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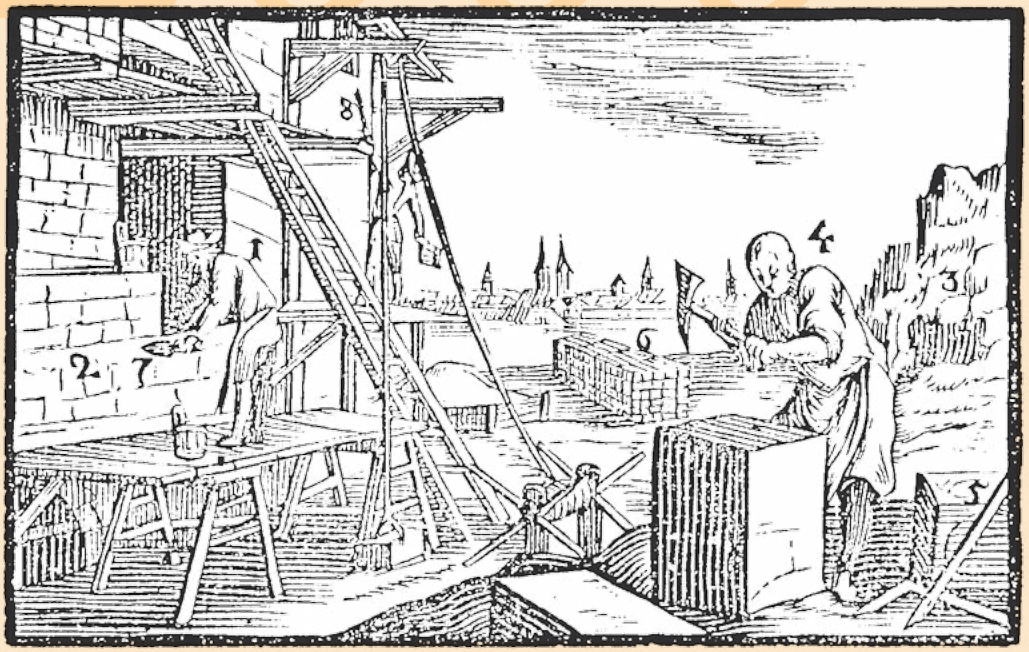
Two Millennia of Lime and Cement Industry in the Czech Lands



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SVAZ VÝROBCŮ VÁPNA ČESKÉ REPUBLIKY
Czech Lime Association

SVAZ VÝROBCŮ CEMENTU ČR
Czech Cement Association

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Introduction...

This publication has been issued thanks to an initiative of companies producing cement and lime and associated with the Czech Lime Association and the Czech Cement Association It breaks down progress in lime and cement production, beginning with the oldest archaeological finds and first written references to the present day. Its core lays in the second half of the 19th and in the 20th century when the transition to modern industrial lime and cement production was made and when optimum production streams and methods were being searched for and had been found, as well as vital technical and technology innovations taking place.

This book has been elaborated on the basis of documents kept in the company archives of individual companies, first of all on the basis of minutes of boards of director´s meetings and the so-called complex analyses of company economy, as well as of professional literature and numerous partial studies published in specialised journals, in particular in the monthly publication "Stavivo" (Building Material). Utilised were also hitherto published company publications and unpublished materials.

Our gratitude should be addressed first and foremost to company recorders and to all those to whom history of the entire

branch and of individual companies was not indifferent. Thanks to their interest, numerous documents and memories have been preserved for future generations.

The publication is divided into four chapters that contain both the evaluation of the subject time period, a basic overview of economic progress and a summarisation of progress in cement and lime production technique and technology. Furthermore, chapters two and three are divided into short sections designated to the progress of individual regions of the Czech Republic.

Also, due to the limited scope, the presented work does not pretend to be exhaustive. A number of important documents are still hidden with authorities and in municipal archives where they are still waiting to be discovered. Anyway, this publication presents a firm overview regarding branch progress, miscarriage, but also success which has been reached. Should this work stimulate interest in more detailed elaboration of individual company histories and in the branch as a whole, then it has come to time.

Summary
Two Millennia of Lime and Cement Industry in the Czech Lands

Though production of lime has had a thousand year tradition in the Czech lands, and in spite of ranking among the developed countries with respect to production progress, due attention has not been paid to the history of the building materials branch yet. Numerous references have been dispersed in various homeland studies or in both contemporary and present company publications, or in contemporary press respectively. Historic data often constitute introductions to professional publications designated to the progress of techniques or technology of lime and cement production. Practically, many of these books, articles and studies are unavailable to a wide public. Some annual publications have not been made available in company archives, and to capture historical progress is thus bound in the personal memories of bystanders.

The present publication has been divided into four chapters. As the basic milestones, firstly political events have been chosen and, secondly, principal changes of technology and changes in respect of property rights have been taken into account. All chapters contain general sections. Only basic development trends have been outlined in the first and fourth one due to lack of information, or dues to the brevity of a historic period respectively. In the second and third one, progress in individual production regions has also been described. In total, nine regions have been chosen, respecting traditional divisions: namely the regions of Beroun, Prague, Čížkovice, Prachovice, Krkonoše (the Giant Mountains), Šumava (the Bohemian Forest), Litovel/Jeseníky (the Ash Mountains), South Moravia, and East Moravia.

Chapter one, ***From the Oldest References to the Early Industrial Production of Lime and Cement****, will present a brief analysis of the oldest references regarding lime or hydraulic bonding materials in the territory of the Czech Republic and in its individual regions. Production in the so-called field kilns or piles is described herein. Similarly to lime burning, quarrying and disintegration of raw materials was also primitive. If knowledge of lime production had not fallen into oblivion in Europe, it was not the case of knowledge regarding the production of hydraulic bonding materials where only the 18th and 19th centuries brought about marked changes; i.e. the centuries where, apart from once again picking up ancient Romans' knowledge, purposeful investigation was performed into individual matters, of their correct mixing, as well as the solution of basic technical and technology issues.*

Chapter two, ***Early Industrial Production, Search for Optimum Streams and Methods (1870-1945)****, will firstly acquaint us with lime industry progress.*

Field kilns were replaced with simple shaft kilns and finally with ring kilns. More complex was the situation in the cement production branch. In the second half of the 19th century there was competition among hydraulic limes (mortar materials burnt of similar raw materials as cement, however, without sintering), slag cements (fine ground slag with lime hydrate), and Portland cement (not yet fully mastered with respect to technology). Decisive for their marketing were their manufacture qualities, price, tradition, but also the complexity of their production. Finally, it was Portland cement that emerged victorious in this competition. Its production technology scored fundamental changes based on the transition to real industrial production. This was enabled by mastering the the control and chemical composition of raw materials as well as controlled burning at temperatures over 1450°C. Decisive was the introduction of continuous shaft kilns and in particular rotary kilns. Among the Czech cement plants, the Králův Dvůr plant became the leading one, first of all due to the construction of a modern plant in the late 20s of the 20th century. Cement was produced there in rotary kilns, applying the dry process by utilising heat in boilers heated waste heat. Its dominant position was also reflected by its leading role in the Czechoslovak cement plant trust that was established in the mid 30s.

From this period basic conditions for the future development of the branch in the Czech lands were established. For example, the pelletizing disc had been developed, the first patent regarding the suspension pre-heater had been filed, and (unsuccessful) experiments were also being carried out with the grate burning process.

The following period called ***Quantitative Extension of Cement and Lime Production (1945-1989)*** *brought about a fundamental change of both ownership and the production management system. Between 1945 and 1948, cement and lime works were nationalised; centralised planning was put through. Cement was considered to be a strategic raw material and extensive funds were directed into the construction and modernisation of cement works. Though various set backs occurred (delayed commissioning of buildings, low attention paid to the environment in the early stages etc.), as early as 1961, progressive production technologies were being successfully introduced - short rotary kilns with suspension preheaters. In the early 60s, the last shaft kilns were phased out and in final years of this period even wet process kilns reached the limits of efficiency, though the last one was commissioned as late as 1977.*

The situation in the lime industry was not so clear as respective production was rather dispersed. As late as the 60s, ring kilns represented the basic kiln systems, when a very high quality of produced lime was reached at the expense of hard physical work in a dusty and hot environment. The fundamental breakthrough occurred in the mid 60s when three modern plants were commissioned equiped with high-capacity

shaft kilns that used coke and, later on, modern regenerative shaft kilns (Maerz) were introduced. Also some problems relating to the control of the burning process and considerable thermal heat build up were gradually overcome.

The outcome of the period may be evaluated as a profound stagnation when no funds were available either for modernisation or for the construction of new facilities. Frequent organisational changes took place during the entire period. Such transformations regarding individual regions have been recorded in respective subchapters.

The final chapter named ***Branch Rationalisation and Modernisation Period (1990-2015)*** *will characterise ownership changes, consequences of the cement and lime consumption decrease in contrast to the expansion of needs with respect to limestone and lime for ecology, as well as production of dry plaster and mortar mixtures. Due to the rationalisation process, non-prospective plants have been phased out and prospective ones have been widely modernised with special stress laid upon environmental issues. The dry process with preheaters has clearly dominated cement production (100 % since 1998); kiln systems for burning lime have also been changed (65 % of shaft regenerative kilns). New conditions have been reflected by newly structured organisation of lime and cement producers.*

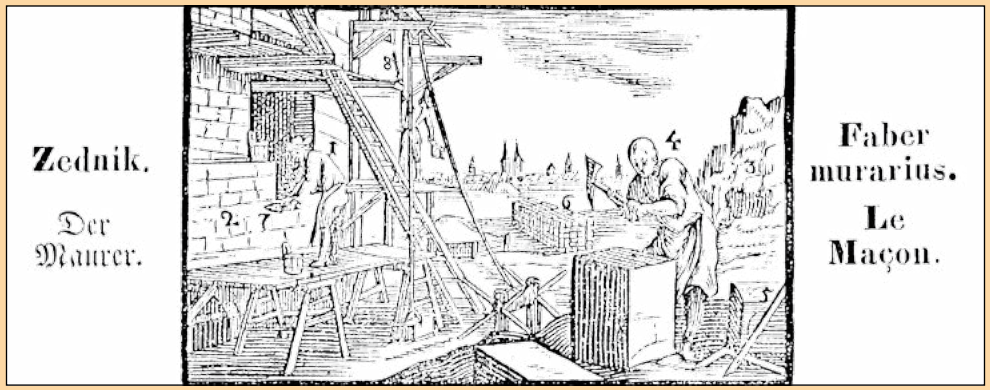
The publication is supplemented with numerous historic photographs, often showing already decommisioned plants, as well as with tables and figures.

1. From oldest references to early industrial production of lime and cement

Lime production has a tradition that has already lasted for a several thousand years. Lime was used in the ancient times, at the dawn of human civilisation, as a bonding agent for mortar, for whitewashing of walls, but also as a fertilizer. Its knowledge is proven to go back to the third millennium before Christ, when Egyptians used lime mortar that contained gauging plaster. The biblical books of Moses that seem to have originated at the beginning of the second millennium before Christ also speak about lime production and its use. In those times, lime mortar was also used in far away China during the building of the Chinese Wall. Findings about lime have also been overtaken by Mediterranean nations and mortar production underwent its biggest expansion in the territory of the Roman Empire, where lime producers called "Magistri Calciarum", enjoyed a considerable reputation. Lime production was even described in detail by the leading builders of that time: Marcus Vitruvius Pollio and Marcus Porcius Cato.

Since time immemorial, limestone and lime have been used for many other purposes. Possibly the first ever encounter of man and limestone took place in karst caves and rock alcoves which provided the first dwelling for humankind, and because of its availability, limestone could have been used to make stone tools – celts, mallets etc. Very soon, limestone was used, among other things, for fertilisation, leather tanning and glass production. The Babylonians made the first lime-sand bricks which they dried in the sun. Lime also found its use in cosmetics: Romans used it to prepare various mastics, e.g. a mixture with fat and egg white. German women achieved their light reddish hue of hair by putting quicklime in it, and then they wrapped their hair in a scarf and allowed the lime to work for a couple of days. In Europe, the use of lime has never been interrupted: unlike with the knowledge of hydraulic binders that have virtually faded into obscurity for several centuries. Things were different on other continents. On the American continent, lime was probably used by the Toltecs no sooner than the 7th century AD. There is an interesting late mention of lime use in metallurgy and for ore processing. These weren't described until the 16th century by Agricola.

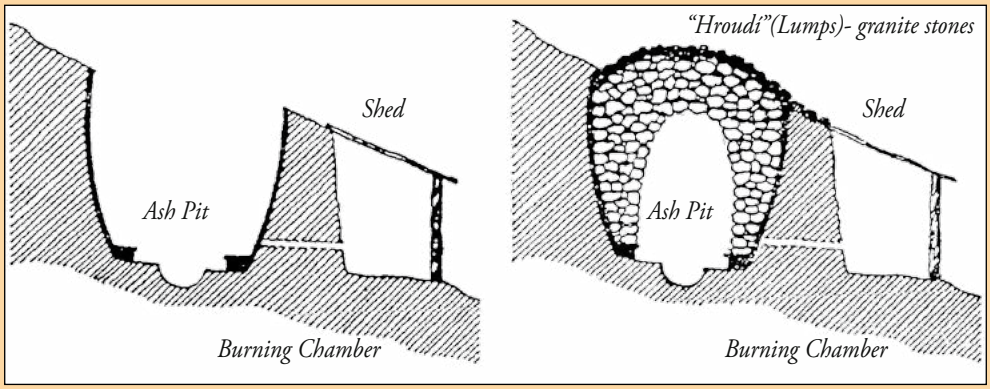
Evidence of lime use in the Czech lands is already taken from the Stone Age, when clay walls were coated with it, and we also have sporadic, but also questionable findings of kilns for limestone burning in some archaeological locations. Yet more significant increase of lime use came to pass only with the arrival of Christianity, after the Roman technique of construction was first used for sacral buildings. Among other things, this is proven by church and secular buildings from the 9th century from the period of Great Moravia, even by the first constructions erected by Czech noblemen. In Prague, around the year 940, duke Boleslav I. built his castle from marlstone bound with lime mortar, and during the same period, small churches that were brick built the same way stood here. We can find brick construction with lime mortar also in Levý Hradec and Budeč. From the end of the 10th century, the first written mentions of limestone processing are available: it has been proven, that The Břevnov Monastery (Břevnovský klášter) owned lime works, and in place of today's Valdstein Palace (Valdštejnský palác) in the Lesser Town, in the 13th century, stood lime works of The Old Town of Prague. In the Middle Ages, almost every larger town had its own lime works and even very small deposits were used for the extraction of limestone. A large expansion of lime production occurred during the reign of Charles IV. Lime was burned mainly from limestone found in Podolí, Braník, Zlíchov and Radlice. The Old-Prague's lime from Braník had been used since the old days for water (aquatic) structures. It was exported under the name of **Pasta di Praga** and allegedly, Venetian palaces and London's waterfronts were being built with it. Bohuslav Balbín mentioned the excellent qualities of Czech lime in his work Miscellanea historica regni Bohemiae that was published at the end of the 17th century.



Pic. 1 *A bricklayer 1 is laying foundations and building walls 2 either from stone, that a quarryman splits in the quarry 3, and a stone mason 4 is hacking (quadrangular) according to the rule (carpenter's square) 5; or from bricks 6 that from sand and clay mixed with water (with water stirred) are made and burned by fire. Then he dabs it with lime (mortar) and using a plaster trowel (bricklayer's trowel) 7 he paints (whitewashes) it 8.*

"Of limestone, I should not even have to mention, when it is common to all the regions, but the excellent quality of Czech limestone itself won't allow me to omit it… Pieces of exquisite lime stone are mined at numerous places in the Czech lands. Lime kilns are by forests everywhere, but mighty rocks that present themselves to the pilgrims on their way to Prague on the right side of the river Vltava, behind Vyšehrad, and blocks being chopped off at Bílá hora, give limestone such snow-white, shiny and pure that when burned and slaked, almost no waste is left over. The whole stone block is actually pure limestone: Prague's lime changes itself into a mushy matter so white that it is suitable to use for plastering figuration, how it is called now. The Italians even call any good Italian lime pasta di Praga."

At first, lime was burned in **field kilns** or heaps (even after the end of the World War II, they were in operation in several places in Slovakia and Hungary). Before the burning took place, it was necessary to prepare the stone. That was called "kiln pounding". Broken limestone was smashed into larger and smaller pieces with iron hammers, so that big flat pieces were peeled from the boulders. When the "forota" (stockpile) was done, "straightening" of the kiln began. For this work, at least two people were needed, however,



Pic. 2 *Cross-section of a small unfilled and a filled lime kiln.*

work went better with three. One stood by the pile of stones at the edge of the kiln and would put proper pieces into baskets or trugs, and then passed them to the other two, who were standing inside the kiln. These two pressed the stones with their bellies to the kiln walls, so that both their arms were free. They were picking out stones and levelling them all round onto a They started with the smaller ones and then, as the wall curved, they took larger ones. They laid them more towards the centre, so the kiln space narrowed as it climbed. They laid stones in a shape of a cupola and this way, they closed the kiln with large flat stones. Then, they covered the top of the kiln with granite boulders: with what were called "hroudí" (lumps).

The kiln was heated for 12 - 16 hours, depending on the quality of wood and also the season. The ash from the kiln was carefully raked out through the ash pit, "so that the lime wouldn't settle in ashes". The lime stone was brought to a white heat, but gaps in between stayed dark red for a long time. If the firing took long enough, the gaps turned pink, and finally, they turned white. That was a sign that lime was burned. After burning, the kiln had to be let to cool off. The cooling took approximately the same time as heating, only in winter it was slightly less. When the kiln cooled off enough so that lime could have been taken at least in gloves, lumps were removed from the top and the kiln was taken apart starting with the cupola. Lime was loaded onto a lime waggon and the lime burner set "out in the world" to sell it.

Mining and disintegration of the raw material was as primitive as lime burning. At first, raw material was broken only with chisels, using wedges or what was said to be charging by fire: fire was started on a rock and once the stones heated up, the fire was put out with cold water – through sudden change of temperature the stone cracked and could be separated more easily. Later, mainly with larger amounts, even gunpowder was used, which was, however, very dangerous. Most quarries were made accessible via a cart-road, but there were some places, where it was necessary to pull out pieces of limestone with a winch. The product, depending on the amount and the distance to the customer, was transported either in pack baskets on the back, in a wheelbarrow, on a cart pulled by a dog, or by a team of horses.

In this case, the lime burners used wagons covered by a tarp, so that the goods wouldn't get wet and be ruined. Back to the kilns, fuel was usually brought (wood and at the very end of this period, coal or coke). The lime was slaked directly at construction sites. It was dumped into a pit and watered. Since great heat arises during the slaking process, it was quite dangerous work. It was recommended to cover the pit, also to prevent the lime from drying out. Only in the last half of the century, **primitive shaft kilns based on their own blast** were built in the Bohemian and Moravian territory. The lime and wood (coal) were either layered into the kiln, or fuel was burnt in a separate burning chamber. Hot flue gases were then led into a shaft, where only limestone was put. These kilns were called "hicovky" ("hic" being a colloquial synonym for heat). However, the placement of the flue gas inlet on the side of the kiln could cause the overburning of raw materials within its proximity and on the contrary, underfiring in the more distant spots. The presented method placed great demands on the operator who had to have considerable experience. In the second half of the 19th century, ring kilns that were developed earlier and proved themselves during brick burning, were starting to be built more often for lime burning. These new types of kilns completely drove out the old heaps from operation in the Czech lands, ahead of the First World War.

A typical area where limestone was mined and processed, perhaps from time immemorial, is the Czech Karst area (Český Kras). However, even here, the origin of the limestone industry will forever remain shrouded in mystery. We can draw the first verifiable information from the analysis of significant buildings (e.g. the Karlštejn Castle, the fortifications of the city of Beroun etc.), but mostly, we have to rely on written sources. A chronicle by Václav Hájek z Libočan mentions lime processing in connection with the construction of two castles: Děvín and Nižbor. However, the author of the chronicle treated historical data with absolutely no criticism, and his work is, aside from some truthful information, just a bunch of fabrications

- in particular, completely arbitrarily, he puts many events in the dim ancient times. This way, for example, to the year of 776 (!) he assigns precisely the origin of Nižbor castle. Nevertheless, mentions of lime processing also appear in the works of other authors, who either came from, or had lived for a long time in the Beroun region. Their reports are more accurate. All the authors, however, have one thing in common: a living tradition and awareness of many years of lime production. This tradition can be documented by a number of privileges that were granted to the Royal Town of Beroun in particular, but also to the surrounding municipalities.

We can find the same amount of documents for the **surroundings of Prague**. Limestone rocks that line the river Vltava on its right bank, have already for long attracted the attention of travellers, visitors of Prague and entrepreneurs. Good quality limestone and its properties were valued throughout the whole of Europe and just to name at least the most important buildings where Prague's lime was used would require several pages.

First written records from other places are only indicative. The first written mention of lime burning in the **Podkrkonoší** area, mainly from the vicinity of Vrchlabí, is tied to the year 1507, when property of gentleman Aleš ze Senova, Lord on Hostinné, was divided. In the agreement, a lime works is also mentioned in connection with the village Čistá. Again, we can assume, that in the area of Podkrkonoší, where there was enough wood for building material, lime was also produced earlier. For local demand, the lime production had continued for sure. In the middle of the 18th century, use of lime is documented in construction also in a wider vicinity: lime from Krkonoše was used for the construction of the fortresses Hradec Králové and Jaroměř.

We dispose of sporadic reports for the **area of Šumava**. As K. Klement writes in his memoirs, the first thing that stuck in his mind was the castle of Rábí, the walls were built on lime mortar, but even gravel on the roads was made out of very pure limestone.

Many details have also been preserved from limestone deposits **in Moravia**. Unfortunately, they are limited only to short and general mentions, or to listings of buildings where lime, or alternatively, other hydraulic binders were used. Many buildings, for example the whole complex of sacral buildings in Kroměříž and many others, would certainly not have been created without the use of quality lime.

Many lime works and heaps for lime burning were operated by nobility under their own charge. This way, for example, the lime works in Mikulovice was delegated under the charge of nobility in 1816, and we learn from period sources, that in those times, small lime works were simultaneously operating in Věstonice, Bavory, Klentnice, Perná and Sedlec.

Information about many small lime works are, unfortunately, hidden in the archives of towns and nobility. Therefore, it is not possible to quantify the production of lime in the Czech lands for this period, and apparently, even after many years, many small lime works will go undetected.

If the knowledge of masonry onto lime mortar was never actually discontinued in Europe, the situation was much different in the case of hydraulic binders.

First evidence **of the use of hydraulic binders** comes from the Mediterranean region from approximately 700 years BC. Based on experience, the Mediterranean nations came to an understanding that lime mixed with earth from certain areas, or with volcanic ash, makes mortar, which hardens very fast even under water and which acquires great hardness.

Alongside the Greeks and the Phoenicians, this knowledge was used particularly by the Romans. During the construction of aqueducts, bridges, arches, walls and dams of sea ports, they used mortar prepared from well-slaked lime and volcanic ash from around the town of Puzzuoli in Campania. The pillars of Trajan's bridge in Turn-Severin have been built out of one part of this Roman cement, 2.8 parts of sand and 2.6 parts of crushed bricks. Many Roman buildings belonged to the then wonders of the world: let us mention for example Pont du Gard in southern France, the bridge and aqueduct from 1st century AD. Stone, from which the bridge is built, is connected by Roman cement and the water trough was also cemented. A mixture of lime with pozzolan was also used for the construction of the marina in Naples, during the construction of the Constantine Basilica, the Colosseum and

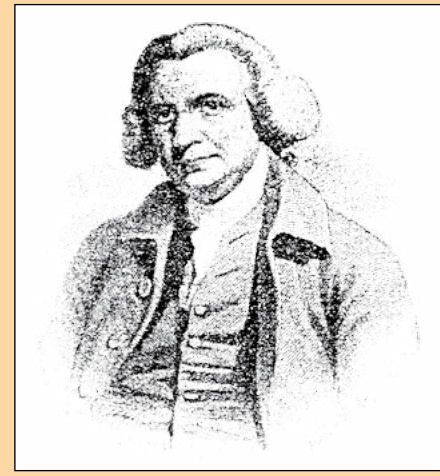
other numerous buildings.The knowledge of how to use this type of concrete went hand in hand with the raids of the Roman armies. In the first half of the 2nd century AD, this technology was applied during the construction of a water line that supplied water to Cologne. In these constructions, pozzolan was substituted by crushed and milled tufa stones and trass.

However, it took many more centuries before mankind moved on from the discovery of hydraulic hardening to industrial cement production. The knowledge of these methods probably disappeared in Europe due to stormy migration of nations and with the fall of the Roman Empire. The golden era of ancient cities and elaborate technical constructions came to an end. It seems to not have been forgotten only in the vicinity of deposits of suitable building materials. The Roman tradition probably preserved itself the longest in the Rhineland. We have evidence of use of pozzolan as far back as the 12th century. **Only the 18th century brought a more significant change** and apart from the continuation of the rediscovered art of the Romans, this already comprised of penetration into the mysteries of nature, if only in the beginning. Based on innumerable attempts, the knowledge of properties of individual materials was constantly becoming more precise. Thanks to these attempts, it was found, that lime made out of pure limestone does not have the ability to create firm mortar whilst under-water and it has to be mixed with clay.

One of the first milestones on the way to modern cement was the construction of the Eddyston lighthouse in the mid 1850's and primarily the book by its author **John Smeaton**, published almost four decades later at the beginning of the 1890's. At that time, numerous attempts with various admixtures were carried out, for example with clay and silicious substances.

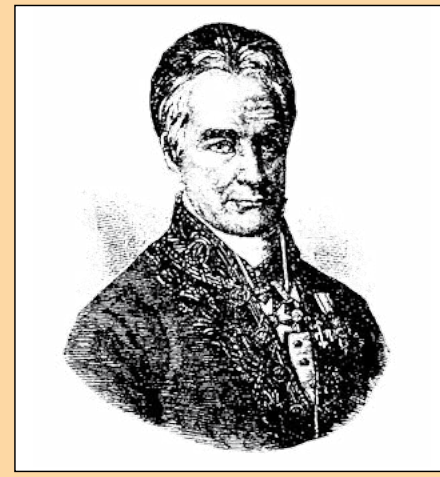
At the end of the 18th century, Roman cement was rediscovered. In 1796, **James Parker** found limestone with high clay content on the shore of Kent and he used it to make cement. Because it resembled Roman cements in colour, it was also called Roman. It found plenty of followers and imitators. Only some products, however, had the required properties.

Fundamentals of real scientific knowledge of limestone properties were laid down by **Louis**



Pic. 3 *John Smeaton.*

Joseph Vicat, a Frenchman who sorted limestone according to its content of hydraulic substances. The main findings of his research belongs the piece of knowledge that "it is not possible to achieve perfect hydraulic mortar without siliceoxide and in every lime suitable for its preparation, it has been found by chemical analysis, that it contains a certain amount of clay compoud off silice and alumminium oxide... ", and if this constituent is not included in the raw material, it is necessary to add it. He called lime with such qualities hydraulic lime and the raw material that originated from



Pic. 4 *Luis Joseph Vicat.*

its burning natural cement. He burned this lime in shaft kilns

Joseph Aspdin is usually considered to be the inventor of the real Portland cement. As is the case of the invention of reinforced concrete, he gathered and generalized knowledge, on which multiple researchers have arrived. On 18th December 1824, Aspdin was granted the British patent for Portland cement production. The patent application briefly describes the production technology of this cement: *"...I take limestone itself and prepare scree or brick dust out of it... However, I also take a certain amount of red clay or clay, I stir them with water until they are mixed completely, be it manually or using a machine. After this procedure, I put this mixture into a mash pan and I let it evaporate… until the water hasn't evaporate completely. Afterwards, I break this mixture into suitable crumbles and I burn them in the kiln, which is similar to a lime-kiln ... A mixture that is burned this way is then milled, beaten or rolled into a fine dust. Then it is suitable for the production of cement that is like artificial stone...".*

To call it Portland was, however, much more than only a well-chosen advertising move: Portland cement was considered to be the best kind of cement in England, it was the one that was valued the most for its properties. Since during the burning of this "Portlandian" cement the sintering limit was not reached, this cement's properties were much closer to the Roman cement than to the Portland cement we know today.

After Aspdin's patent expired, numerous cement works were built in England between London and the mouth of the Thames, since highly suitable tertiary limestone could be found there. A Briton named **Isaak Charles Johnson**, who **emphasized the right mixture of individual compounds, burning beyond the sintering limit** and also promoted the importance of maturing of clinkers, served for further insight into the secrets of Portland cement. In the following decades, issues such as the determination of the correct chemical mixture of raw materials, chemical reactions taking place during cement production and technical and technological aspects were researched. If rapid development of society should have found the corresponding building material, then the development went unequivocally in the direction of the mastering of Portland cement production. In the Czech lands, the technical development was somewhat delayed and so the first cement works on our territory were founded no sooner than at the time when lime production was moving on into its industrial phase.

Pic. 5 *Vicat's shaft kilns.*