was asked, and, indeed, whether the supervisors themselves knew definitely what to demand. In this respect there appears to be a wide difference of opinion as to who gave certain orders, and what they meant, and as to when they were given and/or cancelled; again there was a considerable divergence in the practices followed in their application. One case in point is the boarding up in front of the legs of the timber sets said by some to be universally applicable, by others to extend also up into the arch, but by others to be restricted to holding up short lengths of ground. An approximate date is available for the issue of this order, and it is stated it was subsequently cancelled, though when, and if, this was done, or if the cancellation was observed, is not definitely ascertainable.

In spite, however, of these facts and happenings, it is held that the presumable general expert knowledge of essential requirements on the part of engineering and supervisory staff should have prevented some of the disgraceful conditions found, though even amongst those assumed to know there appears to have been much difference of opinion as to correct practice, and the absence of a specification is therefore all the more regrettable.

The main difference so far as workmanship is concerned between the new and the old type lies in the method of timbering and the effect this has on the placing of the arch concrete. In the new it is held to be much more difficult to know whether the concrete is bearing up against the roof laths, and, moreover, there is not the same incentive in ensuring this that there was with the old bar method, where the bars had to be removed, and where this could not be done unless the concrete or packing held the laths. Again, in the new, the arch bars, which are transverse, and which are left in place, make it impossible to push the concrete forward so as to get it tightly packed over the crown. This applies also when it is placed by the gun, though with it the arch is automatically better filled. Actually with the type of timbering authorized it would be practically impossible, except perhaps with pumps, completely to fill the crown, and either the timbering should have been redesigned or grouting should have followed as is the practice in America. The difficulty appears to have been realized, but no remedial measures were taken, and this may have led to a belief that complete filling was not necessary provided the required minimum thickness of concrete was placed.

No test holes were made by borings in crown of the arch to see that sufficient concrete was going in to give the required thickness. Had this been done, and the fact revealed that the crown concrete was far too thin, it could easily have been rectified by bridging back the laths over the centre of the cap to allow sufficient room for the concrete to be pushed over the top of the cap to fill the cavity behind, as it is practically impossible to fill back to the laths by pushing it underneath the segments; or grouting could have been employed to fill the voids.

The results show that the work done with the concrete-gun is, at least along the arch, much superior to that where hand-work was adopted, and it is unfortunate that, for no apparently good reason, this method was not followed throughout.

The main defects in workmanship lie in the failure fully to fill the arch so as to catch the country. This, as already indicated, applied more particularly where the concrete was hand-placed, and where a considerable variation of practice is evident. Some contractors took every care to fill the shoulders right up to the lathing, whilst others were content merely to place enough to comply with the minimum requirements, and this in some instances without packing the resulting cavity between it and the arch lathing. This is a practice which they should have known was bad and which the supervisors should have observed and checked, but which it would appear some must have condoned. It is, however, along the crown that the poorest results are evident, but the fact that in places the filling is reasonably good shows that a more satisfactory job could have been done if a more adequate effort had been insisted upon. Much has been said about the slumping that would occur along the crown following the vibrating of the profiling immediately after the concrete had been placed in order to ensure a good face on the exterior of the work. Some slumping would necessarily follow, but this could hardly have occurred to anything like the extent evidenced had the lower portions of the arch been properly filled as the crown was approached and the concrete not made too sloppy.

Had the arch work been properly executed the structure must have stood much better, and some of the cracking might not have resulted, or would not have become evident so soon. At the same time the failure of considerable portions must eventually have followed, especially where the 12 in. thickness of wall and 9 in. of arch standard was adopted. This is evident from the cracking now observable in the gun-placed length of the Turakina Tunnel. Here the wall thickness averaged about 16 in. and the arch work was fairly good. No cracks were noticed for about three years, but they have since occurred and appear to be extending. Some of these may be ascribed to cavities over the crown; others are more difficult to explain; but the fact remains that 16 in. thickness is, under the circumstances, not up to proper safety requirements in the class of country involved.

There seems to be no doubt that the engineering staff, because of the ease of tunnelling and absence of the usually occurring difficulties, became imbued with the idea that the ground was safe and that only a relatively thin lining was required. This may have affected considerably the observance of the usual rigid precautions and also resulted in the question of the adequacy of the lining not being considered.

All those directly concerned with the construction of the tunnels appear, from the evidence obtained, and from the frankness with which this was given, to have been keen both to push the work along and also to ensure its being a good job within the limits of their instructions