REPAIRS TO SUMMIT (RAILWAY) TUNNEL ON THE UP-COUNTRY LINE

by

Priyal De Silva

1. Introduction

The author wishes to illustrate the temporary and permanent repairs effected to Tunnel 18, 1,050 ft. long situated approximately one mile from the Pattipola Railway Station and one fourth mile from the summit (elevation 6,226 ft. above M.S.L.) towards Ohiya on the up-country line. This summit tunnel as it is popularly known, which is the third longest tunnel in our Railway, collapsed on 5th January 1951 in the process of carrying out relining work. Temporary repairs were effected, suspending the train service, and working round the clock, and within 5 weeks time through service was resumed. This repair work although of a temporary nature, withstood for 30 years, before permanent repairs were effected in February 1981, after suspending the train service this time for seven weeks.

2. Temporary Repairs from 6th January 1951 — 11th February 1951 (5 Weeks)

According to records available, tunnels on the up-country railway line were being re-lined on a scheduled programme, commencing from financial year 1948/1949. Tunnel 18 in which the seepage was heavy and old lining had deteriorated the most of all the 43 tunnels on this line was attended to initially, but as the relining work on it could not be completed that year, the balance work was taken up in the financial year 1949/1950 and again in 1950/1951. For the purpose of relining at a distance of 325 ft. from the Tunnel portal at Pattipola end, the old lining which had badly perished, had to be removed. A small charge was introduced for expeditious removal of this lining, to avoid laborious chipping, and this resulted in a major collapse at this point. A large quantity of loose earth came down from the cavity so created, which grew larger in size as more and more earth kept falling through. The ultimate size of the cavity was about 12 ft. x 10 ft. at its extremes. Some problems which were encountered whilst carrying out the temporary repair work are worthy of record. The flow of water through the tunnel along the side drains from Pattipola end towards Ohiya was blocked at the collapsed section resulting in the water backing up to waist height at the Pattipola end.

This created a major problem in working inside the tunnel. Although it was risky enough for men to work inside the tunnel, clearing earth, a passage had to be found for the banked up water also to flow through the collapsed earth, as there was no other way of diverting this water. This was because 600 ft. of the track outside the tunnel at Pattipola end is in a double cutting. Even pumping was found to be difficult in the deep double cutting. Therefore, a great risk was taken to open up a path for this water by laying 8 in. diameter pipes through the debris to take the water to the Ohiya side. The falling down of earth was expected to cease sooner or later, with the earth forming an arch higher up the cavity, so that remedial measures could be taken thereafter to close the cavity. With this in mind workmen were employed in pulling out the heaped up earth by means of mamoties with handles as long at 15 ft. to keep the men clear of the cavity. The recovered earth was loaded to railway wagons stationed at Pattipola end. However, this proved to be futile, as more the earth was removed, more was the earth which came down from the cavity, which eventually extended up in the shape of a tunnel. Within a week from the date of collapse, about 500 cubic yards of earth had been removed by material trains, as well as by washing down with the water which had banked up at the Pattipola end. Under these circumstances it is reported that operations had to be reversed at this stage and action taken to fill up to the cavity by bringing earth back by material trains from near by, so that the fall of earth from the cavity was reduced and the men were able to work near the cavity without fear. Earlier, one of the workmen had injured his leg badly due to falling lumps of sandstone rocks hitting his leg. Men also found it difficult to breathe within the tunnel due to the foul air which had to be expelled by laying 2 in. diameter pipes through the debris.

2(1). The new modus operandi was to fill up to the cavity as stated, earlier from underneath and erect two sleeper cribs on both sides of the cavity as close together as possible, so that the R.S. Joists could be driven through the earth from Pattipola end on the cribs, to support rail forms in the shape of arches, which in turn were to support 3 in. planks to cover up the cavity. Two 14 in x 6 in. R.S Joists 26 ft. long were used, with the clear span between the two cribs kept at approximately 22 ft. These cribs were up to a height of 12 ft. 6 in. above rail level to take the R.S.Js and the horizontal stiffening rail of the rail forms. For launching the R.S.Js in position, two other sleeper cribs were erected on a bogie low side wagon and the R.S.Js placed on these cribs. The wagon was

---

Priyal de Silva, BSc(Eng) FPW(England) MIE(SL)CEng, graduated from the University of Sri Lanka, Katubeddie Campus in 1973. Joined the Mahaweli Development Board as Project engineer and was attached to the Bowattenna scheme. In 1975 Mr. de Silva joined the Railway, Served as Asst. District Engineer and is presently the District Engineer, Lower District C.G.R.
then worked into the tunnel and the R.S.Js were slid on to the crib at Pattipola end. They were then pulled through about 16 ft. of earth by means of pulley blocks and chains anchored on to a rail driven into the wall of the Tunnel at Ohiya end of the cavity. Next 05 rail forms spaced at 20 in. apart using tie rods were taken on to the R.S.Js at Pattipola end and pulled towards Ohiya end by means of Union and screw couplings and wire ropes, due to the heavy resistance encountered, one of the R.S.Js tilled and a wire rope snapped. So, two of the rail forms were uncoupled, and only three forms were pulled first followed by the other two later. The forms were not fitting into the tunnel walls exactly and as such heavy packing had to be placed between the planks and tunnel walls so that the planks were tight in order to prevent any earth falling through this opening. The earth between the two cribs was then removed and the legs of the rail forms were then fixed in position and the base concreted to take the load. The cribs were then removed and passage cleared. Since the cross tie of the rail forms obstructed the minimum vertical clearance required for passing trains, the track was lowered by about 2 ft. at the affected point and uniformly re-graded on both ends.

2 (2). The rail forms were later strengthened in 1953 and 1954 by inserting extra rail forms in between those presently inserted, in addition to four more at each end making a total of 29 forms adjacent to each other forming a steel shell directly under the cavity, and four double rail forms 2 ft. - 6 in. apart on each side of the cavity.

2 (3). There is no electricity available at Pattipola Railway Station even now. Initially carbide lamps were used for this work. This in turn created a hazardous problem with the carbide fumes polluting the air inside the tunnel and suffocating the men, due to free flow of air being blocked by the debris at the point of collapse. As the work was to continue for some time, electricity was supplied using diesel generating plants.

3. The Reasons for Effecting Permanent Repairs

The rail forms so erected as temporary supports, though they provided for the required minimum vertical clearance, still fouled at the haunches and the sides with the minimum structure gauge (Vide diagram I). As such, if the door of a carriage was opened in this area, it would have knocked against the rail forms. The problem therefore was to remove these rail forms and sleeper packings and to do a permanent lining which was not foul of gauge. It was also noticed over the years that there was heavy seepage at this point and that the rail forms were fast corroding in addition to the sleepers perishing. The tunnel was thus in imminent danger of collapsing again.

4. Some of the Methods Suggested for Effecting Permanent Repairs

In November 1952, borings were taken by the Railway Bridge Dept. and it was revealed that the cavity was 25 ft. in height above the crown of the Tunnel and that there had been 11 ft. of earth which had dropped on top of the plank shuttering. (See diagram III).

4 (1). In the mid sixties, many consultants, both foreign and local, were consulted for advice on the manner of effecting the permanent repair work, and one of the suggestions made was to cut open the tunnel up to the affected area, but this would have entailed a prohibitive cost, apart from the lack of space for disposal of such a large quantity of rock and earth. As such, this proposal was set aside. Around the same time when an A.D.B. team visited Sri Lanka their advice was sought in this matter and the following alternatives were suggested by them:

(a) Make an open cut excavation up to the cavity.

(b) To drill from top and concrete the cavity from the top.

Mr. J. P. Senaratne, former Chief Engineer, Way and Works, made a suggestion to sink reinforced concrete cylinders up to a certain distance above cavity and then from there up to the cavity with steel shutters with windows and then to fill up the cavity with rubble through the windows and finally re-line the affected area without disrupting the train service. However, this was consuming time as no blasting could be done over the affected spot and as such, this idea too had to be dropped.

4 (2). The Geological Survey Dept. was called upon to carry out borings in the area from the hill top to ascertain the type of rock and also the probable size of the cavity. According to the borings and the soil tests carried out, it was revealed that the rock was fractured quartzitic gneiss with weathered feldspar and that the cavity extended 25 ft. or so above the crown. The overburden at this point is about 100 ft.

4 (3). Finally in 1976 Mr. P.M. Sithamparappillai, Specialist Engineer, Geology then attached to the M.D.B. was consulted and he recommended pressure grouting to consolidate the loose earth above, and to form a curtain of grouting. The Drilling Unit of the Irrigation Dept. was then called upon to do the pressure grouting. Altogether 1,100 bags of cement were grouted, the mixture varying from 1 : 3 and 1 : 4. The mix could not be made richer, due to the tendency for the pipes to get blocked, as the grout pumps had to be kept far away from the affected area, so as not to interfere with the train service. Mr. Sithamparappillai further advised that once the consolidation grouting was done the rail forms may be removed in stages and in situ concreting carried out. However, removing the rail forms in stages was not very feasible as the planks and sleepers which were above the rail forms and on the sides were about 9 ft. long or more, and there was no way to cut them short. As such, rail forms covering a length of 9 ft. had to be removed at one go.

4 (4). About the same time Prof. Dayantha Wijayasekara of the University of Moratuwa along with Mr. L. S. de Silva, former General Manager (Technical) of the Railway, and later attached to the University of Moratuwa, whilst advising the then G.M.R. on the method of permanent repair to be adopted, suggested that precast concrete panels be inserted in segments...
Two Plates pulled and Rock Bolted. Third Plate being pulled on the background is old corroded Rail Forms.

Concrete Haunches assembled on the Wagon about to be taken in for Launching.

Concrete Segments assembled on the ground outside the Tunnel.
Concrete Crown Placed on Tractor Shovel Bucket.

Concrete Crown about to be placed in position with the Tractor Shovel.
5. Permanent Repairs (February 1st 1981 to March 24th 1981)

The design of the precast units are given in Appendix (I). The diagram of precast Units which are in five segments are shown in Diagram II. It was decided to carry out the permanent repair work in the months of February and March as rain was unlikely to interfere very much with the work during this period. The corroded rail forms were cut by the flame at the cross tie and at the two legs and a chain was entangled to the upright between the cross tie and the crown and pulled by means of the loco. All rail forms on either side of the exact cavity were removed in this manner, and the sleeper planks fell down along with the rail forms. Then any sleepers or planks protruding out of the steel shell consisting of the 29 rail forms which are adjacent to each other, were cut by axe and brought down. At that stage the loose earth which had come down from the cavity in 1951 could be seen. There was about 2 ft. of loose earth above the planks and the tunnel lining in the crown area, and about one and a half feet at the right hand side haunch facing Ohiya. At this stage it was decided to drive in 3/8 in. M.S. plates 16 in. wide, across the cavity, flush with the sides of the cavity and the tunnel lining.

5 (1). To commence this operation a sleeper crib 12 ft. high was erected on the Ohiya side of the cavity and a 3/4 in. rod was sharpened at one end and was driven through the earth, above the rail forms and planks to penetrate out at the Pattipola side of the cavity. The cavity measured about 12 ft. - 0 in. across and as such, one long rod which spanned the entire cavity could not be driven at once; hence, a short piece was driven first and to its end another piece was welded and driven further. Next, once the rod penetrated at the Pattipola end an eyelet was welded to the rod with a wire rope intact and the rod was then pulled back to the Ohiya end with the wire rope. In case it refused to move the Union and screw coupling was used. Once the wire rope emerged at the Ohiya end, the rod was taken out and the 16 in. wide M.S. plate with a fabricated cutting edge on one side was connected to the wire rope by drilling a hole on the M.S. plate close to the cutting edge. Then the plate, which was 8 ft. long was pulled by the wire rope attached to the winch of the crane from Pattipola side and once about 7 ft. of the plate had gone into the earth, another plate 8 ft. long was welded to the earlier plate and again pulled by the crane till the first plate had penetrated from the Pattipola side a sufficient distance. Seven 15 ft. long lap welded plates were so inserted side by side, with guides being fixed to the last six so that each was able to move on the side of the one previously inserted without overlapping each other. The last plate was 22 in. wide and by these plates an area measuring approximately 15 ft. x 10 ft. of the cavity was covered. The main handicap at this stage was smoke which emanated from the crane inside the tunnel. The crane utilised was an old 7 ton steam crane, which did not possess very much of brake power of its own, as a result of which it had to be always kept coupled on to a train due to the 1 in 44 gradient inside the tunnel. As such added to the smoke from the crane, even the exhaust fumes from the Diesel Loco were in circulation inside the tunnel. Therefore the loco had to be worked out of the tunnel on and off for sometime till the fumes subsided, or a long string of empty wagons had to be attached between the crane and the loco so that the loco was kept outside the tunnel throughout. This again created a problem because the Driver of the loco was unable to see the hand signals.

5 (2). Once the plates were driven in the above mentioned manner, the ends of each plate were rock bolted, welded on to two steel ribs at each end and two K.V. rail forms made to the tunnel profile were welded to the plates at the two ends and legs concreted, to support the plates. Then the corroded rail forms were removed in lengths of 4 ft., whilst supporting the plates with K.V. rail forms spaced 4 ft. apart. Please see Appendix 2 for stress calculations. According to calculations, the maximum permissible distance between K.V. rail forms should be 2 ft. 6 ins. if the elastic limit is not to be exceeded in the plates. However, in order to obtain working room for launching the concrete segments a certain amount of risk had to be taken in working up to yield point of the steel, by having the K.V. rail form supports at 4 ft. centres. The crown portion of the 2 ft. wide concrete panel could not be raised vertically into position once the other four segments were placed. As such, it was necessary that the crown portion had to be raised two ft. away and then brought towards the two haunches and placed in position. Hence, the need to have a clear length of 4 ft. for this operation.

5 (3). A concrete footing was built for the concrete panels as per Diagram II. A groove made out of two K.V. rails was provided to place the bottom most segments in between. The five segments of the concrete arch were placed on the ground outside the tunnel and assembled. A separate K.V. rail arch which fits on to the underside of the concrete arch was fabricated and placed in position. Each leg of the concrete arch consisting of two segments were welded together and fixed on to the leg of the K.V. rail arch on the underside by means of bolts and nuts through the two holes on the concrete segments. The crown portion of the K.V. rail arch was separately fixed on to the concrete crown segments in the same manner. The two legs were loaded to a modified bogie low side wagon as shown in Diagram IV and the crown loaded on to a modified tractor shovel bucket—Diagram V. Both these modifications were designed at site. Next they were taken inside and the haunches were first slued into position by means of crow bars and released in stages with the pulleys fixed on the top of the wagon. The haunches were kept in position supported by an acrow pipe prop against a bracket on the K.V. rail. The crown portion was then placed using the tractor shovel. Each concrete arch was connected to the next by means of 5/8 in. rod running through at the four joints. The entire concrete arch was kept in position till concreted after
welding the K.V. rail segments on the underside of concrete arch. Altogether eighteen concrete arches were placed in a distance of over 40 ft. keeping a 3 in. gap between the arches for better bonding and to facilitate drilling holes for concrete grouting and water seepage.

6. Conclusion

An effort had been made to place on record for the information of the present membership and also the future generations, the ingenious methods adopted in effecting both temporary and permanent repairs to tunnel No. 18 on the up-country railway line, whilst highlighting the problems involved and how they were overcome. The permanent repair work was carried under the direct supervision and guidance of the author. It is needless to mention the difficult working conditions under which this work was carried out, in a climate not at all conducive to easy working, and at the same time looking after the safety of the workmen. However, the fact that the work went on smoothly and was completed in a comparatively short period of time speaks volumes for the cooperation received from all grades of officers and workmen.

7. Acknowledgements

I take this opportunity to express my deep appreciation of the very able and useful work carried out by the late Mr. Edwin Black, who was then the Deputy Chief Engineer, Mr. N. A. Vaithialingam, the then District Engineer and Mr. J. Paul Senaratne, the then Asst. District Engineer, in effecting the temporary repairs. Particulars of work carried out by them are in record in the Departmental files. My thanks are due to Mr. Senaratne in particular for volunteering to clarify certain work details for me at the time of preparing this paper. The permanent repair work was entrusted to me by Mr. S. Amarasuriya, Director, E.S.B. when he was Chief Engineer, Way and Works and I thank him most sincerely for the opportunity he provided me to do something noteworthy for the Railway at the very start of my career.

I am also grateful to the present G.M.R., Mr. L.A.A. Peiris and the present Chief Engineer, Way and Works, Mr. D. C. Lelwela for permitting me to present this paper, extracting information from the Departmental files, and releasing details of the permanent repair work organised and executed by me. My sincere thanks also go out to my Engineering friends, colleagues and superiors who visited the site whilst the work was in progress and encouraged me with their compliments and advice. I will be failing in my duty if I do not record my sincere appreciation of the efficient work carried out by the Railway Bridge Dept. Staff, and the cooperation extended by all the field officers and other staff engaged in the work. The drawings and sketches for this paper were prepared by Mr. H. V. Perera, D.O.A. on my personal instructions and I am thankful to him for his services. Last but not least, I must record the very valuable advice and guidance given by Mr. P. M. Sithamparapillai, Prof. Dayantha Wijayasekera and Mr. L. S. de Silva in a consultancy capacity in connection with the permanent repair work, as referred to in the body of this paper.
APPENDIX 1

DESIGN OF PRECAST UNITS FOR THE PATTIPOLA TUNNEL, NO. 18

The exact measurements of the Precast Units will have to be made at the site or determined by the plan available at the Drawing Office before casting is done. Since the Bending Moment is zero anywhere in the parabolic arch, the axial load on each segment is considered for design purposes. Segment A is subjected to maximum axial load. Consider the arch in four segments for design purposes.

The weight of each crown section

\[ = \frac{1}{2} \times 2 \times \frac{2 \times 9 \times 150}{4} \]

\[ = \frac{2025}{2} \text{ lbs.} \]

Axial load on A

But self weight on A

\[ = 2 \times \frac{1}{2} \times 9150 = 1350 \text{ lbs.} \]

\[ \therefore \text{Total Axial load} = 2025 + 1350 = 3375 \text{ lbs.} \]

Applying formula

\[ Po = 0.85 \times \frac{Ag + fyAst}{x \times 0.613} \]

Assuming 2 Nos. of 16 mm. = (5 1/8") placing longitudinally, 2 Nos. for each Unit.

\[ Po = 122,400 + 11,034 \]

\[ = 133,434 \text{ lbs.} \]

This is very much greater than 3375

\[ \therefore \text{Section is Safe.} \]

Now using 3/8 in. bars (10 mm.) transversely at 1 ft. centers (nominal reinforcement).
For calculating the distance at which temporary K.V. rail forms should be placed to support the M.S. plates.

Using Pauker's theory (for sandy soils)
Using formula \( H_c = \frac{6u}{8} \)

When \( H_c \) = equivalent height of soil in ft.

\( 6u \) = Uniformly distributed, ultimate or critical contact pressure of soil T/ft.\(^2\)

\( 8 \) = Unit weight of soil in T/ft.\(^2\)

\( H_c = \frac{6u}{8} \)

\( H_c = 8 \)

\( 6u = H_c 8 \)

\( 6u = 10 \times 120 \) T/ft.\(^2\)

\( = \frac{1200}{2240} \cap 0.5 \) T/ft.\(^2\)

Assuming that K.V. rails are at a distance of \( L \) ft. apart

\( f = \frac{W}{\text{Tons per foot}} \)

\( f = \frac{8}{L} \times 6.25 \)

\( = \frac{16}{3} \) T/in.\(^3\) — for a height of 10 ft. of soil.
DIAGRAM 1

TUNNEL PROFILE SHOWING OLD RAIL FORMS AND SLEEPER PACKING TO ARREST EARTH FALL IN 1951.
TUNNEL PROFILE SHOWING CON. FORMS IN NEW POSITION AS PERMANENT REMEDIAL MEASURES IN 1981
TRANSPORTING SIDE CONCRETE FORMS TO TUNNEL
BY MEANS OF BLW WITH IMPROVISED RAIL TRESSEL

DIAGRAM IV

CONCRETE CROWN FORM BEING PLACED BY
MEANS OF A TRACTOR SHOVEL

DIAGRAM V