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BRIDGES IN ARCHITECTURAL TREATISES AT THE BEGINNING OF THE MODERN PERIOD

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Great Italian architects of the beginning of the modern period took inspiration from antiquity. They analysed forms, dimensions, proportions and ornamentation of Greek and Roman buildings and implemented results of their studies directly in designs of palaces, villas as well as bridges that often, particularly in trade cities in the 15th and in the 16th century, were built in order to replace the old - timber ones. A manuscript of a treatise *De architectura libri Decem* written between 10 and 20 B.C. by Pollio Marcus Vitruvius that was found in 1415 in the Sankt Galen Cloister in Switzerland, appears significant for new perception of ancient architecture[1]. New style in architecture which was born at the end of the 15th century in Italian Toscana, migrated for the next two centuries to the north and east of Europe. Style called Italian Renaissance was promoted as a result of the influence of wonderful buildings on European travellers visiting Italy as well as thanks to readers of richly illustrated treatises on architecture written by creative architects. The work of Vitruvius became an inspiration and an example followed by the architects of the modern period. In the 16th and in the 17th century dynamic growth in publishing activities took place in the whole Europe and reached an unprecedented scale. This growth was initiated by the invention of the technique of printing in Dutch Haarlem and by publishing the Gutenberg Bible in 1455. Techniques of intaglio printing: engraving and aquatint were invented to illustrate printed books. The engraving method enabled to depict buildings, therefore bridges too, in a realistic and very precise way. In the 16th and in the beginning of the 17th century treatises published in print were commonly read in Europe. Works listed below bring up the subject of bridges:

- Leon Battista Alberti, *De Re Aedificatoria libri decem* printed in 1485, after the author's death[2],
- Sebastiano Serlio, *Tutte l'opere d'architettura*, 8 books printed from 1537 to 1547[3],
- Andrea Palladio, *I Quatro Libri dell' Architettura*, published in Venice in 1570[4],
- Vincenzo Scamozzi, *Dell idea della architettura universale*, published for the first time in Venice in 1615[5],
- Fausto Veranzio, *Machinae Novae Fausti Verantii Siceni*, published in Venice in 1616[6].

[1] P. M. Witruwiusz, *O architekturze ksiąg dziesięć, De architectura libri Decem,* Państwowe Wydawnictwo Naukowe, Warszawa 1956.
[2] L. B. Alberti, *Ksiąg dziesięć o sztuce budowania, Libri De Re Aedificatoria Decem,* Państwowe Wydawnictwo Naukowe, Kraków 1960.
[3] The books were published as a whole in 1584. S. Serlio *Tutte l'opere d'architettura di Sebastiano Serlio Bolonese,* F. de Franceshi, Venetia 1584.
[4] A. Palladio, *Cztery Księgi o Architekturze*, *I Quatro Libri dell' Architettura*, Państwowe Wydawnictwa Naukowe Warszawa 1955.
[5] V. Scamozzi, *Dell idea della architettura universale*, Per Girolamo Albrizzi in Venezia, MDCCXIV.
[6] F. Veranzio, *Machinae Novae Fausti Verantii Siceni Preparazione Di Mario Schiavone*, Luigi Maestri Tipografo, Milano 1983.

The oldest treatise on modern architecture based on the work of Vitruvius was written by **Leon Battista Alberti** (1404–1472). Alberti, who was born in Genoa, was a painter, a poet, a musician, a philosopher, as well as an architect. He was the author of the first Renaissance treatise on painting, in which he formulated the principles of perspective in a scientific way. In another treatise entitled *Ten books on the art of building* we can find the earliest guidelines as to where and how to build bridges. Chapter VI of the fourth book discusses "...Bridges both of Wood and Stone, their proper Situation, their Peers, Arches, Angles, Feet, Key–stones, Cramps, Pavements, and Slopes". "The Bridge, no doubt, is a main Part of the Street", as we can read at the beginning of this chapter[7].

Alberti described the bridge over Rhine near today's Coblenz built by Gaius Julius Caesar in 55 B.C. during the Gallic Wars as an example of a timber bridge. Caesar when constructing the bridge supports: "...fastened together two Timbers, leaving a Distance between them of two Foot; their Length was proportioned to the Depth of the River, and they were a Foot and an half thick, and cut sharp at the Ends". Two pairs of such timbers driven into the bottom of the river "he laid across from one to the other, Beams of the Thickness of two Foot, which was the Distance left between the Timbers drove down; and fastened these Beams at the End". "Over these other Beams were laid across and fastened to them, and a Floor, as we may call it, made over them with Poles and Hurdles"[8].

When writing about stone bridges Alberti devotes much space to location of supports. He recommends selecting rocky shores and places, where water flows slowly, which can be determined during observations of flood water or observation of flow of nuts thrown into the water. In his opinion "the Thickness of the Pier [should A.M.] be one fourth of the Heighth of the Bridge". Further we read that "The Arches ought upon all Accounts, and particularly because of the continual violent shaking and Concussion of Carts and other Carriages, to be extreamly stout and strong"[9] He recognized semicircle arches as the strongest but when these arches appeared to be too high he used arches of circular sector. In an arch structure "nor should the Chord itself be longer than six Times the Thickness of the Pier, nor shorter than four Times"[10].

In chapter VI of the eighth book of the work of Alberti he writes about "the Methods of adorning the Haven, Gates, Bridges, Arches, Cross–ways and Squares"[11]. When describing the roof covering Ponte Elio, today known as Ponte Sant'Angelo over Tiber in Rome, which is supported by 42 marble columns and covered with copper and beautifully decorated, Alberti recommends strengthening bridge railings with square pedestals on which one can erect columns of height equal to the width of the bridge. "The Height of this Side–wall with its Zocle and Cornice must be four Foot" – wrote Alberti. "The Causeway on each Side for Women and Foot Passengers" located on both sides of a bridge roadway (lined with silica) "must be raised a Foot or two higher than the Middle of the Bridge"[12]. Alberti's recommendations were undoubtedly applied in designs of majority of Renaissance bridges. Their reminiscences can also be found in contemporary regulations of construction laws.

Leonardo da Vinci (1452–1519) was certainly the most outstanding artist, architect, designer and inventor of the turn of the 15th and the 16th century, recognized years later as a genius of all time. After long standing apprenticeship at the Florentine studio of Andrea del Verrocchio, a painter and a sculptor, da Vinci was employed in 1485 by Ludovico Sforza – the ruler of Milan, as a court painter and engineer[13]. At the Duke's court, in the years 1485–1490, he created the greatest inventions in the field of engineering: a flying machine, an armoured vehicle, an air screw and a swing bridge[14]. Movable bridge by Leonardo consists of a heavy abutment and a swing span designed as a timber arch. Both are fixed to a pylon located in the centre of rotation by two pairs of cable stays.

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[7] L. B. Alberti, *The Architecture of Leon Batista Alberti in Ten Books,* Printed by Edward Owen, London, 1755, http://archimedes.mpiwg-berlin.mpg.de, access 2012.08.08.1:20 p.m., p. 250.

[8] L. B. Alberti, op. cit., p. 251.

[9] op. cit., p. 258.

[10] op. cit., p. 259.

[11] op. cit., p. 572.

[12] op. cit., pp. 575-576.

[13] In Milan, Leonardo painted the famous portrait of Cecilia Gallerani, known as the Lady with an Ermine, he conducted studies on architectural structures based on a central plan and the drum-shaped dome for the Milan Cathedral. F. Zöllner, *Leonardo da Vinci Dzieła wszystkie,* Taschen GmbH, Kolonia 2011, pp. 82-83, 94-95.

[14] F. Zöllner, op. cit., pp. 570-657.

Leonardo had never worked out his numerous, mostly unfinished designs and had not printed them in the form of arranged treatises[15]. His draft notes, sketches and drawings were taken over by his heirs and in 1588 they were acquired by a sculptor and an art collector Pompeo Leoni (1533–1608). Due to his actions *Codex Atlanticus* (Fig. 1) was created in 1604 in Milan with 1119 sheets with Leonardo's works and then subsequent codes came into being[16]. Among „Disegni di macchine et delle arti secreti et altre cose di Leonardo Da Vinci raccolti da Pompeo Leoni" several bridge designs can be found:

• two timber bridges for fast assembly with beam superstructure on pile trestle supports (Fig. 2),

• movable bridge with a swing span of an arch construction (Fig. 3),

• multispan one-chord truss bridge (Fig. 4),

as well as two floating bridges (the first one on vessels and the second one most likely on pontoons), temporary mobile bridge on wheels and two military bridges, both consisting of bascule span on mobile support, used for conquering fortifications[17].

12 volumes of Leonardo's works, called Paris manuscripts (from A to M), are stored in France. In the *Paris Manuscript B*, consisting of 90 pages, there are, among others, architectural studies on ideal city - „La città Ideale", conducted by Leonardo in the years 1487–1490, during his stay at the court of Duke Sforza in Milan[18]. Epidemic that prevailed there in the years 1484–1485 inspired the artist. For hygienic reasons he designed an ideal city on separated levels: the upper one for pedestrians and the lower one with channels and roads for vehicles, that could not do without many bridges and viaducts. There are several concepts of bridges in the studies on ideal city such as a stone arch structure, a timber truss structure with parallel chords (Fig. 6)[19] and the most interesting strut-truss span structure, unknown in other bridges from that time, which is shown in the picture marked with 23 (Fig. 5)[20]. Was similar construction implemented for the so called German Bridge over Vistula in Torun built in 1500?[21]

In the *Paris Manuscript L*, containing 94 pages of notes, sketches and drawings from the years 1497-1502, concept of one of the most famous bridges of Leonardo da Vinci is illustrated. The sketch shows an arch span of huge length (Fig. 7)[22]. On the 3rd of July, most probably in 1503, Leonardo sent a letter to Sultan Bayezid II, where he offered spanning the Golden Horn Gulf in the Bosporus Strait (from Galata to Istanbul) with a bridge. "I could raise an arch so high that nobody would be able to pass it because of its height. (...) I could construct it in such a way that even a sailing ship could pass under it..."[23] wrote Leonardo. According to a recent research of a drawing from the manuscript "structure of the bridge is made up of two vaults in shape of circular sectors", made of timber and joined together with vertical walls of variable height which form a wooden box in cross-section. Total length of the bridge was supposed to have 350 m (600 ells), width 23 m (40 ells) and the span raising nearly 41 metres (70 ells) above water level was 233 m (400 ells) long[24].

Roman arch bridges made of stone were described by **Sebastiano Serlio** (1475–1554). Distinguished architect of the Mannerist Epoch that came from Bologna, studied in Rome at Baldassarre Peruzzi[25]. In

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[15] As a result of the occupation of Milan by the French, after 1499 Leonardo moved to Mantua and to Venice, to finally return to Florence. There he performed works in the field of architecture, military and water engineering for Cesare Borgia. His last creative years Leonardo spent at the French court of Francis I de Valois and died in the residence in Cloux, which was a gift from the King.

[16] These works were inherited by Arconati Galeazzo, who gave them in 1637 to the famous Biblioteca Ambrosiana in Milan. Napoleon Bonaparte's troops took them to France and only the Atlantic Code returned to Italy after the Congress of Vienna.

[17] P. Leoni, *Disegni di macchine et delle arti secreti et altre cose di Leonardo Da Vinci raccolti da Pompeo Leoni*, Milano, 1604.

[18] F. Zöllner, op. cit., pp. 554-564.

[19] Z. Wasiutyński, *O architekturze mostów,* PWN, 1971, p. 271.

[20] Z. Wasiutyński, op. cit., p. 271.

[21] A probable view of the bridge in Torun before 1632 has recently been created on the basis of a drawing of an unknown author dated to 1631 and a drawing of an English traveller Peter Mundy from 1643. Analogies to the drawing by Leonardo are astonishing though it is difficult to draw more definite conclusions solely from this similarity. M. Mistewicz, *XVII-wieczne mosty przez środkowo-dolną Wisłę w świetle ikonografii, kartografii i źródeł pisanych*, Wydział Architektury Politechniki Warszawskiej 2012, unpublished, pp. 137–138.

[22] L. da Vinci, *Manuskrypt L*, *karta 66r*, Bibliothèque de l'Institut de France.

[23] Copy of the letter that is stored in Istanbul in the Topkapi Palace (document no. E 6184) according to F. Babinger, *Vier Bauvorshläge Lionardo da Vinci's an Sultan Bajazid II (1502/3,)* Nachrichten Der Akademie Der Wissenschaften in Göttingen, no. 1/1952, after J. Rymsza, *O kładce dla pieszych wzorowanej na projekcie Leonarda da Vinci,* Inżynieria i Budownictwo, Nr 11/2009, p. 640. This letter has been translated by Iker Evrim Binbas of Oxford University, http://www.flickr.com/photos/swamibu/289269862/ access: 2012.08.10. 12:17.

[24] J. Rymsza, op. cit., p. 641.

the book *Il trerzo libro di Sebastiano Serlio Bolognese* published in 1540 in Venice by Francesco Marcolino da Forli, Sebastiano Serlio included illustrations of four ancient bridges in Rome, which he named: Ponte Palatini, Pons Milulus, Ponte Elio and Ponte Tarpeio. All of them were of stone arch structure[26].

• Pons Aemilius called by Serlio Ponte Palatini, Ponte dei Senatori and also Ponte Santa Maria was built by censors M. Aemilius Lepidus and M. Fulvius Nobilior in 179 B.C.[27] This probably the first stone arch bridge over Tiber in Rome is composed of five spans, richly decorated with bas-reliefs (Fig. 8)[28].

• Pons Milulus drawn by Serlio, also known under the name of Ponte Milvio, was built by Gaius Claudius Neron in 207 B.C. on via Flaminia[29]. The bridge shown on the engraving is 8,5 metres wide and has got four arch spans from 15 to 24 m long[30].

• The bridge built in 134 B.C. during Emperor Hadrian's reign, called with his second name Ponte Elio or Pons Aelius, nowadays known as Ponte Sant'Angelo, is described by Serlio most in detail[31]. The bridge shown on the engraving is composed of eight stone spans: three of them are 18 metres long, two are 7,5 metres long and others 3,5 metres long (Fig. 9)[32]. The wonderful colonnade covered with a roof, earlier described by Alberti, is not visible on Serlio's engraving.

• Ponte Tarpeio, later known as Pons Fabricius and recently as Ponte dei Quattro Capi was built by curator viarum Quintus Fabricius in 62 B.C. The bridge shown on the engraving through the Tiber branch, that is 5,5 m wide and 62 m long, crosses to an island - Isola Tiberina with two long spans 24,2 and 24,5 metres long[33].

There is also a drawing of a timber roof truss in one of Serlio's works and right below it a drawing of a timber bridge span. Due to the fact that several different structure solutions are applied in one span, this kind of timber bridge system has been defined as disorderly (Fig. 10)[34].

The greatest number of modern bridge designs are included in „The Four Books of Architecture" published in 1570 by **Andrea Palladio** (Andrea di Pietro della Gondola, 1508–1580), an architect, who used to build bridges too[35]. In 1560 he accomplished a timber bridge over Cismone river near Florence, in 1569 a timber bridge over Brenta in Bassano and around 1580 a masonry arch bridge of stone and bricks over Tesina in Torri di Quartesolo.

In Venice in 1570, Palladio published *The Four Books of Architecture* that was inspired by the earlier mentioned work of Vitruvius. He drew for the first time and just like Alberti described in detail the bridge over Rhine built by Gaius Julius Caesar. In the third book he presented drawings of eleven bridge structures including four timber trusses. He also showed his solution, implemented for the timber bridge over Cismone with two trapezoidal trusses, each of them consisting of five vertical posts fixed to chords and reinforced with cross braces. The span length was 100 Venetian feet, which is 30 m (Fig. 11).

Another design of a timber one-span truss, with two parallel chords curved in shape of a circular sector arises interest too (Fig. 12)[36]. Palladio provides height of this truss as equal to one-eleventh of the crossed river's width. He described and drew a bridge over Brenta in Bassano as well, roofed with a beam reinforced with trapezoidal struts and composed of five spans, each of them 34Ľ feet (around 10 m) long (Fig. 13)[37].

In his treatise an ancient stone bridge over Bacchiglione in Vicenza was described too. Rebuilt in modern times it was composed of three arches, two of which were 22″ feet long each and the middle

[25] Afterwards he worked in Venice and at the French court of Francis I of Valois in Fontainbleau.

[26] S. Serlio, *Il terzo libro di Sebastiano Serlio Bolonese,* F. M. da Forli, Venetia, 1540, pp. 86–87.

[27] At the beginning wooden spans were put on stone pillars of the bridge and then in 142 B.C. replaced with stone spans.

[28] C. O'Connor *Roman bridges. With photographs, sketches and diagrams by the author,* Cambridge University Press, Great Britain 1993, p. 67.

[29] After having been destroyed by the Carthaginians the bridge was rebuilt in 110 B.C. by censor Marcus Aemilius Scaurus and then decorated with a triumphal arch by the Emperor Augustus.

[30] A. Rosset, *Starożytne drogi i mosty,* Wydawnictwa Komunikacji i Łączności, Warszawa 1970, p. 160.

[31] The bridge connected the Mausoleum of Hadrian with the Campus Martius.

[32] A. Rosset, op. cit., p. 159.

[33] C. O'Connor, op. cit., p. 66.

[34] Z. Wasiutyński, op. cit., p. 271.

[35] A son of a craftsman from Padua became a leading creator of the Italian Renaissance. He created many architectural designs of villas, urban palaces and churches in the Veneto area. From 1570 he was engaged by the Republic of Venice as a consultant for architectural matters.

[36] The structure is clearly similar to a structure implemented 250 years later by Lewis Wernwag for the Colossus bridge, after D. J. Brown, *Mosty, trzy tysiące lat zmagań z naturą,* Warszawa, Arkady, 2007, p. 36.

[37] A. Palladio, *Cztery Księgi...*, pp. 167-171.

one was 30 feet long (around 9 m) (Fig. 14). "The arches have a frezza a third of their diameter; their archivolts [modeno] are a ninth of the diameter of the smaller vaults and a twelfth that of the middle one; the archivolts are cut as though they were architraves" – wrote Palladio.[38]

In Palladio's work we can also find a design of a stone bridge prepared according to his idea (Fig. 15). A three-span arch structure in the same proportions as in case of earlier described ancient bridges, was supposed to be equipped in three loggias resembling porticos: one above the middle span and two above abutments, and in six rows of merchant stalls. Palladio designed the bridge „in the middle of a city which is one of the largest and most impressive in Italy and the mother city of many other cities"[39]. Where was that beautiful bridge planned to be built? Probably in Venice, where in 1587 Vincenzo Scamozzi and Antonio da Ponte strove for implementation of their designs of Ponte Rialto by the town authorities[40].

Another treatise on architecture that the issue of bridges was written by **Vincenzo Scamozzi** (1548–1616), and published for the first time in 1615 in Venice[41]. In the second part of book eight of his work *Dell idea della architettura universale* there is chapter XXII „Del ponte temporaneo fatto ...", in the title of which he mentions and later in its content describes the temporary Caesar's bridge over Rhine. He presents appearance and method of construction of the bridge, that we earlier find in the treatises of Alberti and Palladio. Three drawings of timber bridges are included in Scamozzi's treatise:

• timber, beam bridge on pile supports called „Ponte foris e periganente" (Fig. 16),

• temporary timber bridge over Rhine built by Gaius Julius Caesar in 55 B.C. during Gallic Wars,

• timber truss bridge covered with a roof „Ponte artificiosis de legami armati coperto", according to his design (Fig. 17).

The last of mentioned bridges was shown in a longitudinal view and surprisingly in its central part a cross-section with a support was placed. On the bridge a colonnade was designed covered with a roof decorated with sculptures as well as a loggia resembling a portico above the middle span. Above trapezoidal struts structure of the middle span of the bridge, timber truss was shown with its upper chord shaped in a form of a circular sector. The question remains if Scamozzi intended to implement these two different solutions for one structure or he showed an alternative solution on the same drawing.

Bridge structures which were nearly three centuries ahead of their creators' time, can be found in a book of inventions, published in 1616 by **Fausto Veranzio** (Faust Vranèić ok.1551–1617)[42]. Among bridge constructors and great inventors of the 16th and the 17th century he is a person undoubtedly distinguished. The fact of having assembled and tested a parachute in 1595 in Venice - „Volans Homo" (Fig. 18) earlier drawn by Leonardo da Vinci, brought him the fame of an inventor. Veranzio had fluent command of seven languages. He worked out a dictionary that contained 5000 words in several languages *Dictionarium Quinque Nobilissimarum Europae linguarum, Latinae, Italicae, Germanicae, Dalmaticae et Ungaricae*, and was also published in 1595 in Venice[43].

Slightly more than twenty years later, in 1616 in Venice Veranzio published a work titled *Machinae Novae*[44], that contained 49 illustrations showing machines and devices invented by him, described in Italian, Latin, German, Spanish and French.

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[38] A. Palladio, *The Four Books on Architecture,* translated by Richard Schofield, Robert Tavernor, Cambridge, Mass. United States, MIT Press Ltd. 2002, p. 186.

[39] A. Palladio, op. cit., p. 187.

[40] D. J. Brown, *Bridges,* Macmillan Publishing Company, New York 1993, pp. 36-37.

[41] An architect, son of a builder from Vicenza, created in Venice from 1581.

[42] He was born in an aristocratic family, residing in Šibenik in Croatia, being at that time a part of the Republic of Venice. In the early youth he attended schools in Venice and then studied mathematics and engineering at the University in Padua. He made a journey to Hungary with his uncle, the archbishop Antonio Veranzio, who was a writer and a diplomat. Next he moved to Prague, to the court of Rudolf II, where he performed the duties of a chancellor of Hungary and Transylvania region. In 1609 Fausto Veranzio came back for permanent to Venice, where he joined the Confraternity San Paolo and devoted himself to inventions of technology. Strongly related to European scientific circles Veranzio cooperated with German mathematician, astronomer and astrologer Johannes Kepler (1571–1630) and with Danish astronomer Tycho Brache (1546–1601), both distinguished scientists, whose works significantly influenced the development of science. He died on the 27th of January in 1617 in Venice and he was buried in accordance with his will on the Prvić island near Šibenik. After F. P. Miller, A. F. Vandome, J. Mc Brewster, *Fausto Veranzio,* Alphascript Publishing U.S.A., U.K., Germany 2011, pp. 1–8.

[43] F. P. Miller, op. cit., pp. 1-8.

[44] F. Veranzio, *Machinae Novae Fausti Verantii Siceni Preparazione Di Mario Schiavone,* Luigi Maestri Tipografo, Milano 1983.

Apart from bridges, designs of modern windmills and watermills are presented among others in this work[45].

The ideas of Veranzio and suggested technical solutions are very innovative, often several centuries ahead of their practical application. Among Veranzio's inventions described in *Machinae Novae* there are also seven bridges of different span types:

• timber beam - „Pontes Vienna Austriae" realised in Vienna,

• timber triangle-truss with a portal frame – „Pons Duarum Trabum" (Fig. 19),

• „tied arch of dovetailed and bolted timbers" reinforced with cross braces of X type[46] – „Pons Ligneus" (Fig. 20),

• masonry vault "restrained by iron eyebar tie rods, braced by the further rods suspended from the arch"[47] – „Pons Lapideus„ (Fig. 21),

• cast in bronze, arch with a deck supported on a chord[48] – „Pons Areus" (Fig. 22),

• cable-stayed, composed of a timber deck with beams and stays made of iron eyebars and fixed to two masonry towers[49] – „Pons Ferreus" (Fig. 23),

• suspension, with ropes supporting partially stiffened timber deck (assigned for military purposes)[50] named „Pons Canabeus" (Fig. 24).

Moreover there is a drawing in the book showing a basket ropeway used for river crossing, which was also called a bridge by the author: „Pons Vinius Funis".

The bridge with a triangle-truss span – „Pons Duarum Trabium" is exceptionally interesting. Two triangle-trusses are connected in the upper and lower part with two cross beams that together with two posts form a portal frame. The design is a very valuable source when searching for structure models of truss spans that were implemented for bridge structures over Vistula in Warsaw in the second half of the 16th century and in Torun in the first half of the 17th century. Special admiration is brought about „Pons Ferreus" - the first known bridge design of cable-stayed superstructure[51] with beams and stays made of iron eyebars and „Pons Canabeus" - a bridge design of temporary structure suspended on most probably hemp ropes threaded between timber sheave blocks[52].

The concepts of bridge structures provided Fausto Veranzio and Leonardo da Vinci by and large exhaust the a list of solutions known to builders in the next centuries.

The beginnings of modern times brought about a considelable interest in ancient architecture and engineering. In times of the Renaissance structures were built beautiful in their classical form. They referred to ancient buildings known from written accounts or still existing at that time. Apart from their natural function of overcoming water obstacle on communication routes bridges became an important element integrating urban space. Merchant stalls were placed on them and representative loggias that enabled to admire ships on a river. Bridges enriched landscape of urban public space, therefore they were decorated with sculptures.

However it is the length of a bridge span that is considered to be the significant determinant of modernity when speaking of technical capabilities of an epoch in permanent getting through space. Medieval builders of monumental vaults achieved spans that were 72 metres long[53]. Length of bridge spans built in the Renaissance returned to dimensions proven in practice by Romans, exceeding merely 100 Roman feet i.e. circa 30 metres. Often bridges were not built, in spite of communication needs in the areas where nature did not provide convenient conditions.

Next to great architects, authors of Renaissance treatises restoring ancient canons of building, we meet visionary-constructors, like Leonardo da Vinci or Fausto Veranzio, who deliver concepts of new solutions. Their technical thought being hundred years ahead could find practical application in the next centuries thanks to the invention of new materials and development of new building technologies. They created the basis enabling engineers from the

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[45] F. P. Miller, op. cit., p. 2.

[46] D. J. Brown, op. cit., p. 35.

[47] op. cit.

[48] op. cit.

[49] op. cit.

[50] op. cit.

[51] M. S. Troitsky, *Cable-stayed Bridges. Theory and Design*, Crosby Lockwood Staples, London 1977, p. 4.

[52] A sheave is a wheel having a groove in the rim for a rope to work in. http:/www.en.wiktionary.org/wiki/sheave, access: 2012/08/12, 4:39 p.m.

[53] Stone span of the bridge over Adda in Trezzo built in the years 1370-1377, after J. Głomb, *Pontifex Maximus Ponad przestrzenią i czasem,* Wydawnictwo Politechniki Śląskiej, Gliwice 1997, pp.79-80.

turn of the 20th and the 21st century to cross natural barriers with a 1080 m long cable-stayed span[54] and 1991 m suspended span[55].

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[54] Stonecutters Bridge in Hong Kong (opened to traffic on the 20th of December 2009), after D. J. Brown, op. cit., pp. 196-199.

[55] Akashi Kaikyō bridge built in 1998 (within the framework of the Honshū-Shikoku Bridge Project) in Japan, after D. J. Brown, op. cit., pp. 170-173.