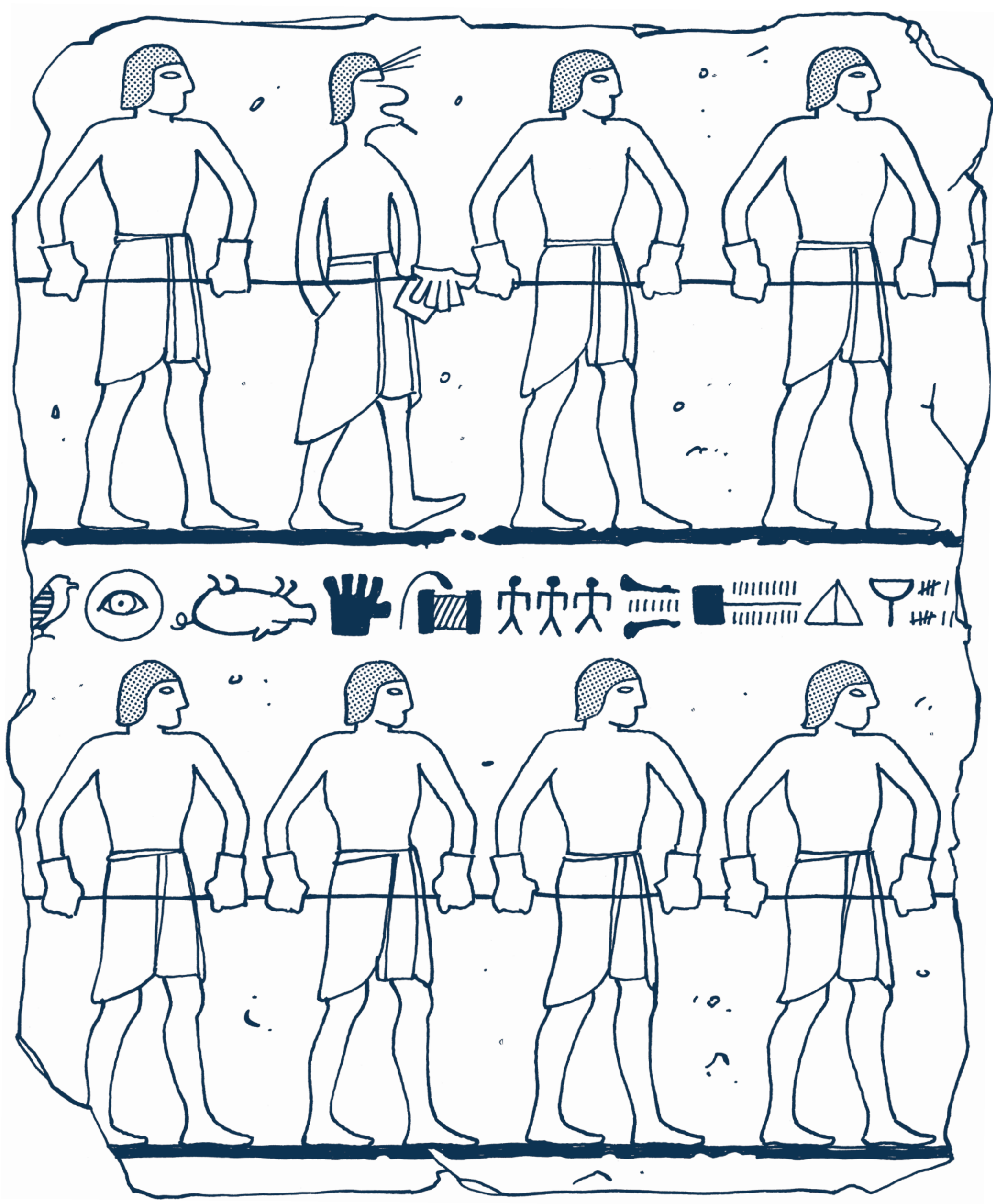
CASAR®

SPECIAL WIRE ROPES



A Short History of Wire Rope

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by Dipl.-Ing. Roland Verreet

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1 The use of ropes in early civilizations

Ropes made of hides, hair or plant materials form part of the earliest achievements of human civilization. The oldest illustrations of ropes are dated from approximately 12000 to 9000 BC. Remnants of ropes found in Finland are supposed to be from the Mesolithic period (9000 – 3000 BC), others found in Egypt and made of camel hair are more than 4000 years old.

Some mural paintings in Egypt (ca. 2000 BC) show the production of ropes made of papyrus, leather or palm fibres (Fig. 1).

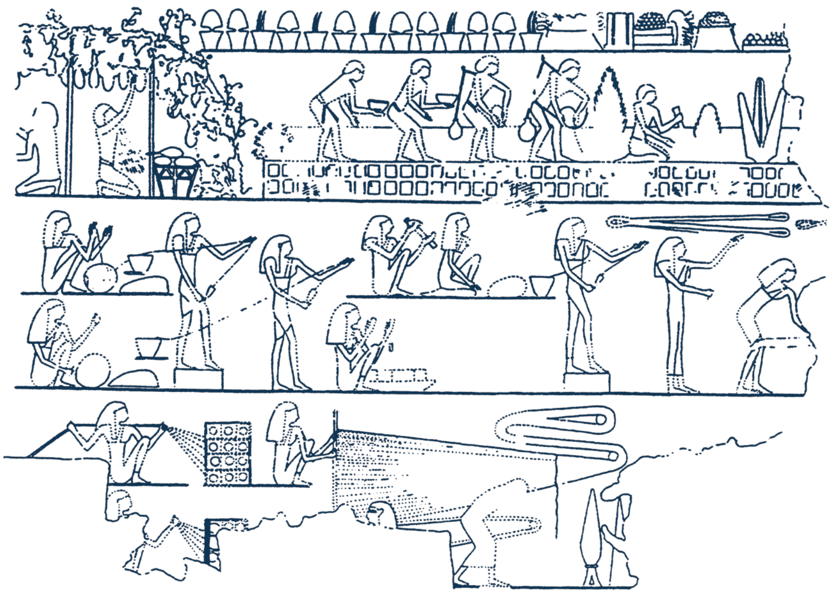

Fig. 1: *Rope production in Egypt 2000 BC*

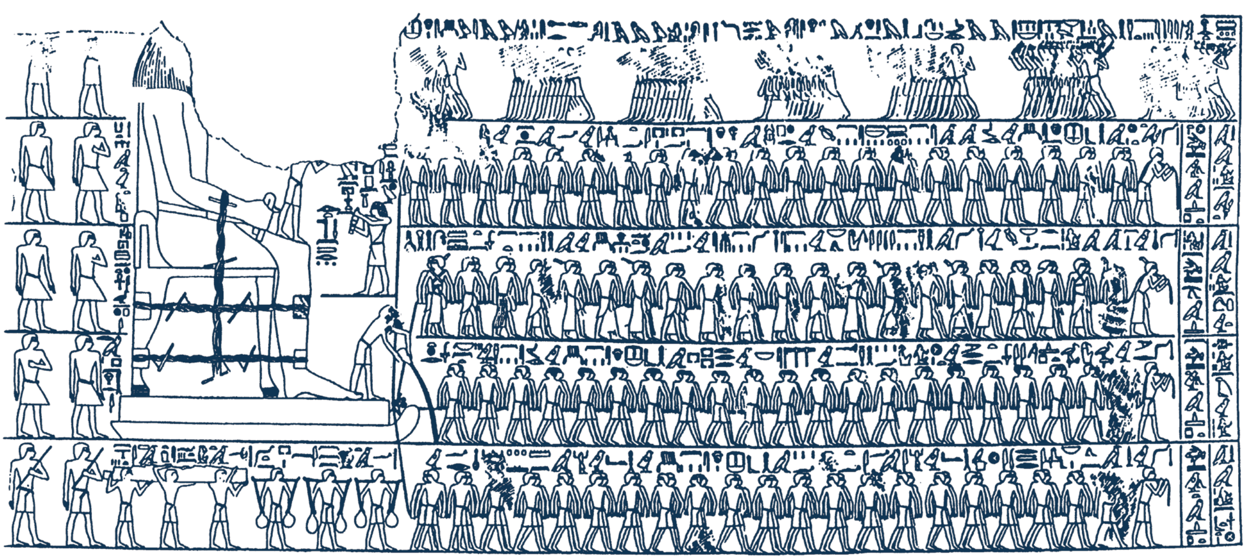

Fig. 2: *Rope application in Egypt 2000 BC*

Ropes were used for making fishing nets or traps, but also for lifting and dragging heavy loads.

Fig. 2 shows about 200 men dragging a colossal statue on a sledge with the help of 4 ropes. One man pours a liquid in front of the sledge to reduce the friction. The statue itself is secured with taut ropes.

2 Ropes in the Middle Ages

After perfecting the skill of making ropes in ancient times it was virtually unaltered for nearly 2000 years, so that about 200 years ago ropes were being manufactured in the same way as at the beginning of the Christian era.

Leonardo da Vinci, the technological genius of the 15th and the 16th century, made two sketches of machines for the production of ropes which, as so many others of his inventions, were never built. In his work we can also find the drawing of a die for manufacturing iron wire which would have made the production of wire ropes possible.

In his famous work "De re metallica" (1556) Agricola strikingly demonstrates the importance of rope as a means of transport in the mines of his time.

In 1586 the papal master-builder Frederico Fontana supervises the erection of an obelisk in St.Peter's Square in Rome. After months of planning the stone weighing 327 t is erected by the fantastically concerted action of more than 900 men, 75 horses and with the help of a great number of reeving systems (Fig. 3).

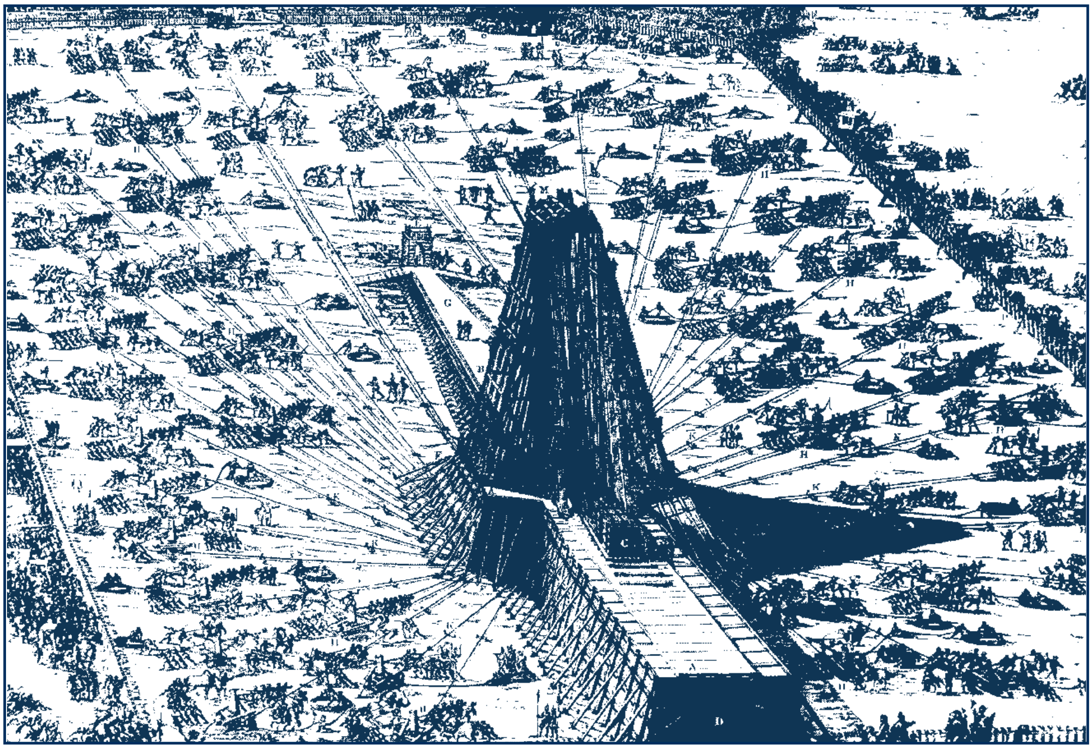

Fig. 3: *Erecting the obelisk in St.Peter's Square in 1586*

The invention of the wire rope has made it possible to build mobile cranes with more than 1000t lifting capacity, and today moving structural elements weighing several hundred tonnes is a cut-and-dried affair for any renowned crane rental firm.

3 The Albert Rope

At the beginning of the 19th century hemp ropes and iron chains were used as means of hoisting in the mining industry. Hemp ropes were expensive to import and could only be applied in dry pits. Iron chains were not safe to operate because the proverbial failure of only one link inevitably resulted in the fall of the load.

Between 1824 and 1838 the mining engineer Albert from Clausthal in Germany (Fig. 7) continually tried to improve transportation in pits. He realized the advantage of the hemp rope, in which the load bearing elements are in parallel arrangement; but he also saw the advantages of the higher tensile strength of the iron chain. His attempt to combine the advantages of these two hoisting means marks the very birth hour of the wire rope.

Fig. 4: *A die*

In Albert's times the production of iron wires was very costly. First small iron lumps were hammered into a long shape and then, after sharpening one end they were successively pulled through the bores of a die (Fig. 4) which became thinner and thinner until they finally showed the diameter desired.

At that time many wire drawers spent their working day on a swing: after they had set it in motion they grasped the wire end sticking out from the die with a pair of pliers and pulled it out bit by bit using the energy stored in the movement. Of course the swing was abruptly slowed down so that it had to be "recharged" before the procedure could be repeated.

The production of wires was less tiresome if water power was available to drive a drawing bench. Typically this consisted of a pay-off capstan, a die and a driven tag-up capstan (Fig. 5).

Today the hard metal die has replaced the drawing iron and the water wheel has been replaced with the direct-current motor. Additionally, modern machines carry out several drawing sequences directly one after the other in one operation cycle. The heat generated during the process of reshaping the wire is abducted through a cooling system. But basically modern wire drawing machines are composed of the same elements as at the time of mining engineer Albert.

The first wire rope in the history of the universe showed a diameter of 18mm. It consisted of three strands with four wires each which had a respective diameter of approx. 3.50mm (Fig. 6) and was twisted by hand.

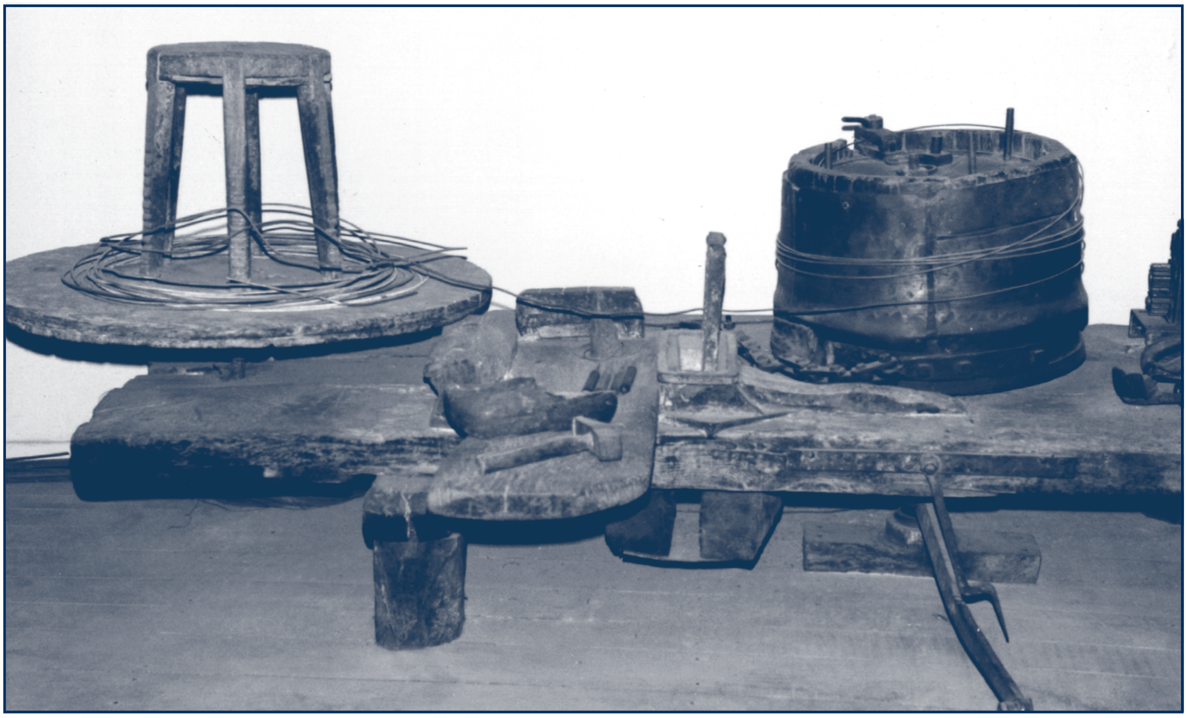

Fig. 5: *Drawing bench*

On 23 July 1834 it was tried out in the 484m deep shaft of Mine Caroline near Clausthal and worked to the full satisfaction of its inventor. It had six times the load capacity of a hemp rope of the same diameter and four times the load capacity of a chain eight times its weight. On the drum it required only one third of the space a chain would need.

The most relevant advantage for the operator was, however, that the imminent failure of the hoisting means was indicated well in advance by single wire breaks. Thus a defective patch could either be mended by splicing or the whole rope could be discarded in good time.

Whereas within living memory all fibre ropes had been carried out in regular lay Julius Wilhelm Albert chose Lang lay for his wire rope. This meant that the outer wires found favourable support conditions on the lead sheaves and where they contacted their neighbouring strands inside the rope they were perfectly parallel. Consequently the first wire rope of the world was completely free from wire crossovers.

In the Albert Rope all wires consisted of the same raw material. They were of the same diameter, their production conditions were the same and also their length and shape in the rope. Additionally, all wires of the Albert Rope could be inspected from outside. It is this last feature that distinguishes the first wire rope in history from all later rope designs and therefore Mr Albert deserves a place of honour among the great inventors of modern times.

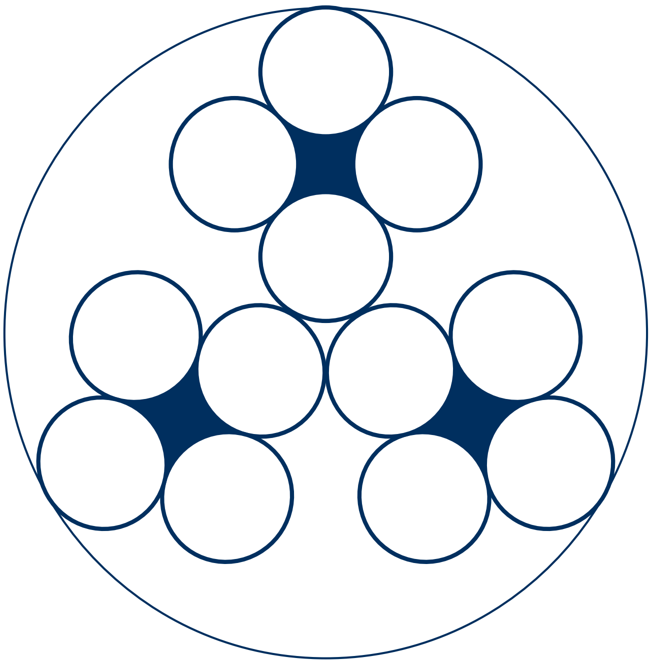

Fig. 6: *The Albert Rope*

Wilhelm August Julius Albert was born in Hanover on 27 Jan 1787, Mayor J.Albert's son. From 1803 to 1806 he read law at the university of Göttingen. In 1806 he was offered a position at the "Bergamt", the Mining Office at Clausthal. Thanks to his competence he was appointed judicial advisor in 1807 and in the following year he became President of the Mining Office. In 1812 he was conferred the title of "Bergrat" and in 1835, after his pioneering invention, he was promoted again ("Oberbergrat"). After serious illness Albert died in the night from 4 July to 5 July 1846, not even 60 years old.

In his article "Die Anfertigung von Treibseilen aus geflochtenem Eisendrath" (Manufacturing Mine Hoist Ropes From Braided Wires), published in the then leading mining periodical "Karstens Archiv", Albert described in great detail the design of the first wire rope, the process of production and his experiences while testing it. Thus he enabled all those round the world with an interest in the matter to produce their own wire ropes of the same design without having to go through all the tests. He also carried out the first bending fatigue tests of wire ropes and paved the way for 4- and 6-stranded ropes. Today these tests are considered to be the first fatigue tests ever performed on a scientific basis. The introduction of the fibre core and the improvements in quality and price resulting from mechanically closing wire ropes led to a very rapid spread of iron ropes in Europe and North America.

Fig. 7: *Oberbergrat Albert, the inventor of the wire rope*

4 Strands with a centre wire

The call for ropes with higher breaking strength and greater flexibility inevitably led to the design of ropes with a higher number of wires. Strands with 6 instead of 4 outer wires were developed which were twisted round a centre wire of the same diameter (Fig. 8).

This, however, meant a partial change for the worse of Albert's invention: the centre wire lay stretched in that strand whereas the other wires formed a helix. As a result the rope elements were of different lengths and had a different shape in the rope. And it was not possible any more to inspect all the wires because the centre wire remained concealed from any angle.

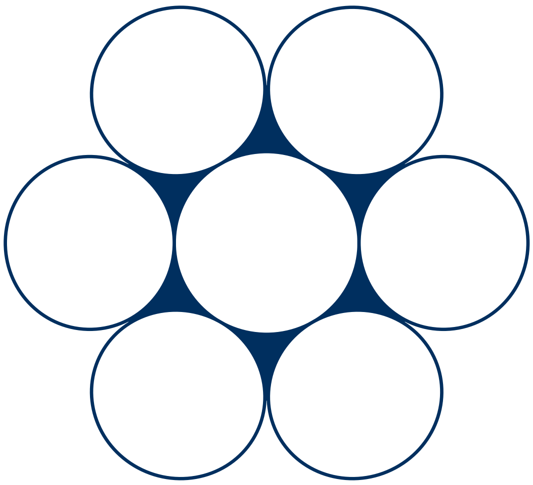

Fig. 8: *Strand 1 + 6 wires*

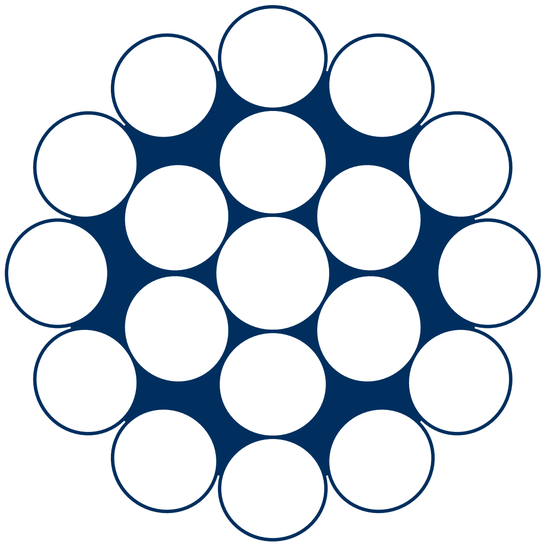

Fig. 9: *Strand 1 + 6 + 12 wires*

5 Multi-layer strands

The next step was the introduction of multi-layer strands. Round a strand of 1 + 6 wires another layer of 12 wires of the same diameter was twisted (Fig. 9). In order to achieve a uniform loading of all the elements one saw to it that the wires of the latter layer were of exactly the same length as those of the first layer. This was exactly the case if the wires of both layers were twisted at the same angle to the strand axis.

Unfortunately this choice of lay lengths generated innumerable wire crossovers in the strands, which, due to the high local pressures, led to the premature failure of the wires. Without being realised this step of development resulted in another partial deterioration of Albert's invention.

6 The parallel lay strand

Probably the most relevant further development of wire rope was the invention of the parallel lay strand by Tom Seale in 1884. Tom Seale was the Director of the Cable Car owned by the Governor of California, Leland Stanford. This cable car, named California Street Line, is still in operation.

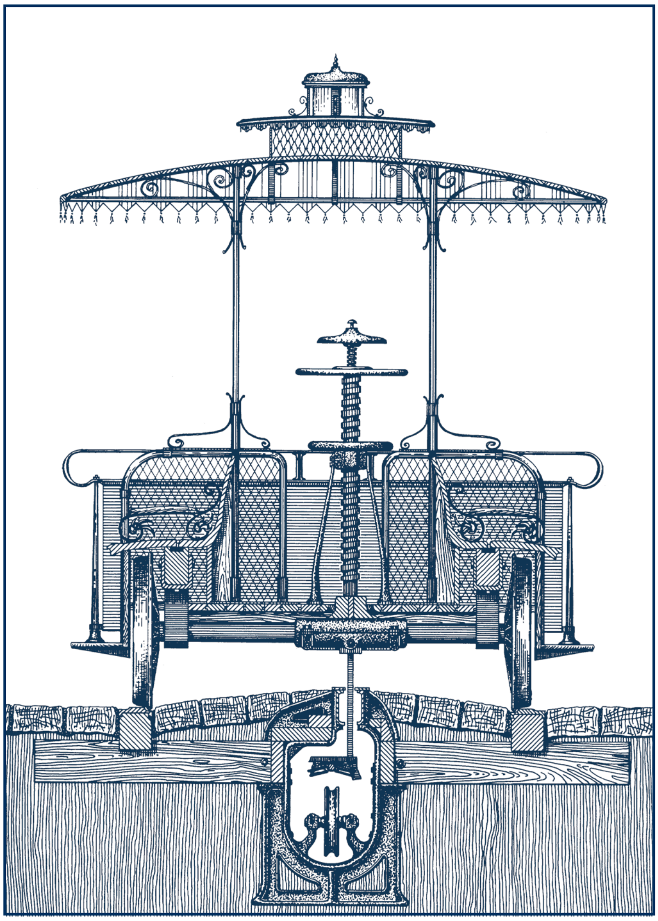

Fig. 10: *San Francisco Cable Car*

The steep acclivities in the streets of San Francisco made it impossible for the horses to pull the trams. Even steam engines could not manage the slopes because of their own weight. Therefore the so-called cable cars were used. As the situation required their cars were attached to or disconnected from circulatory, endless underground traction ropes (Fig. 10).

The heaviest cost factors of the cable cars were constituted by the wire ropes themselves and the repair costs of rope failures. Therefore Tom Seale tried to improve the service life of the ropes. He found out that the ropes failed because of internal wire breaks, which he first thought were caused by the lack of internal flexibility. He was sure to remedy that disadvantage by using strands with strong, abrasion-resistant outer and thin flexible inner wires. He got hold of wire samples of different diameters and manufactured different strand samples by hand.

During his experiments it happened again and again that the thicker outer wires fell into the valleys of the wire layer underneath and then tended to follow the helix of that layer. Seale noticed that a strand of this design, with the same number of wires in both layers and with the right diameter proportion of the wires, resulted in a very solid strand which was also very round. He also detected that he could avoid the crossovers within the strands if the wire layers were arranged in a parallel way.

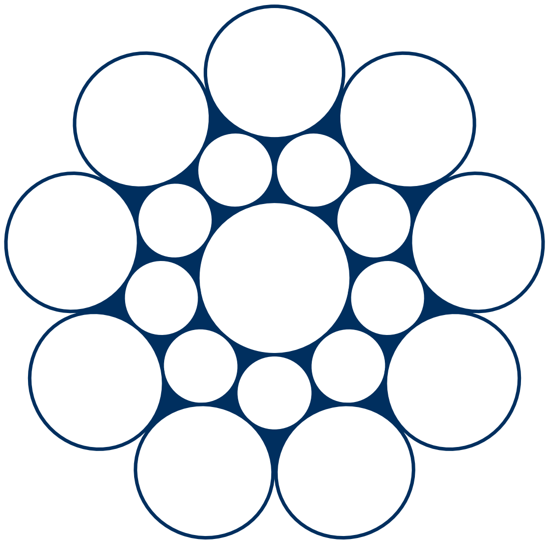

Fig. 11: *Seale strand*

In his patent document (1885) he wrote: "*This gives great flexibility to the strand and in the cable, with solidity and compactness, while the wires of the outside or covering of the heart lie upon a comparatively smooth and not upon a surface of ridges, as in other constructions, where there exists considerable difference between the lay of one surface and that of the other, or where the outside wires cross the heart wires.*" Tom Seale persuaded a rope manufacturer to produce a rope according to his invention. He used this rope on the Cable Car which he operated. The first rope manufactured from parallel lay strands achieved an excellent service life.

Seale granted a number of licences for his invention (Fig. 11), which made his design widely known. In the period following, those manufacturers who were not granted a licence tried out various strand designs to elude Seale's patent. Thus the eighties of the 19th century were the time when the wire rope industry experimented frantically and the most fantastic designs were tested. Again and again the attempt was made to manage with only one or as few wire diameters as possible.

Only a few years after Seale's application James Stone, an American engineer working for the rope manufacturers Washburn & Moen, detected the weak point of Seale's patent: Seale had confined himself to strands whose outer wires were thicker than those of the layer underneath. Stone manufactured a conventional 19-wire strand in the parallel lay and filled the resulting cavities with filler wires. The Filler strand was born (Fig. 12).

In 1889 James Stone obtained a patent for this strand design which today, more than a hundred years later, is probably the most widely used multi-layer strand design in the world.

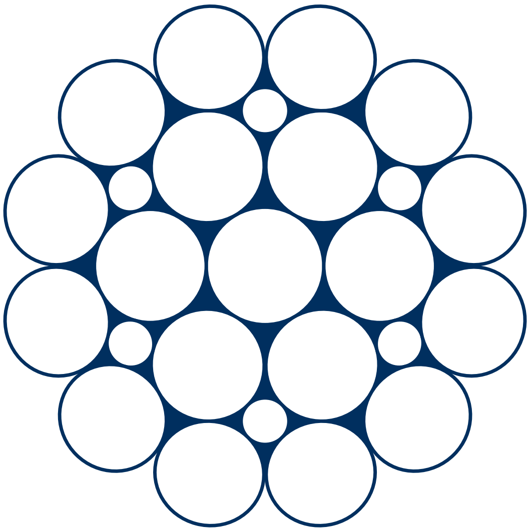

Fig. 12: *Filler strand*

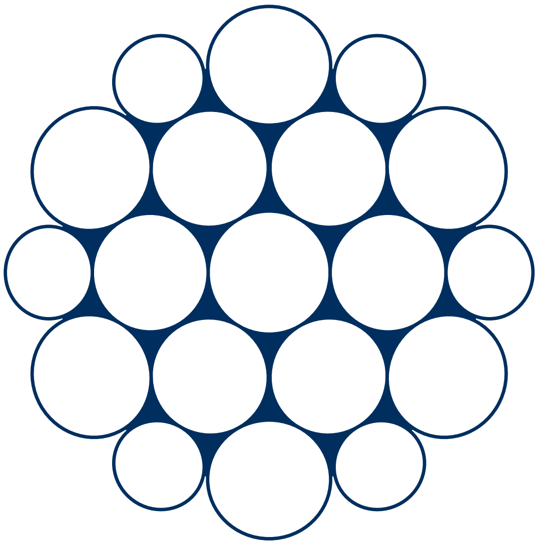

Fig. 13: *Warrington strand*

It is likely that also the Warrington strand (Fig. 13) was developed between 1884 and 1890. Its inventor is unknown and even the origin of its name is uncertain.

With a precision that was sufficient for the requirements of the time it could be manufactured from a centre wire and two more wire layers of the same diameter. The cavities in the outer layers could be filled with a wire of a different dimension.

The first drawing of a Warrington strand can be found in the notebook of the German emigrant John Roebling who made a name for himself as the designer of Brooklyn Bridge and founder of the American wire rope industry.

At the bottom of the drawing of the strand Roebling had written: "*This is the true proportion.*" (Fig. 14) John Roebling died 15 years before Tom Seale invented the parallel lay strand. Had he realised the importance of his sketch *he*, and not Tom Seale, would have gone down in the history of technology as the inventor of the parallel lay strand.

The name Warrington strand probably goes back to the city of Warrington in Great Britain which in the 19th century was the home of two wire rope factories, the Whitecross Company and the Warrington Wire Rope Company. Unfortunately the catalogues of the two firms do not contain any hint that Warrington strands were actually manufactured in Warrington at that time.

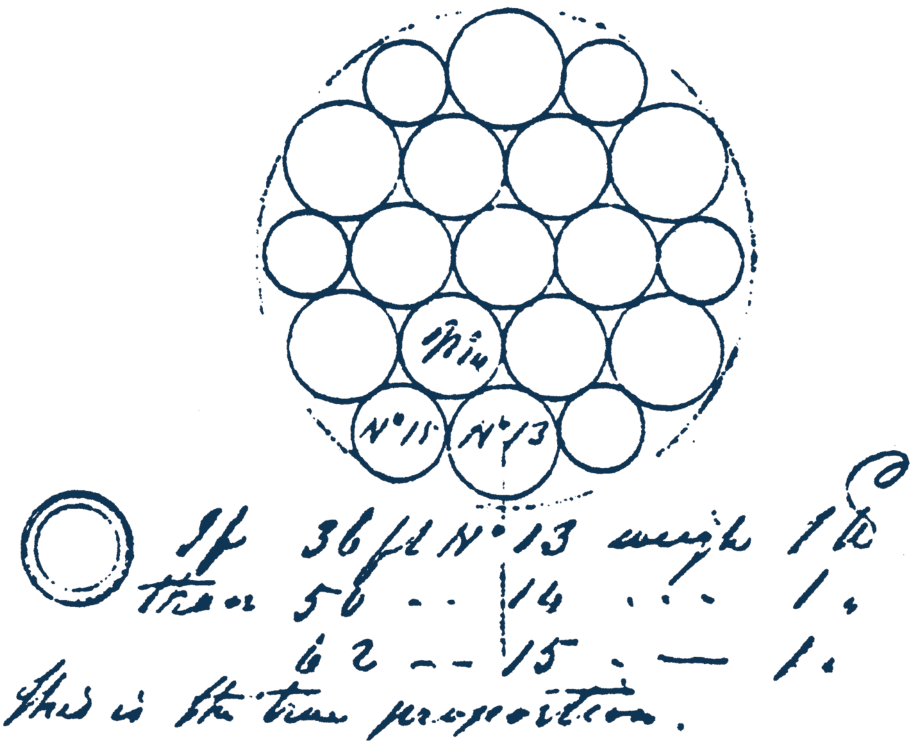

Fig. 14: *Warrington strand in Roebling's notebook*

7 High-tensile steel wires

The development of high-tensile steel wires was another landmark in the history of wire rope. The Englishman James Horsfall was granted a patent for the heat treatment of wires. His patent document was a masterpiece of disguise, and consequently for a long time his competitors were unable to copy his technique. Until today heat treatment of wires is called “patenting” after this mysterious patent.

Steel wire for wire ropes was first used for the suspension ropes of the East River Suspension Bridge, commonly called Brooklyn Bridge. The bridge was opened in 1883 and was then the highest building of the New World (Fig. 15). The ropes were manufactured at the rope factory of John Roebling, who, as mentioned above, was also the designer of the bridge.

John Roebling died shortly after an accident on the construction site. His son Washington, who had worked as his assistant until then, continued the building activities on the bridge. Due to staying in the diving bell for so long during the construction of the standing piers he fell ill with the notorious Caisson disease, which paralysed him for the rest of his life. From a room facing the bridge he watched the building progress through his binoculars. His wife acted as a mediator between him and the construction site. Thus she acquired great expertise and is today counted among the master-builders of the bridge.

The hanger ropes of Brooklyn Bridge were replaced only a few years ago after more than a century of service life, and the original main cables are still in use.

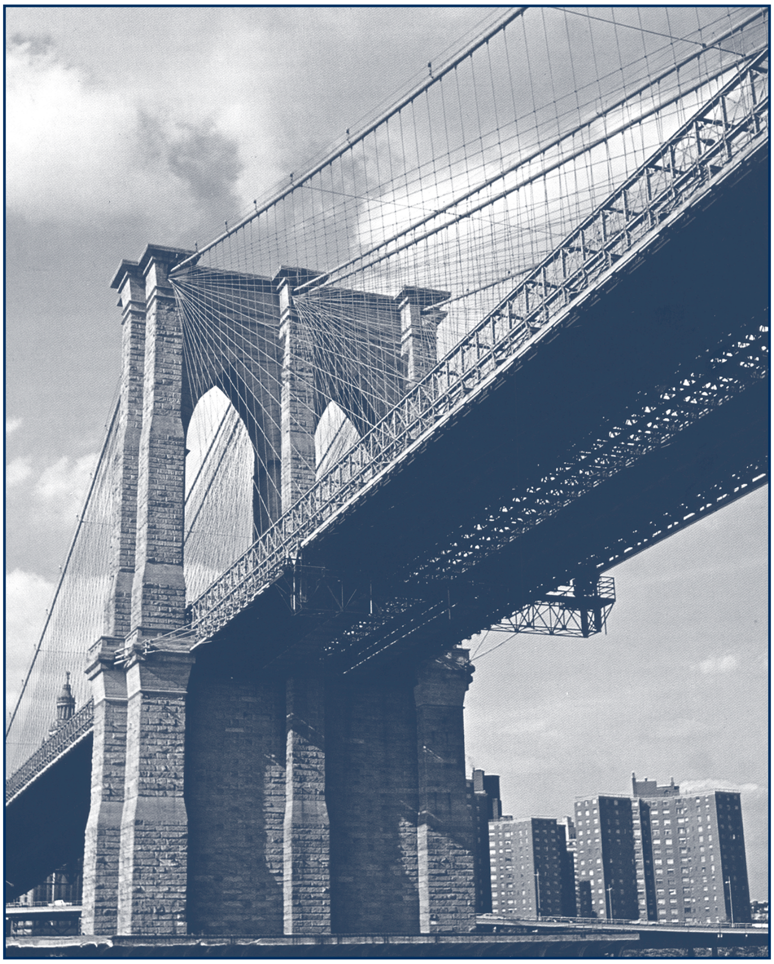

Fig. 15: *Brooklyn Bridge*

8 Preformation

Using steel wires instead of iron wires caused some unprecedented problems for the wire ropers: high-tensile steel wire was much more rigid than iron wire and it was difficult to work it into a helix.

In 1886 some Mr Moxham was granted a patent for a method of winding strands round a bar, thus forcing them into a helix which later they were supposed to adopt in a rope with a slightly bigger core. Seemingly the costs of two closing operations were too high; at any rate, Moxham´s invention never gained any economic importance.

Preformation as we know it today was not invented before the 1920s. American Chain & Cable faced the problem of having to produce 8 million end connections per year for the brake cables of automobiles. As the ropes would open up and unlay after cutting they had to be secured with the help of seizings, which was very costly. So the company tried to find means and ways of preventing the wire ropes from opening up. In 1922 an employee of the said company, named Connor, developed the “Quill” (Fig. 16), a device that is still widely used in the USA today.

In 1925 the self-employed engineer Briggs, retained by American Chain & Cable invented a different solution: He developed the preforming head with rollers which, virtually unaltered, is still in use round the globe (Fig. 17).

American Chain & Cable granted licences for the technology of preformation to rope factories all over the world, and this business was so lucrative that they stopped their own rope production and concentrated on training the licence holders and collecting the licence fees. This was because the licence agreements stated that the licence holder had to charge a price supplement on a preformed wire rope of 25%, of which he had to pay over the major part to American Chain & Cable. However, preforming wire ropes became commonplace very soon, and now the rope manufacturer had a problem when a customer ordered a rope that was not preformed because such a rope, for which he would get less money was more expensive to produce than a preformed one because the preforming head had to be removed from the machine at high costs. In the course of time more and more manufacturers “forgot” to remove the preforming head from the machine.

9 The Lang lay rope

John Lang was the production manager of R.S.Newall & Co. in England. He studied the wear characteristics of wire ropes and found out that the free length of a single wire would increase on the surface, if the wires in the strands were twisted in the same direction as the strands in the rope. From this finding he concluded that also the pressures in the sheaves would be distributed along a greater length, which would reduce the amount of the pressure and consequently reduce the wear.

That was John Lang's error: It is true that the wire showed a greater free length on the rope's surface, but Lang failed to recognise that for this reason the wire appeared less frequently on the surface. He may be pardoned though. Even today his error can be found in the publications of many a firm. His ideas led however to the development of the Lang lay rope for which he was granted a patent in 1829.

His employer R.S.Newall & Co. was not impressed by the advantages of the Lang lay rope and therefore John Lang joined Craddock Company and granted them the exclusive right to manufacture ropes of his patented design. In the English speaking world these ropes are still called *Lang lay*, *Langs lay* or *Lang's lay* ropes.

In 1888 G. Craddock & Co. took Whitecross Company, one of the two Warrington rope factories, to court accusing them of violating Lang's patent. Whitecross pleaded

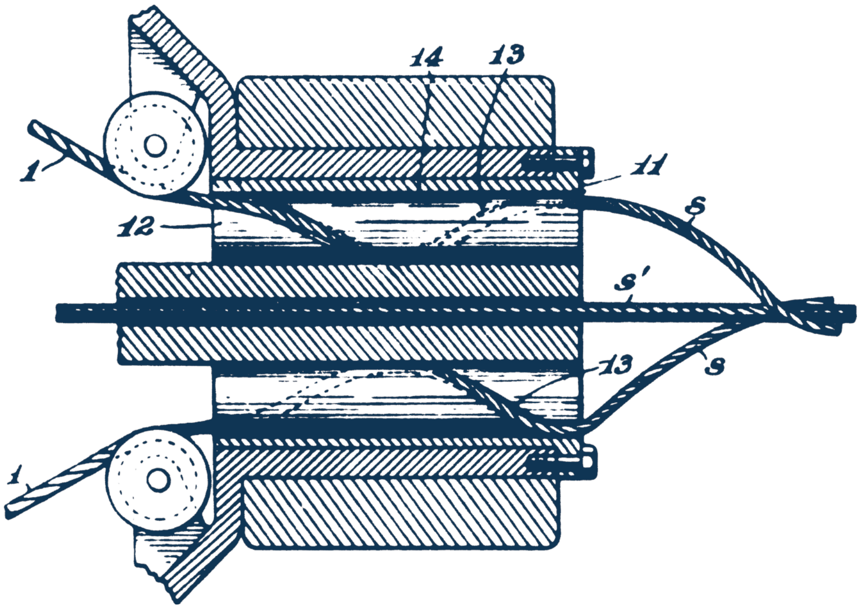

Fig. 16: Quill

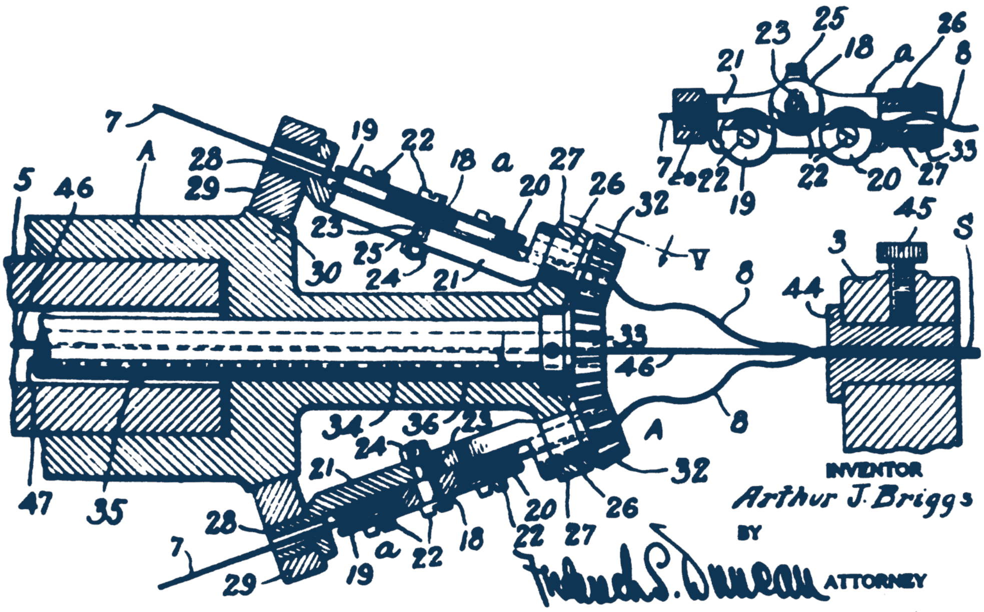

Fig. 17: Briggs' preforming head with rollers

their case successfully by referring to a piece of Albert rope in a British museum. And indeed, as mentioned above, that rope had been manufactured in Lang lay some 50 years before. Obviously the knowledge about Lang lay had been forgotten in the course of time. Unfortunately the said piece of Albert rope from the museum does not exist any more.

10 The locked coil rope

One of the licence holders of Lang's patent was the rope factory of Sir George Elliot, a coal magnate from Cardiff in Wales. His production manager, Arthur Latch, commissioned his cousin Telford C. Batchelor, an engineer, to investigate the problems of the wear of wire ropes. The answer came promptly: Batchelor, who had never dealt with wire ropes before, unceremoniously declared the problem was that the rope manufacturers used *round* wires for making ropes. He suggested to alter the cross section in such a way that *flattened* surfaces would come to lie at the patches of wear. In addition, the cross section of the wire should be chosen in a way which would anchor the wire within the rope.

Easier said than done. Until then nobody had even considered to draw wires other than with round cross sections. After all, a die was nothing but a metal sheet with a round hole in it. Nevertheless Arthur Latch managed to persuade the son of James Horsfall, the inventor of the "patented wire", to carry out costly experiments. Finally the production of shaped wires was achieved and Batchelor's idea materialised.

In 1884 Latch & Batchelor applied for a patent for the so-called "locked coil" ropes.

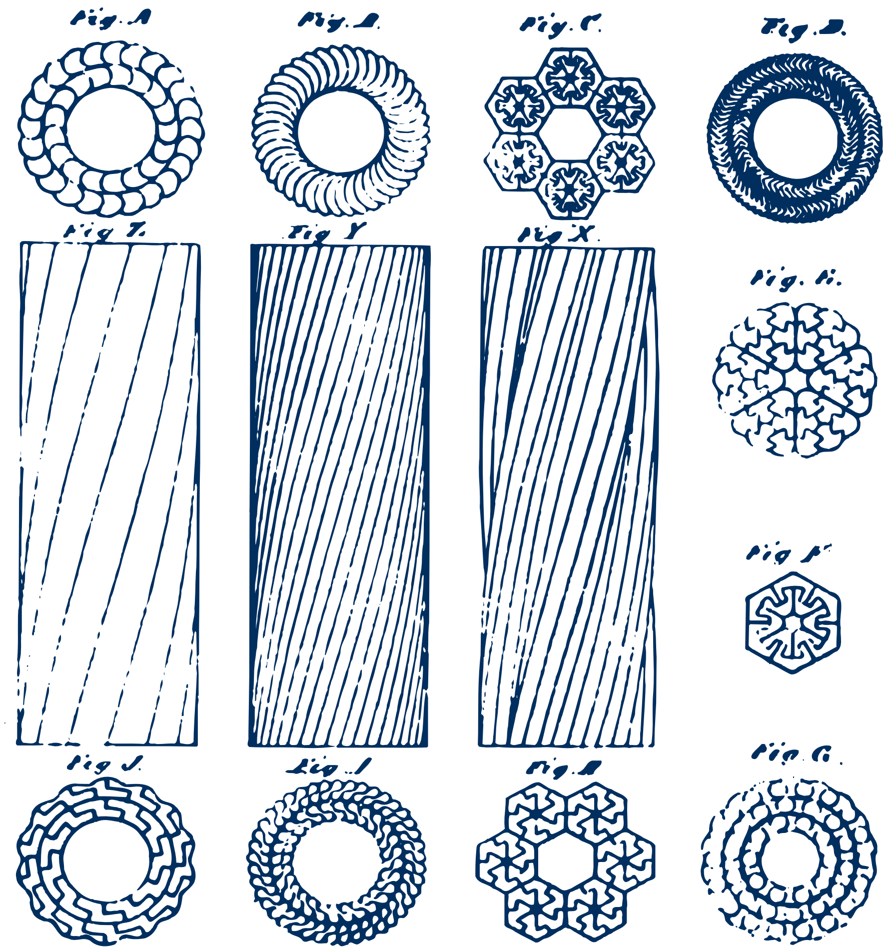

Fig. 18: *Latch & Batchelor's locked coil ropes*

The illustrations in their patent document show the most fantastic shapes of cross sections (Fig. 18).

George Elliot & Co. constructed a rope closer without backtwist, and in 1885 the first rope samples could be shown at an inventors' exhibition.

11 The flattened strand rope

Latch & Batchelor were still not satisfied with their achievements. After hours they experimented with other configurations and their efforts led to another invention, the flattened strand rope. They manufactured the first rope of this design in 1887 and their patent document is dated 1888. In 1894 a further improvement followed, a core rope made from triangular strands.

12 The rotation-resistant wire rope

Latch & Batchelor's locked coil ropes and half-locked coil ropes could only be installed under great difficulties, because the shaped wires had to be stranded without a backtwist and consequently showed a very strong tendency to twist. In 1887 Batchelor developed an epoch-making improvement of his own invention. He closed his locked coil ropes from layer to layer alternatively in left-hand and in right-hand lay. By this procedure the tendencies of the respective layers to unlay, caused by the method of production, compensated one another almost completely. The new ropes could be installed without the danger of untwisting and under load they exercised hardly any moment on the end connections.

But it was nearly another 20 years before the first rotation-resistant spiral strand rope was produced. In 1901 Bruntons in Scotland began manufacturing wire ropes and in 1902 and 1903 they carried out first experiments to apply Latch and Batchelor's method (closing various layers in the respective opposite direction) on stranded ropes. In 1904 the spiral strand ropes were successfully employed for the first time. Today Bruntons is one of the very few independent rope factories in Britain.

13 Double parallel lay ropes

In 1884 Tom Seale had invented the parallel lay, which avoided wire crossovers within the strand. At the beginning of the 20th century this improvement was also applied on wire ropes. The earliest publication known to the author referring to a rope in the double parallel lay, in which the wires in the strand as well as the strands in the rope were closed in parallel lay, is a patent document by George C. Moon dated 1920. The text, however, gives rise to the assumption that there were applications before that date.

14 Ropes made of compacted strands

In 1891 Charles J. Banks from Washington (Durham, England) applied for a patent for a method of compacting strands. His patent document shows a strand composed of round wires. Immediately next to the stranding point the strand is compacted by six dies in a way that its wires take on the shape of sectors (Fig. 19).

Although Banks describes all the advantages of compacted strands in his patent document, his invention was first not destined to succeed. This probably goes back to the difficulties during the production process. One may assume that before the invention of Widia steel the dies could not cope with the high stresses during the compacting process. So it was to be more than sixty years before an English rope manufacturer rediscovered the procedure of manufacturing strands for pre-stressed concrete.

In the late seventies of the 20th century the first wire ropes manufactured from compacted strands were simultaneously offered for sale in Germany and Britain.

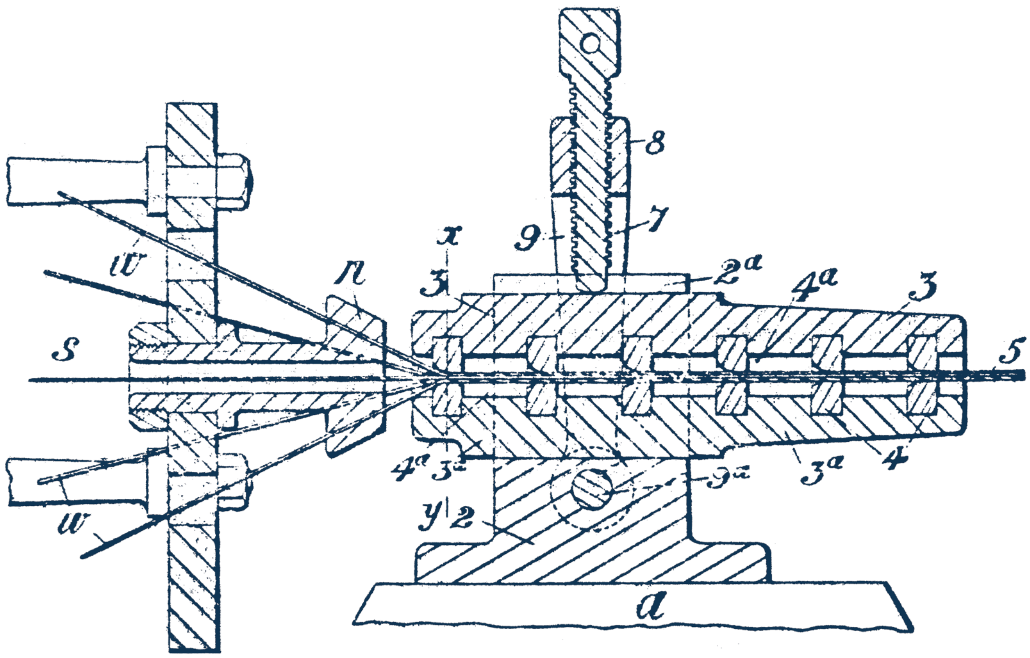

Fig. 19: *Charles Banks' compacting unit (1891)*

15 The intermediate plastic layer

In the early sixties of the last century some manufacturers began to provide the wire ropes with an outer coating for the use in extremely aggressive environments. Admittedly this protection was very effective, but according to industrial standards it was illegal: The number of broken wires is the most important discard criterion for wire ropes, and if these broken wires cannot be detected because of a coating, the wire rope is not safe (cf. also DIN 15020, sheet 2, clause 3). In 1972 Casar solved the problem by coating with plastic only part of the wire rope, its independent wire rope core, which was thereby protected against corrosion. The intermediate plastic layer was born.

It took some time before the by far more significant advantages of this intermediate layer were recognised: the improvement of the structural stability of wire rope, the reduction of pressures between independent wire rope core and outer strands and more protection against internal wire breaks.

16 The future of wire rope

In the long term ropes made of high-tensile fibres will doubtlessly displace wire ropes in many fields of application. They are lighter, not susceptible to corrosion and (at least some of them) amazingly fatigue-resistant. In other fields, however, steel wire ropes will maintain their position for the foreseeable future: after all, wire ropes have a higher modulus of elasticity and are less sensitive to abrasion and mechanical damage than their light-weight competitors. Moreover, in contrast to many ropes of high-tensile fibres steel wire ropes are resistant to ultraviolet radiation and they indicate their state of discard with considerable reliability. Their most important advantage, however, is the fact that the manufacturers and users of wire ropes can lean on the experiences of nearly 170 years of wire rope history – and there will be many more to come!

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