

The Kaimai Tunnel

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1 INTRODUCTION

The 8.9 kilometre long Kaimai tunnel was driven through mixed volcanic formations in the North Island of New Zealand between 1969 and 1976. Tunnelling conditions were extremely variable and there were two sections of exceptional difficulty.

At the west portal, the tunnel was driven through alluvium and crushed and weathered fault material. While this was being done, a collapse occurred which resulted in the loss of four lives.

At 4 kilometres from the west portal, a buried debris slope was encountered containing a significant proportion of carbonaceous material. Very heavy loads developed and there were large inflows of water. Multiple heading techniques were used in this section of tunnel.

This paper describes tunnelling conditions and support requirements at two sections of the Kaimai tunnel where difficult ground was experienced.

2 GEOLOGY

The Kaimai range is part of a major volcanic block which extends South from the Coromandel Peninsula to the Mamaku plateau. The steep scarp of the Okauia fault defines the western flank of the range. To the east, the Kaimai Range slopes gently down to the Tauranga basin.

breccias, tuffs and sediments of the Aongatete volcanics and Waiteariki Ignimbrites ranging in age from 1.26 to 0.84 million years.

3 INVESTIGATION

Before the commencement of tunnelling, a total of 23 boreholes were drilled with an aggregate length of 3709m. Because of the depth of cover and difficulty of access, this work was limited to 3.5km from the east portal and a short length at the west portal.

It was recognised that tunnelling through the alluvium, colluvium and fault material at the west portal would be difficult. Boreholes in this area were both vertical and inclined. A short drive was excavated into the face, of necessity 30m above tunnel grade as the approach cutting to the tunnel had not been excavated. A shaft was sunk to investigate water flows in the fault material. Geophysical work was carried out involving the use of seismic refraction, electrical resistivity, magnetic susceptibility and gravity methods although none of these produced information of significant value due to the extreme variability of the material.

Although none of the boreholes or the drive fully penetrated the fault zone, the investigation at the west portal was sufficient to define the nature of the material through which the initial section of

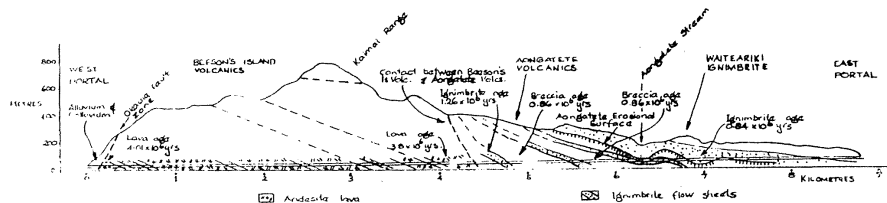


Fig. 1 Tunnel long section

A geological long section of the tunnel line is shown in Fig. 1. The Beesons Island volcanics are composed of a stratified sequence of andesitic lavas, autoclastic breccias, tuffs and locally derived volcanogenic sediments. The lavas, which range in age from 4.1 to 3.5 million years, dip east at low angles, presumed to be related to the building of a stratiform volcano. The volcanics are truncated along the western side of the range by the steeply dipping Okauia fault. At the foot of the range, colluvium from the fault scarp overlies alluvial deposits.

On the eastern side of the range, the Beesons Island volcanics are overlain by ignimbrite sheets,

the tunnel would be driven and its probable extent.

At 4 kilometres from the west portal the cover over the tunnel was 400m and this, together with the difficulty of access, precluded any effective investigation drilling. General knowledge of the stratigraphy and progressive logging of the excavated tunnel indicated that, as the tunnel advanced towards the interface with the Aongatete volcanics, the easterly dipping lava beds would become thinner and the proportion of interbedded tuffs and breccias would increase.

Work at the west portal commenced with the excavation of the approach cutting. Water inflows became greater as the depth of the cutting increased, and the final section was excavated with some difficulty through saturated alluvium.

At this stage, the merits of the use of a full face tunnelling machine were being considered, and no decision had been taken on the excavation method or on which construction agency would carry out the work. In order to avoid delays, it was decided to excavate a drive through the alluvium and fault material, with the objectives of, firstly, enhancing the information gained from previous investigation, secondly, penetrating the fault to lower the water table and thirdly as a basis for later excavation of the full tunnel section.

A circular tunnel cross section was required through this zone because of the high overburden pressures expected. The tunnel cross section also had to be of adequate size to permit the passage of a fully assembled tunnelling machine, should this be needed once a face was established in the Beesons Island volcanics. The drive was therefore at invert level and designed to allow the construction of the invert of the circular tunnel prior to the excavation of the remainder of the section.

A portal for the drive was established in the alluvium, with the face above the portal supported with timber. It is evident that some relaxation occurred while this was being done. The drive was advanced to 50m with some difficulty, and at this point face conditions became so unstable that it was decided to construct a concrete bulkhead and grout ahead through the fault material to consolidate the ground and to control water inflows.

While this work was underway, the decision was taken to purchase a full face tunnelling machine for excavation of the volcanics. Planning for the enlargement of the first section of the tunnel was put in hand and a method was developed which required the excavation of a full width top heading using steel supports founded on temporary footings (fig. 2). A moveable truss system was then planned to carry the load from the sets while these were supported from the previously constructed invert.

The temporary drive was enlarged using this method of advance. It quickly became evident that there was inadequate forward support to enable the system to succeed due to the nature of the ground and the relaxation which had occurred as a consequence of the construction of the temporary portal and the invert drive. The situation was secured, but only after substantial settlement had occurred.

The advance of the temporary drive was replaced by one which required the progressive enlargement of the tunnel section commencing with a vertical cut to take advantage of the concrete invert already constructed. Timber support was to be used over a short section of tunnel until full circle steel supports could be placed (Fig. 3). This system was in use when the collapse occurred, but at the location of the failure, the top heading had been widened to full tunnel width prior to providing support from the invert.

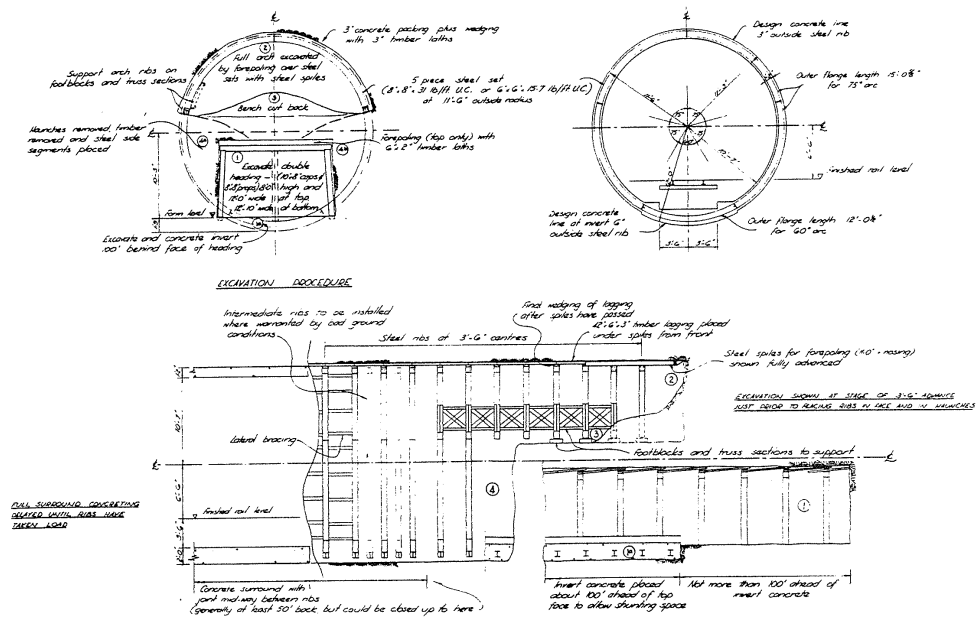


Fig. 2 Planned Tunnel Enlargement

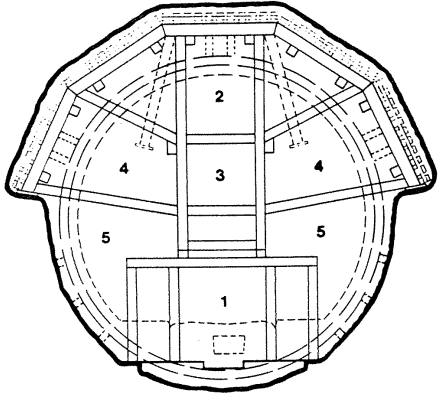


Fig. 3 Cross Section - Multiple-stage Timbering

5 TUNNEL EXCAVATION - 4 KILOMETRES FROM WEST PORTAL

When the tunnel from the west portal had penetrated through the fault zone into the Beesons Island volcanics, a full face tunnelling machine was introduced. This was not successful, so it was transferred to the east portal, excavation from the west continuing by conventional drill and blast means. Full face excavation using explosives was generally possible, although there were short lengths where other techniques had to be adopted due to the instability of the ground.

At 3900m conditions became very difficult. The tunnel was being driven through beds of tuff, breccia and conglomerate by use of a heading and bench system. Severe loads developed accompanied by heavy inflows of water, the loads being sufficient to cause complete failure of the heading sets, which were 203*203*52 column section at 0.6m centres. Further investigation drilling ahead of the face indicated the presence of an old debris slope with a substantial zone of carbonaceous material. Considerable quantities of water were associated with this discontinuity with a total of 300 m³/h eventually flowing from a 50m length of tunnel. It was obvious that the worst of the material had the potential to develop heavy loads and would require full support, including the face. The length of tunnel involved was short - only 50m - so the only reasonable approach was a multiple heading system (Fig. 4).

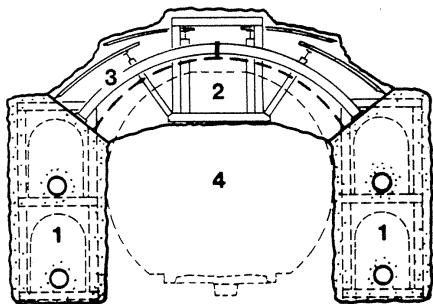


Fig. 4 Multiple Heading System

Concrete bulkheads were constructed across the tunnel at the face to provide the necessary stability for commencing the headings. Lower side headings were driven first using false sets at 0.6m centres and main sets at 1.2m centres. The latter were four piece square sets fabricated from 200*150*52 rsj. Concrete lining with an arched roof was maintained to 1.2m from the face. Upper side headings were then driven on top of the lower side headings using the same system. On completion both upper and lower headings were cleaned out and completely filled with concrete except for longitudinal drains.

Excavation of the arch was commenced by driving a crown heading supported on 200*150 sets at 1.2m centres; this heading was kept a maximum of 2.4m ahead of the subsequent enlargement. Crown bars were erected in the heading, and the excavation driven sideways over an intermediate longitudinal bar to the top of the side heading concrete. Sets (250*250 UC) were founded on the side heading concrete at 0.6m centres and primary concrete placed immediately to the inside flange. The central section was then removed in stages with a concrete sub-invert placed immediately. This 50m section was the most difficult in the whole tunnel. Based on an analysis of failed supports, it is probable that loads reached 530 tonnes per metre of tunnel.

6 CONCLUSIONS

Some conclusions can be drawn from this brief description of the driving of two short, difficult sections of the Kaimai tunnel.

At the west portal, extensive investigation work preceded the commencement of tunnelling. While this was not totally successful in defining the extent of the fault zone, it enabled the nature of the material through which the first section of tunnel would be driven to be predicted with reasonable accuracy. The fact that a collapse occurred resulted from a series of technical decisions which created a situation where the ground support was inadequate.

In the case of the section at 4 kilometres from the west portal, prior investigation was impracticable and there was only the most general indication of the type of conditions that would be encountered. The successful excavation of this section where ground conditions were more difficult than at the west portal resulted from the ability of experienced staff to adopt a flexible approach and to quickly evolve the correct technical solution.

Tunnelling will always be a difficult and challenging occupation and will require a high level of investment in investigation. However, even with the most intensive investigation, conditions will still occur which cannot be foreseen. Of equal importance is the need for tunnelling to be directed by those who have the necessary experience to be able to quickly evaluate changing conditions and plan how these are to be overcome.

7 ACKNOWLEDGEMENT

Material for this paper has been drawn from previously published information.

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