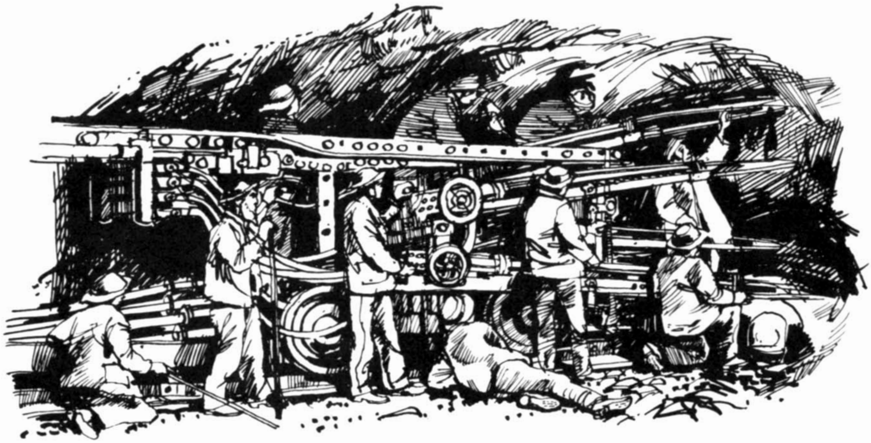
On the same day, the leader and one member left the Base Camp for reconnaissance of the Chubugerdabusa Vesuten Glacier while 2 other members left for the Carupatoriwan Glacier. Climbing was concluded on 24 July on the return of the 2 reconnaissance teams to Base Camp.

In conclusion, we would like to point out that some of the peaks and glaciers are called by different names by local people, such as Chogolisa is called Chogolinsa and Trinity Peak is called Tasa. We took the opportunity to name the peak we climbed (which was temporarily called Chogolisa West Peak) Pruppoo-Brukh, (a mountain which has 3 important meanings) and the necessary procedures have been taken with the Pakistan Government authorities.

Members

Leader H. Akiyama (Electrical engineer), Second leader H. Miyahara (Engine man), K. Nakamura (Electrical engineer), M. Yajima (Service man), H. Narita (Conductor), M. Osawa (Electrical engineer), S. Kobayashi (Engine man), T. Nakamura (Electrical inspector), T. Mori (Electrical inspector), Y. Hosoki (Service man), A. Kida (Passenger service man), S. Anji (Passenger service man), T. Matsumura (Chiba University Hospital), M. Ratif (Liaison Officer).



65 The 'Perforatrice' at work in the Mont Cenis (This and next 6 drawings: P. Sharp)

Tunnels through the Alps

Paul Sharp

The Alps stretch across southern Europe in 3 main sections, the Western, Central and Eastern Alps. They occupy much of Switzerland and include the Bernese Alps, the Pennine Alps to the south of the Rhone Valley, and to the E, the Adula, Todi, Bernina and Rhaetian Alps. Further E is the Tirol and Austria. They form a barrier across the centre of Europe, isolating the N from the warmer S, keeping apart ancient cultures, giving individuality to northern Gothic and southern Classicism, allowing them to mix only with reluctance, delaying the surge northward of the Rennaissance.

However, they have never been entirely impassable. Well-known routes have existed since the dawn of humankind, usable as a rule only in the summer. The lowest pass is the Brenner, between Italy and Austria, which divides the Tirol. It is 1370m high and was used by the Romans and the travellers of the Middle Ages. A carriage road since 1770, it seemed the natural choice for the first railway between Germany and Italy, which was opened in 1867. The next 50 or 60 years, as European industry and capital expanded, were to see a continuing development of rail communication between the N and S of Europe in spite of the difficulties created by this mountain region. Railways require tracks with easy inclines; much thought and surveying went into the preparation of the routes to maintain grades suitable for locomotive traction. The demands on the civil engineers were exacting. Viaducts spanning ravines, cuttings through barriers of rock, embankments and tunnels all had to be planned and constructed often along precipitous mountain sides. It was quite impossible for trains to climb over the barriers—the routes had to go through them—to tunnel.

Tunnels have always held a deep fascination for man. The legends of ancient times are full of references—the myths of the Labyrinth, Persephone, the Styx; later came the horrendous romanticism of the Gothick novel, and the early SF of Jules Verne and Edgar Rice Burroughs with their tales of journeys to the centre of the earth. Nor must we forget the Hobbit. All this combined with Freud knows what makes a strange and sombre contrast to the wide vistas above ground. Who atop the Jungfrau thinks of St Gotthard and Simplon? Yet they are essential factors making possible one's visit. Easily taken for granted, like so much else in our world today, we accept them without a thought of the difficulties, and the skills required to overcome them. The great sub-alpine tunnels mark laborious but progressive steps in the 19th-century march of engineering development.

Natural tunnels were made by the seas and rains long before man began his relatively puny efforts. Sea caves like the Blue Grotto, Capri, and Fingal's Cave in the Inner Hebrides result from the set of sea currents and the grinding effects of shingle and breakers working on soft areas of the coast. On land, especially in limestone areas, pot-holes like Gaping Ghyll are the work of rain dissolving limestone rock. Vast cave systems can result, enlarged further by the grinding of stones carried by the flood waters in the tunnels, which occur wherever the strata is compact enough to support the roof. Devonian rocks (Devon and the Eifel), Carboniferous (Wales and the Pennines), Jurassic (Bavaria) and the Cretaceous limestones (Pyrenees, the Alps, and Eastern Mediterranean) frequently produce natural tunnels. These have been used by animals and man since prehistory—the cave paintings of Spain and the Dordogne find primitive echo in today's pedestrian subways sprayed with aerosol graffiti—slogans for modern cavemen. With the possibility of nuclear wars, a large proportion of the world population is somewhat preoccupied with tunnels for survival.

With so many natural tunnels in existence and inhabited by man his earliest works must have been the adaptation and enlargement of some of these, first for dwellings and tombs, then for mining and quarrying, and ultimately, as societies became more sophisticated, deliberate tunnelling for drainage and water supply. Early civilizations carried out tunnelling on a large scale, embellishing the entrances with architectural features of which present engineers could well take notice. The Romans were great tunnel engineers. Pliny describes a 5½km tunnel under Mount Salviano for the draining of Lake Fucino. Forty shafts and inclined galleries were sunk and the excavated material was loaded in copper buckets and hauled out with windlasses. It took 30,000 labourers 11 years to cut, using tube drills, carborundum and water.

The word tunnel comes from the French tournel—derived from the Latin

'Tourna', meaning a cask. It now describes a more or less horizontal passage made through the earth without removing the material above, as is frequently done for surface tunnels in our cities when subways are constructed today. Such a method is not possible when the route lies at a great depth below the surface as in the Alps. The approach is often gained by deep valleys, the peaks above being many hundreds of metres higher.

Practical tunnelling did not advance beyond Roman methods until the application of gunpowder. Seventeenth-century engravings still show pickaxes, hammer and chisels in use, with wood fires burned at the ends of the headings to split the rock. Ventilation was by shaking cloths at the heading or by screens of boards erected at the entrance to deflect the prevailing wind into the workings. In the 18th Century the canals required considerable tunnelling activity which increased even more with the building of the railways. Provision for tunnelling became one of the ordinary parts of a contractor's specification.

Usually a small tunnel is made—this is called 'driving a heading'. When possible vertical shafts are sunk along the length of the tunnel—retained in the days of steam to act as breathers for the release of smoke from the locomotives. When these shafts are driven upwards from the tunnel to the surface they are called 'risings'.

The different conditions created a wide range of new techniques. One of the most effective was Brunel's 'shield' made of timber, in several sections. It anticipated the modern shield of steel, which holds up the roof, contains the excavated material, and gives space for building the containing walls. As each section is completed it is moved forward by jacks in a telescopic fashion. The next great advance was the use of compressed air for tunnelling through water-bearing

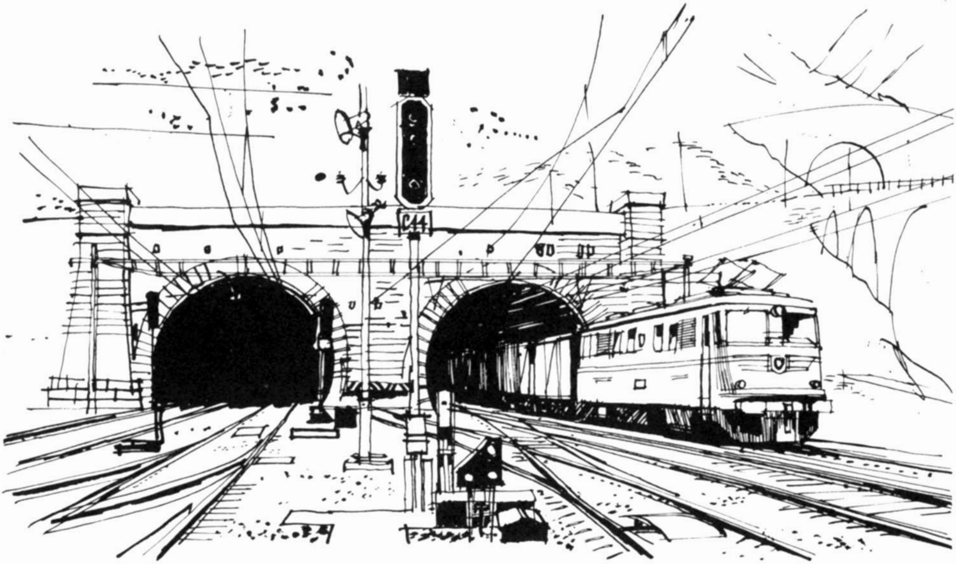
66 Men working in the Shield at the rock face in the Simplon rock. Lord Cochrane took out a patent for this idea in 1830. Men could work in pressures up to 4 atmospheres. This method, combined with shield techniques made underwater tunnelling at last practicable, but the methods were not in regular use until 50 years later.

In the Alps great thicknesses of rock overlie the tunnels and the work had to be done without the sinking of shafts, entirely from the ends. The main problems were finding the best method of excavating and then transporting the material out of the headings, and disposing of it. In the latter half of the 19th Century four great tunnels were made through the Alps. They are the Mont Cenis between Mondane in France and Bardonecchia in Italy; the St Gotthard between Goschenen and Airolo in Switzerland; the Simplon from Brigue to Iselle, linking Switzerland and Italy, and the Arlberg in the Austrian Tirol on the Bludenz–Innsbruck line.

In 1857 the first blast was fired in the Mont Cenis works below the pass which may have been used by Hannibal's elephants. The work was begun by hand methods; before power drilling was introduced in 1861, the rate of progress only averaged 25cm per day on each side of the Alps. With compressed air drills progress was increased five-fold. With the exception of 300 metres, the whole of the tunnel is lined with brick or stone. The first train passed through this great achievement in 1871, hauled by a Sardinian State tank engine bearing a bouquet on its right tank. In this same year Italy became a united kingdom and the Papal temporal power ended.

The St Gotthard Railway Company was also formed in 1871. The St Gotthard Pass was one of the oldest trans-alpine routes—the hospice was mentioned as early as 1331. A direct N–S railway route through the Alps was being considered as early as 1848. In 1869 the Berne Conference decided that to join the Reuss and Ticino valleys by a long tunnel would be the best answer. French politicians opposed this, fearing that traffic through the French Mont Cenis route would suffer, but they were unable to influence the plan, so work began in 1872. Besides the long summit tunnel 80 other tunnels and 400 bridges were to be built. The Swiss, German and Italian governments all helped with the finance. Besides the Gotthard tunnel, 14.8 km long, a spiral tunnel was cut at Wassen and at Fieso and Giornico 4 helicoidal tunnels were made. Mechanical drills were used from the start and the main tunnel was cut by first driving a top heading 2½m square. This was then enlarged sideways and finally the floor of the tunnel was removed to the correct level. Air for working the drills was compressed to 7 atmospheres by 2000hp turbine pumps. The 8 years work (2500 men laboured day and night in 3 shifts) claimed the lives of nearly 200 workers including the engineer Louis Favre who began the project, but died in the workings. Conditions were appalling—ventilation was by the air discharged from the drills and was far from adequate. Rock-falls were frequent, crushing men and equipment.

Finally the two tunnels from N and S met in February 1880. On Christmas Eve, 1881, a ballast train made the first through run. In the following May the tunnel, then the longest in the world, was officially opened. It was worked by steam locos until 1920. Today it is worked by 6000hp Co-Co electrics capable of hauling 600-ton trains up the grades at speed. Freight trains of twice this weight are handled by adding a second loco in the middle of the train. Due to the curves speed is limited to 45mph. The locos are powered by multi-current motors able to use both the Swiss 15,000 volts AC and the Italian 3000 volts DC. Stock from all over Europe makes up the trains and besides the TEE trains the range of international specials



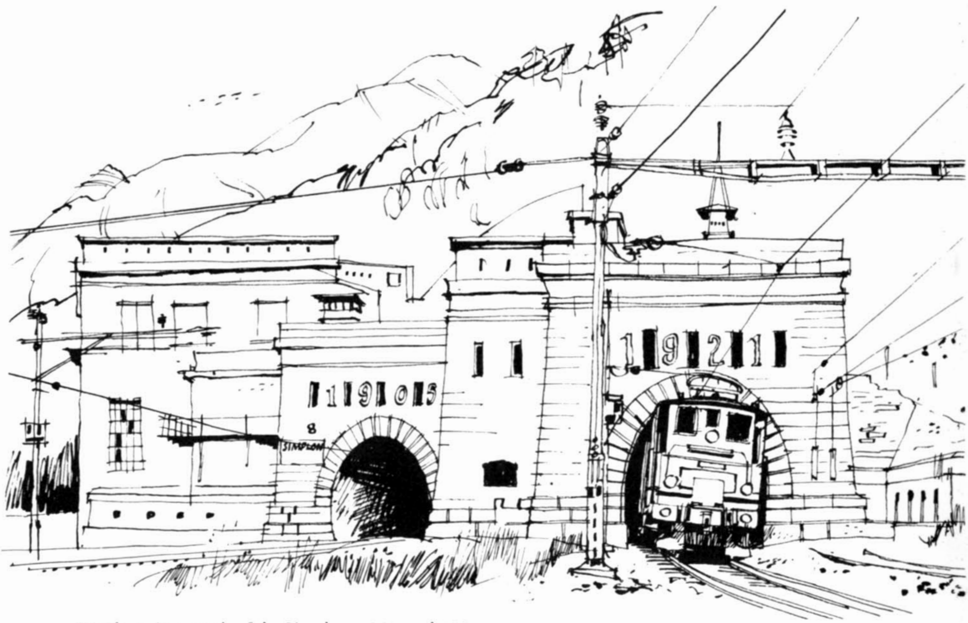
67 An express freight leaving the St Gotthard

include the 'Metropolitano', 'Night Riviera' and the 'Italia'. Besides this through traffic, there is also the local car transport shuttle between Goschenen and Airolo. Drivers who do not wish to climb the extra 900m over the pass can drive on/off the flat waggons worked as push pull units. The complicated heavy traffic is handled by block signalling which allows several trains in the tunnel at the same time. At the centre is a cross-over complex, and a display at Goschenen shows the exact position of every train in the tunnel. More than 220 trains a day use the tunnel—millions of passengers and millions of tons of freight pass through every year, including 400,000 cars using the car shuttle.

The northern approach to the St Gotthard is by a 30km 1 in 40 gradient, by which the trains climb over 600m up the Reuss valley. At Pfaffenspring is a completely spiral tunnel to lift the line another 35m. Next comes the famous stretch near Wassen, marked by its white church, under which the train plunges. It then crosses the Reuss and goes into another semi-spiral. Through this and it is travelling N instead of S, passing the village and then entering another semi-spiral which turns it S again; over the upper bridge, it is lifted yet another 120m to Goschenen and the entrance of the main tunnel. Twelve minutes in the tunnel and you are in the southern sun and a new world. The line descends 900m in 48km. The 24km between Fesso and Giornico runs through a series of ravines and also passes through 4 more spiral tunnels. The Piano-Tondo and Tavi tunnels are side by side on the same slope. As the train enters the first one the second can be seen 90m below down the mountain side. To eliminate all these complexities the Gotthard 'Base tunnel' is now being planned—45km long from Amsteg to Giornico—solid rock all the way—a straight and almost level line.

In 1880 the Austrians began their great tunnel in the Tirol Alps. This was the Arlberg on the Innsbruck–Bludenz railway. It was completed in just over 3 years. The main heading was driven along the bottom of the tunnel and shafts were opened 25 to 75m apart. From these smaller headings were opened to the left and right. The tunnel was then enlarged to its full section at different points along its length simultaneously, in lengths of 8 metres. Each operation took about 20 days with a further 14 days to install the masonry lining. Both pneumatic and hydraulic drills were used. After blasting, sprays of water were used to lay the dust and help ventilate the tunnel. Each day 900 tons of material were taken out, and 350 tons of masonry were transported in, by trains of wagons.

Eighteen years later the fourth great trans-alpine tunnel was begun. A road had been engineered by Napoleon in 1800, 67km long over the Simplon pass. With the opening of the Mont Cenis and St Gotthard tunnels it was now virtually disused. The Simplon tunnel took 7 years to build and is over 19km long. Not only is it the longest tunnel through the Alps, it is also the lowest, being driven at an altitude of 705m, 2135m below the surface. At first a single tunnel was bored; a second being completed, to one side of the first tunnel, in 1921. The 2 are connected by oblique galleries every 180m. The difficulties encountered were incredible, but the improvement in work methods and safety precautions enabled the accident rate to be reduced compared with previous tunnels. In 7 years the toll was 60 lives. A wide tunnel would have been impossible due to the condition of the rocks; only a single track bore could be driven through the collapsing strata. So great was the weight of rock above the borings that the floor was frequently forced upwards and had to be pinned down by building heavy masonry inverts. The heat was intense; water spraying was used to reduce it to a tolerable 89°F. Rock temperature reached 130°F. Half a km from the Iselle entrance the 'Great Spring' was struck—releasing 10,000 gallons of cold water per minute at 600lb per square inch pressure into the workings. This at least lowered the temperature to 54°F. In contrast on the Italian side hot springs were encountered. Such incidents led to the temporary abandonment of work until the springs were contained, by diverting or sealing off. This tunnel claimed the life of one of the leading engineers, Brandt, who designed the drills used on the tunnel. He died from injuries received in a rock-fall early in the work.



68 The twin tunnels of the Simplon, 1905 and 1921

This route up the Rhone valley allows comparatively high speeds, and many expresses are timed at speeds in excess of 60mph. The 'Cisalpine' makes the 150km between Lausanne and Brigue in 85 minutes in spite of speed restrictions at various points. The entrance to the Simplon is 2½km on from Brigue. Again we find car transport facilities. Signalling is automatic; in the early days there was a signal box in the heart of the mountain, manned in shifts. The Italian TEE 'Lemano', the 'Simplon Express' and the 'Lombardie' are among the fast trains that link Paris and Italian cities, through the Simplon tunnel.

After the completion of the Simplon line there was still a need for access to the S from Berne for both Swiss and French traffic, from the Rhine to the Rhone basins. Much of the route was already in existence in the form of small independent lines. A company, the Berner Alpenbahn Berne–Lötschberg–Simplon, was formed to buy up these small lines, combine them and build an extension through the heart of the Bernese Alps; up the Kander valley, then through a tunnel under the crest of the Alps to the Rhone watershed in the narrow valley of the Lonza. Here the line emerges 425m above the valley floor. By descending the N valley wall the line joins the Simplon line at Brigue.

The tunnel delayed the work; in the summer of 1908 blasting broke through into an unsuspected underground lake beneath the Gasternal. Twenty-five workers died and the bore had to be abandoned. This part of the tunnel was eventually sealed off. Curves were introduced to take the tracks under the Kander higher up its course. The scheme succeeded and the two teams met in the middle of the mountain on 31 March 1911, when Chief Engineers Moreau and Rothpletz climbed through the hole to shake hands with due ceremony and be photographed.

69 Engineers at the meeting of the headings in the Lötschberg

The Lotschberg tunnel is double tracked but much of the line is single working. Unlike most Continental railways it used the British old style bull-headed rail and chairs. During construction considerable use was made of American-type wooden trestle bridges. Elegant stations were built and some very individual locomotives employed. For the opening through to Brigue in 1913 a number of 2500hp electric locos were built which at the time led the world in technical development. Since then to the present day the line has constantly introduced new and more powerful locos culminating in the 8800hp double Ae 4/4, which haul trains of 600 tons up grades of 1 in 37 at the full permitted maximum speed of 75km/hr. Automatic signalling, even on the single track passing loops, is by remote control. After half a century of progressive history the line has been absorbed by the Swiss Federal Railway.

The Alps have a wonderful array of narrow gauge lines. In the easternmost canton, the Grisons is a sparsely populated and remote area, known in Roman times as Ratia. Here the metre gauge system is called the Rhaetian Railway. Before the building of the St Gotthard tunnel there was considerable road traffic in the area, but after its opening this diminished. The canton decided it must have a rail system of its own, which would serve the growing resorts of Davos, St Moritz and Pontresina. The present Rhaetian railway is made up from a number of independent lines which amalgamated in 1906 and were later extended. This included the line from Chur, from Landquart to Thusis, and beyond up the Albula valley. This route provides very spectacular scenery and the railway has added a series of beautiful and impressive viaducts—notably the Landwasser, sharply curved with its arch springing out of a precipitous rock-face which is tunnelled. The train now approaches the Albula tunnel up a grade of 1 in 29. Before it reaches the tunnel 4 spiral and 2 part spiral tunnels are needed to gain the height. After Bergun, Breda lies only 6km ahead—but 417m above. The line still graded at 1 in 29 enters the series of spirals at Rugnux and Toua, then over a viaduct, and through the Zoundra spiral. Thus the train climbs 1070m in 43km to the 6km Albula tunnel. This was a problem to bore due to cold underground rivers which at one time delayed the work for 15 months. It took 3½ years to build. The tunnel brings the line from the Rhine to the Danube watershed. It is dead straight and its ends can be seen from the centre point.

The W branch of the Rhaetian system connects at Disentis with the Furka–Oberalp line, while S it runs into the Bernina line as far as Tirano. There are no long tunnels but the ever recurring curves, loops and spirals are with us all the way. The Furka Oberalp actually crosses 335m above the St Gotthard tunnel line.

The S branch of the Rhaetian system is the old Bernina line to Tirano, while W from Disentis the route is the latest line to be built, the Furka–Oberalp's 96km to Brigue in Valais. Separating the Rhine and Rhone river systems are the high passes of the Furka and the Oberalp with the Urseren valley between them. This line was not completed until 1926. Due to the extreme weather it only runs in the summer months. Tunnels were bored beneath both passes, saving 275m in altitude in the case of the 2½km Furka tunnel. Even so the tunnel is 2135m above sea-level, the second highest rail summit in Switzerland.

One of the most curious tunnel systems is on the Jungfrau railway. After climbing up the side of the mountain from Kleine Scheidegg the 2-coach train enters the tunnel which takes it to the terminus—still in the tunnel—at the Jungfraujoch. The tunnel is cut just inside the cliff face of the mountain. At the Eigerwand halt there is a 5-minute stop; passengers can look down on Grindelwald, 1830m below. Still tunnelling, the line loops back on itself, climbs to the Eismeer and finally the terminus 3454m above sea-level. Galleries take the tourist to the Berghof, and the famous Ice Palace, and to the glacier where sledges drawn by huskies can be hired.

70 The station at the Jungfraujoch

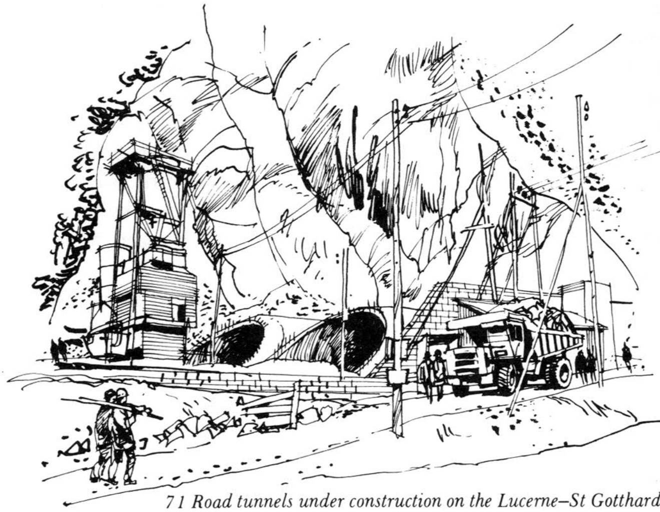
In the latter half of the 20th Century we in the UK, all too aware of the Beeching axe, have accustomed ourselves to the idea that railways are in decline. The construction industry concentrates on road building which in UK requires few tunnels. These when they do occur are usually under rivers. In the Alps it is a very different scene. The railways are extremely vigorous and technical development is eagerly pursued. Road building proceeds apace as here, but due to the extreme terrain and the experience gained in rail tunnelling it is a natural step to make road tunnels. Just as the railways became integrated with the European systems so have the roads, for Europe is no less road vehicle happy than we are. In the Alps the old roads were famous for their hairpin bends and mountain face zig-zags. The new roads are equally remarkable for their even grades and sweeping curves in spite of narrow valleys and precipitous slopes, thanks to the tunnels which are being built under most of the passes. The extensive use of snow sheds and barriers make them usable throughout the year. In many cases they are making obsolete the efficient though somewhat tedious roll on–roll off train transporters. The San Bernadino road tunnel is 7km long, cutting out a climb of 1830m over the pass. It is an essential part of Switzerland's super highway from St Galen on the Upper Rhine to Northern Italy. Dual carriageways and great concrete bridges carry the traffic S through scores of shorter tunnels into the Via Mala, where much new tunnelling has been undertaken to straighten and widen the road.

The Great St Bernard in the Rhone Valley was the first of the passes to be tunnelled for all round the year road traffic. The road runs with the railway to the railhead at Osiers; then it sweeps in wide curves across the valley, past a high dam, until it reaches the 5½km of avalanche shelter extending to the N entrance to the tunnel. Though first considered in the 19th Century and detailed plans were made in the 1930s, work did not begin until 1958. In the following year work started at the Italian side and in April 1962 the bores met and the 5½km tunnel was completed and opened in 1964. It is 1900m above sea-level, well lit, equipped with traffic signals and telephones. It is usable all the year, saves over 600m of climbing and required 17km of new approach roads. The Swiss–Italian frontier is crossed in the tunnel.

Other road tunnels under the Alps have been recently opened and are still under construction, especially in the St Gotthard areas. Brunnen is now by-passed by a tunnel but the 900m climb over the pass still remains for the present. Work is well advanced on a tunnel expected to open in the early 80s. Its 16km length will rid the N2 of the inconvenience of loading and off-loading on to the trains. All round the year working should be usual as provision for snow and avalanche shelters is generous. To the N from Lucerne the road has been greatly developed. The dual carriageway runs S, tunnelling under the Lopperberg and on down the W side of Lake Lucerne, through a 4km tunnel under the Seelisberg peninsular, and then S to the Reuss valley and so to St Gotthard.

The Mont Blanc road tunnel joining Chamonix and Courmayeur was begun in 1959 and completed in 1962. It is 11.6km long at an altitude of 1220m. Works of a similar nature are going on elsewhere throughout the Alpine region—a 20th-century repeat of the 19th-century endeavours—but with much improved technical expertise and a higher degree of safety. The latest to be opened (December 1978) is the Arlberg road tunnel—at 14km the longest in the world.

Today's climate of economic uncertainty and perplexing political situations with all the resulting social pressures makes it too easy to feel that the forces of order and stability which made possible these great achievements under the Alps are in decline. Some say it all began to end after the 1914 war. Certainly the peak of rail travel seemed to be passed as far as passenger traffic was concerned. Yet today's Common Market and the growing together of what were once deeply separated nations give a more optimistic complexion to the scene. One of the main life forces of Western culture is communications. In the centre of Europe the great rail and road tunnels will continue to serve the European community of nations and in an ever developing and more sophisticated way. New techniques of traffic control, civil engineering and transportation will be developed—but only as a superstructure to the basic achievements of those 19th-century tunnelling successes, achieved in unbelievable hardship and danger by teams of heroes who drove the tunnels through the great barriers of the Alps.



71 Road tunnels under construction on the Lucerne–St Gotthard highway