

The initial instructions from Head Office to the district officers were largely verbal and given during visits of the Inspecting Engineer. For this reason, apparently, there is no record on the files of the official number of the plan to be used, nor of any specification having been sent, and, except that the only plan available was that prepared for the Gisborne tunnels, it is really largely surmise that this was the one adopted. However, from the absence of any copies of it, and of any specifications in the District, Resident, or Works Engineers' offices, it seems very doubtful whether any were ever supplied. Plans were, however, provided giving full particulars of the type of timbering and of the steel profiling for the concrete work. These showed the tunnel dimensions and, *inter alia*, some measurements of the required concrete thickness. It was apparently from them that the tunnels were built, but without any directing or explanatory specification. Whilst the details of the timber and of the profiling they afforded were complete, those of the concrete were ambiguous and the interpretation unfortunately adopted, possibly justifiably, was that a wall thickness of 12 in. and a crown thickness of 9 in. was all that was required. This should be compared with the general thickness of 19 in. placed at Gisborne. Neither plan gave details of weepholes nor of the footings, and the latter as actually constructed are only 1 ft. deep and 1 ft. 9 in. wide, which in country of the class encountered is quite inadequate.

The Fordell Tunnel was started before Turakina and, though hard rock was not encountered, the ground stood well, that at the north end being a firm sandy clay and at the south end a soft papa. Neither showed any immediate signs of side pressure, and for this reason, presumably, no attention was paid to the adequacy of the wall thickness. As the work proceeded, and when Turakina was opened up, the country changed to a fairly compacted sand, but on exposure becoming loose sand requiring close lathing to prevent it rilling down. Moreover, considerable pressure was evident, necessitating the use of intermediate timber sets in parts of the Fordell and almost entirely throughout the Turakina Tunnel. This should at once have made it quite plain that the intended wall thickness was insufficient, especially realizing the vibration inevitable during the passage of a heavy locomotive followed by a long train. This was even more serious because of the restriction to the minimum of 12 in. in the thickness of concrete due to the boarding-up of the legs (in some places into the arch). It must have been obvious to any one with knowledge of tunnelling that the ground was very heavy and the timbers were taking considerable weight. As the timber gave way or rotted the entire weight would be supported by the concrete alone. No change was made in the wall thickness except instead of increasing it virtually to reduce it to the minimum of 12 in., or in places even 11 in. The question of its adequacy or otherwise does not appear to have been raised, and no reports referring to the matter appear on the files.

Another factor which should have drawn attention to this matter is that shortly after the commencement of tunnelling the ground was found to be so loose that anchors could not be provided for the mechanical scrapers intended to be used. They were therefore abandoned, and all spoil was hand-shovelled throughout.

In this respect, therefore, though an American type of tunnel was adopted, American practice requiring the proportioning of the concrete thickness to the class of country was neglected; and again, instead of placing the concrete by using a concrete gun, or pump, and finally grouting up any cavities in the arch, which are more difficult to avoid with its timbering than with the old type, all the Fordell and much of the Turakina concrete was hand-placed, and no grouting whatever was done.

Thus, whilst the change was made to provide for mechanization of the work, this was abandoned, and with it the use of the well-proved safe standard type of tunnel in the construction of which all concerned were fully experienced.

#### WORKMANSHIP

The work was done by co-operative contractors, there being four parties always at work, one at each end of both tunnels, each having a head man who was a member of the party, in charge of operations. These head men, and a sufficient number of each party, were tunnellers with considerable experience in the construction of railway tunnels as built to the old standard design. A number of the other men were new to tunnel work, but there was admittedly a sufficient leavening of experienced men to permit the satisfactory carrying-out of the job. None of them, however, had been engaged on tunnels built to the design adopted.

The Public Works overseers and supervising foremen were experienced miners and, except for one foreman, had had considerable experience in constructing railway tunnels, but again to the old standard and not to the new design. Their records in the Department are good.

Neither workmen nor supervisors were therefore by experience familiar with any pitfalls attaching to the new type of work. At the same time their experience was quite adequate to teach them what had to be done to ensure a good, sound job. For example, they would be expected to know that all concrete must be of the full thickness; that it must bear up against the solid country, except where otherwise specially approved; and that then solid packing must be inserted between this and the concrete. Nothing more than this is called for by the design adopted.

The working parties each signed a contract which embodied a schedule of the rates payable for the different classes of work involved, but not a specification relating to the requirements of the tunnel work and the methods to be followed in executing it. They either received, or had access to, the plan previously referred to, giving details of the timbering but which was ambiguous regarding the concrete thickness, and deficient as to the placing of weepholes and the dimensions of the footings.

They were thus mainly dependent for details on verbal instructions given as and when necessary by the supervising staff, or otherwise on their assumed knowledge and experience of what is essential in good tunnel-construction practice. The absence of any specification, and of any written instructions, unfortunately makes it impossible to know whether they did all that