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THE STONE BRIDGES IN SOUTHERN ITALY: FROM THE ROMAN TRADITION TO THE MIDDLE OF 19TH CENTURIES

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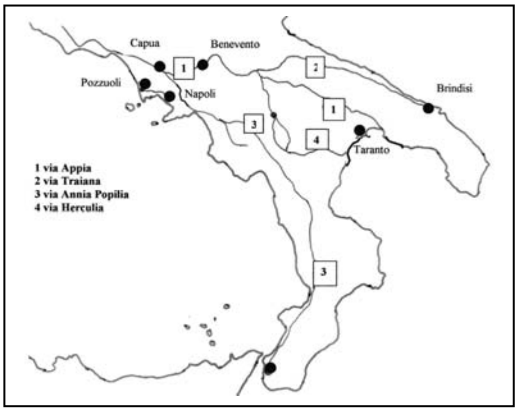
Abstract : Built to ensure military and administrative control of the provinces of the Roman Empire, the consular roads had in the wall bridges their acme. The roads of Southern Italy – *via Appia, via Traiana, via Popilia, via Herculia* and another roads- particularly in Campania region, retain many more bridges. The structures located in the surrounding of Naples deserve special attention because of the peculiar construction material which characterizes all the bridges in this area: the *pozzolana* .With the fall of Empire and its fragmentation in various Stats, these roads lost their role and where in fact abandoned; nonetheless, various bridges have survived and they where the inevitable benchmark for Renaissance scholars: proportions, use of Roman arches enable the discovery of ancient forms at the utmost expression of harmony, solidness and comfort. In the 17th century, a period of great cultural ferment started in the Reign of Naples too: new sciences, exchange amongst scientific institutions, increasing trade made necessary the renewal of roads. A first state board to administer and plane bridges and roads was set up – Giunta di Direzione delle Strade- made up of dignitaries rather than technicians whose bureaucracy made development programs slow and difficult. During the Franch decade (1806-1815), a broad reform program involving all sections of public administration giving rise to the Real Corpo degli ingegneri di Ponti e Strade, which continued to operate even after the Restoration: study tours, widespread contacts amongst European technicians and scientists lead to the acquisition of new technologies and materials with the abandon of wall structures.

1 INTRODUCTION

In 270 BC Rome conquers *Taranto* and *Reggio Calabria.* With the adjunction of these two important cities it establishes its control over the entire South of Italy. The Roman Republic had fought a long war against the Samnites who had joined in alliance with the other peoples of the South and were culturally and commercially related to the cities of *Magna Graecia.* The aim of such a war was to conquer the fertile lands of the *Campania* and *Puglia* regions and establish new commercial ties with the Middle East. After the conquest took place, Rome recognized the importance of keeping the new Roman Republic territories under military and administrative control and, therefore, it invested on the construction of a road system able to guarantee such monitoring.



1 Map of consular roads in the South of Italy

The *Via Appia*, going from Rome to *Capua* and commissioned by the Censor Appius Claudius Caecus in 312 BC, was prolonged towards the South- East. In 191 BC the pavement in *saxo quadrato* (polygonal basalt blocks) was 132 miles long. In 268 BC the Appian Way reaches the Samnite city of *Beneventum.* In 114 AD, under the authority of the Emperor Traianus, a deviation - called *Via Traiana* in honour of the commissioner's name - was built. This road lead to the city of *Venosa* (Horace's birthplace) in the *Lucania* region and to the city of *Brindisi* on the Adriatic sea for a total of 540 Km.

The change from unpaved to paved roads was an important shift towards innovative techniques. Touchstone slates resting on a pebbled base and laying in entrenchment allowed for the filtering of rain waters and resisted the erosion of time.

As a matter of fact, large tracts of this road are still perfectly preserved. Because of its magnificence, the *Via Appia* was also called *regina viarum* ("the queen of roads"). It allowed for horse shift stations and traveller resting spots every 12-15 Km. On the other hand, its construction had not been an easy task due to the crossing of the Apennine mountains and the presence of many torrents which dried in summer and flooded in the rainy seasons. The lack of bridges forced travellers to undergo uncomfortable and dangerous boat crossings.

The poet Horace describes a journey of this sort in his satire I,5. He was travelling with Maecenas and Virgil towards the Adriatic Sea from which they would go to Greece. On their way down to the South of Italy, they made a first stop in *Capua*, at their friend Cocceius' villa and then, shortly after, in a small in. Horace complains about drunk men leading the boats, annoying mosquitoes and noisy frogs, slippery roads until, finally, they reach *Brindisi*: "*Brundisium longae finis chartaeque viaeque".* In the same satire Horace refers to the famous bridge in the *Campania* region, mentioned in the Peutinger Table, a copy of the Roman

Military Itinerary Map, made at the time of the Emperor Theodosius in 380 AD which was copied many times, during the following centuries. The persistent number of copies, dating up to the late Middle Ages, prove that the *Via Appia* was still efficient at the time.

Among other famous Consular ways, is the *Via Popilia* which went from *Capua* to *Reggio Calabria* and was the only connection with the *Calabria* region. There was no maintenance of the road for centuries, up until 1804, when Joachim Murat finally ordered its reconstruction. The *Via Herculia* in the *Lucania* region should receive mention along with the road connecting *Neapolis* and *Puteolis*. This short but important way connected the military harbours (the Roman fleet led by Plinius the Elder was in the *Lucrino* harbour when the Vesuvius erupted in 79AD) and the civil residences (the aristocratic villas in *Campi Flegrei*).

2 THE ROMAN BRIDGES

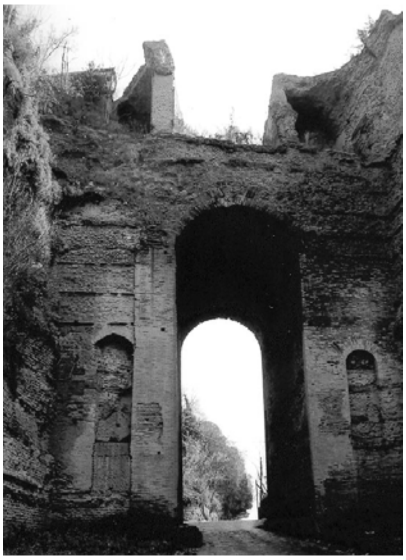
Noteworthy traces of Roman high construction skills are to be found also in the South of Italy. Unfortunately, though, the effect of time was intensified by the loss of constructions due not only to the German mines and the Anglo-American air forces during the last World War but also to a change of road traffic priorities. Last but not least, damage has occurred thanks to the carelessness – as Nascè underlines in the foreword to book on the bridges of the *Piemonte* region - of architects and archaeologists.

In ancient times, the bridges were built entirely in wood or in masonry with wooden frames. During the last part of the Republican Period a technical and symbolic change occurred: bridges were made entirely of stones in order to resist the action of time through the centuries and, therefore, to represent the power and endurance of the *pax romana*.

Among the bridges that were destroyed during the Second World War, the *Capua bridge*, on the *Volturno* river deserves special mention. This noteworthy structure is positioned so that the river's flow runs central to its arches. It measures are 80 m in length and 7,50 m in width. It is composed of five arches, each presenting a different span, the biggest one being 18 m wide and made of brick piles 5,40 m thick. Given its importance, Frederick II of Swabia and Charles King of Spain had it restored. Nonetheless, it was destroyed along with other constructions in 1943; the *Leproso bridge* in *Benevento*, instead, was only damaged. The bridge underwent various restorations through time and is still in use. As recorded on the nearby Honoray Arch, the bridge ran along the borderline between the *via Appia* and its prolongation towards the *Puglia* region, the *via Appia Traiana*.

Let alone the other bridges on the southern consular ways, the structures located in the surroundings of Naples, in the *Campania* region, deserve special attention because of the material with which they were built, the so-called *Pozzolana.* This masonry material is typical of many buildings and bridges of this area and will be described below.

On the way from *Puteolis* to *Neapolis*, passing through the *Campi Flegrei,* are the remains of two viaducts. The first was built on *Monte Dolc*e (Sweet Mountain), near the *Solfatara* volcano, the other bridge is located in the area of the *Agnano* thermal baths. Both bridges are strongly inclined, the slants are 16% for the first and 12% for the second, and they were constructed following the typical Traian period technique: the wall core is filled with *pozzolanica* concrete mixed to chunks of trachyte, the external part of the walls is in *opus* *mixtum* that is to say, with an alternation of horizontal bands of *bipedales* or *sesquipedales* bricks and neat panels in *opus reticolatum*. The corners of the abutments present a teething made of small regular blocks of tufaceous stone. The double ring head arches rest on *bipedales,* while the barrel vaults are made of concrete. In order to go along with the sloping, the arches were not built rampant. This typology, in fact, is quite foreign to Roman architecture On the contrary, the vault's springing line were built with a gradient elevation on trachyte bearing. The different heights of stone piles and supports allowed for a constant slant of the viaduct.



4 2 Arco Felice today and in an 18th century print

As Galliazzo highlights in his important work on Roman bridges, the careful use of selected materials – bricks, trachyte, tufaceous stone – in the alternation of bands and panels reaches admirable results in the Traian period and can be recognized in many other constructions located in the same area.

Furthermore, near Naples, on the via *Domitiana*, we find the *Arco Felice* bridge which was built in 95 AD as a passageway through mount *Grillo*; the bridge was modified many times through the centuries. It's brickwork supporting arch is 20 m high and 6 m wide.

Originally, it was covered with marble panels and adorned with statues standing within two levels of niches.

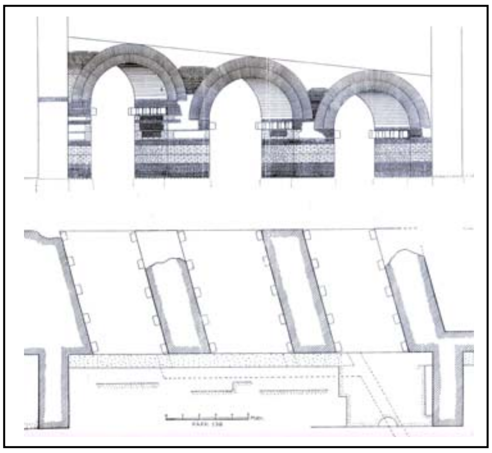
The bridge is very similar in structure to an honorary arch and its original beauty can be admired in an 18th century print. Today it stands without its marble covering, with its partially walled niches and with an almost complete remake of its facing of the wall. Only the barrel vault intrados, the triple ring head arch in bipedales, part of the west façade and a considerable portion of the pavement in polygonal basaltic blocks can bare proof of the original magnificence. The two viaducts above mentioned present similar problems: the reading of their structure is quite difficult because they are almost entirely covered by bushes.

3 CONSTRUCTION TECHNIQUES

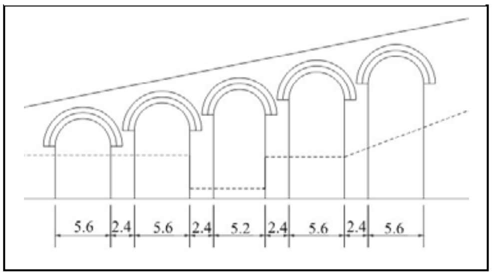
The relation between the piers' thickness and the arches' span is an important issue concerning all archstructures. The Renaissance Treatisers reconsider such topic and lead to the first scientific studies of rules that, until then, had been simply passed on by tradition.

In the most important Roman bridges we notice a change from a ratio of ½, as in the *Fabricio* bridge, to one of ¼ , as in the *Castel S. Angelo* and *Milvio* bridges.

Among the *Campania* bridges, the *Apollosa* bridge, which has unfortunately been destroyed, presented a ratio of 1/3. The *Chianche* bridge presents a ratio of 1/3 in the central section and of ¼ towards the abutments; furthermore, we find ½ in the *Agnano* and *Monte*



3.Agnano terme Bridge



4 Ratio between the piers thickness and arches span in the previous bridge

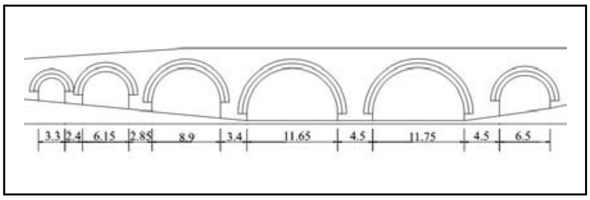
Dolce viaducts. Such relations rarely go beyond 1/4: only in certain structures the piers, positioned so that the flow of water runs central, sustain arches with a larger span.

The *Cervaro* viaduct, located on the v*ia Traiana,* in the *Puglia* region, is an example of this kind, presenting a ratio of 1/6.

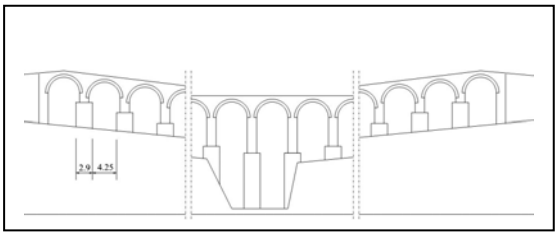
Bridges built during the Augustus age go beyond mere structural aspects and seek to achieve a monumental character with a regular geometry and a stable ratio between peer and arch proportions.

This tradition will survive through the years up to the emperor Traianus under whom an important innovation takes place. In Galliazzo's terms, logical and structural goals substitute "geometrical symmetries". Thus, different spans for piers and arcades and different levels for springing represent a break with the predefined geometrical schemas.

In the *Chianch*e bridge, the larger span arches are positioned so that the flow of water runs central but, as you proceed towards the two asymmetrical abutments, the apertures decrease in size. In the *Ronaco* bridge – presenting constant pier thickness and arch span – it is the different heights of the springing line that regulate the slant on the superior level.



5 Ratio in the Chianche Bridge



6 Ratio in the Ronaco Bridge

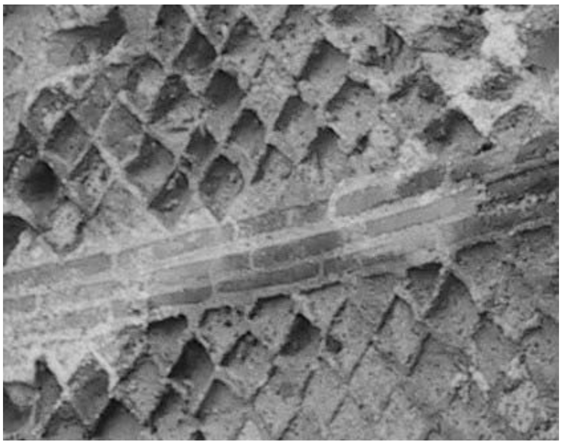
Last but not least, in the two bridges near Pozzuoli, the considerable slant is compensated by almost constant arch span proportions and an increasing springing line. All these cases represent felicitous structural and formal solutions which are in harmony with environmental diversities and specific area priorities.

Bridges dating the same period have analogous traits even when they are located in different regions. However, the conditions of the sites and the type of construction material that was used in each area naturally differ.

The Campania region is a volcanic land par excellence – its West portion essentially- and allows for the use of a peculiar construction material which characterizes all the bridges in this area: the pozzolana or pulvis puteolana .

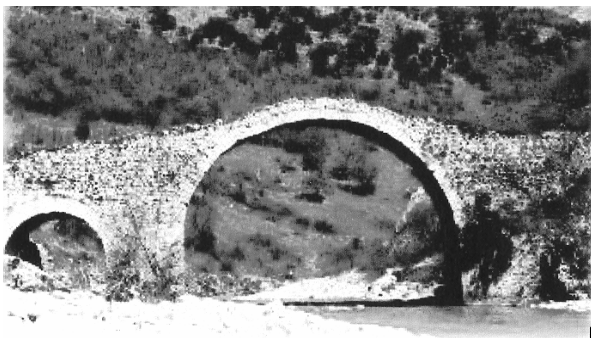
The construction of walls with outside layer of stones or brick functioning as a permanent mould and a core made of mixed Hydrated lime, head of stone or pebbles, water and sand was already known in the 3th century B.C. The advantages of this kind of wall, compared to those built entirely of brick or stones, is that the material can be easily transported and the plasticity of the mix require no skilled workman.

It was discovered that the substitution of ordinary sand with the volcanic type of the *Campi Flegrei* area (near *Pozzuoli*) led to a type of hydraulic mortar which was highly resistant, even under water. Such results were due to the reaction of silica (SiO2) and alumina (Al2 O3) to lime which resulted in a mix called aluminate of hydrated lime and hydrosilicate of lime, both leading to a better result.. The use of the *cementa*, a mix of mortar and heap of stone, for hydraulic constructions such as riverbed foundations and harbour docks, is attested by Vitruvius. What follows is prescription: “Once the sand has been collected from the regions between *Cuma* and the *Minerva* promontory two parts of it should be mixed with one part of lime … bottomless thanks are to lowered into water, strongly secured by struts. “

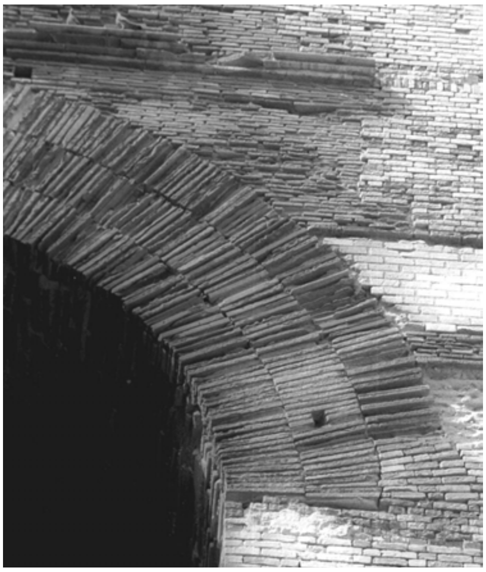


7 Opus reticulatum and Hydraulic mortar

A relevant standardization of construction elements concerned natural or artificial stone structures beyond the ground level: tufaceous volcanic stone cubilia (truncated pyramid elements, 8cm in width and 20cm in depth) were used in opus reticulatum and could be easily handled and cut in the quarry; square bricks, 4cm in thick, ranging from *bessales* (19x19cm) to the *bipedales* (cm 59x59). Furthermore, such measures could be divided in standardized submultiples when the brick are used as alternative to hard stone for bands, arches and corner pillars. The problem of a different shrinkage of the external structure and of the concrete core was solved thanks to the use of bands made of 4 or more *bipedales* , either whole or cut in triangles, which have the function of distributing the weight and avoiding dangerous detachment between the surface and core structure of walls. The external panels were generally built in *opus incertum* or *opus reticulatum*. The use of external strong buttress was necessary when the core was particularly large and, therefore, the risk of differential shrinkage was high.



8 Annibales Bridge 1th century BC



9 Arco Felice triple ring

The materials and the patterns aresignificant codings of the period in which the bridges was built: the *opus incertum*, with small sized rocks, dates the third centuries B.C. and was used even before that time; the *opus quasi reticulatum* starts to be used at end of second centuries B.C. and evolves, shortly after, in the organized pattern of *opus reticulatum*.

There are differences among vaults and head-arches as well: the oldest examples, starting from the first centuries B.C., present external rings made in local hewn stone and core in *opus cementicium*; later on, from the Augustus period onward, there was a standardization of the brickwork , with head-arches presenting single, double or triple rings, generally independent.

Given the above mentioned qualities of *pozzolanico* concrete, the round barrel vaults, or slightly flat vaults are built in this material and then plastered

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4 FROM THE END OF THE ROMAN EMPIRE TO THE 17TH AND 18TH CENTURIES

The extended network of roads which was built through the centuries ceases to have its reason to be with the fall of the Empire, the barbaric invasions and the fragmentation of a unified political entity into a constellation of states. The invasion syndrome which lasted from the end of the Empire up to the Middle Ages was translated into castles and fortified towns. During this period, bridges were considered unsafe constructions and their presence was seen as a cause of weakness. Therefore, the urban bridges received a minimum of maintenance but those that were located out of the urban settings were abandoned - along with the Consular ways – to the destructive effects of weather, river floods, wars or, in some cases, were torn down in order to recycle construction material. In Northern Europe the various States reached an early political and economical stability. The South of Italy, on the contrary, underwent a long period of conquering invasions by Arabs, Normans, French, Spanish, Austrians

We agree with Benedetto Croce that the numerous foreign occupations did cause damage, poverty, frequent and ineffective rebellions but should not be considered the only obstacles to the economical and social development of these populations; on the other hand, it is difficult to imagine how cultural and scientific institutions could have developed at all in such an instable situation.

As a matter of fact, during the Spanish domination (1503-1707) an alternation between pure plundering and significant accomplishments takes place. The Viceroy Don Pedro of Toledo, for example, ordered the construction of the *Regi Lagni* - a channel network - for the transformation of the swamps North and South of Naples into valuable cultivations. During those same years, the dramatic conditions of the royal roads underwent a revision finalized to the re-activation of the roads. The royal administration, *Tavolari*, as well as engineers were both appointed for this kind of work. The former dealing with bureaucratic aspects such as economical quantification and measurement of the work, the latter with the technical and structural aspects. Unfortunately, due to the overlapping of roles, the two categories developed a power conflict that lasted several decades until, finally, in 1751, a royal law (*PRAGMATICA*) was issued in order to limit the power of *Tavolari* and entrust the engineers with the management and planning of the work. Although, in the beginning, there was no clear distinction between Architects and Engineers, the latter became military technicians, therefore, marking a difference with the competence and roles of the former

Thus, a differentiation of roles took place: on one hand, military engineers, who were professional soldiers as well as engineers, had the task of dealing with defense systems; on the other, architects and engineers, belonging to the new category of Royal Engineers, dealt with civil architecture, that is to say maintenance and construction of public buildings, streets, bridges and hydraulic systems. The institutional referees for these experts were **The Royal Roads Committee** and the ***Regi Lagni Committee***.

In the meantime, at the beginning of the seventeenth century, Naples began to receive new cultural inputs from the European nations. The circulation of new ideas was favoured by the ongoing commercial relations. Such a cultural context lead to the rise of the first Academies, such as the *Accademia del Cimento* in Florence or the *Royal Society* in London, in which the old Aristoteleian models underwent critical revision on the basis of new scientific perspectives. Mathematics, geometry, mechanical physics and astronomy became the main interest of the Academies with the disapproval of the more conservative groups in Naples who considered math as "*a magical and obscure art*".

Despite these conservative views, the Neapolitan scholars started to gain a reputation abroad and received due recognition not only by the French and English Academies but by intellectuals such as Leibniz as well: the Galileian lesson becomes a shared knowledge of the local scientific community and the study of theoretical and experimental "natural philosophy" left its traditional schemas behind and moved towards the "*hidden truth of the great book of Nature"*.

The new century saw an increase of cultural exchange with foreign intellectuals who were attracted to the archaeological discoveries of the South of Italy and gave their contribution to the debates within the Academies: the calculus tracts by La Hire and Hopital and Newton's *Principia* along with infinitesimal calculus became the kind of knowledge which would be handed down to the new generations.

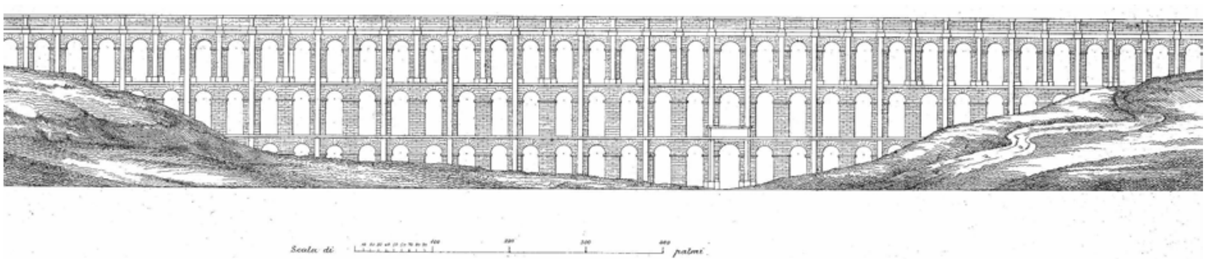
The institutional atmosphere was a positive one. In 1734, Charles of Bourbon became King of Naples and began his renovation politics. The new Reign was able to compete with the other European states thanks to the technical and scientific studies developed in its Schools and Military Academies. During this period many intellectuals were called to work for the Royal Administration and, therefore, abandoned the free Academies.

In 1742, three chief engineers and seventy operators at various levels form the so-called ***Engineer Corps*** which broke up in 1788 and was absorbed by the ***Genius Corps***. The latter was based on the French model and included the ***Hydraulic Engineers Corps*** as well.

The practical and theoretical knowledge of these technicians increased thanks to frequent journeys abroad. In 1787, four Officials of the Hydraulic Engineers Corps travelled to France and had the fortunate opportunity of meeting Perronet who had founded, in 1747, the ***Ecole des Ponts et Chaussées*** of Paris. Basic texts at the time were written by Bélidor, Gautier, regarding bridges, and - among the Neapolitan experts the theoretical and experimental studies of Galiani, the mathematical theories of Fergola and the studies on the statics of buildings by Vincenzo Lamberti should not go without mention.

In this innovative context, the new emerging technical and scientific experts seemed to defend the substitution of pure intuition in statics with a technical and experimental control.

Important architects, such as Vanvitelli and Fuga, coming from the Vitruvian school, disapproved this kind of innovation and strongly defended personal technical expertise deriving from field work as the main form of control on structures. Vanvitelli, in person, endured in harsh conflict with the younger engineer Lamberti on issues regarding lesions of the cupola of the Jesus Church on the basis of his mistrust of the new sciences and his disapproval of the employment of mathematical means to solve statics and balance problems.



10 Vanvitelli: Acquedotto Carolino

This situation led to a conflict between “old-fashioned” architects who refused the new scientific construction achievements and the new experts who strongly defended them. A progressive exclusion of architects took place and these obsolete experts ended up discussing styles and decorations in the Academies of art.

In the meantime, Charles of Bourbon ordered the re-establishment of existing roads and the construction of new ones with bridges: the communities benefiting of these new structures were appointed for the financing although the choice of the sites in which to build new streets and bridges often fell on areas connecting Naples with *Royal Sites* or with the royal hunting manors. Examples of this kind of policy are the segment of the *Strada delle Calabrie* leading to the royal hunting manor of Persano, or the bridge built by Vanvitelli or the connecting road between Naples and the new royal palace location, the city of Caserta. The new Royal Palace was built by Vanvitelli along with the impressive aqueduct (*Acquedotto Carolino o Ponti della Valle*) which served the purpose of bringing water from the Apenine mountains to the royal palace and its garden fountains. The shape and proportions of the aqueduct recall those of the ancient Roman ones although the reinterpretation accomplished by the great architect reveals his personal genius.

When Charles of Bourbon ascended to the throne of Spain and was substituted by Ferdinand IV, the re-establishment and construction of roads slowed down: an efficient control and a high quality of work were lacking.. A strong mark and the final detachment between the royal power and the intellectual class was determined by a short republican experience (*Repubblica Partenopea)* which ended with the re-establishment of the monarchy and the death or exile of many scholars and scientists of the Reign.

During the reign of J. Murat, in the Napoleon period, a political and administrative modernization took place and led to the creation of the Polytechnic and Military School. This institution encouraged the teaching of math and chemistry sciences, of military skills, of graphic arts and of all those disciplines that were necessary for the training of efficient experts. Furthermore, following the French model, The Corps for Bridges and Roads and, shortly after, the Engineer Corps for Bridges and Roads were founded in order to "*train a class of men equal to the great Perronet, Prony, Bossut*". Last but not least, the School for applied techniques of bridge and road construction, no longer a military institution, brought forth Murat's project. The return of the Bourbon domination, after ten years of French government in Naples, created a new paralysis. Although Ferdinand IV himself recognized the inefficiency of these new organizations and decided to submit them to strict surveillance, not much was accomplished.

Fortunately, in the following decades, men of great competence and will, as de Rivera, would save and develop the existing Institutions and would determine the undertaking of great work such as the construction of the *Giura* suspension bridge during the years between 1830 and 1835. But this is another story.

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