CONSTRUCTION AND MAINTENANCE OF THE TREBIZOND-IRAN TRANSIT ROAD

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PROBABLY few thoroughfares have given such long and almost uninterrupted service throughout history as the Trebizond-Iran transit road. To it the town of Trebizond owes its birth in the year 756 B.C., to the fact that the Romans used the town as a transit port in their military campaigns it owes its rise, and to-day its prosperity depends to a great extent on the export and import traffic of Persia and the North Eastern Turkish provinces passing through its gates.

With the object of recapturing some of the Persian trade which during the Great War had been forced to follow other routes, the Turkish Government began, in 1931, to take steps to modernize the old road which had been allowed to fall into disrepair. The road, which is 640 kilometres (397.7 miles) long, being classed as a National road, has been divided into two sections under the direct control of the Ministry of Public Works, and it is with the first of these two sections, beginning at Trebizond and ending at the Kop Pass, 242 kilometres (150.4 miles) away, that this article deals.

In general location the road follows a North and South direction for the first 90 kilometres (56 miles) crossing at the 69th kilometre (43 miles) the Zigana pass at an altitude of 7,000 feet. Following the river Harshit the road then turns almost due East, passes the small towns of Torol and Gumusane, rises at the 160th kilometre (100 miles) to a height of 6,000 feet, and leaving the River Harshit, descends into the plains of Bayburt. Thence, following the course of the River Choroh for 20 kilometres (12.4 miles) it turns South-east, rising to its culminating point at the Kop pass at the 242nd kilometre and an altitude of 8,100 feet (Fig. 1).

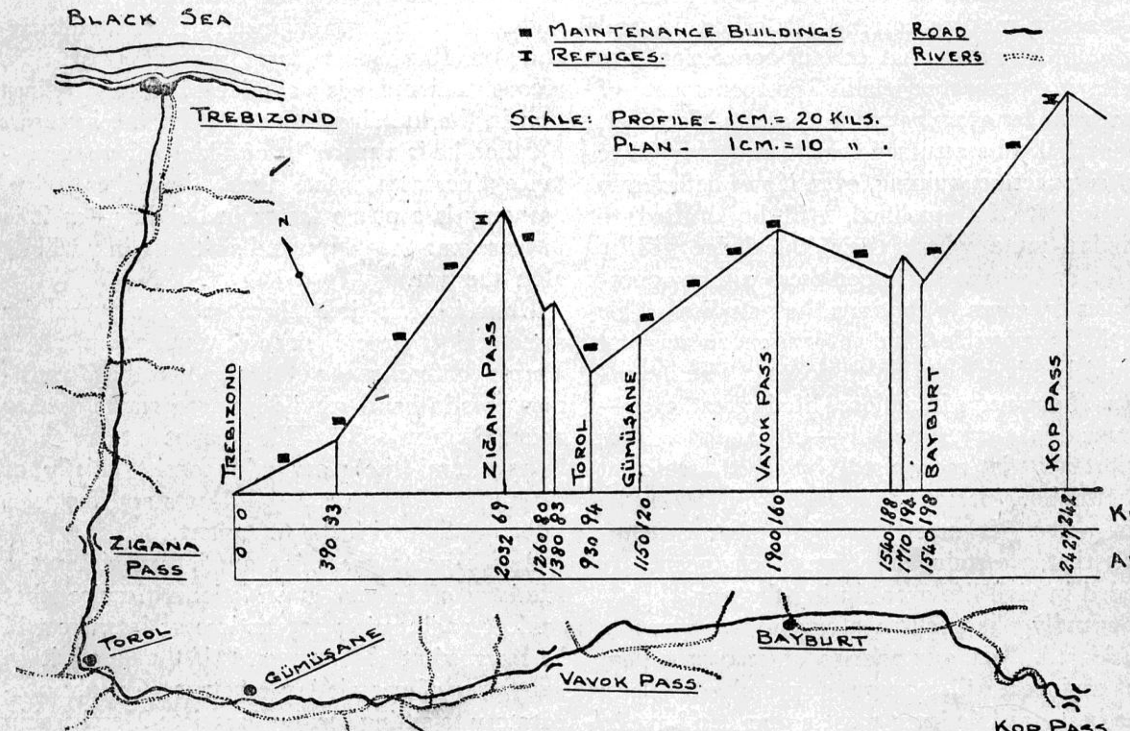

Fig. 1.

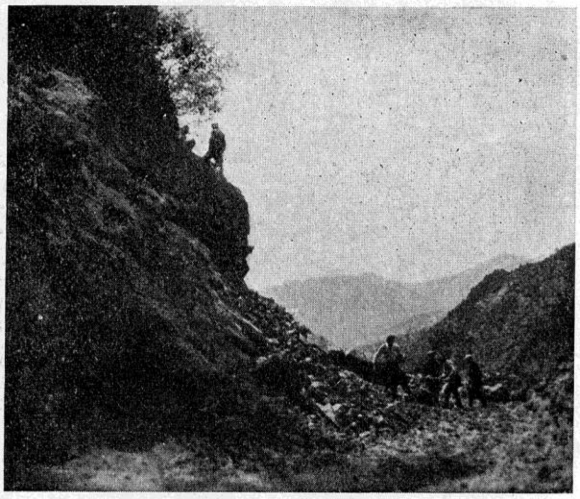

Fig. 2. Excavation.

The leading requirements to serve as a basis of construction were roughly as follows:

1. A macadam road wide enough to accommodate two lines of medium weight, medium speed traffic. Maximum gradient not to exceed 7°, and minimum radius of curves not to fall below 30 metres (98 feet) where possible.
2. Maximum use to be made of the existing road, and maximum economy to be exercised throughout consistent with sound practice.

The existing road (Figs. 2 and 3) was found to be in a very bad state of disrepair. The primitive nature of the formation had further been accentuated by the scouring action of mountain torrents and the heaps of debris brought down by heavy rains and not thoroughly cleared. Apart from a few works in masonry the road was almost devoid of culverts, and primitive timber decked bridges were the general rule. The road surface was extremely bad, most of the old macadam having completely disappeared.

The progress of the work may be divided into the following sections:

1. Determining the new location.
2. Protecting torrent banks from scour.
3. Dealing with landslides.
4. Bridge, culvert and retaining wall building.
5. Drainage and surfacing.
6. Protecting the road user.
7. Organising a system of maintenance.

1. Determining the New Location.

The entire centre line of the new road was staked out over the old road, great care being exercised in determining the station points and the radii of curves with the view of making a maximum use of existing works and excavation. Local deviations were introduced when sections were met with where the gradient was excessive or the radii of curves unnecessarily small. Where the road was threatened by scour comparative estimates were made and either the road was deviated or defensive measures were adopted.

One section of the road is driven along a thick stratum of coarse granite underlying a stratum of massive limestone. The weathering of the granite, due to the decomposition of the felspars, under the action of hail and heavy rain produces a liquid mud which pours down the hillsides, blocking up culverts and depositing itself in layers over long stretches of road, sometimes as deep as ten feet. Clearing the debris in such cases is both lengthy and expensive, therefore preventive measures were sought. Varying with the slope of the hillside there is a period of flow of rain water after which it begins to dislodge the products of weathering of the rock; therefore it was thought that if this distance was roughly determined and longitudinal ditches interposed to catch the rain water and lead it to the nearest culvert the nuisance would be avoided. In order to reduce the length of slope thus treated to a minimum, and also to provide maximum headroom for culverts, the road was deviated to approach the overlying layer of limestone as far as conditions permitted. These parallel longitudinal ditches have been formed with a slope of about 20°, this effect being attained by grading the ditches with an apex between the depressions leading to the culverts. The results obtained were quite satisfactory.

Landslides contributed a great deal in influencing

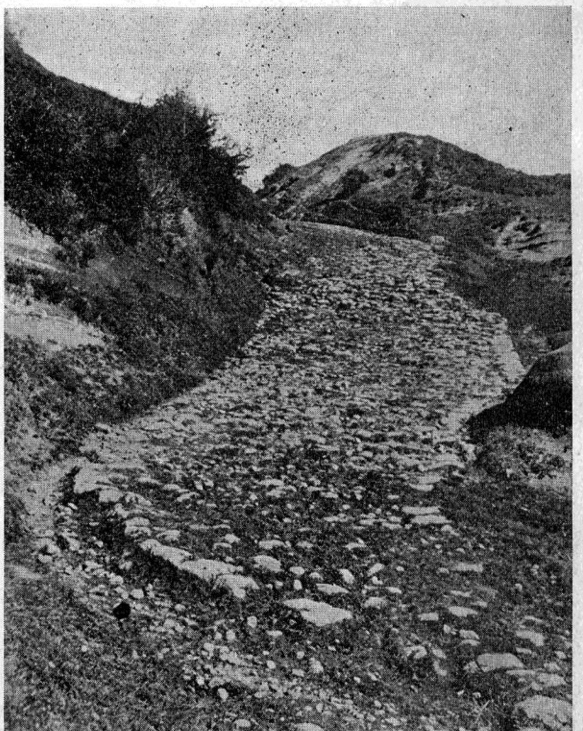

Fig. 3. Section of old Transit Road trodden by Xenophon and his Ten Thousand.

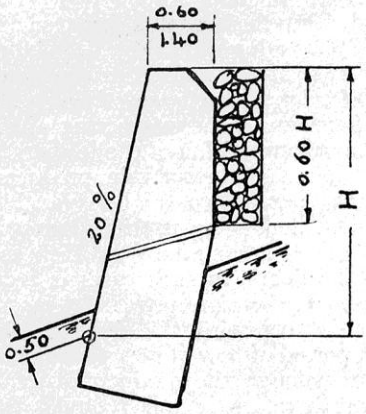

Fig. 4.

the final location of the new road. These were treated according to their nature and their causes as explained below.

2. Protecting Torrent Banks from Scour.

Of the 242 kilometres of road a length of 90 kilometres follows the course of torrents which though almost dry during the autumn and winter months, yet when fed by the melting snows and the torrential rains of spring and summer become the very impersonation of raging destruction.

Before passing on to the cases usually met with, a description of the works employed may perhaps not be out of place. These were :

(a) Walls.
(b) Riprap or rock blocks.
(c) Submersible and non-submersible directional weirs.

(a) *Walls.* Figure 4 shows a typical retaining wall cross section. Walls are constructed of masonry in cement mortar. Stone being abundant all along the road the backs of walls were packed with a stone fill, varying in thickness between 0.60 (24 inches) and 1 metre (39 inches) thick. The

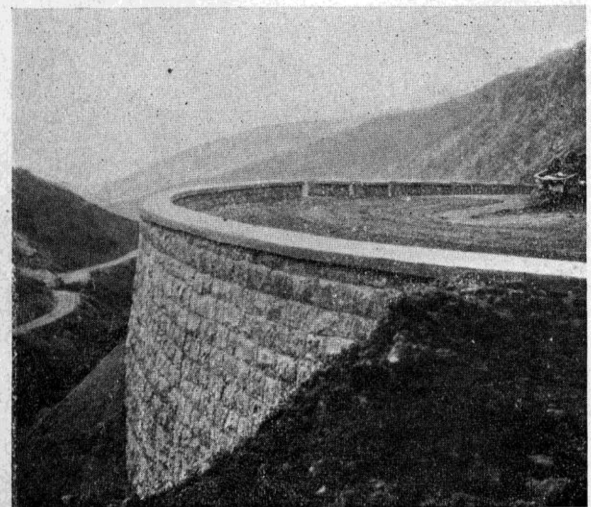

Fig. 5. A Bend of the Zigana Pass.

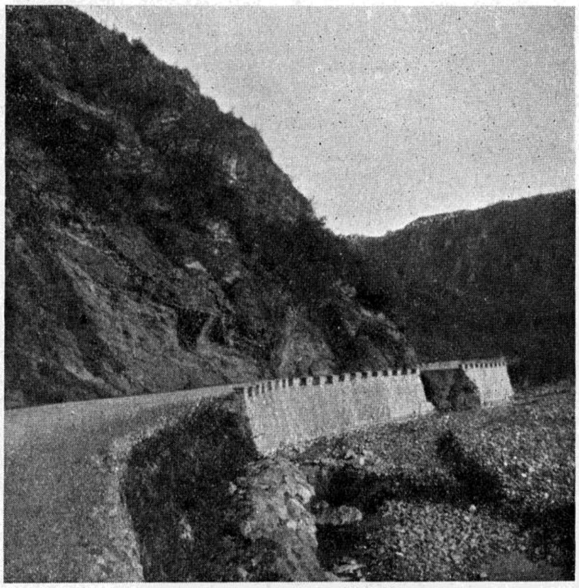

Fig. 6. Masonry Wall.

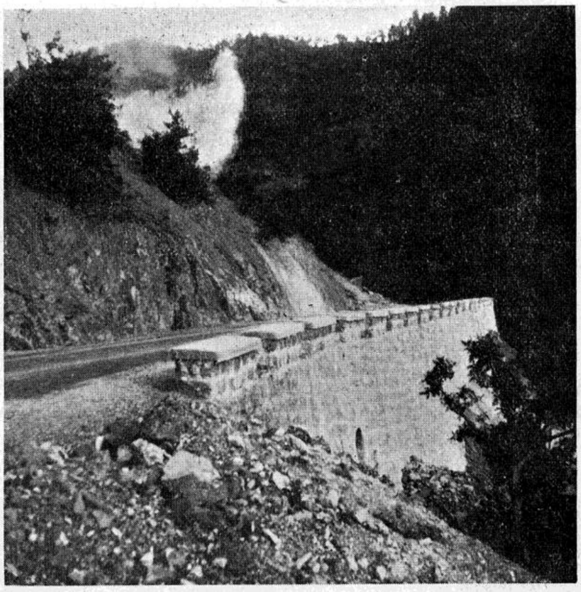

Fig. 7. Retaining Wall.

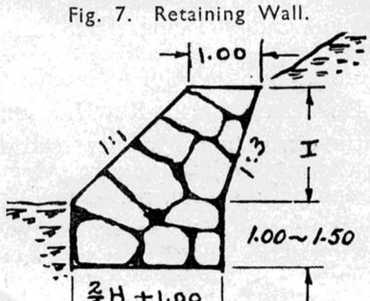

Fig. 8.

masonry was extended as far down as the level of water in the foundation would allow, the remaining portion being constructed of concrete of an approximate mix of 250 kg. (550 lbs.) cement, 0.55 m.cub. (1,750 lbs.) sand and 0.65 m.cub. (2,030 lbs.) aggregate, usually gravel (Figs. 5, 6 and 7).

(b) *Rock Block Protection.* Fig. 8 shows a typical cross section of the rock block protection adopted. Giving the work a definite section was found to give better results than just throwing in the blocks and allowing them to settle at will. It was specified that where possible the volume of each individual block forming the face in contact with the water was not to be less than 0.75 m.cub. (26.5 cubic feet). The extreme limit for the remaining blocks was 0.40 m.cub. (14.1 cubic feet). The whole of this work was accomplished without the aid of machinery. The blocks forming the face were placed with their lengths at right angles to the face and sloping backwards. The sloping back was used for the sake of economy. Foundation depth was from 1 (39 inches) to 1.50 metres (59 inches), the latter seldom being exceeded (Fig. 11).

(c) *Weirs.* Figs. 9 and 10 show a non-submersible and a submersible directional weir respectively. The non-submersible type acts by intercepting the main current of water and forcing it to change its direction, thus protecting a portion of the bank behind it. The submersible type (Fig. 13) points upstream and by allowing the current to pass over it deflects it at right angles to itself and therefore

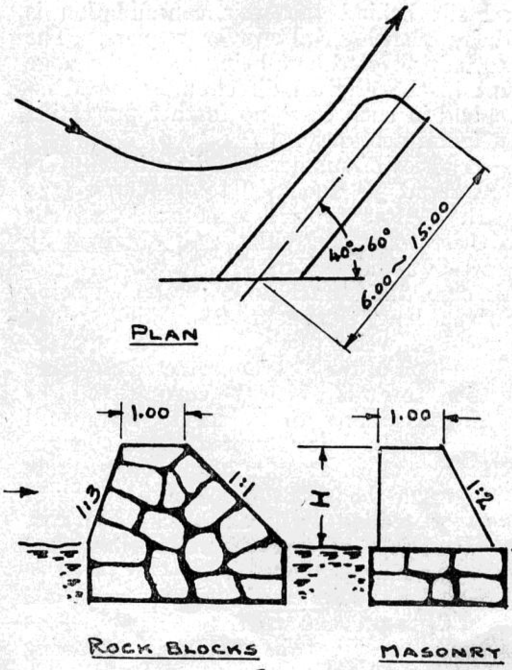

Fig. 9.

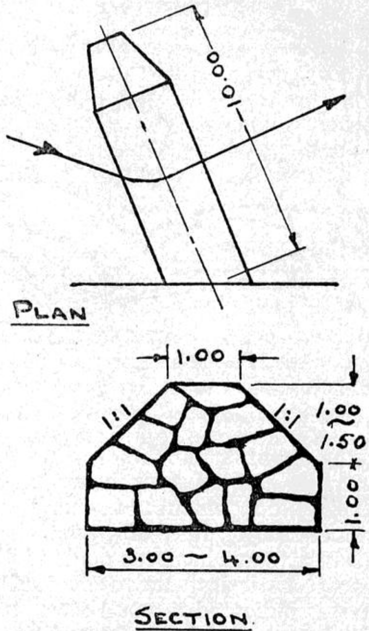

Fig. 10.

away from the bank. Typical cross sections adopted are shown in the figures. Where the slope of the torrent bed and the volume of water were not excessive, both types were built of rock blocks. Where the bed slope and volume of water were considerable, the non-submersible type was built of masonry in cement mortar with rock blocks and concrete foundation, while the submersible type had two metres length of its nose reinforced by filling the voids between the blocks

Fig. 11. Rock Block Protection.

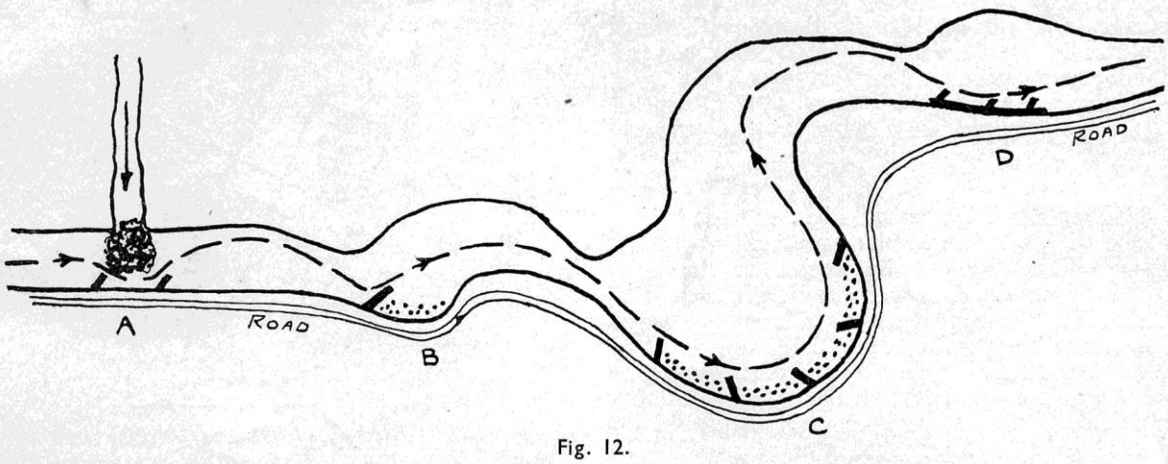

Fig. 12.

with concrete, about 2 m.cub. of concrete being needed per weir, the mixture being 200 kg. of cement (441 lbs.), 0.45 m.cub. of sand (1,430 lbs.), and 0.75 m.cub. (2,383 lbs.) of gravel.

In Fig. 12 an attempt has been made to illustrate the more characteristic destructive effects of torrents in flood. At *A* is indicated a small steep tributary torrent which has washed down a quantity of debris and rocks and partially filled up the bed of the main torrent before the full force of the flood has reached it. The flood water has in consequence been forced towards the opposite bank and this bank and part of the road have been seriously damaged.

Conditions indicated at *B* and *C* are similar in nature and differ only in magnitude. A rocky projection in the opposite bank has forced the flood water towards the road, and bank and road have been washed away. At *D* is shown a case where the main current has been deviated towards an existing wall and part of the wall has been demolished through foundation scour.

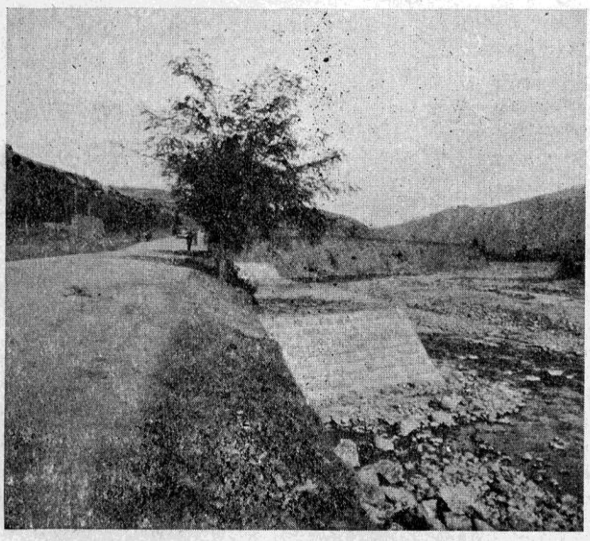

Fig. 13. Submersible Weirs Protecting Old Wall.

The precautionary measures taken to meet such contingencies were as follows:

At *A*. In the main stream two short non-submersible directional weirs are placed respectively a little up and down stream of the tributary torrent. The first directs the current on to the debris, the second prevents the current from being re-directed on to the bank until the debris has been completely cleared by the flood water. The weirs are necessarily short in length in order to avoid too great a constriction of the channel and non-submersible weirs are adopted because of their more definite directional effect.

At *B*. A long non-submersible directional weir is constructed at the upstream end of the curve. After the accumulation of a certain amount of sand and silt behind the weir, consolidation is obtained by planting willows or poplars. The stretch to be protected here being short, a change of current in the original direction becomes improbable, and in such cases no further protection has been found necessary.

At *C*. A series of submersible directional weirs are placed about 30 (100 feet) to 40 metres (130 feet) apart. After deposition of sand and silt between these weirs consolidation is obtained by planting willows and poplars.

In this case, the stretch to be protected being comparatively long, the adoption of widely spaced non-submersible weirs would have been unsatisfactory by reason of the long unprotected stretches between them towards which the current could be re-directed. Assuming the weirs to be spaced 40 metres apart the cost of protecting this length by a masonry wall of average height on concrete foundation would be about £300, in the case of continuous protection by rock blocks the cost would be about £250, whereas the weirs constructed cost only £55 each.

At *D*. Short non-submersible weirs were placed along the wall to prevent scour.

In general as a result of observation the following facts seem to stand out.

Rock block protection, because of its ability to settle in the event of scour without losing its protective qualities, is cheaper and superior to protection by masonry wall unless a good foundation is obtainable at a reasonable depth.

Where the narrowness of the channel or the height of road level makes the use of a wall imperative and there is the least possibility of scouring action taking place, the wall should be protected, by short non-submersible weirs where the channel is narrow and by submersible weirs where the channel is wide.

Stretches of banks not exceeding, say, 100 metres in length which are liable to scour are best protected by a single long non-submersible weir. Willows should subsequently be planted to consolidate the protected bank.

Stretches of bank exceeding 100 metres (328 feet) in length which are liable to scour are best protected by a series of submersible weirs placed approximately 40 metres (131 feet) apart and the banks consolidated by the planting of trees.

3. Dealing with Landslides.

Landslides occurring in this locality are due primarily to infiltrations of water in a porous stratum, followed by sliding on an impervious stratum; and secondly to the lowering of torrent beds due to scour and a consequent loss of support at the foot of the slopes ultimately resulting in earth movements.

Where the thickness of the porous stratum was not great, longitudinal and transverse drains were used in the ordinary way.

Where drainage costs became prohibitive and the torrent bed at the bottom of the slope happened to be narrow, a new support was provided at the foot of the slope by raising the torrent bed. This was effected by building one or more small weirs of rock blocks, about 3 metres (10 feet) high, across the torrent bed, and directly under the slide, the number depending on the length of hillside affected by the slide and the steepness of the torrent bed. The torrent was then allowed to fill up the spaces between the weirs with its own debris. A second set of weirs of the same height were then built a short distance upstream from the first, and again allowed to fill up. In this way the torrent bed was raised to the desired level, the sliding mass again found the support it had lost, and movement gradually decreased and finally stopped. Judged on the results obtained the cost was in every case absurdly low.

In cases where movements were considerable, and where either of the methods described above was found to be impracticable, a local deviation of the road was introduced, and where movements were slight the small depressions caused were left to be cared for by the maintenance organisation (Fig. 14).

4. Bridge, Culvert and Retaining Wall Building.

A typical retaining wall cross section has already been shown in Fig. 2. A local abundance of good stone has led to the general adoption of masonry as a building medium. Walls subject to the continual action of water were built with cement mortar, whilst those only occasionally coming under the action of water were bound with a mortar composed of 1 m.cub. (3,177 lbs.) sand. 0.25 m.cub. (about 790 lbs.) slaked lime and 100 kg. (220 lbs.) cement. Where conditions were favourable plain lime mortar was used for cheapness.

Reinforced concrete pipe culverts were used for spans up to 0.8 m. (32 inches). These were found to give satisfaction in mountainous districts because, being cast *in situ* and in one piece, exaggerated slopes could be provided and the culverts thus kept clear of debris. Reinforced concrete slabs were used for culverts up to 5 m. (16.4 feet) span, and reinforced concrete beam bridges with superimposed decks for spans up to 14 m. (46 feet). For longer spans each case was treated according to individual requirements.

A list is given below of a few bridges recently constructed:

(a) Reinforced concrete viaduct at 100th kilometre Three continuous spans of 9 m. (29.5 feet) and overhang, on columns founded on rock.

(b) Old packhorse track bridge repaired and modernised at 106th kilometre. Total span 138 m. (453 feet). Six new spans added and old bridge levelled and widened with reinforced concrete.

(c) Reinforced concrete through bridge over the River Harshit at 108th kilometre. Beam

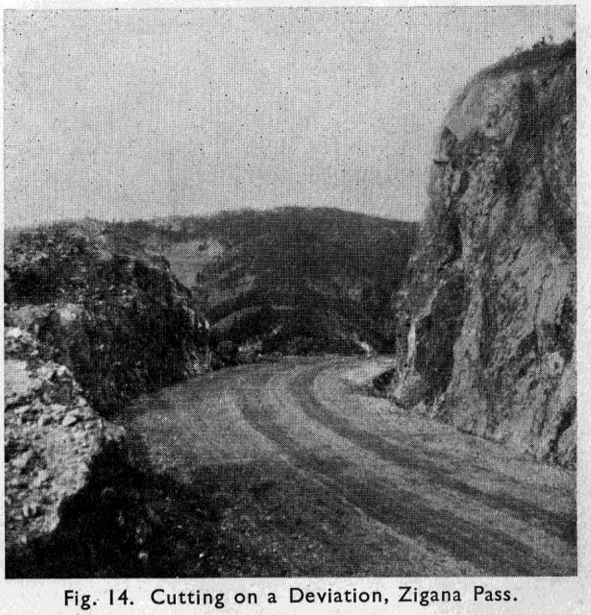

Fig. 14. Cutting on a Deviation, Zigana Pass.

Fig. 15. Gorge of the Harshit.

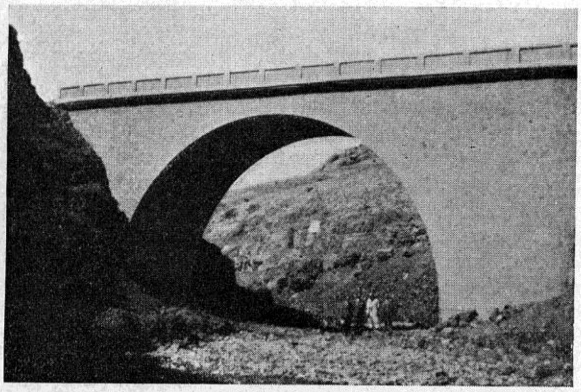

Fig. 16. Plain Concrete Arch Viaduct.

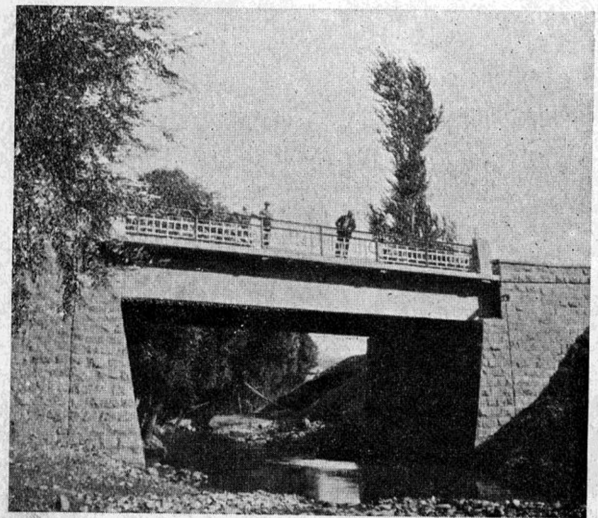

Fig. 17. Reinforced Concrete Bridge.

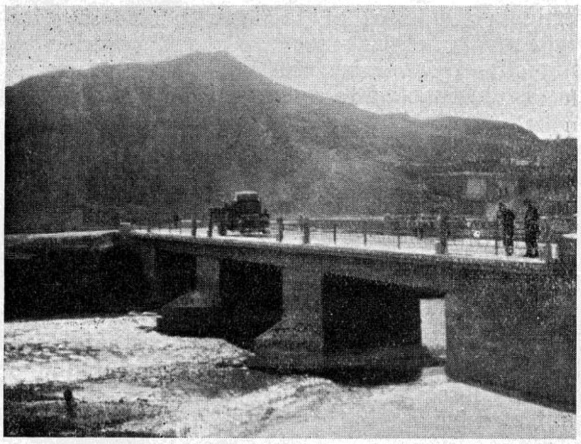

Fig. 18. New Deck on Old Piers.

bridge of 19 m. (62 feet) clear span. Free end on R.C. rockers, masonry abutments on concrete foundations and timber piles.

(d) Plain concrete semi-circular arch viaduct at 153rd kilometre. Clear span 20 m. (65 feet) on rock foundations.

(e) Reinforced concrete beam bridge at 177th kilometre. Two freely supported spans of 10 m. (33 feet) each. Masonry abutments and piers on concrete foundations and timber piles.

(f) Old timber decked bridge over River Choroh at 197th kilometre, repaired and modernised. Old piers repaired and redecked with reinforced concrete. Total span 33 m. (108 feet).

(g) Plain concrete arch bridge over River Choroh at 217th kilometre. Clear span 15 m. (50 feet) on rock foundations.

(See Figs. 15, 16, 17, 18 and 19).

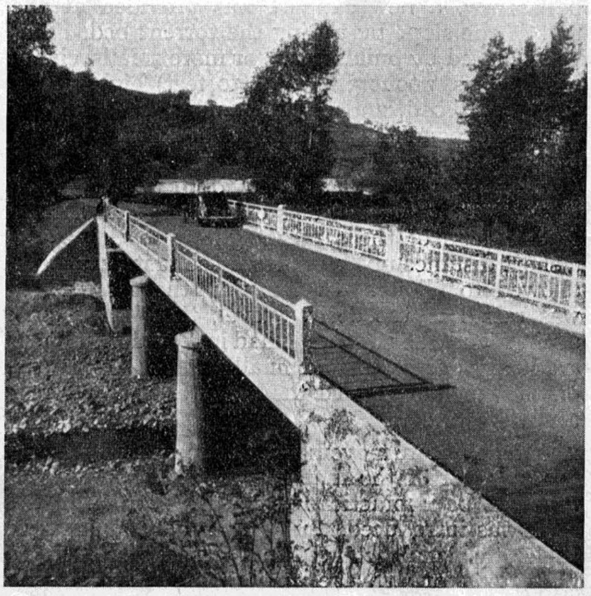

Fig. 19. Typical Concrete Bridge.

5. Drainage and Surfacing.

The least width of road formation is 7 m. (23 feet), of which only 5 m. (16.4 feet) is being metalled. Unfortunately the very important factor of consolidation of earth fills could not be dealt with thoroughly owing to lack of appropriate machinery. Tamping was done by hand and wherever possible fills were allowed a year to settle before rolling was undertaken (Fig. 20).

The road surface is of parabolic cross section having a normal maximum rise of 11 cm. ($4\frac{1}{3}$ inches) at the centre, this being increased to 15 cm. (6 inches) over stretches which are liable to heavy snowfalls and sudden thaws. Subsoil drainage is provided by open ditches of depths varying from 0.50 m. (20 inches) to 1 m. (39 inches), but stone filled cross drains sometimes reaching a depth of 2.50 m. (5 feet), have been used where the bearing and water retaining properties of the soil were found to be unfavourable.

The road foundation consists of a layer of large stones of an average thickness of 15 cm. (6 inches) placed by hand, the voids being filled in with stone chips and rolled. The thickness of the broken stone layer varies between 15 cm. (6 inches) and 20 cm. (8 inches). Experiments are at present being made with the sandwich system of cement bound macadam.

6. Protecting the Road User.

Chief among the causes leading to loss of life and damage to property are skids, head-on collisions due to unavoidable sharp bends in mountainous regions, sudden blizzards in mountain passes during the winter months, and avalanches.

The number of accidents due to skids has been considerably reduced by fencing in the lower side of the road with reinforced concrete posts of 15×15 c.m. (6×6 inches) cross section reinforced with four 10 mm. ($\frac{3}{8}''$ dia.) steel rods, the posts being spaced two metres (6′ 6″) apart. The posts are 1.70 m. (5′ 6″) long, 0.90 m. (3 feet) being sunk into the ground and packed with a stone fill. The posts are tied together with a single steel rod of 32 mm. ($1\frac{1}{4}''$) diameter passing through the tops of the posts, which are painted black to make them clearly visible during and after heavy falls of snow. Such protection, provided along the most dangerous stretches of the road, has been found sufficient to prevent loaded lorries, unable to right themselves after a skid, from leaving the road.

International danger signs, supplemented by additional signs warning drivers to keep to the right and make use of their horn, have been extensively used.

Each winter until recently, both the Zigana and Kop Passes have taken their apparently appointed toll of life, a local superstition being that the Zigana Pass alone required an average of ten lives each winter. (Fig. 23.) Conditions during a blizzard in these passes have to be experienced to be

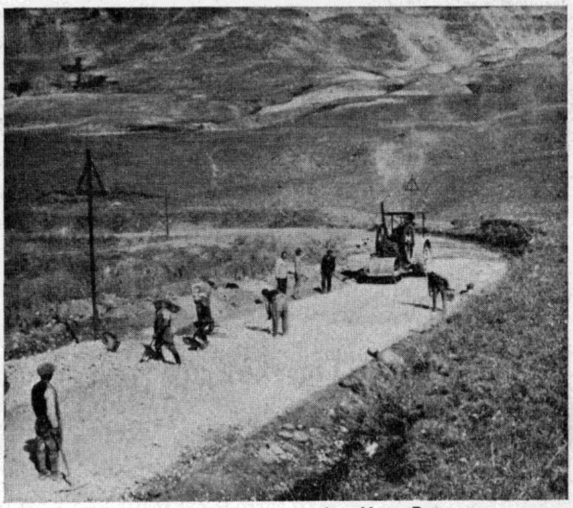

Fig. 20. Rolling on the Kop Pass.

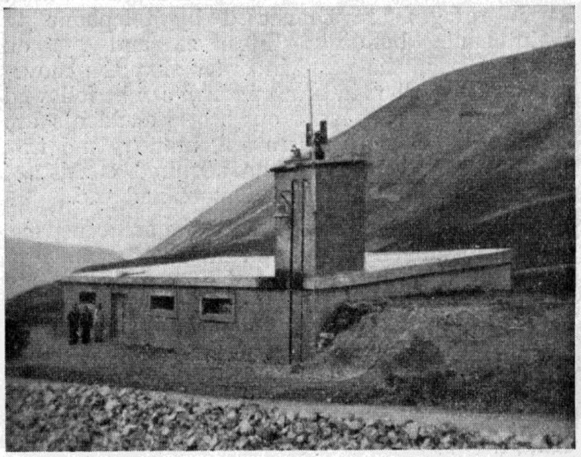

Fig. 21. Refuge on the Kop Pass.

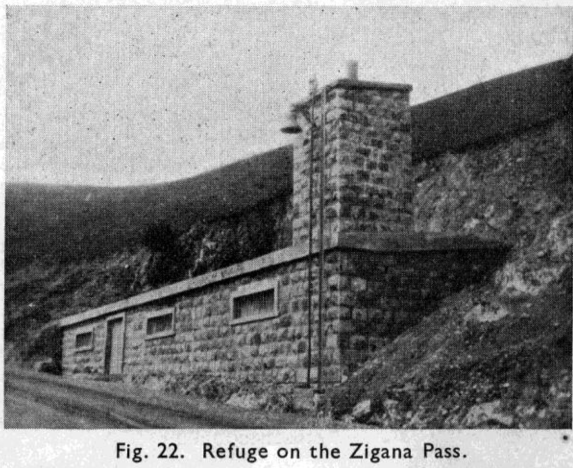

Fig. 22. Refuge on the Zigana Pass.

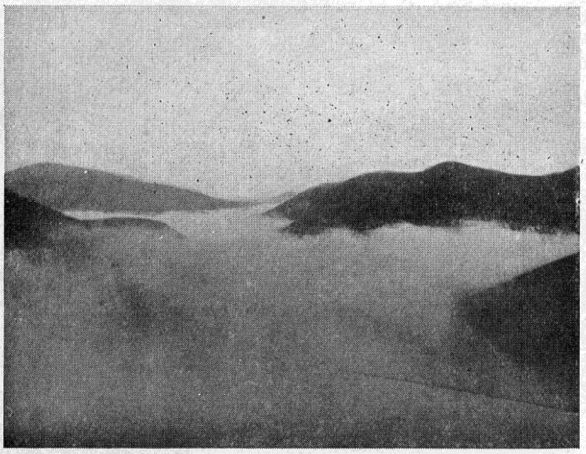

Fig. 23. Above the Clouds on the Zigana Pass.

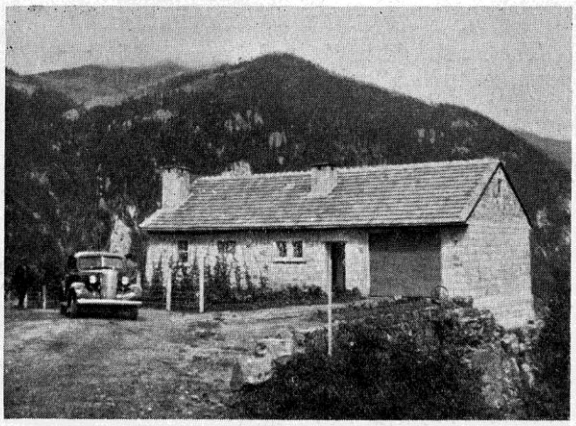

Fig. 25. Maintenance Building.

believed. Refuges have now been built at dangerous points (Figs 21 and 22), and posts painted black, and placed at short intervals along the road, guide the traveller through the blinding hurricane. These refuges are connected by telephone to maintenance buildings (Figs. 24 and 25) on either side of the pass, in order that the movements of travellers in time of storm can be followed and search parties sent out when accidents are suspected. Refuges where tea, brandy, and first aid are provided free when required consist of two large rooms, a stable, a store and w.c.

Throughout the winter avalanches are a menace, though fortunately they are restricted to the steep slopes of the Zigana Pass. They are especially dangerous in the month of March when the massed snows begin to soften under the influence of the warming atmosphere. Accumulations of snow caused by the prevailing winds and local depressions in the mountain side are the chief causes giving rise to avalanches, which tend to occur at the same points each year where their danger length with relation to the road axis is seldom greater than 60 to 70 metres (200 to 230 feet). Reinforced concrete sheds (Fig. 26) built as a series of portal frames placed transversely to the road axis, and having a sloping roof, have been built at some of the most important danger points. These sheds allow the avalanche to pass over them and effectively prevent any snow from finding its way on to the the road.

7. Maintenance.

The road is required to carry the transport of not less than two hundred thousand tons of goods a year. The greater part of this traffic occurs during the summer and autumn months and the probable daily maximum is one thousand tons. Over 90% of the traffic is average weight fast motor traffic.

Constant and relentless attention is required to prevent the plain macadam surface from disintegrating during the hot, dry summer months, and to protect it from the action of water during alternate falls of snow and rapid thaws in the spring. The road surface is preserved by interposing a thin layer of sand between it and the tyres of vehicles. Good river sand is found in

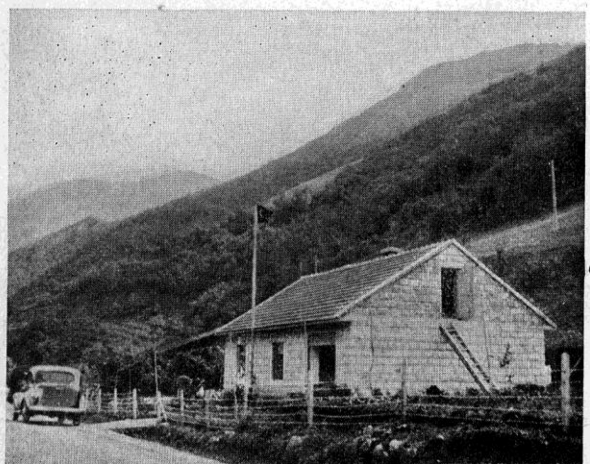

Fig. 24. Maintenance Building.

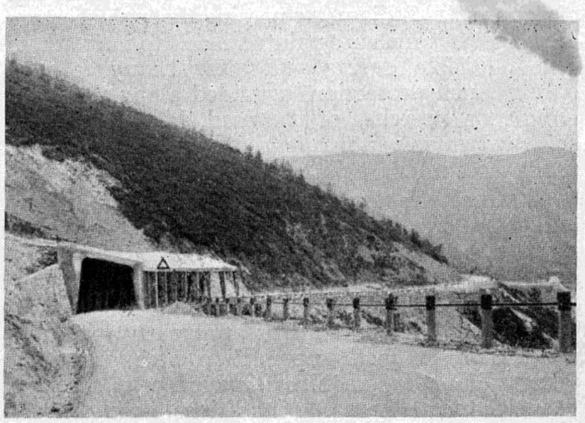

Fig. 26. Avalanche Shed.

Fig. 27. Keeping the Road Open.

sufficient quantities along the greater part of the road. It is scarce in the neighbourhood of mountain passes, but a fairly good clean sand has been obtained by washing certain soils with the abundant snow water available in spring, thus appreciably cutting down the transport costs. Sand is graded and transported from the stream bed to the road by a one-horse cart and then distributed by a three-ton lorry; it is then applied to the metalled surface and by constant sweeping kept there in a uniform layer, averaging about 5 mm. ($\frac{1}{5}''$) thick. Surface maintenance and the keeping of the ditches clear in normal conditions, necessitates the employment of 100 men for the 240 kilometres (150 miles) section under consideration. The average good condition life of the road surface is six years.

Resurfacing is done by laying a 10 cm. (4 inches) thickness of broken stone on top of the existing

Fig. 29. Southern Slope of the Zigana Pass.

surface and rolling. For this method of resurfacing to be satisfactory the old surface must be in a fairly good condition, and not potholed to the extent of absorbing an important proportion of the new stone. The life of six years mentioned above is consistent with this condition.

The washing down of debris by rain and hail following cloudbursts has already been mentioned as involving a heavy item in maintenance costs. To illustrate this fact one typical instance will be recalled: on July 3rd of last year (1938) at six o'clock in the evening a cloudburst occurred at the 96th kilometre and in less than fifteen minutes a mass of 2,000 m.cub. (2,616 cubic yards) of debris was deposited over a 400 m. ($\frac{1}{4}$ mile) length of road. Within an hour 50 men had been

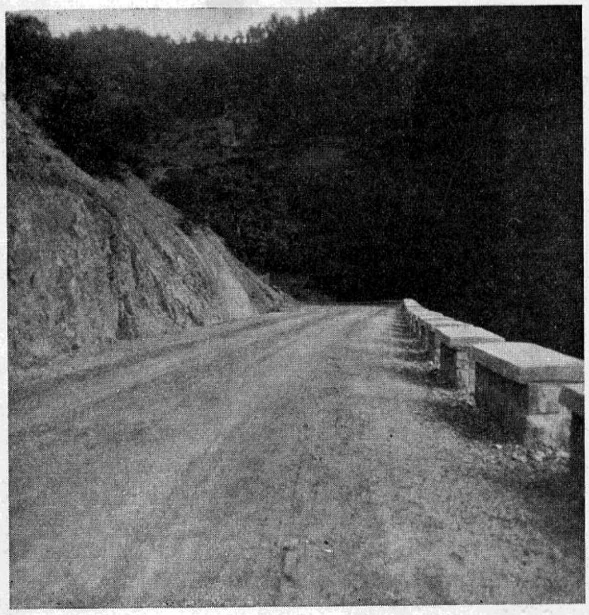

Fig. 28.

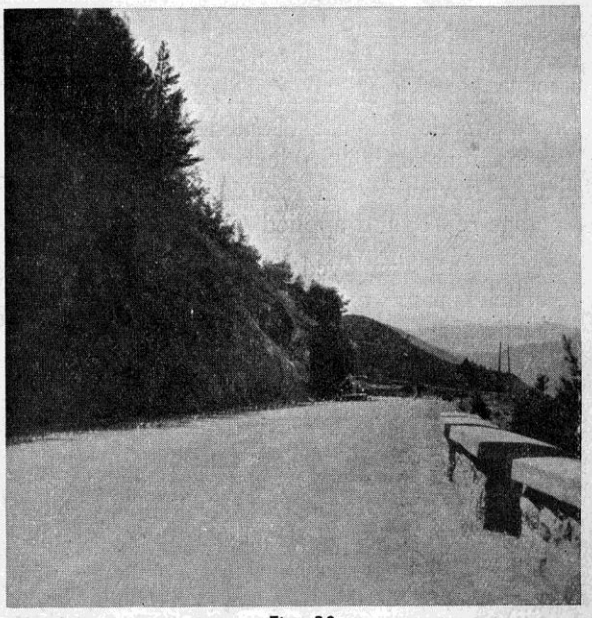

Fig. 30.

brought to the spot in lorries and by nightfall their number had been increased to 100. By ten o'clock in the morning of the following day, after working all night, a passage had been cleared of sufficient width to allow the first motor lorry to go over. The same day a second cloudburst occurred at the 99th kilometre and another 2,000 m.cub. (2,616 cubic yards) of debris was deposited but over a rather wider area. In this case traffic was interrupted for three hours.

The road is usually completely freed of debris by the end of September.

Autumn, a long and peaceful season, ends abruptly with the first violent snowstorm of winter. The ranks of the lowland maintenance gangs are now thinned, and concentrated at refuges in the mountain passes. Additional men are taken on and all are provided with sheepskin coats, caps, felt-lined boots and goggles. They have to cope with temperatures often falling as low as 40 degrees Centigrade below freezing point. They are equipped with large wooden snow shovels and hoe-like picks for ice breaking. They are quiet, orderly men of a high courage and seemingly limitless endurance. To them no call for sacrifice is ever too great, no instance of devotion to duty too exaggerated; their faces seared and blackened by the cold and lashing snow they carry on the task of keeping the road open throughout the winter with an indestructible good humour which pulls them through. (Fig. 27.) Two snow ploughs, fixed to 3-ton lorries, assist in the lower lying sections.

The men are normally housed in maintenance buildings built at 20 kilometre (12.5 miles) intervals along the road. These buildings include rooms, kitchens and sanitary accommodation for both men and engineers. A garage is also part of the standard equipment of these buildings.

The approximate yearly maintenance costs for the whole section, converted into £ units are as follows:

Maintenance of road surface.. ..	£6,000
Clearing debris	1,000
Clearing snow	1,200
Resurfacing by rolling	3,000
Incidental expenses	800
	£12,000

Figs. 28, 29, and 30 show sections of the completed road.

RECENT ENTRY IN THE SCHEDULE OF RESERVED OCCUPATIONS

We are informed in a letter from the Ministry of Labour and National Service that a recent entry made in the Schedule of Reserved Occupations reads " Student engineering apprentice or learner " with reservation at and above the age of 18, and applied to the following:

A man employed in industry or under articles to a professional engineer, who is certified by a university or technical institution or a professional institution of engineers as within two years of the satisfactory completion of a course of study with a view to offering himself for the first time for:

(i) an engineering degree;

(ii) an Engineering Higher National Certificate;

(iii) an Associate Membership of the Institutions of Civil, Mechanical, or Electrical Engineers or the Associate Fellowship of the Royal Aeronautical Society;

(iv) or an examination of similar standing to that of an engineering degree.

The definition is intended to cover under paragraph (iv) the case of the Institution of Structural Engineers, which is not mentioned specifically under paragraph (iii).

We are further informed that in view of the great urgency of the position, it was not possible to consult the Institution of Structural Engineers before making this entry, and the Institution is requested to assist in the operation of this arrangement by furnishing a certificate, where necessary, in respect of student engineering apprentices or learners coming within this definition.