The bridges of Semmering: an audacious masonry work in order to connect Wien with Trieste

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ABSTRACT: In Vienna, in 1841, it was decided to build a railway to join the Austrian capital to Trieste notwithstanding the enormous problems linked to the characteristics of the natural environment. The project was assigned to the engineer Carlo Ghega and his name is indissolubly bound to the imposing railway extending beyond the Semmering saddle, between Styria and Lower Austria, for a total length of 41.7 km.
Both the structural and building aspects of this work are extraordinary. It sees the masterly use of bricks as well as stone, combined with designing skills that also took into consideration the architectural aspect. The blend of all these elements brought the Semmering to be awarded UNESCO world heritage status for the way it set out the beauty of the landscape: *the Semmering Railway represents an outstanding technological solution to a major physical problem in the construction of early railways* […] *creating a new form of cultural landscape*.

The Semmering railway is rightly considered to be Europe's first high mountain railway (max. altitude 898 m asl). It was built with the purpose of creating a link between Vienna, the capital of the Austro-Hungarian Empire, and Trieste, the main port. The project was part of a large scale connection planned to link Hamburg and Trieste (which had already been conceived across Styria in 1825). The simple definition of railway line is not exhaustive to describe the stateliness of the Semmering railway. It is in fact a "system of engineering works" entailing bridges, tunnels and geotechnical works (Fig. 1). Owing to its complexity it can well be classified as one of most important engineering works of the 19th century.

At that time, the "Rundbogen", the round arch, that counts Schinkel amongst its founders, was imposing itself in the historical revival environment of architecture. The engineering performance of the masonry arch system was yet to be superseded in 1853 and only later would the introduction of iron and steel be seen. There is no trace of these materials in the Semmering viaduct, proving the efficacy of the traditional building method that showed unexpected adaptability and flexibility qualities and served its purpose also after the electrification of the railway line. The title of "Roman work" is particularly appropriate for the viaduct and it reveals the model of reference used by Carlo Ghega, who recovered the style of the great Roman infrastructures, especially bridges and aqueducts, while at the same time providing directions about the building techniques implemented. His constructions are dominated by traditional materials such as stone and bricks, which find their best use in arches.

The curriculum vitae of Carlo Ghega (Venice 1802-Vienna 1860) is in itself proof of his skills: at the early age of seventeen, with a degree in engineering and architecture and a PhD in mathematics, he started to work in road planning; from 1836 he worked in the railway sector - assigned to the works of the connection between Vienna and Trieste by the Austrian bank Rotschild and, towards the Carpathian region, in Galicia. The high quality in technology that had been reached in those years is considered by the higher echelons of politics to have been the main ingredient for the progress made in the Habsburg Empire, its engineers being essential for the process of modernisation.

Figure 1: Semmering panorama, painting by Johann Varrone 1895 (Kos, 1984)

From an economic point of view, apart from the needs of war, the emperor recognised the great importance of the railway, which played a leading role in the infrastructure aimed at creating new connections, and emphasised the functions of the port areas as part of the economic development. This explains the large size of Austrian investment in S*üdbahn*, aimed at connecting Vienna – Ljubljana – Trieste, on one side and the consequent progressive growth of Trieste on the other side (Fig. 2).

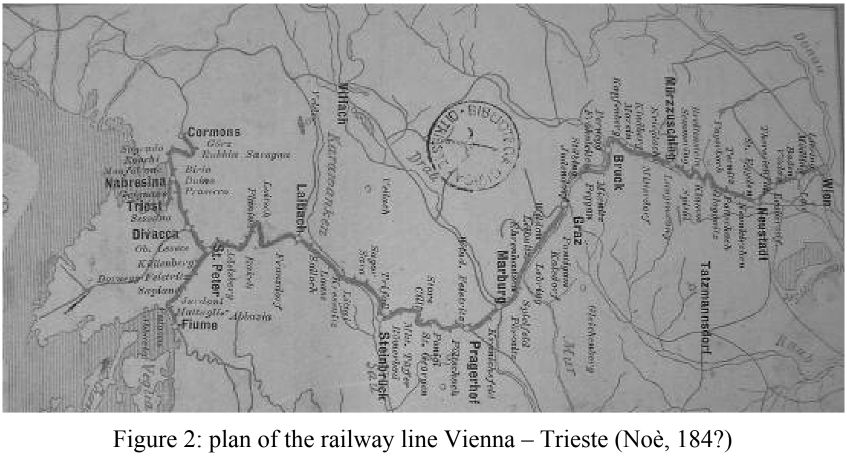

Figure 2: plan of the railway line Vienna – Trieste (Noè, 184?)

The creation of an axis to connect the main ore fields of Northern Europe, Vienna and Trieste was financially supported by Rotschild from 1836 and originated from the idea of Franz Xaver Riepl, a mineralogy teacher at the Polytechnic of Vienna. In order to bring the project to perfection, a technical commission was appointed. It was headed by the Counsellor of the Court Ermenegildo Francescani, who like Carlo Ghega hailed from Venice. Carlo Ghega was called to Vienna and, before starting the works, he accompanied a Rotschild representative on a survey trip to Germany, Belgium, France and England in order to study the railway works and to meet experts in that sector such as Gorge Stephenson, who invented the steam locomotive. In Belgium, Carlo Ghega was able to appreciate the use of sleepers, which he then had used in Austria. 1841 was a turning point: the various sections that had been built on behalf of private initiative were nationalised and became part of a general national plan. The most pressing problem was to build the stretches presenting insurmountable difficulties but which were necessary and urgent to join the lines that were already operating. The main obstacles were: surmounting the fenland around Ljubljana, the lack of water to supply the locomotive in the Carso and overcoming the Semmering saddle at an altitude of 980, which today is the boundary between Styria and Lower Austria.

These tasks were assigned to the engineer Carlo Ghega, who started what seemed to be an impossible project in August 1842, after he had been on a long journey to America. He was convinced that it was necessary to introduce the locomotive in order to increase the efficiency of the communication system, which until then had seen the use of carts and horses for the particularly difficult sections.

The project of the section going across the Semmering was the prototype of the mountain railways. The planned length was 42 km and it had been projected to be built in harmony with the environment and to “bring out the symbiosis between nature and technology”, but it needed a locomotive that could overcome a difference of level of 25 m per km and such a locomotive had yet to be invented. The historical events that occurred in 1848, triggering starvation and the need to quickly create employment, favoured the adoption of Carlo Ghega’s projects, already presented between 1844 and 1847.

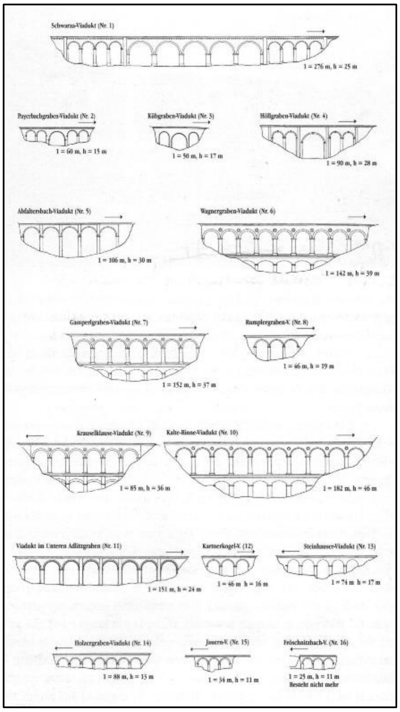

Figure 3: view of the sixteen Semmering viaducts in successive order (Rampati, 2002)

A further stroke of luck was the Cabinet reshuffle and Baron von Bruck's appointment to the Ministry of Public Works. Von Bruck was founder of Lloyd Triestino and supported the urge to connect Vienna and Trieste, since he predicted that the future cutting of the Isthmus of Suez would turn the port of Trieste into the fulcrum of the traffics with East Africa and the Far East.

After examining the project from a technical-descriptive point of view, it can be seen that the railway system presents 16 viaducts with masonry arches (the tallest being 46 m high), with a total length of 1607 m, partly built on a curve, and 15 tunnels, with a total length of 4526 m, overcoming a difference of level of 459 m. The importance of this work is given by many elements: the astonishing 113-arch arcade with a span ranging from 7.56 m and 19.85 m, the technical difficulties connected to the place and the time it was carried out, the building method implemented and the large numbers that characterise this work: 64.5 million bricks, 80,000 stone ashlars and 20,000 Austrian, Hungarian, Croatian, Czechs and Italian workers with their wives and children.

The section was started on 7th August 1848 in Gloggnitz, it went through the valley of the Schwarza river along the left bank at the foot of the Silberberg, across the river and the valley of Reichenau near Peyerbach, turning over to the opposite side towards Eichberg. It then penetrated the valleys of Adlitz and Myrten crossing the rivers Wagner and Gamperl on tall viaducts and travelled along the famous and impassable walls of the Weinzettelwand, through closed tunnels joined by open tunnels, until the Breitenstein station. Then further on the Krauselkleuse, over a tall viaduct above the Kalte Rinne and after a wide bend it reached the Semmering station, after travelling through the longest (1,443 m) and highest (898 m asl) tunnel of the stretch, which was at the time the longest and highest tunnel in the world. From there the route went into the Fröshnitz valley across the southern slopes of the Semmering until the Mürzzuschlag station. The stretch was 41.8 km long (only 21 km as the crow flies), half of which are on bends, thirty of which having a range of 189.7 m.

This section was decided after decades of studies, starting in 1839, to choose the most direct connection that would take into consideration the economic, political and military requirements.

The railway ravelling across the Semmering saddle was built creating for the first time, as said before, viaducts on a curve and on steep slopes. The sweep range lies between 284.5 and 189.7 m, the incline grade reaches in some points 22‰.

Figure 4: late 19th Century print (Chapuy, 1870)

In order to solve the problems arising from the calculations of the structures – these were still to be refined and were based on simple algorithms – experimental methods were implemented, which then became fashion. The dynamic load impact of steam trains was not measurable with mathematical precision and the load generated by the centrifugal force of the train entering a bend of the railway section required the viaducts of that time to be *engineering works of no minor importance than tunnels* […] (Saitz 1988, 24). To overcome all these difficulties Carlo Ghega, together with his engineering staff, implemented not only classical methods, but also various important experimental innovations, which he had tried out *in situ* and tested in his previous yards, especially road yards.

Both the single and the double arch viaducts are characterised by a univocal structural planning. The foundations are made of stone: the large pillars rest directly on the rock layer to guarantee a correct dissipation of the weight force (Fig. 5). As for the structural aspects of the bridge itself, these can be divided into two main categories: one includes the sections where the lower part of the pillars is made with large stone blocks that were extracted *in loco* and the other includes the parts with the pillars whose lower part was built with bricks and which are the most commonly used in viaducts. Imposing coupled round arches with a span ranging from 6.6 m (the Kübgraben viaduct) and 19.9 m (the Schwarza viaduct) support the rail top. The arch is connected to the rail top by stone and brick masonry, whereas the pillar and the arch are connected by a stone impost. The more demanding viaducts are characterized by two orders of arcades: the first arcade and its piers are built of cut stone and the second order stands out for its proportions and is entirely made of bricks.

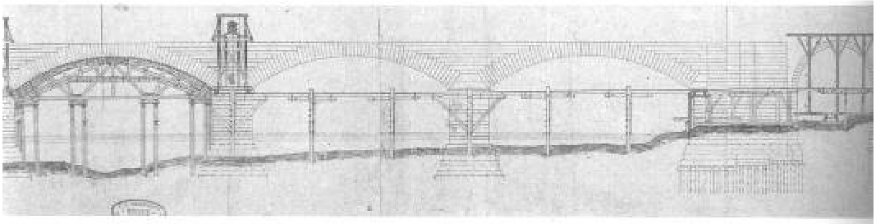

Figure 5: view of the Schwarza viaduct showing the position of the scaffolding and of the centrings

These imposing double arches were built in four wythe brick masonry. They are concentric and structurally independent, even though they are bonded, and they represent the strong point and the innovation put into the field by the engineer Carlo Ghega. As can be seen in the photographs of the yard (Kulturbahnhof Museum Mürzzuschlag), the vaults were built in layers by means of large centrings. The procedure was simple and well organised: once the wooden planks had been placed to support the centrings, the arch was built fitting the bricks in order to bind the structure. After the first arch was completed the following arch was built bound to the first (Fig. 6). This technique seems to have been implemented in all fourteen yards involved in the general work.

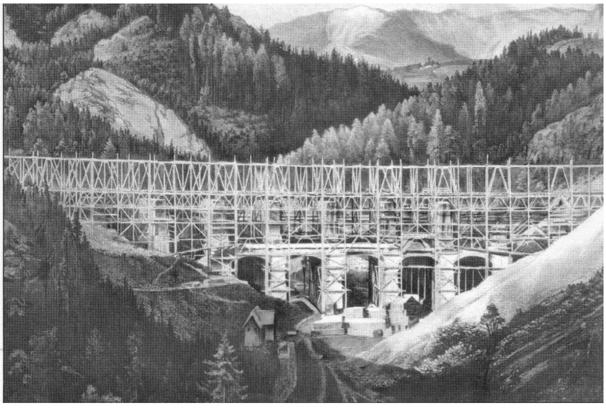

Figure 6: the building of the Kalte Rinne viaduct (Rampati, 2002)

A roadbed was placed on the road top and a stone bank along the sides of the entire stretch to guarantee a good base for the rails and to drain the water in case of heavy rainfall.

Because of the climatic conditions and the stress of the weight, many of the brick arches were then reinforced with counter arches made of reinforced concrete whereas others were plastered (fig. 7).

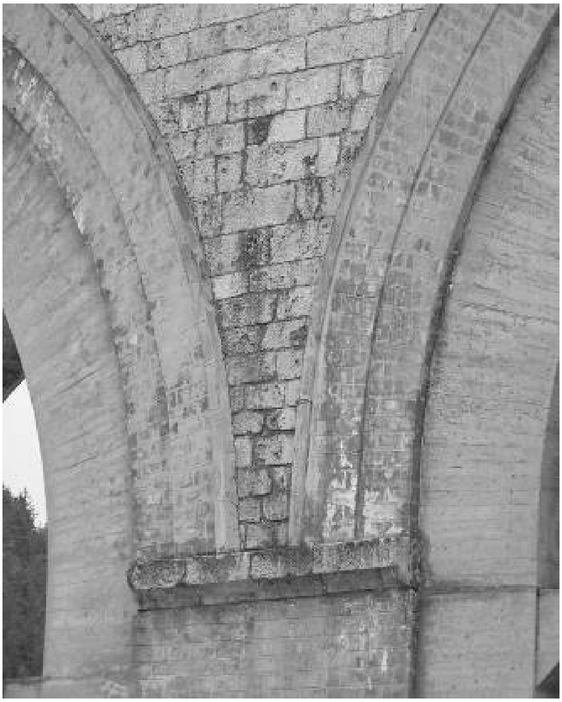

Figure 7: detail of one of the arches showing the brick structure and the concrete reinforcement of the vault (photo 2007).

Within the complexity of the work, the stone and brick tunnels deserve a special remark. The works were particularly demanding because in the mid-19th century the works were carried out by hand (Nobel invented dynamite only in 1866). For tunnels exceeding 300 m in length the ancient and well-known *Quanat* technique was applied: small tunnels were created inside the main tunnel to drain the water from the digging area. Carlo Ghega set the maximum length of the tunnels at 1,500 m so the yard could be systematically surveyed and excessive waste of time and financial resources for only one work avoided. This became one of the strong points of the project: the planner, whose task was to examine the project of the railway line, contested the previous choice to build long tunnels (one of which was nearly 6 km long and would have taken almost twenty years to complete). He decided to face the geological and geotechnical problems: the pressure exerted by the mountain, the presence of clay and the quantity of water in the soil which would inevitably cause the ground to give way slightly and large quantities of water to penetrate.

Also in this case the use of bricks and stone for the vaults is remarkable. Altogether, 2,020,000 m³ were moved, 1,390,000 m³ of rock were exploded and most of the resulting material was used to build containment walls, stations and buildings. Considering the time the S*üdbahn* railway was built in, including the Semmering section, the farsightedness of the planner is astonishing. He wanted it to have two tracks from the beginning and for this reason, during the following 150 years it did not need any major adapting or widening work, not even at the bridges and tunnels. The works on the route of the railway were let out on contract in lots at a public auction. Two different contracts were let out as far as the blocks of buildings were concerned, one for the workforce and one for the material supply. The State was responsible for the rails, the sleepers, the points and the signals. Apart from the two terminal stations there were also stations in Peyerbach, Klamm, Breitenstein, near the Semmering tunnel and in Spital. The distance between two stations varies between 6480 and 3860 m. There are also fifty-seven guard's boxes which are between 1512 and 330 m from each other.

The problem of finding a locomotive that was suitable for the kind of route was very skilfully solved by Carlo Ghega, who suggested Baron von Bruck to call a competition for the best constructors, clearly notifying the type of route, the slopes to overcome and the loads to transport.

This railway line has not lost its charm. Its structural characteristics and beauty continue to fascinate and astonish millions of tourists, technicians, engineers and simple enthusiasts, who consider it to be a valid expression of the *"architecture of the landscape and the technical-experimental daring of an engineer"* (Fig. 8).

Figure 8: train on the Semmering viaduct (Rampati, 2002)

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