

4. *South End* (Wood and Party), (9 m. 36 ch. to 9 m. 62 ch. — 26 ch.)—

- (1) For the first 10 ch. the country is the same as along Sullivan's length, followed by 2 ch. all coarse gritty sand. From this point to the end, some 14 ch., it consisted of shingly sand traversed by three horizontal beds of clay pug.
- (2) The first 8 ch. of concrete were gun-placed and the balance hand-placed.
- (3) In the gun-placed work the only cracking is a length of  $1\frac{1}{2}$  ch. along the right side spring. In the hand-packed the first chain has no cracks, but this is followed by some 15 ch. of rather badly cracked arch with some 7 ch. of side wall cracks mostly along the left side.
- (4) The average thickness of concrete is (inches)—

	Hand-placed.	Gun-placed.
Left wall .. .. .	13·0	17·1
Right wall .. .. .	12·7	17·0
Left shoulder .. .. .	8·7	15·6
Right shoulder .. .. .	9·5	16·7
Crown .. .. .	7·8	15·0

- (5) In the gun-placed length the walls are good, but there are cavities over the arch for approximately half of each length concreted. The hand-placed work is poorly done, the wall thickness being under requirements in places with large cavities over the arch and inadequate thickness. Gun-work must be regarded as reasonably satisfactory. Hand-work poor and shows no great effort to fill shoulders and crown.

5. *South End* (Eade and Party), (9 m. 62 ch. to 9 m. 67 ch. — 5 ch.)

- (1) Except for  $1\frac{1}{2}$  ch. of slip at the end the country, was packed sand with some pug seams.
- (2) All concrete was hand-placed.
- (3) The work is free from cracks.
- (4) The average concrete thickness is (inches)—

Left wall .. .. .	13·8
Right wall .. .. .	14·4
Left shoulder .. .. .	13·2
Right shoulder .. .. .	15·0
Crown .. .. .	10·8

- (5) The walls and shoulders comply very reasonably with the requirements, but there are cavities over parts of the crown. On the whole the work shows attempt to do a good job.

## CAUSES OF FAILURE

The causes of failure are really twofold - firstly, in that the strength provided by the design, as interpreted from the drawings, was inadequate; and, secondly, in that the workmanship was in some major respects faulty and very greatly reduced the strength which would otherwise have been available.

As a result, costly repairs are now required, but the extent of these has been greatly increased by failure properly to investigate the cracks when these were first reported, and to take measures then so to amend the design as to prevent their occurrence along the length still unstarted.

## DESIGN

The design adopted was new to this country and followed American practice by having vertical side walls instead of these being arched in accordance with the standard hitherto followed for New Zealand railway tunnels.

There is nothing inherently unsafe in this design of structure, as wide experience elsewhere in all classes of country has amply demonstrated, provided the wall thickness is made adequate. Where this becomes relatively great there is some waste of concrete, but a section of this type has the advantage, during construction, of being easier to timber and of offering better facilities for the mechanization of the work. It was for these reasons that it was adopted.

It has been used previously in New Zealand only in some of the Waikokopu to Gisborne railway tunnels undertaken shortly before, but the design as adopted there was for use in hard rock having horizontal beds with no side pressure, and the side walls were lined with pumped concrete generally 19 in. thick placed against the solid ground. Under these conditions it proved entirely successful.

There are no records of the preliminary investigations made to establish the class of country likely to be encountered at Fordell and Turakina. No boring was done (this was not exceptional) and no geological report was obtained. It was, however, apparently considered that hard rock would be met, as amongst the first plant to be supplied was a full equipment of rock drills. It is difficult, however, to determine how such an assumption was justified and why no real preliminary investigation was carried out.

There are also no records of the preliminary discussions regarding the design, but the matter was certainly not referred to the Designing Engineer, and he did not take part in discussions. This also is not exceptional, as he is usually not consulted unless extraordinary difficulties are anticipated and these were reasonably not to be expected. It would appear that it was decided that the ground would prove similar to that met with on the Gisborne railway and that the same design could be used, as no special plan or specification was prepared.