Foreword

Today we are witnessing the dawn of a new era of railway construction in Switzerland. The required capacity of the planned network and the necessity nowadays to consider ecological factors call for the construction of deep long tunnels through the Alps. The 19 km long Vereina Tunnel has just started operation and the two Base Tunnels Gotthard (57 km) and Lötschberg (35 km) are already under construction. At the centre of these developments, tunnelling as one of the oldest disciplines in civil engineering is faced with great challenges and undreamed of technical possibilities. Besides constructional aspects, political and planning features are also very important in the realisation of these structures.

With this background it is worthwhile casting a look back at the beginnings of Alpine tunnel construction and some of the benchmarks of its development up to the 50s and 60s of the last century. The first major Alpine rail crossing was the 12.2 km long double-track Mont Cenis Tunnel between Italy and France, which was built in 1857–1871. An innovative feature of this project was the mechanisation of blast hole drilling. Based on the compressed air power transmission principle as proposed by the Swiss physicist J.D. Callodon, a drilling carriage was constructed and commissioned by the Italian engineer G. Sommeiller, a pioneer of Alpine tunnelling. The next major tunnel project, the 15 km long double-track Gotthard Tunnel in Switzerland (1872–1881), saw the substitution of gunpowder by dynamite, invented in 1875 by Alfred Nobel. Other Alpine tunnelling projects became famous for overcoming immense geological difficulties, amongst them the Arlberg Tunnel (1880–1884, 10.3 km long in Austria).

The early Alpine railway tunnelling culminated in the 19.8 km long Simplon Tunnel between Italy and Switzerland. The complete structure consists of two parallel single-track tunnels (Simplon I and II) with cross cuts every 200 m. The topographical conditions of the Simplon site, where the overburden reaches 2200 m, meant that tunnelling operations could proceed only from the two portals. With its great length, high rock temperatures (up to 55.4 °C), geological site investigation limitations, and both squeezing and bursting rock conditions, this tunnel is one of the landmarks in the history of tunnelling. Simplon I was built in 1898–1906, Simplon II started operation in 1921. The 14.6 km long Lötschberg Tunnel as a continuation along the south–north railway line was constructed between 1908 and 1913. For almost 70 years, the Simplon was the world's longest railway tunnel until, in 1984, it was surpassed by the 54 km long Seikan Tunnel in Japan. The design and construction reports are associated with the German engineers A. Brandt, K. Brandau and K. Pressel, and Swiss engineers Ch. Andreae, E. Locher, F. Rothpletz, E. Wiesmann, et al. For the first time, squeezing rock was correctly interpreted in relation to the formation of a plastic zone around the underground opening. One of the fundamental features of squeezing rock – i.e. the rock pressure decreases with increased tunnel convergence – was clearly formulated by Wiesmann as follows: "For every fraction of a millimetre of rock deformation, the rock pressure decreases."

The period after World War I was dominated by the construction of hydroelectric power plants, reaching its peak in the 1970s. The significant volume of underground work associated with hydro schemes in the Alps can be measured by the length of water tunnels – more than 10,000 km – and the many rock caverns for underground power stations. This period saw another revolutionary change in tunnel construction technology. Based on developments in the US, timber props were gradually supplemented by steel support systems. During this same

period, substantial progress was made in the technology of drilling and blasting, most notably fostered by Swedish scientists, particularily by U. Langefors.
A big technological step in the history of tunnelling was the employment of shotcrete and rockbolting as new ground support elements for tunnels. The first so-called gunite machines were invented in the US and further developed in Germany where, as early as the 1920s and 1930s, they found regular application in both mining and tunnelling. Reinforced gunite lining was applied in a number of tunnels in the UK (e.g. the Mersey Tunnel), which led to the publication of a handbook on Cement Gun Work in London in 1934. Thanks to the refinements and patented inventions of Swiss engineers, shotcrete machines reached the industrial production stage in the 1950s and 1960s. The scene was set for the widespread application of shotcrete as temporary support. The Austrian engineer L. Rabcewicz, wrote in 1964: "The first successful application of surface stabilisation by shotcrete for tunnels in unstable ground as an integral part of the driving process, instead of using timber or steel as temporary support, was carried out at the Lodano-Losogno Tunnel for the Maggia hydroelectric scheme, Switzerland 1951–1955."

The introduction of rockbolting technology for tunnels was also the result of efforts on a broad international scale. Lang (US) concluded in his 1961 state-of-the-art report on rockbolting: "A special tribute must be paid to the US mining industry for its work in initiating and developing the use of rockbolts." Systematic research on the effectiveness of rockbolting was carried out in 1948 by the US Bureau of Mines, in Sweden and in connection with the giant Snowy Mountains Scheme in Australia. In the Alps, systematic rockbolting for tunnelling was initiated during construction of the 11.7 km long pressure tunnel of the Isère Arc hydro scheme in France (1951–1953). For the first systematic application of shotcrete and rock bolting in a large cross-section traffic tunnel (Schwaikheimer Tunnel, 1963–65) credit is due to the German engineer J. Spang. Widely recognised personalities, like T. A. Lang (USA), A. Sonderegger (Switzerland), F. Mohr (Germany), M. J. Talobre (France), among others, substantially contributed during the 50s and 60s of the last century to the art of tunnelling, leading to the full development of the so-called 'shotcrete tunnelling method', or 'sprayed concrete lining (SCL)' method which in German is referred to as 'Spritzbetonbauweise". Thus tunnelling with shotcrete support and rock bolts and other means of support evolved on a broad international scale.

This book is concerned with the history of four major deep long tunnels through the Swiss Alps having a total length of 87 km: The Gotthard Railway Tunnel, the Simplon Tunnel, the Lötschberg Tunnel and the Gotthard Road Tunnel. The construction of these tunnels falls in the time period between 1872 and 1980.

The original version of this book was published in 1996 in German. It has emerged from the exhibition 'Historical Swiss Alpine Tunnels' which first took place in 1996 at the Museum for the Art of Civil Engineering in Ennenda, Canton Glarus, Switzerland. Further exhibitions were then subsequently organised in several cities in Austria, Germany and Switzerland. The book is now also available in French and Italian.

Zurich February 2000

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