

## **Park Lane improvement scheme**

by

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and

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Mr O. A. Kerensky (Freeman, Fox & Partners) in congratulating the Authors on the scheme at Hyde Park Corner, said that the traffic was now travelling much faster and that the splendid scenery had not only been preserved but had been improved. Mr Rayfield and Mr Clayton were among the leading practising traffic engineers in Gt Britain. He had attended some lectures by Mr Clayton some years ago, and knew that some of the Author's work was still used today in spite of the many further scientific achievements by various learned bodies.

137. He confined his remarks to Mr Granter's Paper, dealing first with construction. Referring to the use, for the first time in Great Britain, of ICOS walls and remarking on the Author's courage in using them he asked if they could be used as structural elements—in the scheme they had been used non-structurally, as shuttering or cofferdams.

138. He asked why the underpass had been constructed in situ and whether any pre-cast work, which had been successful in other places, had been considered.

139. Phasing of the works must have given a headache to everyone. He wondered whether it had been necessary to change some of the traffic plans and what claims there had been from the Contractors if this had been necessary.

140. He found the pedestrian underpasses confusing and tiring. For old people they must be exhausting. Referring to the murals, he said that undoubtedly they were interesting, but were they not a waste of money? Surely busy Londoners would not notice them.

141. Commenting on the general finishing of the underpasses both for traffic and for pedestrians, he pointed out that the cost of finishes for the main tunnel had been 10% of the cost of the tunnel, and the cost of finishes in the pedestrian underpass had been 80% of the cost of the structural work. He suggested that a study group be formed to try to discover cheaper ways of finishing underpasses, of which there would be many miles in urban areas. None of the finishes was entirely satisfactory and all were expensive. He wondered whether, after all, concrete cast against some specially designed shutter would not be the best answer.

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\* *Proc. Instn civ. Engrs*, vol. 29, October 1964, pp. 293–340.

It is regretted that the file containing all written contributions to this discussion was lost. Those who made written contributions are invited to resubmit them for publication.

142. He was somewhat critical of the fact that the underpass led on to the verges between two fast moving traffic streams. He had tried to stay on this verge as an experiment but had found it a little frightening, and wondered whether the verges would be used.

143. He congratulated those concerned on the underground car park. This was losing money because cars were still parked in the streets, but that would not continue much longer and then the garage should pay for itself.

144. Regarding heating of the underpasses, he wondered whether this was justified. If everyone adopted this principle surely there would be a shortage of power in cold weather.

**Mr K. C. Torrance** (London Transport Board) congratulated the Authors on their very wide ranging Papers, and elaborated on one or two points which were of particular interest to London Transport.

146. Before work was started alongside the escalator shaft it was realized that failure of the strutting system to prevent ground movement could cause cracking of the cast iron escalator lining. In order to prevent such movements, which could in an extreme case cause catastrophic failure, heavy closely spaced struts were to be used. Unfortunately it was not possible to derive a relationship between change in diameter and change in stress which would enable permissible limits to be set to movement of the sheet piling. Also it was not known with any certainty what stress already existed in the cast iron.

147. It was evident that the iron could already be locally stressed almost to breaking point, but it was not thought likely that the general stress level was much above  $4\frac{1}{2}$  ton/sq. in. What they were able to determine from specimens cut from the tunnel iron was that the ultimate tensile stress varied from 7 ton/sq. in. to 12 ton/sq. in., and that the modulus of elasticity for these specimens, calculated on a stress range of 0-4 ton/sq. in., varied from 13 to  $19 \times 10^8$  ton/sq. in.

148. As Mr Granter had pointed out, the ICOS process had not been used in Great Britain before and little evidence had been available to show what ground movements were likely to result when it was used in clay. Strain and diameter measurements made in the escalator appeared to show that ground movements due to the ICOS process were of the same order as those resulting from the use of augered piles. The comparative evidence was by no means conclusive owing to the varying depth of the escalator and other factors, and he would like to see further work done on this.

149. The maximum recorded change in strain in the iron due to the piling was equivalent to a stress of about  $\frac{3}{4}$  ton/sq. in. tension before the dumpling was removed and the maximum recorded change during the whole of the works was about 2 tons/sq. in. This was ample evidence that the piles were being allowed to move.

150. He admitted that at this time, with less than half the work done alongside the escalator, they had been seriously concerned for the safety of the shaft. Factors which militated against the maintenance of the strut loads and stabilization of the ICOS walls included timber packings, which were eventually replaced by steel, and the leaking of oil from the Freyssis jacks or their connexions.

151. Pressure gauges had been fitted but it had been understandably difficult for the constructor to convince every man of the importance of maintaining the loads in the jacks and accidents had, of course, happened. It had therefore been found necessary to institute a regular routine for reading the pressure gauges throughout the day and night. Despite all precautions, however, on at least one occasion the loss of load in one strut had first been detected by means of the strain gauges inside the escalator shaft. It might be that on any future works of this nature it would prove worth while to install the Freyssis jacks, together with their associated connexions and pressure gauges, as complete and well-protected units less liable to damage by men working alongside.

152. A factor which, in the event, had caused less trouble than had been expected was the effect of daily and seasonal changes in temperature. Daily variations resulted in regularly repeating variations in strut loading which had a negligible effect on the tunnel, and seasonal variations were absorbed by the slight adjustments necessitated in any case by the slight leakages.

153. Mr Granter had referred to the attempt made to return the tunnel to its original shape. This had been done by jacking massive loads into the large number of struts in one bay whilst the strain gauges were constantly read and re-read. Field telephone communications had been maintained during the operation and the effect of each increment in loading had been noted before any further increment was authorized. The result to the escalator tunnel had not been quite what had been hoped, since the side of the tunnel appeared to flatten slightly, but the tensile stress at the crown of the tunnel had been slightly reduced.

154. As Mr Granter had said, the insertion of additional struts and higher loadings had resulted in a general improvement in the stress conditions in the escalator tunnel and the peak values of stress had never again been reached. Ground movement was still continuing but the readings taken since the completion of the contract indicated that the highest recorded values were not likely to be reached again.

Mr Donovan H. Lee (Donovan H. Lee and Partners) said that both Papers were excellent, and he thought that all those familiar with the site and the work would agree that from the moment the work started the traffic seemed to move more easily, and there seemed to be less delay. This was extraordinary—usually there was a considerable hold-up when a comparatively small roadway improvement was undertaken, but on this occasion the traffic flow had been better.

156. He congratulated Mr Granter on his Paper, and regretted that Mr Fuller had been unable to take part in the meeting.

157. ICOS walls had been used but the method had been different from that adopted in Milan where two walls had been put down and digging had been carried out to provide the roof of the tunnel, then the roof had been concreted. Everything dug since then had been dug as a tunnel under the roof which had been concreted. Would Mr Granter comment on the more expensive method adopted at Hyde Park.

158. In Toronto, for the east-west subway now under construction, it had been decided not to use ICOS or any similar method but to dig all the work in the open. Sheet piling had been used and the modern method of anchoring back into the ground was employed instead of strutting from the front.

159. Everyone would agree with the Authors that the old Hyde Park Corner roundabout had been very bad. The weaving length had not been great enough, and the vehicles rushed at each other.

160. The Authors had raised the question of whether the underpass should lie north-south or east-west. The Paper suggested that the balance between the two was fairly even, and even that a north-south underpass would have been preferred. It would not simply be a question of the number of vehicles. There was even a cost factor against the east-west direction. With separate tunnels each side of the escalator subways, the risk of each being a single lane tunnel could not be taken because in the event of accident and fire the fire engine could not get to it. This meant two double lanes, but still the traffic figures were only 1400. The Authors therefore had to make two, two-lane underpasses going east-west whereas on their own argument, if they had adopted the north-south direction, they could have had one spare way. There might be some reason for their choice which the Authors had not given.

161. Comment had been made on the finishes. In an underpass with which he was concerned more interest had been expressed in soundproofing. The lighting was very good indeed, but a cheap durable lining which also absorbed a lot of sound was also needed for this type of project.

Mr D. G. Jarvis (Holland, Hannen and Cubitts Ltd) congratulated Mr Granter on an interesting and detailed Paper which gave engineers and contractors not connected with the work a good picture of the problems involved. It had also been very interesting to those who, like himself, were concerned with the many technical problems of carrying out the work as well as the safety of installations, traffic and pedestrians. He had been pleased to note that the number of accidents had fallen during the construction period, but it had occurred to him, judging from the number of red lamps that were smashed, that perhaps some accidents had not been reported.

163. Mr Granter had given particulars of the pre-tender planning and site investigation which had been carried out, but in spite of this, many problems remained to be disclosed by the Contractor. No doubt the investigation of all existing services and future requirements, for instance, had given the L.C.C. Chief Engineer and his assistants many headaches, as it certainly had the Contractor as the site had been opened up.

164. Mr Granter in his Paper had covered all the major problems involved in the design as well as in the construction of the works. Mr Jarvis therefore proposed to deal briefly with four points which seemed to him to merit emphasis and which might possibly have some wider application.

165. In practical terms the ICOS/Veder process had undoubtedly proved to be suited to the site conditions as well as the mixed nature of surrounding structures. Not only had it been a major help in keeping down the noise of construction, but the whole underpass construction had been carried out with quite negligible disturbance to ground and structures alike, and this he thought had been a notable achievement. The stiffness of the diaphragms as opposed to other forms of construction had proved a great practical advantage, as also had the cast-in-situ construction which was integrated, as it were, with the ground, and although it was difficult to convince engineers on this point, there was no evidence at all of any ground movement during the excavation for the diaphragms in the bentonite-filled trench.

166. The success of this process suggested that considerable economy and speedier construction could be achieved if the diaphragms were used as part of the permanent structure. This had, in fact, been carried out successfully elsewhere.

167. A major factor in the planning and execution of the work had been the heavy traffic to be dealt with throughout the works, and he referred to the excellent co-operation from the Metropolitan Police. The L.C.C. had, in consultation with all the authorities concerned, provided a complete scheme for tenderers for traffic and constructional stages.

168. In his experience, construction stages in one form or another laid down by the engineer seldom seemed to suit the contractor. The Park Lane contract had been no exception to this. He suggested that a provision could often be made in contracts of this kind for joint consultation, after the award of the contract, to finalize such matters.

169. This sort of consultation had, in fact, taken place to re-phase traffic arrangements, but it seemed to him that only the great urgency of the matters had brought all those concerned together, and he would rather have seen this taking place as a matter of course at the outset.

170. Quite admirable drawings had been provided by the L.C.C. showing existing and new services over the whole site. Every conceivable type of service had been encountered in the work, from co-axial television cables to hollowed wooden pipes—the latter, happily, not in operation. As usual, accuracy of the information supplied had not been guaranteed and the Contractor had had to allow for any effect that these services might have on his work. In fact, it had been quite impossible to obtain even half the information necessary from the authorities to discharge this obligation. Although these matters were usually handled with some understanding by engineers, he suggested that extreme cases such as had been met on this contract highlighted the need for more realistic clauses, to deal with matters of this kind.

171. At the time, this had been the biggest urban improvement scheme carried out for many years and it might be of interest to note what were the characteristics of this type of large-scale urban work. For a contract of this magnitude, a comparatively large organization was required, and this had to be backed up by a site installation capable of dealing with the very many varying requirements of the work. A staff averaging some 55, for instance, had been necessary at Hyde Park, and this was high for construction work of this order.

172. Site installations had also been of greater capacity, and more numerous, so as to cope with fluctuating demands and tempo. Much more detailed planning of the work was entailed with the many authorities who tended to guard over-jealously their own particular interests, and all these were essential if the work was to run efficiently and economically and to provide as little interference as possible with the life of the city. He suggested also that engineers, too, had a bigger part to play in the success of this type of work, in that the degree of their preparation and particularly co-operation required was also greater.

Mr J. A. Neill (Messrs Flint and Neill) said that it was not clear from the Papers what consideration had been given to the amenities to be afforded by the tunnel design. Had it been taken as read that this generation could afford to keep the water out, and the light on, and to have the comfort of that cosy eggshell finish? The total price of these amenities could well be the difference in our balance of payments. Beauty in the wide open spaces above was essential and had been achieved. A figure of 44% for the finishes and lighting for subways seemed reasonable although he had not seen the murals, but 15 to 20% for the underpass itself might be considered extravagant.

174. The cost of lighting had not been given but it could well be 5% of the whole. Was this necessary? Why not have graduated darkness as one entered instead of graduated light as one left?

175. Were finishes necessary? This feature alone seemed to account for about 8% of underpass costs, which accorded closely with figures for another underpass of which he had knowledge. There were tunnels which for their surface finish had the rough hewn rock.

176. Why keep the water out? It was impossible to tell the cost of waterproofing from the Paper but it could well account for 5% if not more. It would be of interest to know what measures had been adopted for sealing leaks and how effective they had been.

177. Was 2 ft 6 in. enough to prevent wall shyness? Could some research be put in hand about ventilation problems? This tunnel was not particularly long. There was a theory that natural ventilation by the traffic itself could be adequate, and it seemed that some useful research could be done into this problem.

Mr C. B. Stevens (G.K.N. Reinforcements Ltd) said that in Appendix I on page 13 tender costs were given for the underpass which included a figure of £144 000 for electrical installations. This was one-sixth of the cost of the structure. Could the Authors give a breakdown of this figure to show the cost of the supply and installation of the road heating equipment alone?

179. It appeared from the description of the road heating that considerable care was needed to lay the heating elements and to allow for any future creep of the tarmac which might occur. He also understood that the optimum temperature of laying the sand/asphalt covering had been the same as the maximum temperature before the protective sheathing to the element would be damaged.

180. What considerations had been given to the use of a low voltage system incorporating a steel mesh which appeared to be more robust and easier to lay? This would not be affected by the hot tarmac, would act as reinforcement and serve

to retard any creep. Secondly, what type of heating would the Authors recommend for any future road heating schemes?

181. Mr Kerensky seemed to draw a veil over road heating, but the recent circular from the Ministry bore out the necessity for road heating at least where gradients would otherwise cause traffic blockage or unpleasant accidents during severe weather conditions. Under normal winter conditions it was necessary only to melt early morning ice or snow. From then on the traffic would keep the snow melted.

Mr F. H. Small (London County Council) said that Sir Joseph Rawlinson was unable to be present owing to ill health but had sent a short note on the Paper which Mr Small read.

183. Sir Joseph said that two aspects of the Park Lane scheme were worth emphasizing. First, the arrangements made to cope with the very heavy traffic during the months of construction were, according to the police, very successful. This was largely due to the generous allowance made for the width of temporary roads, particularly in the park, and the decision to make these roads in concrete, thus avoiding the risk of their becoming unusable owing to heavy traffic and bad weather after months of very hard wear. Secondly, considerable thought was given to the method of constructing the underpass immediately adjacent to the hospital, and as far as he was aware no measurable movement of the ground was recorded. A real effort was also made to provide good temporary footways for pedestrians, and he believed that on the whole this was largely successful.

184. Mr Small also added some comments of his own. As had been made clear in § 10, there had been no possibility of diverting traffic away from the area of the improvement work as all other roads to and from the West End were already heavily loaded. The most careful consideration had therefore been given in planning the staging of the work to the volume of traffic to be dealt with and the width of temporary roads to cope with this problem. The fact that, despite a steady increase in the volume of traffic during the construction period, the traffic flowed without any serious holdup, and flowed more smoothly than before the work started, was evidence of the success of the pre-planning done. It was a tribute to the co-operation of the Metropolitan Police directing the traffic over the various diversions.

185. It was originally intended that the temporary roads should be constructed with a hard core base and tarmac surfacing, but finally it had been decided to construct these of unreinforced concrete 12 in. thick with no surfacing. This had been a wise decision, because if there had been any breaking up of the temporary roads under heavy traffic it would have been difficult, if not impossible, to carry out repairs to these roads without obstructing the traffic, as there would have been nowhere to divert the traffic while the repairs were carried out.

186. He also referred to the construction of the underpass adjacent to St George's Hospital where the excavation had been about 27 ft below the hospital foundations and only 3 ft away from the corner of the building. The fact that the maximum settlement recorded on the wall of the hospital building on completion of the work had been less than one-eighth of an inch was evidence of the correctness of the precautions taken during the work, as described in § 38 of the Paper. It was, however, also worth emphasizing that there had been no less difficult a problem in constructing the underpass tunnels adjacent to the escalator shaft at Hyde Park Corner station. Here again, the new work had been only about 3 ft away from the shaft at each side, and as the tunnels had converged over the shaft as it reached a lower level, the vertical clearance between piles and the cast iron rings of the shaft had been only 3 ft.

187. The special precautions taken in these circumstances, as described in part by earlier speakers and in § 40 of the Paper, had been fully justified by the close control afforded, the ability to observe the effect of the excavation on the escalator shaft and the ability to take without delay the necessary steps to prevent undue distortion of the cast iron rings.

Professor J. K. T. L. Nash (King's College, London) said that the method of building a wall in a mud filled trench seemed at that time to be almost like magic and the engineers concerned with it had had to be quite satisfied that it would work. Having had the experience of using it not only on this job but on a number of other jobs engineers now knew that when properly used, this expedient was good.

189. Work of this nature was already being done in Milan and elsewhere, but in this case London clay had to be dealt with and no one was able to say what the effect of bentonite mud would be on London clay or a clay very much like it.

190. At that time, no stability analysis had existed, but it had not been difficult to extend classical theories in order to include the mud loading and equations to this effect had been published in an Institution Symposium.\* These indicated that the critical condition was likely to arise where there were granular soils with a high ground water level. It was known that when this condition existed the trench could fall in, because a few had done so, but fortunately in this case the Engineers were dealing with clays and no trouble of that sort had arisen.

191. Next, it had seemed possible that the mud would soften the clay by running into the fissures, and this seemed to be rather too difficult to establish. Samples of the clay had been taken in 1½ in. sampling tubes, and these had been immersed in mud under pressure. The strength had been measured and was found to have decreased considerably. The test had been repeated using 4 in. diameter tubes, and it had been found that the softening extended only to a depth of about ¼ in. This had therefore wrecked the 1½ in. sample but had not damaged the 4 in. sample, so that it appeared that this was a surface effect only.

192. Lastly, they would have liked to know what sort of lateral displacements took place in the ground when a trench of this sort was opened. No successful measurements had been made. It was known that St George's hospital cracked only very slightly, if at all, as did the Decimus Burton screen.

193. Dr Ward would say more about the measurements taken on the escalator tunnel, but it would have been useful to have had measuring devices in the ground, and he hoped that if anyone else were carrying out work of this sort they would make provision to take full measurements, because there was still much to be learned about this method of work.

Mr E. F. Humphries (G. Maunsell & Partners) said that comment had been made about the reduction in traffic. In his experience of any major work in the London area, as soon as motorists knew that work was going on they avoided the area, but in every case, the moment that the motorist knew that the work had been completed, the traffic built up there again, in this case much in excess of the previous traffic. This in no way detracted from the admirable arrangements made for the Hyde Park job, which he personally had found excellent.

195. Mr Granter was aware that some work had been done and published in the technical Press seven or eight years previously about experiments to determine the length of vehicle tunnel which could be used without forced ventilation to deal with motor fumes. A figure given in that research had been about 1200 ft. The Hyde Park tunnels were just over 1000 ft, and it might be that the L.C.C. had thought it wise to put ventilation into the tunnel as it was getting near the limit.

196. Another vehicle tunnel was 790 ft long and no forced ventilation had been put in, although provision had been made in the roof of the tunnel for ducts and for the installation of plant later if it were necessary. After several years' operation it had proved not to be necessary.

197. Several comments had been made about linings and one speaker had asked

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\* NASH J. K. T. L. and JONES G. K. The support of trenches using fluid mud. *Symposium on grouts and drilling muds in engineering practice* (held at Instn civ. Engrs, May 1963). Butterworths, London, 1964, 177-180.

whether a lining was necessary. One difficulty which occurred in tunnels was due to mud being carried through the tunnels by vehicles. This was thrown up not only on to the walls to a height of several feet but over the roof and ceiling. It would be interesting if Mr Granter would state the measures which had been necessary since the opening of the tunnel for washing and cleaning. This was a serious problem, and he did not know how it could be avoided. It meant that the lining of the tunnel must be washable with detergents and it must retain its light colour, because lighting engineers were strongly of the opinion that a light coloured surface must be provided for the walls so that vehicles could be seen against them.

198. Assuming that an alternative method had been considered of the graduation of light outside the tunnel, had thought been given to the use of an awning such as that outside the Orly underpass? The lighting was graduated from relative values of about 1000 in normal daylight to 100 under the awning and 10 inside the tunnel. One could see a vehicle under the awning from outside and then in the tunnel from under the awning. With a 400 ft length of awning the eye adjusted itself to the light inside the tunnel. Perhaps Mr Granter would comment. Possibly the appearance of the awning, which would have come well up into both approaches of the east-west tunnel, had ruled out the proposal at the Hyde Park underpass.

199. Another question which had been raised, associated with lining, lighting and cleaning, was noise. As one drove through an underpass of 800 to 1000 ft in length, one normally drove with the windows closed, and the noise was not great enough to require elaborate measures to absorb sound, which in any case would be prohibitive in cost and would probably counteract the requirements of reflexion and washability. He did not think that such elaborate measures were necessary, and perhaps the Authors would comment on the point.

200. A similar point arose in connexion with all the pedestrian subways, excellent though they were on the Hyde Park Corner scheme. The subways were elaborately lined on the ceilings to absorb sound. This must have been very expensive, and, in the light of experience, he wondered whether the Authors thought it necessary.

**Dr W. H. Ward** (Building Research Station) said that Mr Granter had noted in his Paper that the Building Research Station had been asked by London Transport to keep a watch on the movements and deformations of the escalator lining at Hyde Park Corner where the two cut-and-cover underpass tunnels had been constructed on either side. This work had been necessary in order to make sure that the travelling public could continue to use the station safely. The Building Research Station had carried out observational monitoring of London Transport tunnels during constructional disturbances on several former occasions. He believed that the work had been of great value to all parties concerned, not only to London Transport but also to the various consulting engineers and contractors.

202. The monitoring of the tunnels was carried out by means of special strain and displacement measurements on the linings. Observations were made to check any movements which occurred before any new external disturbance was created, and they were continued as the work progressed in association with each constructional operation. This led to relationships being established as for example between the approach of an excavation and the distortion of the lining, and enabled any adverse trends to be anticipated so that suitable modifications might be made in the new works to avert damage. Alternatively the results might indicate that it was wise to proceed with caution, working at night when the trains were not operating. On the other hand the monitoring sometimes showed that an operation which had been considered to be rather dangerous could proceed quite safely. Since these methods of monitoring had been introduced, disturbance and unexpected incidents, which in the past had sometimes involved fracturing of the lining, had been avoided enabling the public to use the underground system with greater safety.

203. The operation of constructing two underpass tunnels alongside the escalator,

and about five feet away on each side, was one of the most hazardous he had had to monitor. He did not think that either the readers of Mr Granter's Paper or the travelling public appreciated the delicate nature of the operation.

204. A ring of escalator lining properly bolted together would not even stand up freely under its own self weight. In the more critical sections at Hyde Park Corner many feet of overburden had been left over the lining, while within about 5 ft on either side the ground had been completely removed. Without any doubt he had formed the opinion that this system provided virtually no resistance to lateral spreading and that the escalator lining would squat just as much as the lateral supporting arrangements used in the underpass excavations allowed. In fact, the supporting arrangements had allowed the ground and the escalator tunnel to distort.

205. It was not possible to carry out an excavation by any known process or any process that was likely to be used in the future without causing some movement of the ground. It might be possible to finish certain forms of construction with no net movement, but in the process of excavation there was certain to be movement. With these conditions in mind, and in the light of previous experiences with the distortion of cast iron tunnel linings, he had expressed the view that it was desirable to limit the changes in the 24 ft diameter of the escalator tunnel to about  $\frac{1}{4}$  in.

206. In order to keep the lateral yield of the ground about the tunnel within such small limits, it was clear that the underpass walls needed to be pushed apart to counteract the inward movement associated with excavation. This the Contractors attempted to do, but in many cases the strutting system employed could not accept sufficient load.

207. In addition, insufficient attention had been paid to the yield of the transverse diaphragms between the eight bays illustrated in Fig. 21 and Appendix 2, due to deflexion of the steel beams and compression of the wooden wedges. The yield of these diaphragms, although they were transverse to the tunnel, caused lateral movement of the escalator tunnel alongside the adjacent unexcavated bays.

208. Three typical vertical cross sections, A, C and E, through the escalator tunnel and the underpasses and also the changes in the vertical and horizontal diameters of the tunnel plotted against time were shown in Fig. 25. The positive sign represented an increase in diameter. Between June and October 1961 the ICOS and bored pile walls were constructed and from October 1961 to April 1962 the bulk excavation for the underpasses and their main construction was carried out.

209. Section A was one of the most critical sections where the tunnel was situated abreast of the underpass and its construction had led to an appreciable squatting of the tunnel lining—a maximum change in diameter of over  $\frac{1}{4}$  in. The reverse movement in the vertical diameter shown in March–April 1962 was the only significant rectification of the squatting action brought about by increasing the lateral load in the strutting system and was mentioned in § 40(a) of the Paper.

210. At Section C the movements associated with the walls had been larger than at the other sections on account of their position relative to the tunnel and the greater depth of the tunnel.

211. At Section E, on account of the depth of the tunnel relative to the underpass, the horizontal diameter of the tunnel had at first decreased during the bulk excavation, but as the excavation became deeper, the horizontal diameter had increased. This was a typical example of the response of a tunnel lining to the changing shape and position of a surface excavation.

212. Observations on vibrating-wire strain gauges fitted to the ribs of the tunnel segments were taken much more frequently than the diameter measurements shown in Fig. 25. They gave a more detailed picture of the distortion of the lining, a more precise monitoring of the operation and were confirmed by the diameter measurements which could not be made conveniently at close intervals.

213. At each of the sections shown in the figure there was no bulk excavation immediately alongside the escalator during the period June–October 1961 when the

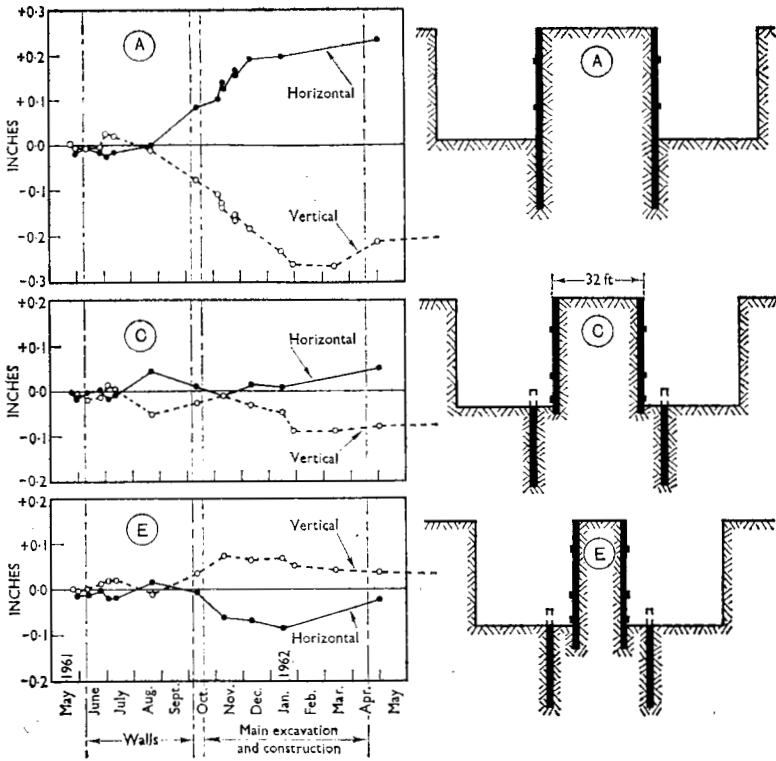


FIG. 25. DISTORTION OF ESCALATOR TUNNEL DURING EXCAVATIONS

walls were being constructed alongside, but bulk excavation was taking place upstream and downstream of the area excavated in alternate bays and this affected the diameters of the tunnels at each section to a minor degree. The diameters of the tunnel had changed by a maximum amount of about 0.09 in. at Section A during this period, but Dr Ward did not think that the amount associated with the adjacent wall construction amounted to more than about 0.05 in. On this site the movements were unlikely to have been any greater if plain water had been used in the trenches during the wall construction in place of the Bentonite slurry.

214. Observations had also been made of the uplift of the Hyde Park Corner Station tunnels which lay at a depth of about 70 ft below ground level beneath the Knightsbridge ramp. During the bulk excavation the station lifted about 0.2 in. and he would expect it to continue to lift as the London clay swelled.

215. The main lesson which he had learned from the operation was that he would not carry out the bulk excavation in alternate short bays because it was impossible to control the movements of the temporary transverse diaphragm walls without a very elaborate strutting system. In his view it would have been cheaper and technically more satisfactory to have eliminated the transverse diaphragm and to have taken the bulk excavation out in layers of uniform thickness along the whole length on either side of the escalator, and to have inserted complete rows of struts on either side which were loaded not to a specified load but to a control set by observations of

the structures being disturbed. This would have provided a much better control over the disturbance to the escalator and would have avoided the costly steel and timber diaphragms which had been a source of weak support. With only the same amount of attention given to monitoring the safety of the escalator as on the present job it would have been possible to have kept better control of the movements and reduced their magnitude.

The Author of the Paper on design and construction thanked the contributors for the interest shown in the work at Park Lane.

217. In reply to Mr Kerensky's question about the use of ICOS walls being used as structural elements, the Author said that he understood that they had been so used successfully in a number of cases.

218. The advantages and disadvantages of pre-cast methods of construction for the underpass were, of course, investigated; the use of pre-cast work, however, was rejected after consideration of the various factors involved at the site.

219. With regard to his query § 139, the Author referred Mr Kerensky to § 11. It was always advisable to keep a flexible approach to any problem and re-phasing of the stages resulted from experience gained during the opening stage of the improvement. This was, in fact, to the advantage of all concerned.

220. The Author did not understand why Mr Kerensky found the subways confusing, as many of them passed straight under the roads. Some, of course, had a branch subway but the subways were clearly sign-posted. Old people usually found walking tiring, but the subways were designed to save them from the almost impossible task of crossing the roads between fast moving lanes of traffic.

221. The choice of finishes to the underpass and subways were naturally limited to the available techniques, although it was not true to say that those chosen were unsatisfactory. Improved techniques were always welcome.

222. The problem of the justification of road heating at the approaches to the underpass was simply an economic one, i.e. was it cheaper to install heating and the plant to generate the power required, or to tolerate the expense of widespread traffic dislocation and delay? It should be noted that the power was supplied only in off-peak periods. As Mr Stevens pointed out in § 181, the Ministry had made investigations and, hardly surprisingly, had come out in favour of road heating in such cases.

223. Some criticism had been made in the discussion regarding the attention given in the underpass and pedestrian subways to visual attractiveness and this is perhaps natural from some engineers. However, it ought to be remembered that one way in which a high standard of living manifests itself was in increased visual awareness, as was evinced by the growing influence of the Fine Arts Commission, the Royal Society of Arts, and the Design Centre. A subway was just as much a part of an individual's surroundings as a landscaped park, and however busy a Londoner, he still had time to observe and gain pleasure from the walls and murals of the subway through which he was passing. Disregarding aesthetic considerations would hardly seem a successful way of solving the balance of payments problems referred to by Mr Neill when so much had been made in the past of the lack of design in otherwise well-engineered British goods, and certainly not a successful way to attract tourists and the foreign currency they brought.

224. The Author thanked Mr Torrance, Professor Nash, and Dr Ward for their contributions, which added to the value of the Paper.

225. Mr Donovan Lee had called attention to the use of ICOS walls in Milan. The ICOS process was used for the first time in Great Britain at the Park Lane Scheme and in view of this it was considered desirable to construct the permanent structure in a more traditional manner. However, as Mr Jarvis pointed out in § 166, the extension of the ICOS process could be considered elsewhere.

226. The Author appreciated Mr Jarvis's contribution, which concisely detailed the problems and reflexions of the Contractor.

227. Mr Neill asked if finishes were necessary. Mr Humphreys had largely answered this question in § 197, but the Author added that considerations of lighting required a highly reflective but non-specular surface.

228. In answer to Mr Neill's comments in § 176, it might well be more economical in some cases to let water in and dispose of it in a suitable manner, but this was not a solution which the Author would normally favour. It was not generally difficult to make a watertight concrete structure and this it was hoped to do in the case of the underpass.

229. The small amount of water that leaked into the underpass through very fine cracks in the roof had been dealt with by attaching neoprene strips right across the roof under the cracks. Water which entered ran over the neoprene to one side of the underpass from where it was carried down the wall in a small half-round plastic channel sunk into the wall and thence to a road channel. This method had been very successful.

230. If Mr Neill referred to § 30 of the Paper he would note that asphalt tanking was only used near the underground station and over the ventilating plant room; the cost of this was only a fraction of 1% of the cost of the underpass. The 2 ft 6 in. width appeared to be satisfactory.

231. In reply to Mr Stevens, the cost of the supply and installation of the road heating system was £11 500. At the time the work was carried out, the road heating system most favoured was the mains voltage type although it was agreed that the low voltage system had certain advantages. In the future the merits of each system should be considered for each particular case.

232. The Author thanked Sir Joseph Rawlinson and Mr Small for their contributions to the Paper.

233. In reply to Mr Neill and Mr Humphreys concerning lighting, awnings were considered as a means of graduating the light values at the approaches to the underpass; however as they would have intruded into the space above the approaches, it was decided to achieve the desired effect less obtrusively through the use of artificial light.

234. With regard to the ventilation, it was considered that forced ventilation would be necessary. In the event, this decision had been justified for although little forced ventilation was required at the underpass under normal conditions, all or most of the fans had come into operation under adverse atmospheric and traffic conditions.

235. As Mr Humphreys stated, there was no problem of noise associated with the underpass. With regard to the ceilings of the pedestrian subways, the Author considered it was essential to adopt measures to absorb sound. In other parts of the County of London less expensive methods of absorbing sound had been used, but, regrettably, no work had been done to determine relative cost effectiveness.

236. In reply to Mr Humphreys, the underpass was cleaned mechanically every six weeks with a machine specially designed for the purpose.

237. The Author was always of the opinion that it would have been preferable to have carried out the excavation as mentioned by Dr Ward; however, the method actually employed was preferred by the London Transport Executive.

238. The Author would like to mention that the Improvement had been opened by the Duke of Wellington on 17 October, 1962.

The Authors of the Paper on planning and traffic engineering regretted that there had not been more discussion on the design of the scheme from a traffic point of view.

240. In reply to Mr Donovan Lee, who had asked about the north-south vehicular subway, the Authors said that the first question that had arisen had been that of levels. On the south of the intersection these had been favourable because of the fall of the ground, but had been unfavourable on the north thereby involving difficulties with traffic connexions to Mayfair which had been considered of considerable importance. Services would also have been difficult to handle. Secondly, on

the south side would it be better to terminate the subway at Constitution Hill or Grosvenor Place? Estimated and observed traffic details before the project started had differed somewhat. If one were to have the best of both worlds, a flyunder would have been required in the underpass itself and this would have meant considerable difficulties with the railway since it would have gone under the whole complex of Hyde Park Corner.

241. The cost of taking the subway into Grosvenor Place would have been considerable. The acquisition of the property to provide the necessary width for the approaches and side roads would have increased the cost by about £2½ million.

242. Although the point had not been made in the Paper, estimates of future volumes of traffic had been made for quite a way ahead and other improvements in mind at the time suggested that the east-west subway would ultimately be more fully used than a north-south subway.

243. A point of interest had been raised in connexion with the handling of traffic during the works. The Authors agreed with those who said it was necessary to plan the handling of traffic beforehand. They did not agree that it could be left for discussion afterwards between the contractor and the police. The original design might well be affected to a major extent by the need to carry the traffic during the works. Experience had shown—and in the L.C.C. they were going ahead even more strongly with this policy since the Hyde Park improvement—that the traffic engineers and the works engineers should prepare a plan of the works and the traffic handling together. The problems should be discussed with the police and the local highway authority and a plan worked out. The Authors knew of few cases where such plans had not had to be changed later, but it was only fair to the contractor, the ratepayers, and the taxpayers that the contractor should have a traffic plan on which he could tender even if it was changed afterwards.

244. In this case there was no question that the traffic flow had built up almost at once—there was no evidence that it had dropped—because proper arrangements had been made. What was important was that these arrangements, both the original plan and any alterations made necessary by alterations in the works or experience in handling the traffic, should be made quantitatively using traffic engineering techniques. The Authors did not wish to disagree with Sir Joseph Rawlinson, but they would point out that it was not a question of providing *ample* width but of providing the *correct* width for the temporary road. Calculations on the Hyde Park scheme had shown that one of the roads would be too narrow to take traffic flow. It was tried and experience showed it to be too narrow. After this all widths were recalculated.

245. Other cases of this could be mentioned. Investigations carried out before starting on a major improvement to the southern approach to Waterloo Bridge showed that traffic would be congested in the morning peak hour and to a less extent in the afternoon peak if the scheme were carried out as planned. The alternatives were a different arrangement of the traffic, which would have meant excessive police manpower, or spending £250 000 on a temporary bridge with consequent delay to the works. It had been decided to go ahead with the work as planned which was, under the circumstances, a proper decision. There was congestion but people accepted it, and the volume of traffic dropped substantially as motorists found other routes. Nevertheless there was still congestion.

246. A number of speakers had discussed the pedestrian subways. There was a school of thought which suggested that pedestrians used subways instead of crossing on the level because of the 'amenities' of the subways, i.e. the presence even of show cases or shops would increase the number of pedestrians using them. The Authors knew of no quantitative evidence to support this, but there was plenty of quantitative evidence to support the idea that people would use a subway or footbridge if it was quicker than crossing on the level and would not use it if it was not.

247. Although there was no evidence on the subject, the Authors thought that good lighting and perhaps noise reduction did help. They were not unsympathetic

to those who said that 44% spent on decoration was a great deal. Nor were they unsympathetic with citizens and ratepayers who suggested that these beautiful murals were a waste of money.

248. It had been suggested that it was difficult to find one's way about the subways. Surely we were not without experience of this matter. The old subways at the Elephant and Castle had been there for 50 years and had been used constantly by local inhabitants and visitors.

249. The difficulty at Hyde Park had been in agreeing with all those concerned as to what signs should be provided. Meanwhile temporary signs had been used. There were certain complications when a subway connected to a London Transport station. London Transport wanted their standard symbol put on the signs but this did not necessarily fit the architecture. It was proposed to put up signs with small maps at the Elephant and Castle. These clashed with the recommendations of the Warboys Committee, but they would probably be put up all the same.

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#### CORRIGENDA

The following corrections should be made to the original Paper:

p. 316, last line between the two diagrams should read 4 struts: maximum total load 800 tons,

p. 318, third line should read which folding plates 1-2.

Plate 2, Fig. 13, plan, at South tunnel should read Ventilation duct over.