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75 YEARS OF THE GOTTHARD RAILWAY



Photo, C.F.F.

Federal Councillor Lepori speaks at Bellinzona.

1. Foundation and Financing.

Gotthard and Lukmanier.

The idea of connecting the North and the South of Europe, in the most direct manner, by means of a railway line through, or over, the Alpine barrier arose soon after railways had been invented. Its realization, however, was still delayed for several decades. The original conceptions centred mainly on a railway through the *Gotthard massif*, and on one from Coire over the *Lukmanier Pass*, into the Canton of Tessin. The laying of rails over the Eastern Alps was put forward by Mr. Richard La Nicca of Coire, probably the first engineer to propose the construction of an Alpine line based on comprehensive studies.

The project of a Gotthard Railway was especially supported by the people of Basle and Lucerne. Among the most prominent personalities to start and to second a movement in favour of the Gotthard scheme were: Mr. Johann Jakob Speiser (1813-1865), Managing Director of a Bank in Basle and Chairman of the Board of Administration of the Swiss Central Railway (SCB), Mr. Josef Zingg, Cantonal Government Councillor in Lucerne, Mr. Gottlieb Koller, Engineer at the Federal Department of Posts and

Works in Berne, and Mr. Pasquale Luechini, Civil Engineer in Lugano. On the initiative of the Canton of Lucerne, the first national *Gotthard Conference* was held in Lucerne on the 7th August, 1853. This Conference was attended by representatives of the Cantons of Lucerne, Berne, Schwyz, Uri, Obwalden, Nidwalden, Solothurn, Basel-Stadt and Basel-Land, who decided to give their common support to the construction of a Gotthard Railway.

Gotthard Union.

Another *Gotthard Conference* was held in Olten on the 15th September, 1860, to which the Cantons of Lucerne, Uri, Schwyz, Unterwalden, Zug, Solothurn, Berne, Fribourg and the Management of the SCB sent their delegates. From amongst the delegates at this meeting, a special *Gotthard Committee* was set up, which entrusted Mr. Karl Wetli, Civil Engineer in Zurich, with the task of preparing draughts and estimates for the construction of a railway line from Fluelen to the Lago Maggiore. Mr. Wetli's project, submitted in 1862, provided for a line location being as low as possible and including a long main tunnel.

On the 7th August, 1863, at a meeting of interested parties, representing fourteen Cantons, the

Swiss Central Railway (SCB) and the Swiss North-Eastern Railway (NOB), the former Gotthard Committee was enlarged into the *Gotthard Union*. This Union submitted Mr. Wetli's project for examination and completion to two specialists, Mr. K. Beckh of Stuttgart, Chief Engineer of the NOB, and Mr. R. Gerwig, Construction Director of Karlsruhe, builder of the Black Forest Railway, who presented their report in 1864.

The Gotthard Union successfully convinced the people concerned that it was an Alpine line through the Gotthard which would best answer the requirements of international transit traffic. The voice of this Union was well seconded, too, by Dr. Alfred Escher (1819-1882), National Councillor, Chairman of the Board of Administration of the NOB and of the Credit Bank in Zurich, who had joined the camp of supporters and soon became the leading personality of the Gotthard Railway movement.

The Federal Council could not cast a deciding voice in the battle of opinions regarding the various schemes for Alpine lines which were put forward; according to the Railway Act of 1852, only the Cantons were entitled to grant concessions for the construction and working of railways. The latter were, however, unable to come to any agreement on one definite Alpine project. A decision in the matter had to be brought about mainly by the influence of the Kingdom of Italy, which managed to gain support for a definite Gotthard project from the North German Federation, from Baden and from Würtemberg. In fact, these countries sent diplomatic Notes to the Swiss Federal Council, in which they expressed their desire that a Gotthard Railway should be built. The Swiss Federal Council assented to these requests in so far as it invited the countries concerned to the

International Gotthard Conference of 1869 in Berne.

This Conference lasted from the 15th September to the 13th October, discussing a proposal of the Swiss Federal Council, based on the documentation which had been supplied by the Committee of the Gotthard Union (Project Wetli/Beckh/Gerwig) on the 22nd April, 1869. The deliberations closed with the approval of an International State Agreement, to be sanctioned by the Parliaments of the Subventionary States and to form the *basis* of the Gotthard Railway enterprise.

Gotthard Railway Network.

The State Agreement, ratified by Switzerland in 1870, by the German Reich and by Italy in 1871, rested on the Gotthard Railway Project Wetli/Beckh/Gerwig, which provided for a tunnel between Göschenen and Airolo with a length of 14.920 km. (9 miles 477 yds.) and with the culmination point at an altitude of 1,155 metres (3,789 ft.) a.s.l.

The proposed network consisted of the main trunk line Immensee-Goldau-Göschenen-Airolo-Bellinzona-Chiasso and of the direct branch lines (feeder lines) Lucerne-Immensee, Zug-Goldau, Bellinzona-Cadenazzo-Locarno and Cadenazzo-Dirinella (Swiss/Italian frontier-Luino).

Financing of the Construction.

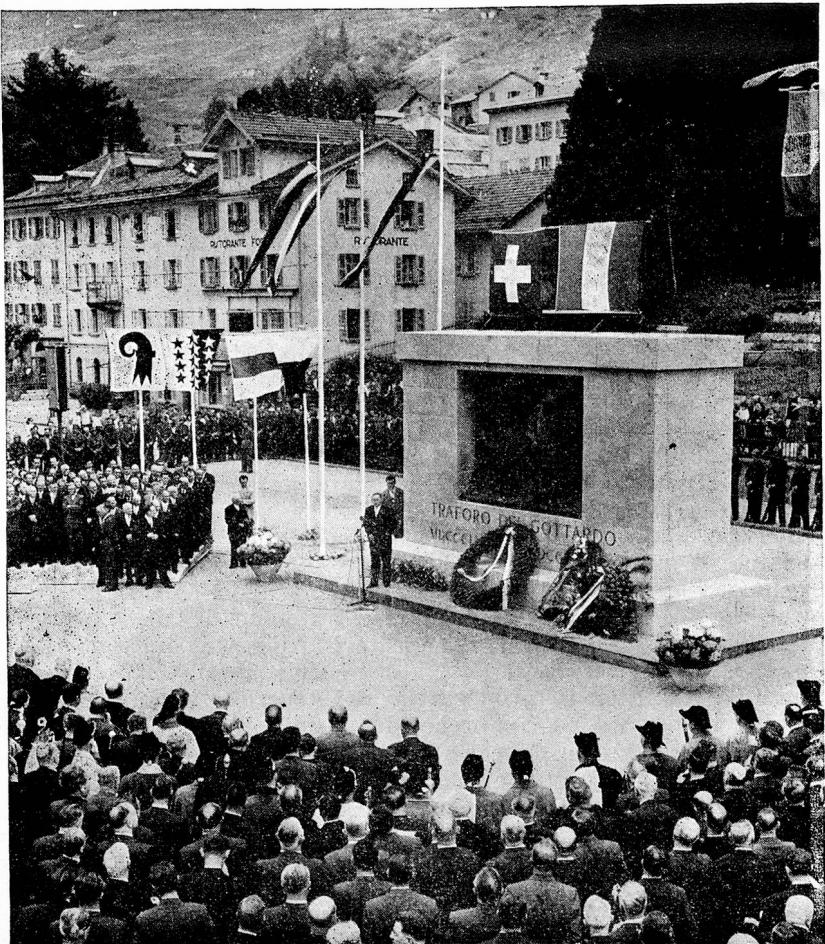
The specialists Messrs. Beckh and Gerwig estimated the cost of the construction programme at a total of 187,000,000 francs. The Financial Plan of the International Conference provided for the above sum to be raised as follows:

85,000,000 francs *subventionary contributions*, à fonds perdu, 45,000,000 francs from Italy, 20,000,000 francs from the German Reich, and 20,000,000 francs from Switzerland (Federal Government and Railway Companies);

102,000,000 francs from *private sources* (shares and bonds). This private capital, 34,000,000 francs in shares and 68,000,000 francs in bonds, was raised by an international syndicate of the three countries concerned, each one contributing an equal part.

The Gotthard Railway Company (GB), with its Headquarters in Lucerne, was founded on the 6th December, 1871. Its Board of Directors, acting during the construction period, consisted of Dr. A. Escher, National Councillor, as Chairman, of Mr. J. Zingg, Cantonal Government Councillor, as Vice-Chairman, and of Mr. J. Weber, State Councillor of Berne, as a third member. Mr. R. Gerwig, Construction Director, was designated as Head Engineer for the direction of the construction work.

In August, 1872, the GB entrusted the task of constructing the main tunnel (Gotthard Tunnel) to the "Entreprise du grand tunnel du Gothard Louis Favre & Cie" in Geneva, managed by Mr. Louis



Photo, C.F.F.

General Manager Wichser speaks before the De Vela Monument at Airolo.

Favre, Civil Engineer; the work was started at the northern entrance in October, and at the southern entrance in September of the same year.

Financial Difficulties.

It appeared, during the course of 1875, that the sum of 187,000,000 francs was by far insufficient to meet the cost of constructing the Gotthard Railway, as conditions had considerably changed since 1869. Furthermore, the tunnelling work, especially that of excavating and of providing the masonry lining, was very much in arrears. Differences of opinion regarding the interpretation of the not always clearly stipulated conditions of the construction contract cropped up again and again between the GB Board and the tunnel building contractors. The GB Board also strongly disagreed with its Chief Engineer, Mr. Gerwig, regarding the delay in finishing the detailed drawings and also for exceeding the available credits (especially in respect of the "Tessin Valley Lines", i.e. the sections situated in the lower parts of the Canton Tessin). Mr. R. Gerwig had to resign, after having been Chief Engineer from 1872 to 1875. His functions were taken over, from 1875 to 1878, by Mr. Konrad Hellwag, Chief Engineer, of Eutin (Schleswig-Holstein), former Supervising Construction Engineer of the Brenner Railway and Director of the North Western Railway of Austria. Mr. Hellwag calculated that the additional costs would come to 102,000,000 francs. And the Gotthard Railway enterprise was, thereby, precipitated into a serious financial crisis, which even threatened to bring the work to a complete standstill. GB shares with a nominal value of 500 francs, of which only 200 francs had been paid in, dropped to 5 francs! However, the leading men — with that remarkable personality, Mr. Alfred Escher, at their head — did not lose courage. That their conscious and unselfish efforts prevailed is proved by the fact that they managed to stem the tide of adversity, to safeguard the continuation of the work in hand, and to bring it to a successful conclusion.

The Federal Council informed the Subventionary States of the critical financial situation in which the common undertaking now found itself and these States agreed, after lengthy negotiations, to provide additional capital.

Second International Conference of 1877.

At this Conference, which was held at Lucerne, the Federal Council submitted a revised programme, including considerable restrictions as compared with that of 1869. It reduced the estimated additional costs to 40,000,000 francs, by providing for the following modifications: the construction, for the time being, of single instead of double tracks on the approach lines to the Gotthard Tunnel (allowing, however, for a later enlargement of the tunnels) the increasing gradients up to 27% (1 in 37), the postponing of the construction of the feeder lines, *Zug-Goldau* (opened 1897) and *Lucerne-Immensee* (opened 1897), on the northern approaches, as well as that of the *Monte Ceneri Line* (Bellinzona-Lugano, finished 1882) on the southern approaches.

Financial Rehabilitation.

The additional expenditure of 40,000,000 francs (the total outlays attained thereby being 227,000,000 francs) was raised by means of further State subsidies,

à fonds perdu, to the amount of 28,000,000 francs, the remainder of 12,000,000 francs having to be found by the GB through private subscriptions. The German Reich and Italy provided 10,000,000 francs each, Switzerland 8,000,000 francs, of which 2,000,000 francs were earmarked for the *Monte Ceneri Line*. Switzerland's 8,000,000 francs were made up as follows: contribution of the Federal Government 4,500,000 francs, of the Gotthard Cantons 2,000,000 francs, and of the SCB and the NOB together 1,500,000 francs.

In regard to the financing of the *Monte Ceneri Line*, the construction of which should have been postponed also, as stated above, a special State Agreement was reached between Italy and Switzerland on the 6th June, 1876, much earlier than expected. According to this Agreement, the contracting States had to put up subventions to the amount of 6,000,000 francs, i.e. Italy 3,000,000 francs, the Swiss Confederation 3,000,000 francs, and the Canton of Tessin 1,000,000 francs. The GB, for its part, provided 5,000,000 francs of private capital. As the Swiss Federal Government was not, in those days, entitled to grant subsidies to railways, a special Law (called Subsidies Act) had to be passed, which was approved by Parliament on the 22nd August, 1878, and by the people on the 19th January, 1879. This Act promised the granting, at a future date, of subsidies for the construction of an Eastern and a Western Alpine line which would, in each case, attain the same amount as the one appropriated for the Gotthard Railway. In point of fact, such a subsidy was, later on, granted to Western Switzerland during the construction of the Simplon Line.

After the financial rehabilitation of the Gotthard scheme, the Construction Budget came to a total of 238,000,000 francs. The Subventionary States approved, in the course of 1879, an International Supplementary Agreement to the International Gotthard Agreement of 1869, and had also managed to collect private capital to the amount of 17,000,000 francs, thereby safeguarding the financial basis necessary for the completion of the Gotthard Railway.

Death of Mr. Louis Favre.

The daring engineer and tunnel builder, Mr. Louis Favre, did not live to see the completion of his great work. He died suddenly of an abdominal aneurysm during a tour of inspection inside the tunnel, on the 19th July, 1879. He not only lost his life in the tunnel, but also his fortune, which had been invested in the financially unfortunate "Entre-

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prise du grand tunnel du Gothard L. Favre & Cie". A monument in the cemetery of Chêne-Bourg near Geneva recalls his great work.

Construction Delays.

Both advance headings driven forward met on the 29th February, 1880, at 11.15 a.m. Before engineers and workers passed the opening from one heading-face to the other, a picture of Mr. Louis Favre was handed across: he was granted this highly merited precedence, though no longer being among the living. He would have been pleased to know, had he been alive, that the deviation from the alignment was no more than 33 cm. (13 ins.) horizontally and 5 cm. (2 ins.) vertically.

As could only be expected, the tunnel was not completed at the fixed date, the 31st October, 1880. The contractors asked for a prolongation until the 31st July, 1881. The actual tunnel, without permanent way installations, was finished only on the 1st October, 1881, i.e. more than one year later as had been stipulated in the building contract.

In the years during which the financial affairs of the Gotthard enterprise were in a critical state, the understanding between the GB Board and its Chief Engineer, Mr. K. Hellwag, also came to grief. The difference between the two parties could not be bridged, and Mr. Hellwag had to leave, also, following the example of his predecessor, Mr. R. Gerwig. His position was now taken by Mr. G. Bridel of Bienna, Chief Engineer of the Jura-Berne-Lucerne Railway. Under his leadership, the approach lines to the Gotthard Tunnel, i.e. the sections Immensee-Göschenen and Airolo-Biasea, the Monte Ceneri-Line, the section Cadenazzo-Swiss frontier (Pino), as well as the Gotthard Tunnel itself, were completed. The socalled "Tessin Valley Lines" (Biasea-Locarno and Lugano-Chiasso) which had been added to the GB network after 1882, had in fact started operations in a limited way (station buildings still missing) already in 1874.

Resignation of Dr. Alfred Escher.

Dr. Alfred Escher, the very soul of the GB scheme, had to give up his positions as Chairman of the GB Board and as Head of the Works Department, even before the financial reorganisation — which he had planned — was completed. The ever increasing personal antagonisms he had had to meet with during the difficult years of the GB had proved to be too much for him. His health had been badly affected, not only by hard work, but also by all the disappointments and adversities he had had to go through. He could not even take part in the opening celebrations of the GB, in May 1882, and died in Zurich on the 6th December, 1882.

Inauguration of Railway Operations.

The inauguration festivities at Lucerne and Milan started on the 23rd May, 1882, and lasted for four days. On the 1st June of the same year, the Gotthard Railway was officially opened to traffic.

The seventy-five years of the Gotthard Railway, which we celebrate this year, are *years of operation*, the GB existing actually since the 6th December, 1871.

Even the first years of operation brought about results that exceeded all expectations. Within a short period, sufficient means were available for the completion of the layout and especially for the con-

struction of the second track on the approach lines. The whole line between Flüelen and Giubiasco was completed in this way by 1896. There followed, immediately afterwards, the construction of the lines Lucerne-Immensee and Zug-Arth-Goldau, which were taken into operation by the GB in 1897. Thus, the whole network of the Gotthard Railway was, after all, completed, as provided for in the State Agreement of 1869.

After its nationalisation by the Swiss Government, the GB network became, on the 1st January, 1909, a part of the Swiss Federal Railways, where it forms the backbone for international transit traffic through Switzerland.

2. Construction of the Gotthard Railway.

A. Gotthard Tunnel.

It was on the main tunnel (15,002.64m. or 9 miles 562 yds.) that work was started first, as it represented by far the most important and time-consuming job within the whole network. The GB entrusted this work, in August 1872, to the "Entreprise du grand tunnel du Gothard, R. Louis Favre & Cie", which undertook to complete the tunnel within eight years, at an all-inclusive price of 48,000,000 francs. Work started on the southern side on the 13th September and on the northern side on the 9th October, 1872. To start with, the drilling of the rock had to be carried out by hand. Only in spring 1873 could pneumatic drills (percussion drills) be put into operation, which was even then restricted to the heading face for a long time. The average progress achieved, per day, was 64 to 75 cm. (2 ft. 1 in. to 2 ft. 5 $\frac{1}{2}$ ins.) when drilling by hand, and 3 m. (9 ft. 10 ins.), given very

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favourable rock conditions even 4 m. (13 ft. 1 in.), when pneumatic drilling was used. The socalled Belgian Tunnelling Method was applied, i.e. a preliminary crown drift, or top heading, was driven, widened out sideways to complete the whole arch of the heading (Calotte), and then the vault was lined with masonry; this was followed by the excavation of the bottom cut, near the centre line of the floor, and, subsequently, of the still remaining side portions, the work to be completed with the construction of the masonry abutments. Various types of pneumatic rock drills were used. It would appear, however, that percussion drills of the Ferroux and Mackean/Séguin types gave the best results, although they would seem very primitive to-day. Whereas during the construction of the Mont Cenis-Tunnel gunpowder had still been used, the blasting in the Gotthard Tunnel was carried out with dynamite.

Compressed air served to ventilate the workings, and to drive rock drills, pneumatic locomotives, and pumps.

Until the constructors had actually broken through the last rock barrier, they were never able to solve the problem of producing adequate ventilation, the power for which they obtained from the waters of the Reuss, Tremola and Ticino rivers. This had, of course, a very adverse effect on the working performance inside the tunnel. Air conditions in the workings were extremely bad, especially in the tunnel sections situated away from the heading face. Owing to lack of compressed air, pneumatic rock drills could only be used at the heading face for a considerable period.

At a daily average, 2,480 men were working near the entrances of, or inside, the tunnel. The northern

workings stood under the direction of Mr. von Stockalper and the southern workings under that of Mr. Bossi, both civil engineers. To start with, the work was carried out in three eight-hour shifts. Owing to the great heat (up to 32.9° C., or 91° Fahr.) and because of the insufficient ventilation, the shifts had to be re-arranged, later on, and reduced to five hours each. Lighting was provided by primitive oil lamps. The workers had to buy the oil themselves — a transaction on which the Building Company even made a profit! Hauling inside the tunnel was carried out by steam engines, near to the entrances, and by pneumatic locomotives, horses or mules, in the inner workings.

Construction Difficulties.

The construction of the tunnel proved to be much more difficult than Mr. Louis Favre had ever expected. Unfavourable rock conditions, especially rotten strata liable to produce pressure, high temperatures, heavy inbursts of water, which could only be drained off very slowly owing to a low gradient (southern side 0.1%, or 1 in 1,000), all this provided the working teams with an arduous task indeed. The most dangerous pressure section (to-day entirely safeguarded by masonry vaults and abutments having a thickness of 3 m., or 9 ft. 10 ins.) is situated practically below Andermatt. The "roof" of the tunnel, i.e. the overlying strata between the floor of the Andermatt Valley and the ceiling of the bore, shows a thickness of only 300 m. (984 ft.) at this spot, as against one of 1,500 to 1,825 m. (4,921 to 5,987 ft.) below some of the peaks of the Gotthard massif (Kastelhorn). As only one heading was driven forward, instead of two parallel headings, as later on in the Simplon Tunnel, the boring, the removal of spoil, the supply of construction material, the draining off of water, the laying of compressed-air pipes, and the whole movement of persons had, in the approaches to the heading face, to be provided for within the limits of a narrow gallery. Needless to say that such conditions considerably hindered the process of construction, and work progressed very slowly, much slower than anticipated. In addition to this, power was lacking for drilling purposes, the ventilation was insufficient and the work badly organised. Many and serious differences arose between Mr. Louis Favre and the GB Board, for they could see, soon enough, that the tunnel would not be finished in time, although the building contractors led a heroic battle against the mountain. Working capital was continually short, too, and it appeared at times as if work would have to stop altogether. Nevertheless, the supervising engineers and their men on the spot stuck to the job in hand, even under the most trying conditions. The completion of this great tunnel is mainly due to their untiring efforts. It is to his technical staff and to the engineers and men in the workings that Mr. Louis Favre had to leave the main task of the actual construction, his time being very much taken up with the difficult financial affairs and with other projects, among them being that of the proposed Simplon Tunnel. A great number of workers lost their lives through accidents, or were seriously injured thereby, while hundreds suffered from illness contracted by the unhealthy working conditions prevailing inside the tunnel. Even for those days, the sanitary and hygienic conditions

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in the workmen's camps at Göschenen and Airolo, as well as in the tunnel itself, left a lot to be desired, also. And the complaints of the GB Board did not help much in this respect. During the construction period of the tunnel, 177 men had fatal accidents and 403 were seriously injured. A monument was erected in Airolo later on in remembrance of the victims of the Gotthard Tunnel, which bears the Italian inscription "Le vittime del lavoro".

The numerous difficulties, all of which Mr. Louis Favre could never have foreseen, prevented the completion of the tunnel within the agreed period of eight years, and the expenditure greatly exceeded the estimates. According to the construction contract, the tunnel should have been completed by the 23rd August, 1880. Mr. Louis Favre's health could not, in the long run, stand up to the continual agitation and to the numerous persecutions to which he was exposed. He died suddenly, during a tour of inspection inside the tunnel, on the 19th July, 1879, and even his worst critics had to admire this dauntless personality.

Meeting of the Advance Headings.

The two advance headings, or alignment bores, met — very much delayed — on the 29th February, 1880, at 11.15 a.m. The deviations amounted to 33 cm. (13 ins.) horizontally and to 5 cm. (7 ins.) vertically. The surveying engineers could indeed be proud of their achievements. Mr. Louis Favre, unfortunately, did not live to see this historic event. After his death, the supervision of the tunnel construction had been carried on by Mr. Bossi, as Engineer in Charge, and by Mr. von Stockalper, as Technical Adviser.

For the contractors, Messrs. Favre & Coy., the tunnelling enterprise ended with a complete financial failure. Mr. Louis Favre had lost both his life and his fortune. It was only in the form of a special favour that the Gotthard Railway Company granted a life pension to his daughter, Mme Marie Augustine Naoum Hava. The total construction cost of the Gotthard Tunnel attained, after the final accountancy, the sum of 66,660,000 francs, as against an estimate of 51,754,250 francs.

B. Approach Lines.

As Approach Lines are considered: the sections Immensee-Göschenen and Airolo-Biasca, the Monte Ceneri-Line (Bellinzona-Lugano) and the section Cadenazzo-Dirinella/Italian frontier), as well as the so-called "Tessin Valley Lines", i.e. those of Biasca-Bellinzona-Giubiasco-Cadenazzo-Locarno and Lugano-Chiasso, which were constructed in 1873/1874.

Location Work.

The construction of the Gotthard network was based on the final project of Mr. Konrad Wilhelm Hellwag of Eutin (Schleswig-Holstein), Chief Engineer of the Brenner Railway and Director of the Austrian North Western Railway. Mr. Hellwag's scheme mainly followed the lines traced by Mr. Wetli in 1862, which had been checked and completed by the experts, Mr. K. Beckh, Chief Engineer of the Swiss North Eastern Railway (NOB) and Mr. R. Gerwig, Construction Director of Karlsruhe. This final project provided for practically the same line location as it appears to-day. After a low-lying line-summit

tunnel had been decided upon, the approach ramps had to be adapted to terrain conditions, while avoiding inadmissible steepness of gradients. The numerous torrents and the liability to snow avalanches falling, or apt to fall, from narrow side valleys into the defiles and canyons of the main valley made it advisable to follow the beds of the rivers Reuss and Tessin, as much as possible. Owing to the particular terrain formation, the valley bassin showed, at certain spots, immense "steps", especially so on the northern approaches, near Wassen, and on the southern approaches, in the Dazio Grande, Stalvedro and Biaschina Gorges. In order to overcome such great differences of altitude, within a short actual distance, the line had to be artificially lengthened by means of horse-shoe curves and spiral tunnels. The location work on both approach ramps and the construction of the Gotthard Tunnel itself may certainly be considered as outstanding examples of the art of engineering, and represent the most magnificent railway works of the 19th century.

The construction of the approach lines (1879-1882) did not offer as many difficulties as that of the Gotthard Tunnel, although it created serious problems, too, especially on the steep ramps of the sections *Erstfeld-Göschenen* (29 km., or 18 miles) and *Biasca-Airolo* (46 km., or 28½ miles) and on the *Monte Ceneri-Line*. These sections are characteristic for the great number of engineering works they include, particularly bridges and tunnels. There are on the mountainous line section between Erstfeld and Biasca no less than 38 tunnels, totalling a length of 30,626 m. (19½ miles), as well as 197 bridges and viaducts of over 2 m. (6 ft. 7 ins.) each. The extensive protection devices and fences which had to be built far up into mountain sides, to safeguard the line against avalanches and falling rock, constituted a tremendous task.

The construction estimate for the "Tessin Valley Lines", i.e. for the 62 km. (38½ miles) Biasca-Bellinzona-Locarno and Lugano-Chiasso, established at 13,500,000 francs, was exceeded by 25,000,000 francs. This was mainly due to inexact planning, considerable deviations from the original location of line, the provision of two instead of one track, too costly station buildings, too short a time allowed for the construction, and the inundations of 1874.

The construction of the whole Gotthard network called for twelve engineers and about 20,000 workers, mainly of Italian nationality. Of this number, 290 persons lost their lives and 877 were more or less seriously injured. The final cost of construction came to 216,410, 134 francs.

3. Completion of the Gotthard Line.

A. Gotthard Railway (1882-1909).

Traffic on the Gotthard Line developed beyond expectations, and soon the good business results permitted the GB to re-construct long sections of the main trunk line, *Immensee-Chiasso*, from single to double track. A start was made in the main tunnel (1883/84) and on the section *Bellinzona-Giubiasco* (finished in 1883). There followed, in 1890-1893, the laying of the second track on the ramps *Erstfeld-Göschenen* and *Biasca-Airolo*; thus by the end of 1893 the whole mountainous section *Erstfeld-Biasca* had double tracks. Immediately afterwards, the GB also constructed, and finished, on the 1st June, 1897, the direct feeder lines *Lucerne-Meggen-Immensee* and

Zug-Arth-Goldau which, although provided for in the International Gotthard Agreement of 1869, had been postponed because of financial difficulties. During the same period, a second track was added to the sections *Fluelen-Erstfeld* and, some years later, to the section *Immensee-Brunnen* (finished 1904). The second track on the section *Brunnen-Fluelen* followed much later, under the management of the Swiss Federal Railways.

In order to adapt the layout to the continued increases in traffic, the GB also enlarged the stations of *Lucerne, Schwyz, Arth-Goldau, Biasca, Bellinzona* and *Chiasso*, in 1883-1908.

B. Swiss Federal Railways (1909-1956).

At the time of its nationalisation, on the 1st May, 1909, the fixed assets (construction account) of the GB, including all complementary installations and protection works, stood at 300,000,000 francs, in round figures.

The Swiss Federal Railways (SBB) completed and re-constructed the Gotthard Line at an expenditure which went into numerous millions of francs. This includes, to mention only the more important works, the *re-construction to double-track* (1944-1948), here put in geographical order :

- of the section *Brunnen-Fluelen* (11.7 km., or $7\frac{1}{4}$ miles) along the shores of the Lake of Lucerne (a very difficult task from an engineering point of view, as the main portion of the second track had to be located inside the mountain), which came to 29,000,000 francs;
- of the section *Giubiasco-Al Sasso-Rivera Bironico* (1922-1934) and of the second Monte Ceneri Tunnel (1,692 m., or $1\frac{1}{8}$ miles);
- of the section *Rivera Bironico-Lugano* (1922-1944), the completion of which was made very difficult, mainly owing to the lack of materials during the Second World War;
- of the sections *Lugano-Melide* and *Maroggia-Chiasso* (1912-1915) as well as of *Bissone-Maroggia* (opened 1956); and
- of the section *Giubiasco-Cadenazzo* (opened 1952).

The Gotthard Line from Immensee to Chiasso has a double-track throughout to-day, except for the short section Melide-Bissone (causeway crossing the Lake of Lugano).

The SBB also reconstructed and enlarged the following stations: *Lucerne* (1926, 1939), *Schwyz* (1926), *Erstfeld* (1920), *Göschenen* (1922, and comprehensive enlargements of the station layout and new motor-car loading ramps are under construction at the present moment), *signal station* in the *Gotthard Tunnel* (1946), *Airolo* (1920, 1956/57), *Bellinzona* (1921, 1929), *Giubiasco* (1952), *Lugano* (1915, 1919, 1934), *Chiasso* (1912, 1914-1923, a further comprehensive re-construction scheme is at present in progress) and *Locarno* (1928).

Considering their importance to south-north-south transit traffic, the following constructional schemes must also be mentioned, although they have been, or are being, carried out outside the actual Gotthard Line: the *Basle-Muttenz Marshalling Yard*, first construction stage, the second stage is to follow; the *extension and electrification of the Basle Connecting Line*; the *new leading-in line* via the Birs Valley to *Basle-Muttenz Marshalling Yard*; the *second track Basle German Station to Basle SBB Marshalling Yard* (under construction); the line *Sissach-Tecknau-Olten*

including the *Lower Hauenstein Tunnel* (8,134 m., or $5\frac{1}{8}$ miles), cost of construction 28,000,000 francs; the connecting line from the *Lower Hauenstein Tunnel* direct to the line *Olten-Aarau*, mainly for freight traffic (1926).

C. Electrification.

The SBB decided, already in 1912, to electrify the Gotthard Line by using single-phase alternating current with a frequency of about 15 cycles (finally fixed at $16\frac{2}{3}$ cycles) and with a contact-line tension of 15,000 Volts. In fact their predecessors, the GB, had previously taken the precaution of securing very important water rights in the Cantons of Uri and Tessin. The first construction project included the section *Erstfeld-Bellinzona* and the two railway-owned power stations *Amsteg* and *Ritom*. When the First World War broke out, in 1914, the construction project for the electrification of the Gotthard Line was ready for the calling of tenders. The matter had to be postponed, however, and was only taken up again in 1916. It was not just a question, any longer, of increasing the efficiency of motive power on steep gradients, but of replacing steam by electric power, because of the scarcity and of the tremendous increase in the price of coal. Electric operation was taken up on the section *Erstfeld-Airolo*, i.e. on the important northern approaches to, and inside, the Gotthard Tunnel, on the 18th September, 1920, and covered the whole line *Erstfeld-Bellinzona* on the 29th May, 1921. There followed, within the compass of the Gotthard network, the electrification of the sections *Lucerne-Erstfeld* and *Bellinzona-Chiasso*, in 1922-1924, and of the sections *Zurich-Zug-Arth-Goldau* and *Basle-Lucerne*, in 1923-1926.

Electrification enormously increased the efficiency of the Gotthard Line. Electric motive power made it possible to increase train loads as well as speed. Following the electrification, in 1922, the speed of trains was increased on this line by 65 per cent, and it showed an average increase of even 100 per cent by 1956, as compared with 1882. In other words, it takes less than half the time to travel over the Gotthard Line to-day than it did in 1882.

(To be continued.)

