo. Instead of usual two chains, this particular one has four chains, i.e. a doubled chain on every side across the bridge pillars were spanned and anchored with split pins in the strong beam of the wooden framework of the stream pillars, owing to its length. Up to four metre long ropes were hung between the chains and carried a bridge layer from lined up planks, several metres long and approximately 30 centimetres wide.

According to photos of the suspension bridge that have been published several times, e.g., from Sven Hedin in 1907,[63] the middle section must have reached a span of more than 100 metres. In spite of the length of the bridge, the northern riverbank was flooded with high water behind the northern bridge pillar.

Despite having 'high volume of traffic' at this most important river crossing of Tibet, still the iron chain bridge functioned

62 Tsering, T. 2001, p.47.
63 Hofmann 1983, p.83

well. Here at this bridge, once riding, pack animals, and those herds that could not cross the several hundred metre wide Yarlung Tsangpo without swimming cross the river in addition to the human traffic. Here, there was also ferry traffic by yak leather boats and wooden ferries.

Over the centuries, many travellers have recounted their adventures on or with the bridge. Von Hesse-Wartegg in 1900 ranks the bridge among the wonders of the world and reports in the "Wonders of the World":

> At it's fastest and at the same time deepest position (of the river) a precipitous rock island rises from its torrential floods, which was to the Tibetans virtually a naturally made bridge pillar. Nevertheless, the width of both arms of the river was still too large for the production of hanging ropes for a suspension bridge made from bamboo poles. Thus in the fifteenth century the Chinese prince Tang Tong had then made four massive chains with links of sixteen centimetres of diameter, forged of iron, spanned here across the river and hung up a bridge rail on ropes into these chains. The immense, half a millennium old work of Chinese engineering art exists even today, but while the chains are only slightly affected by the rust, the network of the bridge rail is damaged to such an extent that the Tibetans have given up the use of the bridge a long time ago and now help themselves to cross the river with two ferry boats. The place at this point of the Tsang-Po is still called Tschak-Sam (Chakzam), that is iron bridge.[64]

In 1904 and 1905, Austine Waddell was a leading medical officer with the Younghusband expedition to Tibet. He compiled a precise report of 'Chakzam' from a military point of view, of importance, is the specification of the bridge. According to his report, the span of the bridge is approximately 150 yard or about 137 metres. Since the description is precise, a relatively long citation will be repeated literally:

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[64] Hesse-Wartegg, p.217.

The old iron suspension bridge spans picturesquely the main stream of the river about 200 yards below the ferry, under the monastery which bears its name, `The holy hill of the Iron Bridge` (Chak-sam ch`ö-ri). It is of the kind met with in Western China, and, according to the local tradition, was built in the early part of the fifteenth century A.D. by the sage T`angtong-the King, now a canonised saint, whose image is worshipped not merely in the adjoining monastery, which he is also said to have built… His monumental handiwork here of itself certainly entitles him to the respect of the inhabitants; for although it is not used at present, owing apparently to the river having burst for nearly half its waters a fresh channel to the north, and so having left the northern end of the bridge stranded amid stream, the structure itself still stands firmly after all these centuries, a magnificent piece of engineering work in the wilds of Tibet. It is about 150 yards in length and 15 feet above flood-level, and stretches between two tall masonry piers which are characteristically given the shape of the sacred chorten. The northern pier stands on a large mound, doubtlessly founded on a rock, on what is now a wooden islet in the middle of the river, and the other stands on the rocky southern shore below the monastery (…). The two double chain-cables, made of 1 inch thick iron links of a foot long, are fastened at each end to great beams built into the piers and into the rocks beyond them. Between and connecting these two tightly stretched cables were suspended, throughout their length, at intervals of about a yard, loops of yak-hair rope, carrying, in their apex below, a footway of planks 1 foot broad and lashed end to end. The bridge was still in use in 1878, when visited by one of our Survey spies, whose diagram of it, here produced, shows the whole river as running under the viaduct, and this is still to occur at low water in the dry season. At present, being out of use, the timber footway and its suspensory ropes have been removed. The chief defects of the structure are its want of lateral stays to prevent the alarming swinging, and its open sides with narrow footway prevent it being used for cattle – only for human passengers, and not more than one of those could pass at a time. No toll was said to be levied for transit over it, as it was kept in free repair by the villagers for the Government; whilst for the ferry the fee of about two pence per passenger, and four pence a pony, went to the local monastery.[65]

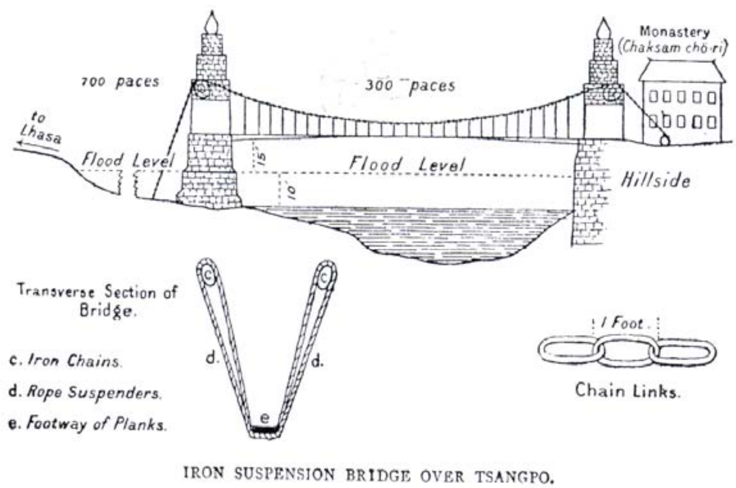

Fig. 31: The European drawing of the Chakzam. Source: Waddell, 1895

65 Waddell 1905, p.312-314. Waddells text is the most precise description of the 'Chakzam'. Indeed, the drawing enclosed by Waddel of a Pandit from the year 1878 is precisely calculated, however, it interprets, e.g., the representation of a 'European house' as well as the profile of a bridge wrongly.

Mc Govern comments in 1926:

> I trembled in the cold, and in order not to remain too near to the ferry hut, I walked up to the cliffs to throw a look at this half a mile downstream situated monastery. Although it has only a few hundred residents, this monastery has some fame, because it is the starting point and the base of the big iron chain bridge, which earlier was spanned here across the Brahmaputra river. The bridge still exists and at the break of dawn, it looked rather picturesque, but it is not useful anymore, because the river has expanded his banks during the last years, so that the northern end of the bridge forms a small island in the middle of river. The Tibetans were not able to develop the suspension bridge up to the new riverbank, and have rather again applied the ferry system. The bridge was good and had endured centuries, built by king Tantong who, born in 1385, is now looked at as a saint of the Tibetan religion. This bridge is not his only architectural work, because he is also supposed to have built 108 temples, altars and seven other suspension bridges across the Brahmaputra. People tell that some of these bridges are still in use today.[66]

[66] Mc Govern 1926, p.202.

Fig. 32: The pillars of the former Nyango Druka Chakzam in the wide river bed of the Yarlung Tsangpo near Tsethang.

The dimensions of the bridge and chain links are:

- Span of the central field: approximately 137m
- Chain links approximately 30 cm long
- Steel Cross Section: approximately 1,8 x 2,5 cm

Nyango Druka Chakzam

About five kilometres downstream from today's Tsethang, there are five river pillars out of formerly many more such pillars of an iron chain bridge of Thangtong Gyalpo. Now the river pillars present themselves of differing heights, however, they fit with their internal wooden constructions and the reinforced two-staged constructional systems out of wackestones from rivers with originally about six to eight metres of height precisely to the standard constructions by Thangtong Gyalpo. Today the river pillars are revered for being associated with Thangtong Gyalpo and carry numerous prayer flags.

The Nyango Druka Chakzam too formed an important component of pilgrims' route. The pilgrim and caravan route from Lhasa to the Yarlung valley, which led through the Yön valley with its significant temples, but also the pilgrim's route to Samye, which lies about 35 kilometres to the west of the former northern bridgehead of the Chakzam, all led across this iron chain bridge. Chan suggests that the bridge across the Yarlung Zangpo, which here is a kilometre long, owned more than 30 stream pillars and the spans of the chains amounted to about 150 metres.[67]

The watchtowers, which also served as additional weights for the anchoring of the chains stood on both sides of the bridgeheads.

[67] Chan 1994, p.379.

Rinchen Ding Chakzam

About 45 kilometres upstream of the Yarlung Zangpo, from Lhatse at the right riverbank, the village of Rinchen Ding, the birthplace of Thangtong Gyalpo is located. A resident of Rinchen Ding reported to the author in 2002, that the bridge, Thangtong Gyalpo erected for the residents of the village across the Yarlung Tsangpo, has possibly the dimensions as the bridge of Panding had before its reconstruction. It is about 1.20 metres wide and permits the trouble-free meeting of people on the bridge, but also the crossing of yaks and horses.

In his long life, Thangtong Gyalpo has erected numerous iron chain bridges. Following are some of the bridges that that bear literature.

The Chakzam at Batang, across the Dajin, a tributary of the Yangtze-Kiang, which belonged to the system of another big road connection from Tibet to China. The caravan route led from Markham in Eastern Tibet to Batang (suspension bridge) and further via Litang, Kangding to Luding (suspension bridge) to Chengdu. Sogde Chakzam, also called Sogchu Chakzam, located in Nub Hor.[68]

China and Tibet

Luding Chakzam

Across the former border river between China and Tibet, Dajin (Ta-Teu), today Dadu He, a tributary of the Yangtze-Kiang, a suspension bridge leads to Luding (Ludin-tscheu). The bridge across the border river was, like the bridge in Batang, an important part of the caravan and courier route i.e. Lhasa - Markham - Batang - Litang - Kanding - Luding to Chengdu. The relatively wide and stately iron chain bridge

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[68] Gruschke 2004, p.155. With a literature reference to Bower.

was compared to Thangtong Gyalpo's other bridges erected as late as 1701.

Cooper writes about the history of this bridge as the 'trip to the location of an overland road from China to India in 1882":

> A day's journey brought us from Owha-lin-pin to the city of Lu-din-tscheu, which, because of the suspension bridge which spans the Ta teu river there, is famous.... The famous bridge was, fortunately, just in a damaged state and made our group cross the river in a more safe kind, namely on a big ferry. While we crossed, the first skipper who was very talkative told to us the history of the suspension bridge across Lu-din-tscheu.
>
> Shortly before the annection of Eastern Tübet by the Chinese, the government in Peking posted a reward of 30,000 Taels for those who would succeed in building a bridge across the Ta-tow-river, which caused serious difficulties in the regular relations between China and Tübet, because of its often sudden swelling and its great depth. The swiftness of the current and the high rocks, which restrict the riverbed let all attempts fail to span the river with stone arches. Nevertheless, finally, a blacksmith came to the city and had the idea of a suspension bridge. The officials, who were authorised to collect ideas from suggestions, accepted his plan and as the Abbé Huc was saying, the bridge was completed in 1701. The construction of the same is very faulty. Nine big chains, not completely as thick as a ship cable, four feet apart from each other are spanned across big square bridgeheads, which are erected on both riverbanks and are firmly immured. The ground is made of simple planks, which show neither a railing, nor are they protected by ballast, and the vibrating careens are so strong that it is sometimes nearly impossible to gain a foothold. Every day from midday until four o'clock in the afternoon, the doors, which lead to the bridge, are closed, and nobody may cross the same, because then the terrible hoist races down the gorge and makes the passage very dangerous. People say that the bridge has performed good services during the first couple of years after its erection,

> however, during the last years the most gruesome accidents would have occurred through the tearing of the chains.[69]

At the beginning of the 20th century, the bridge was strengthened and made more comfortable with two lateral chains each (serving as handrails). The two chains through hanging bars supported the supporting chains arranged below the bridge rail.

Patterson writes about the Luding Chakzam after his trip through Tibet in 'Tibetan Journey' in 1950: "The last solid bridge on the way to Tibet from China".[70]

> This bridge has attained political recognition through the 'long march' by Mao Tsetung and his army, who escaped via this bridge in 1936 with 35,000 men and thereby saved himself and his men the night before the approaching troops of Chiang Kai-shek who at the time were even stronger than him.[71]

During the renovation, the hanging iron was substituted by chains and the bridge rails, namely with closely recumbent cross-pieced wood and wood beams. By then, the bridge was constructed more firmly than before. In this form, the author arrived at the bridge, which was in good condition and surely passable in 1980 as in 1996. Thousands of people now use it daily. Light carriages can pass through it.

Bhutan

In 1433, Thangtong Gyalpo came to Bhutan. His route can exactly be traced.[72]

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69 Cooper 1882, p.181/182.
70 Patterson 1952.
71 Gerner 1999, p.1410.
72 (For this, see the chapter 'Biographical notes on Thangtong Gyalpo' and 'Thangtong Gyalpo's journeys to Bhutan'.)

In Bhutan, the Mahāsiddha not only found open ears for his teachings, but he also found big iron ore deposits. The land was even more depended on consolidated bridges than Tibet, as raft or ferry connections were not possible because of precipitous gorges and torrential rivers, except in some southern and eastern parts of the land.

Thus, it does not surprise that Thangtong Gyalpo in Bhutan immediately put into practise the vision that he had received from Avalokiteśvara, namely to relieve the people from their grievous crossing of gorges and torrential streams or make it possible all through the construction of iron chain bridges. Immediately after his arrival in Bhutan, Thangtong Gyalpo began with the construction of iron chain bridges. While travelling through Western Bhutan, it is interesting to note that the Chakzampa visited especially the places where he found iron ores, as for example Tamchog, also called Damchog, Damchhu, Tashog or Tamtscho, or places that since ages were associated with blacksmiths, as for example Chang Dunkhar - above the Paro airport. Thus, it is reported in the 'History of Bhutan' that in Paro, 18 blacksmiths went to the master to help him and forge iron and further more chain links.[73]

Even more with a lasting effect than in Tibet, Thangtong Gyalpo had left his blessings and his works in the form of traces in Bhutan. He is alive to this day because of his devotion to Dharma, his bridges, but also because of his 17th reincarnation.

Today, in addition to the four existing iron chain bridges, there are chain leftovers or the locations of at least six other iron chain bridges that Thangtong Gyalpo built in Bhutan. This becomes easily evident through the very different figures, beside the 108, i.e. 100 in Tibet and 8 in Bhutan.

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[73] Gerner 1999, p.1410.

The existing iron suspension bridges in Bhutan are: (1) Tamchog Chakzam, (2) Doksum Chakzam, (3) Dangme Chakzam, and (4) Khoma Chakzam

In the following chain bridges, chain leftovers, anchors or supports exist: (1) Tashigang Chakzam, (2) Chaze Chakzam, and (3) Changchi Chakzam

Another three suspension bridges that are more or less extensively described in historical and contemporary literature are: (1) Chukha Chakzam, (2) Wangdi Chakzam, and () Chuzom Chakzam

Tamchog Chakzam

According to the biographical notes in the *History of Bhutan*, Thangtong Gyalpo erected a bridge across the Paro Chhu (*sPa gro chu*) to Tamchog (*gTam chos*) by 1433.[74] The successors of the first Chakzampa built a Lhakhang here,[75] the Tamchog Gonpa (*gTam chos dgon pa*). In 1969, the iron suspension bridge was destroyed by high water. The chains were partly rescued and kept in the attic of the shed behind the Lhakhang where I found them while visiting the place in 1980 and 1992. According to the oral tradition, even other chain parts are supposed to lie buried in the riverbed below stones and sand. To ensure the access to the Tamchog Lhakhang across the swift moving Paro Chhu, a suspension bridge was built from cable ropes after 1969.

As per the royal wish of His Majesty King Jigme Singye Wangchuck, the Ministry of Works and Human Settlements had in 2005, the cable rope suspension bridge again substituted with an iron chain bridge. The foundations of the bridge on both riverbanks, i.e. the bridgeheads bear stately gate superstructures, which is set up so highly that practically no more danger exists through high water. The iron chains used are historical without exception from different places. Some of them are the secured chains of Tamchog itself, four chains are supposedly to originate from Doksum and some from Tashigang.

The soil of the hill on which the Tamchog Gonpa stands, is coloured red by the strong iron content. We can also see metalliferous lodes on the towering rock behind the Gonpa.

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[74] Tshewang 1994, p.100 ff.

[75] Tshewang 1994, p.100 ff. The literary references as well as the oral notes of the present residents differ a lot in this respect. It is certain that even the present owners and residents of Tamchok feel obliged to the tradition.

Finally, the author could discover several ‘mouthpieces’ of ore tunnels further up on top of the mountain.

Fig. 33: The newly erected Tamchog Chakzam (2005) across the Paro Chhu.

However, legend also knows different ways about how the wrought iron reached to this place. Thangtong Gyalpo, while visiting Wang Dhalukha in Thimphu, not far from the village of Genekha, which in the literature is known for its rich iron ore deposits,[76] found rich iron ores. He is said to have requested the residents for those ores, and they offered all iron with a belief that he would not be in a position to transport everything available. However, with supernatural powers the Drubthop is said to have thrown the iron up in the air and landed in Chags, above the Tamchog Gonpa. He is

[76] Rapten 2001, p.6.

then said to have used his knee as an anvil and forged two bridges in one day from the iron, i.e. one for Tamchog Gonpa and the other one, Chaze Chakzam, which was erected only a few kilometres downstream.

Doksum Chakzam

In the village of Doksum, also called Duksom and Drugsum, on the way between Tashigang and Tashi Yangtse as well as Chörten Kora, an iron chain bridge is built here across the likewise very steeply precipitating and torrential Kholong Chhu. This bridge at least is supposed to have been strengthened with chains of the Tashigang Chakzam bridge, after it was destroyed by high water in 1968.

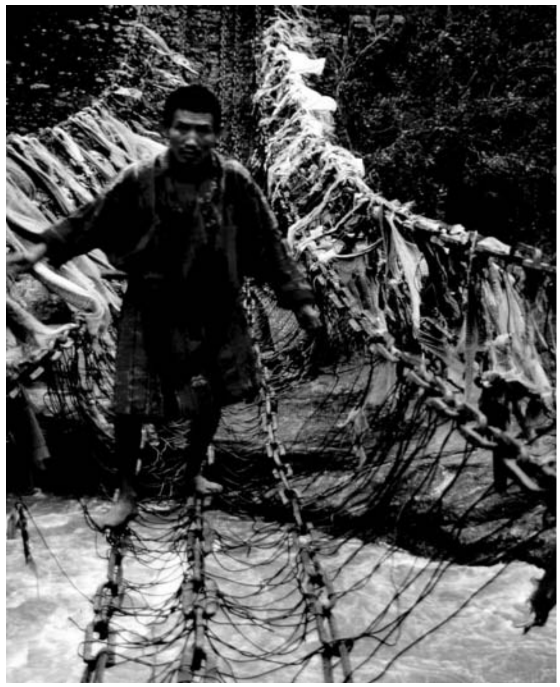

Fig. 34: The Doksum Chakzam in Bhutan, 2003.

In the meantime, a Bailey bridge was built across the Kulong Chhu, even closer to the aperture, which takes up not only pedestrians, but also heavy goods vehicles. The iron chain bridge still serves as access to Tomijangsa. The author could observe the Doksum Chakzam in 1985 and but surveyed it exactly only in 2004.[77]

Fig. 35: The anchorage of the Doksum Chakzam

The span of the bridge stretches to 38.4 metres. The bridge existed out of nine chains until 2004. Three chains carried the bridge rail and three chains on every side formed the railing. At the bridgeheads, the lower three chains had a distance of 66 centimetres (which is relatively wide tread), the lower railing chains were 1.50 metres apart, the above lying

[77] The engineer Horst Taft and the author carried out the measurement work. The bridge was still used in 2004. However, both bridgeheads in particular with the abutments showed considerable damages.

chains two metres, and both upper chain rows had a distance of 2.68 metres. Earlier, plant fibre ropes connected all chains. Later, these ropes were substituted with a network from wire. In both cases, all railing chains help with the support. With recumbent 'handrail chains' that are 2.68 metres apart and which were not meant for touching as arises from the measure, but instead, just as with the 'Chakzam' at Chushul in Tibet, had to strengthen the strong lateral vibrations. The chains correspond to the standard type of the chains of Thangtong Gyalpo.

The dimensions of the bridge and the chain are:

- Span: exactly 38.4 m
- Chain links approximately 31 to 35 cm long and 7.5 to 8.5 cm wide
- Steel cross-cuts measure approximately 1.6 x 2.5 cm

Dangme Chakzam

Karma Ura informed me about an existing iron chain bridge in the Mongar Dzongkhag. The bridge is a part of the caravan way between Mongar Dzong and Pemagatshel Dzong at Kengkhar across the Dangme Chhu. Karma Ura estimates its length at approximately 100 metres. As with the bridges in Doksum and Tashigang, there is a direct connection to the iron ore deposit, which is located about two day's journeys away from Khaling.[78]

Khoma Chakzam

Karma Ura also informed me about an iron chain bridge in the Luntshi Dzongkhag. About 10 minutes walk from the village of Khoma, there existed an iron chain bridge on the way from Lhuntse Dzong to the Monkhar Gonpa, across the tributary of the Kuri Chhu. The bridge had a span of approximately 25 to 30 metres and was now substituted by a

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[78] The information bases on a verbal report by Karma Ura and the report on the iron ore deposit is by Phuntsho Rapten.

wooden cantilever bridge. One of the chains of the former iron chain bridge lies in the river and the other one was incorporated into the wooden bridge.[79]

[79] Oral report by Karma Ura.

Tashigang Chakzam

Below the Tashigang Dzong, an iron chain bridge of Thangtong Gyalpo spanned the Dangme Chhu (*Drang me chu*). Like the Dangme Chu Chazam, the bridge spanned about 100 metres and was constructed in the standard bridge form of the Chakzampa: Two chains bound between ropes from plant fibers, which were later replaced by wire, which carried a walking layer, the bridge rail. In 1968, a high water tore away the foundations of the iron chain bridge and collapsed into the water. The chains were later rescued and partly kept in the Tashigang Dzong, where they lay on the court wall for a long time. Another part of it is hung up on the walls of the former right bridgehead in the Chakzam Lhakhang, which is dedicated to Thangtong Gyalpo.

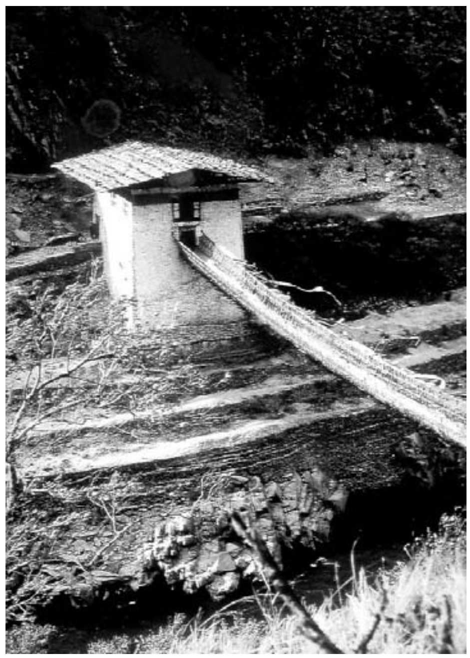

Fig. 36: The former Tashigang Chakzam across the Drangme Chhu. Photo: Fritz von Schulthess.

The dimensions of the chain links are:

- Chain links 33 to 37 cm long, 8 to 8 cm wide
- Steel cross-cut approximately 1.3 x 2.0 cm

A chain link of this bridge was examined metallographically from 1978 to 1979 in the Confederate Technical College of Zurich, Switzerland. The results of this investigation are reported in brief in the segment 'Productions from Iron and Steel.'

Chaze Chakzam

Another suspension bridge was to be found across the Paro Chhu, also called Pa Chhu, about three kilometres to the west, i.e. upstream from Chuzom (*Chu 'dzom*) and half way to Tamchog. The bridge connected the way to the right alongside the Paro Chhu with the villages of Tenchey Khar that is situated high above the left valley, nowadays called Dangkarta, Chippu and Bjee Toed as well as the Choetsi Lhakhang, the Drakten Lhakhang and the monastery of Dangla, which is further apart.

The iron chain bridge had a span of about 35 metres and was washed away by flood in 1968. It was substituted by a suspension bridge from cable ropes and the foundations and bridgeheads of the iron chain bridge were used for it. On 20th February, 2004, road workers who were busy with the preparations for a permanent bridge building as well as a road to the above mentioned villages, found a nearly eight metre long section of the former iron chain bridge in the river.[80] Choetsi earlier was likewise a blacksmith's village and inside the Choetsi Lhakhang, there is an altar dedicated to Thangtong Gyalpo and his son Buchung Gyalwa Zangpo.

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[80] The weekly paper of Bhutan, *Kuensel* reported in detail about the unexpected chain finding on 20.03.2004.

Fig. 37: The new statue of Thangtong Gyalpo inside the Sili Gonpa.

Changchi Chakzam

Shortly after Chukha, Samuel Turner crossed another iron chain bridge and Davis noted this bridge down in his maps. I have searched for this suspension bridge and found the remains of it. It crossed the Wang Chhu between Chochoka, the today's Changchi, and the Sili Gonpa. Next to the road, the remains of the anchorage can still to be found in the bank rocks, and, finally, a part of the chains is kept in the basement of the Sili Gonpa. In the Dukhang of this monastery, the link appears. We find the statue of Thangtong Gyalpo revered.

As long as the iron chain bridge stood, Sili Gonpa could to be reached from the road in a few minutes. Now, without a bridge, it takes about an hour of driving and more than one and a half hours of walk. The Gonpa is cut off by the traffic, and, therefore, nothing was known about the chains available there. The chains hanging in the Sili Gonpa look differently from the other chains that can be traced back to Thangtong Gyalpo. The link length up to 40 cm is possibly the same, the width amounts to about 8 to 10 cm, however, above all, these links are relatively raw and have been forged unevenly and the steel crosscut with about 2.5 x 3.5 cm is bigger than the other chains

Fig. 38: Altar inside the Sili Gonpa with Buddha Śākyamuni in the foreground and the chain links of the Changchi Chakzam in the back.

Chukha Chakzam

Chukha Chazam presents a prominent significance for the history of the iron chain bridges in Bhutan and Tibet as well as the later evolution of suspension bridges in Europe and America. George Bogle used it on his way to Tibet and wrote about it; also, the mission under Samuel Turner in 1786 crossed this iron iron chain bridge. Turner had the bridge exactly described, measured and recorded, and, above all, the precise dimension and accurate drawing set the suspension and iron chain bridge building into motion.

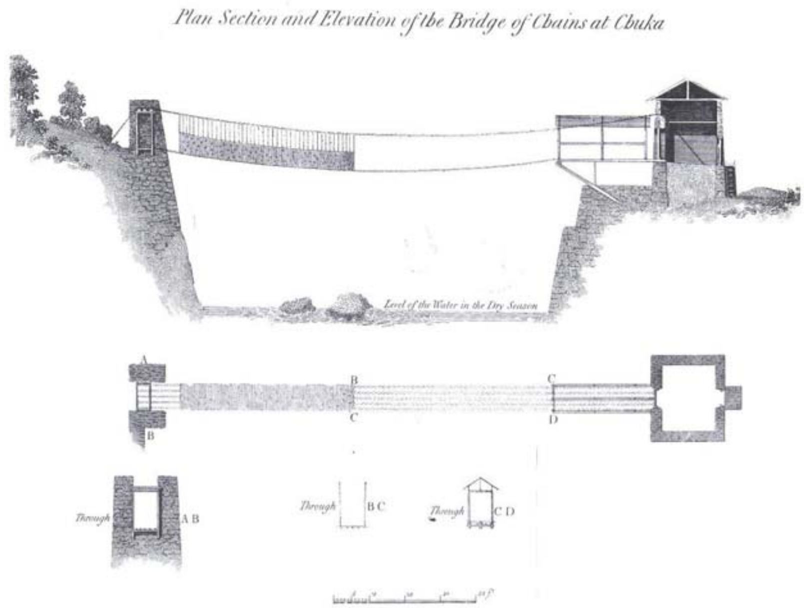

Fig. 39: The drawing of the Chukha Chakszam published by Samuel Turner in 1800 in London after the exact measurement of his travel companion Samuel Davis. Source: Turner, 1800

Turner comments about the bridge:

> We descended the mountain, and crossed the chain bridge called Chuka cha-zum (Chukha Chazam), stretched over the Tehintchieu (Thimchu) river, a short distance above the castle of Chuka, which is reckoned eighteen miles from Murichom. For the best explanation of its construction, I refer to the annexed plan and sections, constructed from a measurement of the different parts. Plate III. A perspective view of it, and the adjacent scenery, is given in Plate IV. Only one horse is admitted to go over it at a time: it swings as you tread upon it, reacting at the same time with a force that impels you, every

> step you take, to quicken your pace. It may be necessary to say, in explanation of the plan, that on the five chains that support the platform, are placed several layers of strong coarse mats of bamboo, loosely put down, to play with the swing of the bridge; and the fence on each side, of the same materials, contributes to the security of the passenger.[81]

The Real Privy Council (Wirkliche Geheime Rat) M. V. Brandt in 1909 translated a report by C. R. Markham about the bridge:

> At Chukha the river is very torrential and wide, and an iron bridge has been hung across it. Five chains are spanned from one riverbank to the other and covered with slats and mats of bamboo, which form the ground of the bridge. Two other chains on every side are spanned about seven feet above the outer chain and connected to it by twisted raw seaweed cords. The bridge is 147 feet long and six feet wide. As soon as one puts the foot on it, it moves from one end to the other.[82]

With 147 English feet, the Chukha Chakzam was about 50 metres long, 1.50 metres wide and the uppermost side chain according to the various accounts between 2.1 and 3 metres high. The bridge was designed as a stress ribbon bridge where the bridge rail from bamboo mats directly overlaid five lower chains. These five chains were linked with plant ropes among each other; likewise, both upper chains and a thick railing with about 1.20-metre height were integrated. The left bridgehead, which foundations reached below the normal water level, was shaped in form of a bridge house that was provided with a cantilevering, roofed wooden construction, which shortened the span of the iron chain bridge to the riverside. The right bridgehead with foundation stood about five metres above the normal water level and was attached to the rock and had at the level of the bridge a heavy wooden scaffolding of about three metres of height above which the

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[81] Turner 1800, p.54/55.

[82] Brandt 1909, p.83/84. Brandt has translated and edited the reports of the trips of Bogle, Manning and C. R. Markham.

upper two chains were spanned, and two string board walls of about 1.50 metre of thickness which protected the wooden scaffolding against lateral toppling.

Lumbolang Chakzam

George Bogle reports about a bridge across the Thimphu Chhu: 'At Lumbolang is a bridge that exists of only two chains.'[83] The place called Lumbolang by Bogle lies half a way between Paga Gonpa and Babesa, i.e. at the today's Khasadapshu. In Khasadapshu, an important bridge across the Thimphu Chhu exists even today.

Chuzom Chakzam

At Chuzom, both the Paro Chhu and Thimphu Chhu unite to the Wang Chhu. Karma Ura reports that after the confluence, an iron chain bridge spanned the strategically important point. In 1974, the author instead of the iron chain bridge found a Bailey bridge already suitable for heavy vehicle traffic. A substantially higher laid and further spanned concrete bridge later substituted it.

Wangdi Chakzam

Below the Punakha Dzong, the winter residence of the Je Khenpo, Pho Chhu and Mo Chhu unite to form Puna Tsang Chhu, which in India is called Sankosh. The most important crossing from Western to Central and Eastern Bhutan led across this river below the Wangdi Phodrang Dzong, and here clearly there is a bridge history written. According to Karma Ura, a stately cantilever bridge divided by a natural stream pillar was constructed in 1684 in place of iron chain bridge. Ura writes: "The bazam replaced an iron chain bridge installed by Thangtong Gyalpo at the same site".[84] The transport links at this point has never lost its importance. In 1968, a concrete bridge with a daring arch again replaced a

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[83] Brandt 1909, p.84.
[84] Ura 2000, p.50.

Bailey bridge, which substituted the washed away wooden bridge, shortly before the turn of the millennium.

Nepal

In Nepal, there was a tradition of the construction of iron chain bridges as well, and some of them still exist to this day. Whether or how far this tradition goes back to Thangtong Gyalpo, cannot be determined according to the present level of knowledge.

In principle, transport and traffic are strongly dependent on ravines and flood in Nepal as they are in Tibet. In 1975, Manfred Taube writes:

> The most vulnerable place of the road network are the river crossings: Fords are not usable during the whole monsoon period, also the crossing with logboats stops in this time, and the small rivers that are otherwise crossed on a simple trunk are likewise not passable during the rainy season. In addition, the usual suspension bridges, that are swaying strongly when someone is passing it, do not contribute substantially to the stabilization of traffic. Entering of the wooden gangways is perilous in many places. While the only wooden cantilever bridges passable for animals must be renewed about every eight years, the rotten planks lying on bamboo ropes are substituted in general only when somebody is braking into it - although, on the other hand, in some places with the participation of the whole village communities a full day is used for the blessing of the bridges four times a year.[85]

Honorary Consul Dr. Manfred Kulessa, generously transmitted first news and photos of the iron chain bridges of Nepal to me and Dr. Hans Renatus provided photos from Eastern Nepal.[86]

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[85] Taube 1975, p.161.

[86] Dr. Manfred Kulessa, Honorary Consul of the Kingdom of Bhutan, as UNDP representative conducted the bridge building program of Baglung and reported to the “Nepal Council for World Affairs” on 18 August, 1977. Dr. Kulessa provided extensive material on suspension and rope bridges in Nepal, in addition to reports on engineer's offices and material from state organisations. Dr. Hans

Renatus during his travels in the eastern Nepal discovered a number of iron chain bridges across the Bhote Kosi and the Khimti Khola rivers. Dr. Renatus has documented the bridges through photographs and made them available to me.

The extensive research resulted in surfacing numerous facts to the iron chain bridges as well as to the blacksmiths and all together proved a good overview on the iron chain bridges in Nepal.

Fig. 40: Iron chain bridge across the Bhote-Kosi in Nepal. Photo: Hans Renatus

Early reports on iron chain bridges in Nepal in the 18th century testifies discovery of iron occurrence and their exploitation, including techniques of blacksmiths in producing the chains. The iron chain bridges then replaced rope bridges from plant fibres, like they were also common in India, Ladakh, Tibet and South America, as well as bamboo, round timber, squared timber and wooden cantilever bridges.

While the rope bridges from plant fibres survived only few years and the wooden bridges were often washed away by the high water, the iron chain bridges provided good services for at least 50 years and mostly survived much longer.

Condition for iron chain bridges was in each case the regional occurrence of iron ore. For example, in circa 1970, numerous iron chain bridges exist in the district of Baglung[87] to the west of Pokhara, but also in eastern Nepal around Jiri. Norman Hardie reports about this during his journey in 1955:

> At the sixth day since Kathmandu, we reached the last of the Hindu villages. High up on top of the hills, we saw mouths of the tunnels leading to the iron ore deposits. At the wayside stood furnaces and black smithy. Mostly a child served the bellows, while it used the long lever arm as a seesawing swing. From those there come the door locks of the Sherpas and the strong chains of the better iron chain bridges.[88]

The chain links and chains were forged by the Kamis, the blacksmiths, a caste of untouchable craftsmen. These blacksmiths played an extremely important role, because they forged not only the chains, but also the anchor constructions as well as for the wood processing and stone treatment tools.

The known iron chain bridges of Nepal with lengths of about 50 metres had a uniform construction. Between two chains in each case a walking layer of approximately 20 centimetre width or a bridge ground up to about 60 centimetre width was hung up with ropes from plant fibres, wire or hanging bars and the iron chains served even as handrails. At least in western Nepal, chain links of 1.5 to 2 cm thick round iron chains had been forged, while Thangtong Gyalpo's chain links in Tibet and Bhutan were designed from rectangular crosscuts. In eastern and northern Nepal, hammered chain

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[87] Groeli 1977, p.3.
[88] Hardie 1960, p.118.

links also exist from rectangular crosscuts, which could be a reference for a connection with Tibet.

In the beginning of the thirties of the last century, the iron chain bridge construction in Nepal received a striking incision, because the ruler of Galkot in Calcutta had anchor chains bought and advanced to Nepal and instead of hand-hammered chains allowed them to be used for suspension bridges. However, the heavy anchor cables did not assert themselves in general, rather 20 years later, in about 1950, a far bigger change already began: At the renovation of bridges, the chains were substituted by cable ropes**.** In the beginning, smaller bridges applied the same technology like with iron chains and later with bigger spans, they used cable rope suspension bridges. The use of cable ropes in Nepal proved to be extremely advantageous, because the cable ropes of the cable railway, which was, stretching many kilometres from Hetauda to Kathmandu, had to be changed regularly, and these used steel cables could serve as a material for many bridges. Thus, in the last quarter of the 20th century, hundreds of new cable bridges could be erected or suspension bridges removed with the help of regional and private programs, like the 'Baglung District Suspended Bridge Construction Pilot Program',[89] but also state programs, like the 'Trial Suspension Bridge Program 1975-1977.'[90]

A significant parallelism is to be ascertained with the bridges of Thangtong Gyalpo in Tibet as well as Bhutan and the bridges in Nepal. However, in particular, Thangtong Gyalpo and his successors built iron chain bridges for the development of the land and to create easy access to the holy sites for pilgrims. The iron chain bridge construction was a

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[89] Groeli 1977. See also: East Consulting Engineers, Kathmandu: Trail Suspension Bridge Study conducted for United States Agency for International Development, Nepal, Kathmandu 1977

[90] Pfaffen 1977.

good action and contributed to the improvement of the karma.

Even in Nepal, bridge building was and still is regarded as a good and socially useful activity. Many of the iron chain bridges, as well as the cable suspension bridges of Nepal, were sponsored by single person or by family clans. In turn, they also maintain them.

Thus, it is reported that a poor man who went to India as an immigrant worker for many years, upon his return used the saved wage for the material of a bridge for his village.

To cite a better example: In 1940, Tikaram Kharel bought anchor cables from Calcutta had a bridge erected across the Dharan Khola in the Panchayat Kadebes. In 1971, after 30 years of its construction, the bridge had to be renovated. The sons of Hiralal, Klimananda and Gopiram Kharel took the responsibility as a family duty and had a new, longer iron chain bridge erected; this time, however, again forged on site.

IV THANGTONG GYALPO'S IRON CHAIN BRIDGE AND THEIR INFLUENCE IN EUROPE

Thangtong Gyalpo, besides being accomplished in many other fields, is especially known for pioneering works in spiritual as well as iron chain bridge building. With his iron chain bridges, he had created a lasting access to the religious sites as well as safe traffic routes. This was confirmed by all European travellers that journeyed through Tibet from 1600 until the middle of the 20th century.

Up to the present work, the influence of Thangtong Gyalpo's iron chain bridges on the European and American suspension bridges did not become a subject of serious study. Despite numerous proofs of the technology transfer from Asia to Europe and later also to America, it is unusual, in western thinking, that beside the religious and artistic treasures of Buddhism, technology from Tibet initiated developments in Europe and America! Regarding the iron chain bridges, two important influences are to be noted: In the 17th century, reports and ideas about iron chain bridges built by Thangtong Gyalpo came to Europe and after 1800, their precise technical details, which led immediately to the construction of suspension bridges in Europe and Asia, became known. Beside the general sequence of events, direct connections can be drawn from the chronological presentation given below:

1430-1460 Thangtong Gyalpo and his followers build numerous iron chain bridges in Tibet and Bhutan. The bridges reach spans of more than 100 metres and are free of corrosion. Some of the bridges are extant to the present day and are still put to use.

1601 Father Matteo Ricci (1592-1610) founds the first Jesuit mission in Peking. From 1601, scientifically compiled reports reach Europe from China and Tibet.[91]

1616 Faustus Verantius (1551-1617) publishes his book 'Machinae Novae' in Venice. The great artists and master builders of the Renaissance like Filippo Brunelleschi (1377-1446), Michelangelo Buonarotti (1475-1565), Leonardo da Vinci (1492-1519) and Andrea Palladio (1508-1580) had all designed stone and wooden bridges, frame, truss-frame and arch constructions but no suspension bridge.

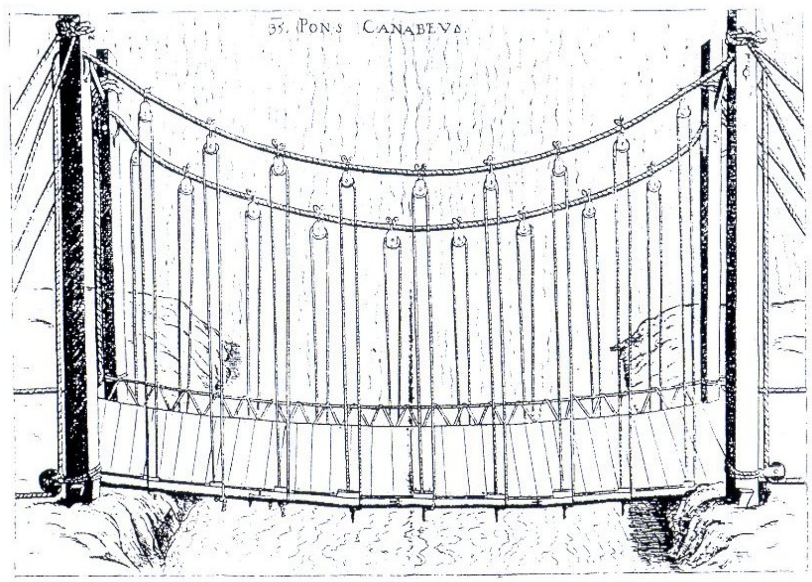

Fig. 41: First model of a suspension bridge in Europe published by Faustus Verantius in 1616. Source: Dietrich 1998

The chain construction of the Twärren Bridge that was erected in about 1218 across the Schöllenen gorge at the Gotthardroute through the Alps was not a bridge, but a path

[91] Leibold 2002, p.113

that was fastened by chains.[92] Verantius in his book takes up the ideas from Asia for iron chain bridges and, moreover, introduces two prototypes of suspension bridges, one a highly hung bridge with textile ropes and another chain bridge with eye bars. While the stone and wooden bridges likewise shown by him are in fact close to reality for being able to build during the period, however, both suspension bridges are relatively far away.[93]

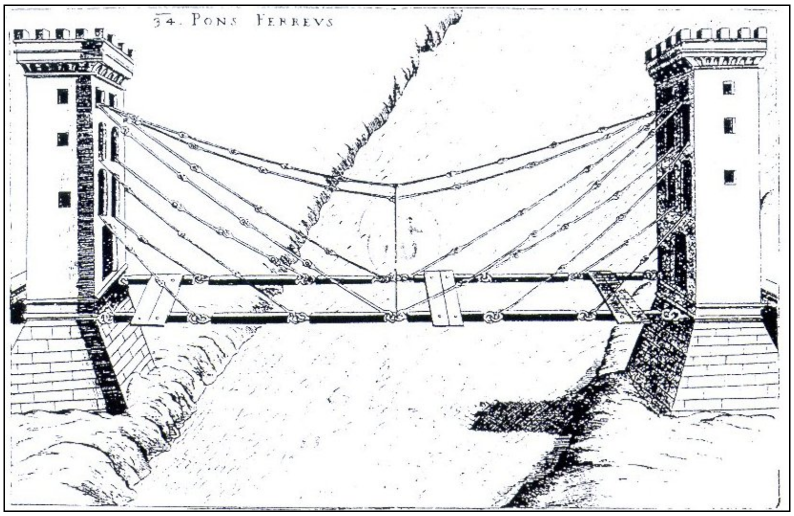

Fig. 42: Another concept of a suspension bridge by Faustus Verantius. Source: Dietrich 1998

1631 The universal scholar Athanasius Kircher (1602-1680) born in Geisa in the mountains of the Rhön in Germany becomes a professor of mathematics, physics and oriental languages and was appointed to the Collegium Romanum by the pope in Rome. The letters and reports of the Jesuit's fathers from China and Tibet and further from the whole

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[92] Peters 1981, p.53.
[93] Verantius 1616.

world end up on, or at least cross Kircher's table with abundance of information from many parts of the world.

1656-1664 The Jesuit Johannes Grueber from Linz at the Danube is sent to China to explore a northern land route to China. Grueber uses the seaway to Macao for the outward journey; and the return journey leads him, according to his instructions, across land from Peking to India. Father Grueber, therefore, was the first European who crossed Tibet. In his letters, Grueber dedicated only few lines to the trip of many months from Peking to Kathmandu, but indeed with enough exact local names, so that the route is to be pursued exactly: Peking, Sining Fu, Kokonor, Nyenchen Thangla mountains, Reting monastery, Lhasa and Kathmandu. It is certain that on his way, he must have at least crossed two bridges erected by Thangtong Gyalpo, one is the Rinchen Chakzam to the south of Reting across the Kyichu river which even exist today and the 'Chakzam' across the Yarlung Tsangpo, that existed up to about 1950. In the letters that he wrote from 1664 to 1665 with travel accounts, Grueber says nothing about iron chain bridges.[94] However, in 1664 Grueber reported precisely to the fraternity general of the Jesuits. What is even more important is that Grueber was in close contact with Athanasius Kircher for many years. Kircher later published the reports that were transmitted orally to him by Johannes Grueber and with his explicit approval in his work, 'China monumentis qua sacris qua profanis nec non variis naturae & artis spectaculis, aliarumque rerum memorabilium argumentis illustrata.'[95]

1667 Athanasius Kircher publishes his large work on China as Tibet was more or less subsumed under the generic term 'Catai' entitled: 'China monumentis ... illustrata' in Amsterdam. Michael Leibold comments on the book: "The

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[94] Grueber 1985
[95] Kircher 1667

state of the literature and the exclusivity of his information enabled Kircher with his 'China ... illustrata' to publish a prevailing and systematising work about China." Especially outstanding technical objects were the bridge building, the Great Wall of China, varnish production, letter printing and the invention of the gunpowder.[96]

The pictures in the work of Kircher, however, were delivered by the already introduced father Matteo Ricci, but even more so, by father Adam Schall von Bell (1591-1666) who worked for many years as a high official at the court of emperor Shunzi in Peking. Kircher was also the first European to present the sketched representation of the Potala, the residence of the Dalai Lamas in Lhasa.

About the bridges, Kircher reports:

> In the province of Junnan one sees across a deep valley through which a creek with very fast waters flows, a bridge, about which is told that it was erected by the emperor Ming of the Hanfamily in the year 65 A.D., and which was not built from brick stones or by the composition of immense stone blocks, but from very strong iron chains which are fastened by hooks and eyes on both sides of the mountain in such a way that a bridge originated from superimposed planks. There are 20 chains from which each has the length of 20 measuring poles (pertica), i.e. 300 hand spans (palmus). If many people cross it at the same time, the bridge sways and moves from here to there, and the crossing people not without fear, dizziness and in fear of falling down walk in a great hurry. I cannot admire enough at all the skill of the Chinese architects by whom they have dared to try such a difficult work to the comfort of the travellers.[97]

The translation presented here follows the Latin text of Kircher narrowly, which is in contrast to others that follow

[96] Leibold 2002, p.114

[97] Kircher 1667, p.213 ff., translated by Margarete Rosskopf, Burchard Schlömer and Dr. Matthias Vogt.

more free translations. Kircher clearly says that people 'narrate' that the bridge has been built in 65 A.D. A 'narrated' date with so many stopovers on the way to Europe is questionable. On the other hand the representation of the length (the reporter must have seen the bridge) is explained very exactly - namely with the measurement common to Tibet - the hand spans.[98] In addition, the technical details, like the anchorage, are reproduced exactly. Finally, Kircher expressively testifies his respect for the work and the architect. It is to be assumed here more from the fact that two circumstances are shown in one trait: On the one hand the story of a bridge from the year 65 A.D. and on the other hand the technology of the iron chain bridge of Thangtong Gyalpo seen by Grueber.[99]

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[98] see moreover: Baumeister und ihre Maßordnungen, in: Gerner, M.: Architekturen im Himalaya: (transl.) „One tala tho, a hand span, equals 12 finger widths (anguli). In centimetres the tala equals a measurement of 20 – 24 cm, the anguli between 1,7 und 2 cm." According to this, the bridge would have had a span of about 60-70m obsessedly.

[99] The representations in the literature do not take up the 'narration,' but mostly contain conjunctive forms or accept the bridge building date of 65 A.D. more or less as given, like Peters, Tom, F.: The development of the great bridge building (Die Entwicklung des Großbrückenbaus): "Suspension bridges from iron chains are of Chinese origin. According to old traditions the first iron suspension bridge originated in 65 A.D. in the Chinese province of Yünnan." After that follows the representation of the bridges by Thangtong Gyalpo at the date of approx. 1420: "The first designer of iron chain bridges about whom we know further details was the Tibetan monk Thang-Stong rGyal-Po (1385-1465) who was active in the Himalayan Mountains. His bridges are all unstiffend. They sway strongly and the gangway lies directly on the chains. Some of it have survived, nevertheless, about 550 years and serve even today the pedestrian's traffic."

Besides, the pictures by way of introduction show Leupold's "Suspension bridge in Sina" and then next to a picture of Thangtong Gyalpo the drawing of the iron chain bridge of Chukha published by

Kircher's "Chinas monumentis .... illustrata" became very popular in Europe and was widely circulated and with it the basic knowledge of a functioning bridge from chains in China or Tibet also found a wide readership in Europe.

668 "China monumentis … illustrata" was translated into Dutch

669 It was followed by a shortened English version

670 The book was translated into French

672 There followed the second edition in Latin and Leibold comments: China … illustrata "was in the 17th century in which a not unimportant number of publications on China was made available, one of the most wide-spread titles."[100]

Turner in 1800 and a photos of the iron chain bridges of Chaze (Choetsi) and Doksum in Bhutan.

[100] Leibold 2002, p.113

Fig. 43: The first draft of an iron chain bridge in Tibet (China) which was published in Europe in 1726. Source: Leupold 1726

‘Theatrum Pontificiale’ or ‘Scene of the Bridges and the Bridge Building’ in Leipzig. The book contains drawings of an iron chain bridge, which practically illustrates Kircher’s description.[101]

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[101] Leupold 1726, TAB LVII. According to the inquiries and expositions made here an iron chain bridge of Thangtong Gyalpo

The Kircher's report and Leupolds drawing corresponds with regard to gorge and torrential rivers exactly to the chain numbers and measurements to Thangtong Gyalpo's bridge across the Sutlej at Tholing, which is preserved to this day, although hidden below a Chinese steel truss bridge for heavy traffic.

However, iron chain bridges for the European engineers were still exotic and strange in 1726. This is indicated by Leupold's text:

> Very much a quaint bridge of chains. Although the number of the copper plates have grown a lot, one still has wanted to add for the sake of curio, something else that is special to Chinese bridges, namely at first: Figure I. Table LVII, a bridge; Because from one high mountain to the other, with 20 immensely strong iron chains, covered only by planks, a bridge was built into the free air and can be viewed at with astonishment. It is supposed to have been built in China at of the city of Kintany.[102]

One meets the curiosity of the 'iron chain bridges' with a lot of care and restraint, and thus it does not surprise that before 1800 in Europe, only few iron chain bridges were constructed. Such a bridge was erected across the river Tees in northern England, approximately two miles above the city of Middleton in about 1740. It is not by chance, that Samuel Turner in 1800 transmits a report by Hutchinson from his book 'History and Antiquities of Durham' about this bridge in connection with the iron chain bridge in Chukha in Bhutan:

> About two miles above Middleton, where the stream showers in a row of cascades, there is a bridge from iron chains hanging from rock wall to rock wall, across an abyss of nearly

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that has been seen is exactly described and probably has been walked upon by father Grueber is presented, but is assigned to the story of a former bridge.

[102] Leupold 1726, § 321.

> 60 feet depth for the passage of travellers, but primarily for miners: The bridge is 70 feet long and a little bit more than two feet broad with a railing on one side and with boards planked in such a way that the pedestrian strolling through it, feels the shaking movement of the chain links and he himself is floating above a roaring abyss with a constantly moving ground below him, so that only few travellers dare to confide in this bridge.[103]

At the beginning of 19th century, this bridge collapsed, and was rebuilt and has then existed till the beginning of the 20th century.

In Germany, an iron chain bridge with a span of approximately 11.5 metres with width of 1.4-metre was built in 1781 in the park at Wörlitz. In its guides and descriptions, it is clear that there is a connection with Chinese or Tibetan iron chain bridges that are presented as models.[104]

Another iron chain bridge, possibly erected around 1794, with a span of about 12.5 metres and 1.90-metre width, stands in the park of Bagno near the Steinfurt castle.[105] Few examples and the extremely low spans show that one had reached to the idea of the iron chain bridge, but by far not yet the courage and the technology, which was realised at Thangtong Gyalpo's bridges.

One may recall the works of father Johannes Grueber, Athanasius Kircher and Jakob Leupold that the Europeans imported the knowledge of iron chain bridge construction from Tibet. In the initial years, the results in Europe were humble. If one hears the refrains of both 'visionary' bridge representations of Faustus Verantius, in Europe until 1800, there were only smaller iron chain bridges and chain footbridges with spans less than 15 metres that mostly

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[103] Turner 1800, p.55.
[104] Grunsky 1998, p.105 ff.
[105] Grunsky 1998, p.102 ff.

originated under the aspect of the exotic charm of models from China, and according to the previous analysis more from Tibet.

In 1800, this scenario changed. In 1774, Warren Hastings, the governor of Bengal and chairperson of the council of the East India Company, sent George Bogle in company of the doctor Alexander Hamilton to the court of the Panchen Rinpoche at Tashi Lhunpo in Tibet. They took their way through Bhutan from May to October 1774 and returned in 1775. In 1776 and 1777, missions followed under the direction of Alexander Hamilton.

In the beginning of 1783, Samuel Turner led another mission of the East Indian Company, who was also instructed to proceed to Tashi Lhunpo. Turner took the same way as Bogle. He was accompanied by accomplished people like Lieutenant Samuel Davis, a drafter and Robert Saunders for botanical, mineralogical and medical studies. Turner and his companions wrote less colourful travelogues, but recorded everything of importance in an academically precise way.

1800 As a result of the cited mission, a book of Samuel Turner was published in London "An account of an Embassy to the Court of the Teshoo Lama in Tibet, containing a narrative of a journey through Bootan and a part of Tibet". This book contains the detailed description and provides an accurately measured drawing of the suspension bridge at Chukha in Bhutan ascribed to Thangtong Gyalpo.[106] Turner's reports and communications were so important that in the same year, a French translation appeared in Paris followed by a shortened German translation in Leipzig in the succeeding year.[107] In 1817, an Italian translation appeared in Milan. Boeder rightly infers to the rapid European translations: "This

[106] Turner 1800.
[107] Boeder, in Thunlam 1, p.17, Bonn 2002.

already points to his importance. He collected a lot of material about the areas in Bhutan visited by him and described his manifold impressions very carefully. On this occasion, especially the countless rivers, the deep gorges, the traffic system, the bridge constructions (bridges from iron chains, wooden cantilever bridges), the architecture ……" interested him.[108]

The development and the unexpected triumphant procession of the suspension bridges in Europe began with this publication of a technically precisely illustrated bridge by Thangtong Gyalpo. In Europe and America and further worldwide, this design first led to iron chain bridges and then to bridges with cables. The developments and connections to Thangtong Gyalpo can precisely be understood through the numerous publications in Europe; however, mention of Thangtong Gyalpo is practically absent.

1801 The Justice of the Peace, James Finley, allows the first iron chain bridge to be erected near Philadelphia in America. The chains are like the chains of the bridges of Thangtong Gyalpo. Some authors report about the first test bridges of Finley from 1796.

1808 Finley registers a patent for iron chain bridges.[109]

1810 Finley publishes the patent for iron chain bridges and by 1820 he built about 40 smaller iron chain bridges with ring links and spans between 10 and 40 metres.[110] Only one bridge of its kind exists to this day, i.e. the 1810 Merimac Bridge which was built in Newburyport.

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108 Boeder, in Thunlam 1, p.17, Bonn 2002.
109 Bujler 2004, p.100.
110 Peters 1981, p.53.

1811 Thomas Pope publishes his book, 'Treatise of Bridge Architecture' in New York on the subject of iron chain bridge for a wide audience in the USA.[111]
1816-1817 A smaller iron chain bridges as pedestrian's footbridge is erected as an experiment in Scotland. Possibly, at the same time a number of scientific contributions on iron chain bridges, which refer to Pope's publications, appear in France.

1819-1820 Captain Samuel Brown (1776-1852) builds the first iron chain bridge, which links to the dimension of the bridges of Thangtong Gyalpo: The Union Bridge across the Tweed close to Berwick with a span of 110 metres. Besides, the chain links are formed not as ring links, but in the form of eye-bars. The eye-bars go back to Verantius and were developed from 1805 by Hawk and Brown.[112]

1819-1826 The Bangor bridge, planned by Thomas Telford (1757-1834), likewise from eye-bars with 176 metres of span is erected across the Menai canal in Wales.

1820-1825 Almost at the same time, the Convey Castle Bridge also planned by Telford with a span of about 100 metres is built.[113]

1823 Navier publishes the basic work for suspension bridges in Europe in Paris: 'Becquey et mémoire sur les ponts suspendus.'. This book presents the development of the iron chain bridges, which is relevant to the current work. At the beginning of the book, Navier shows a bridge from plant fibres in Peru, the sketch of an iron chain bridge across the Tees

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[111] Pope 1811.
[112] Grunsky 1998, p.100 ff. With the eye-bars considerably lower, dead weights of the bridges are achieved. Therefore, they also asserted themselves with the bigger spans more and more.
[113] Bühler 2004, p.100/101.

and one of the fantastic suspension bridges of Verantius and then shows Thangtong Gyalpo's bridge of Chuka in the exact representation of Turner with front view, longitudinal section and cross-cuts. The headline to it is: Pont de Chuka au Tibet.[114] In Turner's book, the bridge is located unambiguously in Bhutan and Navier also shows the right local name: Chuka. However, the reason for taking Tibet as the country of origin cannot be fully understood. It may be surmised that the wrong country name given is could be due to the fact that the invention laurels passed to Thangtong Gyalpo.

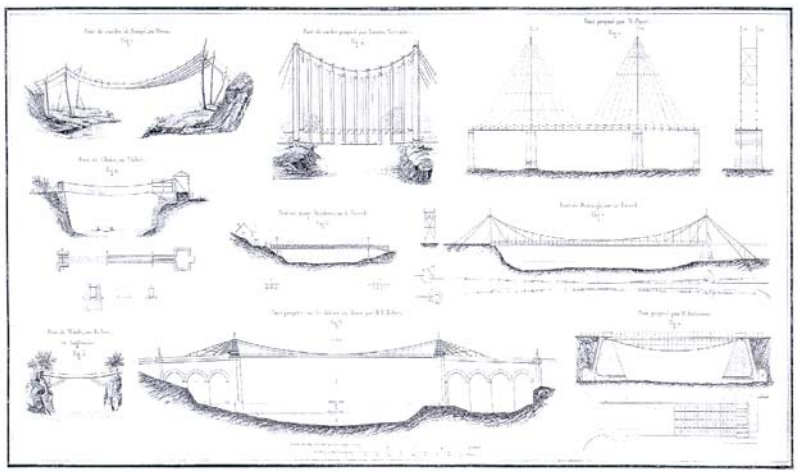

Fig. 44: The development of suspension bridges in the publication of Claude Navier begins after an illustration of a fibre plant bridge with the iron chain bridge at Chhuka as published by Turner in 1800. Source: Bühler 2004

After Naviers book, which was already published in a second edition in Paris in 1830, a richness of contributions and reports to iron chain bridges develops all over Europe and another such flood of iron chain bridges appeared mostly in the form of eye-bar suspension bridges.

114 Navier 1823.

1823 Five iron chain bridges are erected by Wilhelm von Traitteur in St. Petersburg.

1823 Friedrich Schnierch builds an iron chain bridge at Brünn in Austria/Hungary.

1824 Navier himself builds an iron chain bridge in Paris, which, however, was not completed.
1825 An iron chain bridge is built near Nienburg at the Saale. After three months, the bridge collapsed which took the life of 50 people.

1826 An iron chain bridge with a span of 28 metres is built at Malapane.

1827 The British engineer, William Th. Clark (1783-1852) erects the Hammer Blacksmith Iron Chain Bridge across the Thames in London.

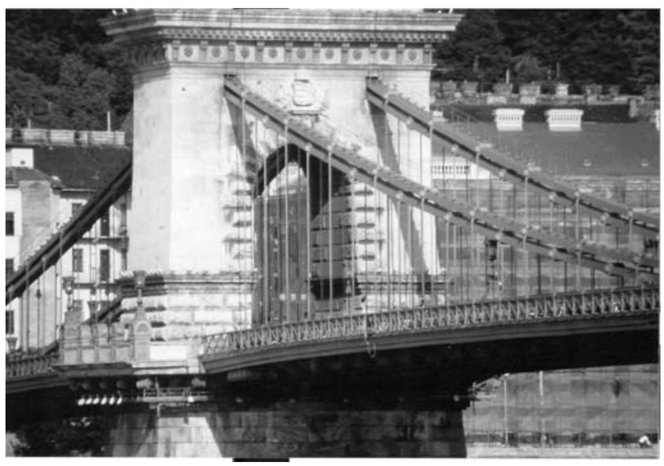

Fig. 45: The iron chain bridge between Buda and Pest in Hungary built in the middle of the 19th century.

1829 As per the sketch of Leo von Klenze (1784-1864), an iron chain bridge is built across the Regnitz in Bamberg.[115]

1839 The 'Iron Hanger,' an iron chain bridge is built at 'Haus Laer' in Meschede, across the Ruhr with about 28 metres of span and a width of 1.90 metre.[116]

1840-1849 The first big iron chain bridge with 202 metres of span is built according to the concepts of the British engineer Clark across the Danube in Budapest which still extant.[117]

1898-1903 The second iron chain bridge, the so-called Elisabethenbrücke after Empress Sissi is erected across the Danube in Budapest. In 1945, this bridge was dismantled.

1926 In Florianopolis, the capital of the Brazilian federal state of Santa Catarina, the iron chain bridge with a span of 340 metres, the farthest free span ever is erected.[118]

Almost simultaneously with the iron chain bridges, suspension bridges with steel cables are also built, which is closely linked to the development of the cable technology.

1816 A pedestrian's footbridge across the Schujkil in Philadelphia with 124 metres of span is erected as a cable suspension bridge.

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[115] Grunsky 1998, p.101 ff.
[116] Monumente 2004, p.32/33.
[117] Dietrich 1998, p.170 ff. The bridge proves in a special way the quality of suspension bridges, because it resists till this day to the strong, two-lane traffic between Buda and Pest.
[118] Bühler 2004, p.102.

1832-1834 Josef Chaley (1795-1861) initiates the construction of 'Grand Pont' near Fribourg across the Saane with 273 metres of span. From 1870 to 1883, Washington August (1837-1926) erects the famous Brooklyn Suspension Bridge across the East river in New York in accordance with the plans by his father, Thuringian John August Roebling (1806-1869), with a span of 486 metres.

1896-1897 The first cable suspension bridge across the Argen at Kressbronn with a span of 72 metres of is erected in Germany.[119]

1933-1937 The Golden Gate Bridge is planned in San Francisco by Joseph B. Strauss and is erected with a span of 1,280 metres.

1998 Finally, the suspension bridge across the Big Belt between Fehmarn and Seeland is initiated with a span of 1624 metres.[120]

One of two suspension bridge constructions which go back to Thangong Gyalpo is a stress ribbon bridge where the chains carry the walking layer directly. Today in the course of the advancement of suspension bridges, stress ribbon bridges (Spannbandbrücke) are also built again.

Thus in 1999, Jürg Conzett plans and erects a 40-metre spanned stress ribbon bridge (Spannbandbrücke) across the spectacular Via Mala gorge at Suransuns in Switzerland. The steel parts are produced from V4A chrome nickel steel. The sidewalk is made from natural granite stone.[121]

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[119] Bühler 2004, p.102.
[120] Bühler 2004, p.108 ff.
[121] Bühler 2004, p.56.

If we look into the future, it is unimaginable that the stress ribbons, like coal fibre ribbons could find use and with it, bridges become conceivable with several kilometres of span in a system that Thangtong Gyalpo invented.

Even if one looks at the bridge building altogether through the adoption of the different materials like wood and stone worldwide, Thangtong Gyalpo with his suspension bridges, far ahead of his time has shown the way.

The famous stone and wooden bridges of the ancient world, had spans of approximately 15 to 30 metres. During the first 1700 years after Christ's birth, single spectacular bridges with spans up to 40 metres were erected. The wooden arch bridge with approximately 20 arches, each with a width of about 34 metres and a bridge bay distance of 51 metres, first built under the Roman emperor Trajan von Appolodorus at about 105 AD in Dacien in today's Romania[122] and the An-ji bridge in China with a level stone arch of about 40 metres of span in 7th century. In addition, the stone bridge of Regensburg, built from 1135 to 1146, and the famous bridge of Mostar, from the Turkish master builder Mimar Hajradin, a pupil of Sinan, erected from 1557 to 1566 with a span of 29.5 metres, belong in this span area.

All the great Renaissance master builders dealt with very far spanned bridges. Thus, Leonardo da Vinci from 1502 to 1503 conceived a wooden arch bridge with 360-metre length and 24 metre width over the Golden Horn in Istanbul, Turkey, which could hardly have been realised then.[123] The examples built in the 16th century have reached spans of 25 to 35 metres; and the famous bridge of Andrea Palladio with a truss construction, the Ponte degli Alpini in Bassano, Italy, across

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122 Dietrich 1998, p.84 ff.
123 Dietrich 1998, p.91 ff.

the Cismone just reached a spanned width up to 12 metres.[124]

The Grubenmann brothers, master carpenters of Switzerland achieved a real jump only in the middle of the 18th century. Ulrich Grubenmann created a wooden bridge across the Rhine at Schaffhausen in 1755, with a span of 19 metres on the request of the Schaffhausen council with an additional river pillar.

This master builder reached farthest span with a wooden bridge across the Limmat in 1764. His brother, Josef Grubenmann shortly afterwards built the Rhine bridge at Reichenau with 71 metres of span.[125]

These bridges were later followed by the steel bridges, in the beginning, with modest spans. In 1769, the first cast steel bridge with about 30 metres of span was erected in Coalbrookdale in England.[126]

The bridges introduced by Thangtong Gyalpo in the beginning of 15th century with 80 to 130 metres of length in Tibet with all materials were achieved in Europe and America only after 400 after years in the 19th century.

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[124] Bühler 2004, p.58. The drawings, outlines and concepts of the renaissance master builders for bridge constructions and the span widths of the bridge of Bassano show conspicuously the discrepancy between wish and reality.
[125] Gerner 2002, p.70-76.
[126] Bühler 2002, p.71-72.

Fig. 46: Thangtong Gyalpo on a mural at Sili Gonpa in Bhutan.

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Additional Notes on the book

The Centre for Bhutan Studies has received a letter from Tenzin Chhophag, the 12th Chagzampa, in December 2007.

The letter states that he (Tenzin Chhophag) has been recognized as the 12th Chagzampa by His Holiness Dalai Lama, Dilgo Khyentse Rimpoche, Mingling Trichen Rimpoche and Sakya Tridzin Rimpoche.

The letter went on to state that in a book (*Chagzampa Thangtong Gyalpo – Architect, Philosopher and Iron Chain Bridge Builder* by Manfred Gerner), the Centre for Bhutan Studies has documented Thangtong Gyalpo's lineage up to the 17th incarnation.

> First, it has been written that the Late Dilgo Khyentse Rimpoche and Kalu Rimpoche have indicated that Sangay Choedzin, currently the Lama of the Zilukha Nunnery, as the 17th Thangtong Gyalpo, and suggested that the boy must be recognized by Sakya Tridzin.
>
> Second, it has been written that Dalai Lama and Sakya Tridzin have recognized Sangay Choedzin as the 17th Thangtong Gyalpo.

The letter questioned the source of information the Centre has used and suggested further investigation. It demanded that the Centre, which is responsible for printing and distribution [the book], should provide answers to the doubts raised above.

Signed by
Tenzin Chhophag

The Centre for Bhutan Studies would like to clarify that *Chagzampa Thangtong Gyalpo – Architect, Philosopher and Iron Chain Bridge Builder* was written by Manfred Gerner in German and translated into English by Gregor Verhufen. The Centre has published the book for the benefits of the Bhutanese reading public since there is limited information on this important Buddhist saint. The Centre is mainly interested with the book, like any other Bhutanese readers, as a rich social document, not for its documentation of who is and who is not the 12th or 17th reincarnation of Thangtong Gyalpo.

We also would like to clarify that CBS has played no role either in its research or in selecting sources.

One of the Centre's mandates is to generate and disseminate information freely to the Bhutanese through research and publication, and publication of the above book is one effort in fulfilling the mandate.

Thank you.