Early Canal Lock Design

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Introduction

The lock is one of the most important features of canals, and their design has often been considered as part of a long and continuous sequence of development. This view tends to ignore local influences, and yet these were highly significant in the design of individual locks. Their design and construction was usually the work of local craftsmen who would have had little or no opportunity to see or discuss developments outside of their own area. In Europe, transfer of technology was not an important factor in canal design and construction until the 18th century. It was only with the publication of books describing the technical aspects of waterway design, such as Zonca's ***Novo Teatro Di Machine***, published in Padua in 1656, Sturm's ***Fang-schleusen und Rollbrücken***, published in Augsburg in 1720, and, most importantly, Belidor's four volume ***Achitecture Hydraulique***, published in Paris in 1753, that local influences on waterway design became less important.

Below are suggested some of the influences on the design of the lock, and how local conditions affected how the lock structures were built. In particular, it looks the development of locks in China, the Low Countries, Italy and France, comparing the major influences affecting lock design, and how local craftsmen coped with these in their design for locks and other hydraulic structures.

Land drainage and Irrigation

Where canals were built for water supply and drainage, there would always be the flow of water to contend with, Such water flows could carry considerable volumes of silt, and locks had to be designed to cope with this. The variations over time of the locks on the Grand Canal of China is the best example of the effects of siltation.

Flood and Tidal protection

In some places where locks were part of flood or tidal protection embankments, they had to cope with large variations in water level. On tidal locks, the level of the water could be highest on either side of the embankment, depending on the state of the tide. This required two sets of gates, with the idea of a chamber lock developing from this.

Siltation and the movement of silt

Tidal and flood locks often suffered from excessive silting, and the lock could be designed to include sluices for clearing the gates and approaches of silt. This was only possible where tidal and river currents could carry the silt sufficiently far away so that it did not return and continue to affect the lock.

Fortification and military use

Locks and sluices were often incoporated into military fortifications to allow access for boats to the inner sections of the fortification, or for flooding areas outside the fortifications during a siege. Early canals associated with the carriage of military goods were often simple in construction, and water usage was not an important factor in their design. One of the best known, the Fossa Carolina of 793, did not use locks, but inclines for small boats instead.

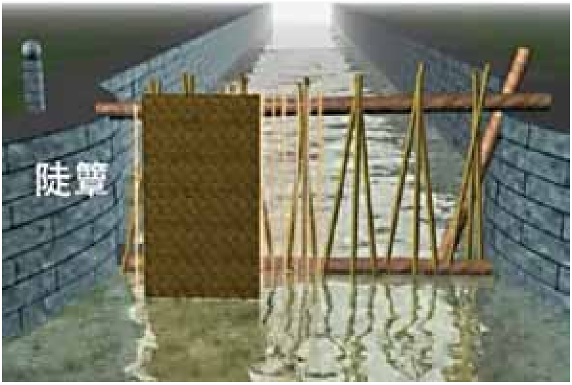
Commercial navigation

Where canals were built for carrying goods, water usage was an important factor. Flash locks were used on the earliest navigations, but their excessive water usage encouraged the development of the chamber lock as we know it today.

Left: The earliest route of the Grand Canal in China, pre-1324 AD, with the Yellow River running to the north of the Shandong Peninsula. The river carries vast amounts of silt, but the canal was kept relatively silt free as it was fed by the clean waters of the Huai River, and this affected the design of the locks built on this section of canal.

In 1324 AD, the Yellow River changed its course to run south of the Shandong Peninsula. A new canal was built to the east of the earlier canal, with locks designed to cope with the increasing amount of silt carried into the canal from the Yellow River, which now crossed the canal near Huaian. The problem of silt increased until the river reverted to a northern course in 1853 AD.

Right: The Alster Navigation in Hamburg, built around 1450, with two flash locks separated by a short canal section forming an early type of chamber lock. Flash locks continued in use on the Alster, but some on the Stecknitzfahrt, below, were converted to chamber locks because their water usage caused problems for the local water mills.



Left: A suggestion as to how the flash locks on the Lingqu Canal were built. A simple framework was erected and covered with bamboo matting to hold back the water. The log on the right could then be loosened, causing the framework to collapse and thus allowing boats to pass.
http://www.thewaterchannel.tv/en/videos/categories/viewvideo/1062/rivers/the-ancient-lingqu-canal-of-china

Right: A flood control sluice at Goederede, south of Europort. The gate, centre right and open in the photo, can be held shut by the levers connected to the winches in the background. It was from such simple designs that locks developed in the Low Countries.

Below: The Stecknitzfahrt, opened in 1398, was Europe's first summit level canal built primarily for navigation. All the locks were originally flash locks. The Palmschleuse, named after the local miller in Lauenburg, was converted to a wooden chamber lock before 1480, along with the two Hahnenburger locks. It was rebuilt again with a circular stone chamber in 1789.

Right: From 1324 to 1855, the Yellow River flowed to the south of the Shandong Peninsula. A new Grand Canal was built to the east of the older one, creating a route from the Yangtze to the new capital of Beijing. This was crossed the Yellow River near Taierzhuang. Although the crossing was designed to keep out silt, over the years this became more difficult as land levels rose because of the silt. Finally, in 1855, the Yellow River reverted to its northern course.

China

The two important historic canals in China are the Lingqu, or Magic, Canal and the Grand Canal. The former was built around 240 BC, linking the north-flowing Xiang River with the south-flowing Li River to create a route from the Yangtze River to Canton. It was used to supply the Qin Emperor's army as they fought their way south, and was the world's first summit level canal. Flash locks were used, the canal being supplied with water from the Xiang River. Pound locks, with gates similar to the flash locks, may have been used at a later date.

Further north, the first Grand Canal opened in 605 AD, using sections of canals built much earlier. Flash locks and inclined planes were used at first, and some were later replaced by chamber locks. However, there was a significant water flow, and usually stop log gates were used as these would have been less affected by any silt carried by water passing along the canal.

The silt problem increased over the centuries after a new canal was built when the Yellow River moved south in 1324. On the new canal, stop log locks seem to have been the norm, including for crossing the summit level on the Shandong Peninsula. Over the years, silt became

Left: By the time Europeans visited China regularly in the late 17th and 18th centuries, silt was a major problem for boats using the canal. Inclined planes replaced some locks, and simple flash locks using stop log gates were also used. These were much less likely to be affected by the increasing volumes of silt entering the canal from the Yellow River.

an increasing problem, and in some places the stop log flash locks were replaced by inclined planes. These had been used earlier, but were a restriction on the size of boat and cargo that could use the canal.

The locks used on Chinese canals were built by local craftsmen to solve specific local problems, particularly those caused by siltation.

Low Countries

Land reclamation and flood prevention were already well established by the time the first navigational locks were built in the Low Countries. The earliest was at Spaarndam, dating from 1253, built as part of the defences for the Haarlemmermeer. The difficulty with contemporary descriptions of this, and subsequent locks, built over the next few centuries, is identifying exactly what was being described and how they were adapted for navigation. Lifting gates seem to have been used initially, but these would have restricted the height of boats passing the lock, so sailing vessels would have had masts which could be folded down.

With variable water levels due to flooding or tidal action, gates often needed to hold back water in both directions. This led to two sets of gates, and the development of the chamber lock towards the end of the 14th century. Early locks of this type had the gates fairly close together as the width of the embankment would have been restricted. Subsequently embankments were widened, allowing the construction of chambers large enough to hold at least one boat.

Above: The Kolksluis was the second lock at Spaarndam, and was built in 1290, rebuilt in 1571, and again in 1778. Originally it probably had lifting gates, with the mitre gates installed during subsequent rebuilding.

Left: The lock at Vreeswijk from a drawing of 1585. Mitre gates had just been introduced, but the lower gate was still a lifting gate.

Florentine merchants regularly visited the Low Countries in the 15th century as part of their wool trade. The establishment of such international trade provides an early opportunity for the transfer of technology, with descriptions of Dutch waterway technology possibly being taken back to Italy.

Left: The lock and windmill driven drainage pump at Tienhoven, near Utrecht. Lifting gates continued to be used on navigable drainage canals, where boat size was small.

Right: Willebroek, on the Brussels Canal, designed for navigation, and built around 1600. Locks on this canal were the first to use ground paddles, an essential feature of modern locks.

Italy

Above: A recent photo of a lock on the Canal de Bereguardo. The canal is still used for irrigation, and the locks have been rebuilt since chamber locks were first used here in 1458.

The earliest canals in Italy, such as the Naviglio Grande of 1179-1209, were built principally for irrigation. The Naviglio was also used for navigation from 1269, and some form of lock connected it with the Milan city moat in 1387 when stone was being supplied for the Cathedral. It is possible that two chamber locks were added in 1438 and 1445 by Filippo da Modena and Fioravante da Bologna. Chamber locks were used by Bertola da Novate on the Canal de Bereguardo, opened in 1458, on the canal at Parma, built 1456-9, and on the first sections of the Canal de Martesana, 1462-70.

Leonardo da Vinci was also involved with canals around Milan, and his are the first drawings illustrating mitre gates. Did he discover the idea, or had Bertola da Novate used mitre gates previously; contemporary reports are confusing. However, Leonardo did designed a gate paddle (sluice) rotating on a vertical axis which seems to have been new to Italy. Similar designs had already been used on drainage sluices in The Netherlands, but the possibility of technology

Right: The Naviglio Grande was originally used for irrigation, but flash locks were built later to allow navigation.

Left: One of the locks Leonardo da Vinci built in the centre of Milan. It has been restored using his drawings as a guide, with mitre gates and the paddles which rotate on a vertical axis.

transfer is extremely unlikely. Until the publication of books on canal technology, the design of lock structures was very much an answer to local requirements.

The one possible example of the transfer of technology was Leonardo da Vinci's move to France at the invitation of the King of France early in the 16th century. Could Leonardo's influence be one reason for the development of canal technology in France over the following century?

France

Canals in France developed from rivers with flash locks, such as on the Thouet, running south from the Loire, through Parthenay. Flash locks had been used on the Thouet, and these were converted to chamber locks by extending them downstream.

The Canal de Briare had locks with straight-sided chambers, which was good practise. When construction of the Canal du Midi started, the walls of the chambers were also straight-sided.

Right: One of the locks old flash locks on the River Thouet at Montreuil-Bellay which has been altered to form a chamber lock. The water mill associated with the lock is off the picture to the right.

Right: The seven-rise flight of locks at Rogny, on the Canal du Briare. As well as stright-sided chambers, the locks were also fitted with ground paddles.

However, a lock wall failed, and subsequently all lock chambers on the canal were built with curved sides. Replacing straight chamber walls with curved is a poor solution to chamber wall instability and suggests that construction and design of locks were still controlled by local craftsmen. Despite this, and the lack of ground paddles, the Canal du Midi still represents the maturing of canal technology, particularly with regard to water supply. It marks the change from construction organised by local craftsmen, to that where an engineer had overall responsibility. The canal also formed the subject for many sections of Belidor's book ***Architecture Hydraulique*** which was used by many canal engineers. The drawings in the book would provide sufficient information for local craftsmen to build a canal, and it marks the beginning of the move to more scientific design of canals.

Right: The Canal du Midi was used to supply water to mills, as here at Castelnaudary. However, the canal was built primarily for navigation.

Left: Locks on the Canal du Midi with curved chamber sides.There are gate paddles, but no ground paddles.

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