The application of belt conveyors in road earthworks

W. A. LEWIS & A. W. PARSONS

Mr D. S. Elbourne, John Laing Construction Ltd

I think it was a mixed blessing that the material excavated on the trial was chalk. Repeated vibration due to transit down the conveyor caused marked deterioration resulting in an unmanageable pudding at the discharge end, but once the inevitability of this was accepted and the resulting handling technique problems were solved an effective all-weather system was created.

59. In § 31 attention is drawn to the need for control of the rate of loading, to optimize production and to obviate overloading, but a high proportion of the surges referred to stem from the over-run of material at each drive head arising from sequential stopping of the system. Unless an instantaneous system is devised, I consider it unlikely that more than 75% of theoretical maximum could be achieved without overloading, whatever the method of loading.

60. The conveyor system selected had the advantage of extreme portability and I am sure it is well suited for man handling in the confines of a mine, but in the open air on a plant intensive job it would be better made up in more massive units. However, there was remarkably little trouble from uneven tracking of the belts, but the idlers and the thin belt together could not cope, and progressive deterioration of the system set in, notwithstanding the increasing intensity and efficiency of maintenance.

61. I am afraid I cannot share the Authors' enthusiasm for a system in which the trunk conveyor runs outside the earthworks. Such a system requires the acquisition and subsequent reinstatement of land, and its location makes it difficult for surveillance, maintenance, installation, extension, removal and so forth. Generally one will not be operating on straight and level surfaces and it is extremely likely, therefore, that the number of change points in conveyors will need to be increased and that the system will get out of parallel with the edge of the cut. Although I believe that in UK practice this vertical excavation is highly desirable and I have an enthusiasm for the bucket wheel excavator whose milling action reduces most materials to an ideal size for conveying, I do not believe that such a system as that shown in Fig. 5 is practicable. I think it requires an unreal delicacy of interrelationship between a number of mobile units which would be difficult to sustain. It is not difficult to devise systems for extending or retracting trunk conveyors which can be effected between shifts; the M27 scheme was planned with that in mind.

62. I consider that the equipment must be reliable and rugged and operate well within its capacity. Even so, its prospects for widespread utilization on roadworks on straight commercial grounds appear to me to be slight. To have any chance at all, it requires a special set of circumstances: a massive cut, a massive fill, and an adequate distance between them, preferably with a major obstacle en route. Highway contracts generally involve working to a tight programme in which there is a clash of priorities between earth moving and bridges. A conveyor system lacks the requisite flexibility, particularly in a situation where different types of material requiring different dispersal points are encountered. This experiment had a major contract period for the excavation followed by a two-year-plus, standard motorway contract, it is a total construction period of a different scale from that which is normally accepted. Its principal scope seems to lie in situations where the engineer has designed the

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road with the use of a conveyor in mind. Instead of forming points of balance on the earthworks on major obstacles, the engineer may be able to plan his earthworks with the most economical movement knowing that a simple and acceptable method of crossing major obstacles is available to him. Environmental advantages of the method are obvious, but to secure its use the engineer must either specify it or create such onerous contract conditions that the more conventional methods are excluded. How does the electrical consumption of this system compare with the gas oil consumption of conventional means?

Mr H. J. Taylor, Dowty Meco Ltd, Worcester

On the full-scale trial, the Authors have described the method of bulldozers feeding the belt conveyor system, and rippers feeding a belt loader in Fig. 12, but little has been said about the performance of this system in controlling the feed rate of material on to the main conveyor system. From background knowledge of this operation I believe that the belt loader had difficulty in controlling the feed rate within the capacity of the belt conveyor system. The loading on the main conveyor system tended to fluctuate over a wide range, with overload conditions frequently existing. In addition, the feed equipment failed to reject oversize material adequately and the main conveyor system was consequently subjected to overload conditions, giving a higher incidence of breakdown and difficulty from spillage stopping the system.

64. As with most mechanical and electrical equipment, belt conveyor systems give their best performance when subjected to duties within their rated capacity, and it is my opinion that more accurate feed control and oversize lump rejection would have reduced downtime and given better overall utilization of the main conveyor system.

65. The Authors make it clear that the initial arrangements for the discharge of material from the conveyor system ran into difficulty on the freshly placed fill, and the alternative system was subsequently arranged with a travelling radial stacker unit running back and forth along rail tracks. The use of rail tracks for mounting the machine would appear to limit the flexibility of the operation.

66. On a number of sites, 60 ft crawler-mounted radial spreader units are being used to handle waste sand into a fill area at 600 ton/h, the spreader unit being fed by a link conveyor which gives flexibility between the main conveyor line and the crawler-mounted unit. The main conveyor system is fitted with a telescopic conveyor head so that there is complete flexibility and the system can be kept running and advanced along the tip area while the material is flowing.

67. In considering the main part of the trunk conveyor system, the Authors have highlighted important considerations, including the general performance and convenience in employing this first-off major belt conveyor system on a construction site, the use of this equipment having been most successful. It was evident that the application of the conveyors to the job, their installation and the general understanding of the equipment by the operating personnel was readily accepted. Belt training, which is normally a problem with those uninitiated in the art of conveying, was no trouble. What is the Authors' opinion on the general acceptability of belt conveyors as a haulage means for constructional sites?

68. The conveyors were supplied as 42 in. wide belts to handle a maximum lump size of material of 16 in. and a rated capacity of 1200 tons/h. Is this a suitable specification for future applications? Was it, in fact, the correct specification for the job?

69. At the specification stage the system was intended to work with better feed arrangements and handle a smaller size material than was ultimately experienced. For future applications of a similar nature, the belting specification is obviously all-important but, in addition to the calibre of the belting employed, rigorous inspection and maintenance of belt joints will require attention. The performance of the idler sets has to be considered against the specified duty for the conveyor system and the actual duty and overload conditions to which the equipment is ultimately subjected.

Early failure of many idler sets may have resulted from conditions experienced because of failure of the feed system to regulate adequately the loading within the rating of the system. Clearly overload conditions and excessive size of lumps in passing along the full length of the conveyor system can damage the whole length of the trunk conveyor. Idler sets of heavier design can be used on future installations.

Mr G. A. Banks, Fletcher Sutcliffe Wild Ltd

Belt conveyors have been used for many years with many difficult materials, including clay and chalk, and at present my company is involved in handling fly ash, also using a caterpillar tracked radial spreader. Fly ash, with its high water content, is a most difficult material to handle.

71. In § 43 the Authors refer to a delivery period of nine months, which I think might be unacceptable to contractors. I would dispute the nine month period and suggest that it could be reduced by stocking the necessary components against an estimated demand by using standard machines used in other industries; in this way the delivery period could be reduced to three to six months. It would mean that the manufacturers would have to know the sites, the likely horsepower, etc., involved so that standard machines could be used.

72. It is clear (§§ 43 and 46) that economics are very important; if there were 12 potential sites up to 1976, hiring of components could be a more than adequate way of overcoming the fact that contractors already have scrapers, dumpers and so on readily available. They do not require a capital cost to use these machines but just a revenue for running costs. Conveyors have been hired, and I think it would be useful to do this in the road construction industry.

73. This exercise has shown the application of belt conveyors in a new environment. The know-how gained and the resources in use in the coal and steel industries could now be made available to the road construction industry.

Mr A. W. Worrall, Chief Resident Engineer, Hampshire County Council Sub-Unit SERCU

I was the Resident Engineer on the advance earthworks Contract. With a contract using a belt conveyor as a means of transport I found the impact of the scheme on the public was considerably less. On this Contract, interference to the public at plant crossings did not arise, in contrast with previous and subsequent contracts, and complaints and third party claims were virtually non-existent.

75. I would question the advantages in the use of licensed land beside the site of works.

Mr D. H. Harris, South-Eastern Road Construction Unit

In my view, the further use of conveyors will be best justified in areas where there are good environmental reasons. I think a comparison between earth moving using conveyors as here and using conventional plant at Portsmouth would strengthen the case for conveyors. One hears of all the difficulties of any system, but in this area conventional earth moving would have required extensive advanced bridge construction, taking time and requiring early expenditure of funds. Also the probability is that conventional earth moving here would have been severely restricted in working hours because, although the Chief Resident Engineer had no complaints about the conveyor, he would have had many if dump trucks had been driven through Paulsgrove estate and on the A27. I think these two factors would have shown that the unit costs of conventional earth moving would have been a lot higher.

77. Clearly the Transport and Road Research Laboratory envisaged in the original studies a bucket wheel excavator. It appeared to me that to use a conveyor without the bucket wheel excavator was adopting only half a system. But, as far as I know, in the mid-1960s there were no suitable bucket wheel excavators on the market.

There is a conflict here: a large machine is required to keep the conveyor in use, but large machines of that nature are not suitable on motorway works. Apart from the difficulty of getting them there and the sheer bulk of them, there are also major difficulties in providing electrical power if they are to be operated in that way. The Paper mentions 55% as being the utilization of conventional earth moving and over 60% as the best by the conveyor. However, these percentages do not take account of the fact that conveyors can work for more hours of the day than conventional plant.

78. I agree that it would be impracticable to go outside motorway boundaries in designing any future system, particularly if the future of conveyors is more likely to be in urban areas where there are environmental problems. It is difficult to get sufficient land to build a motorway and, I am sure, quite impossible to get additional land for location of conveyors.

Mr M. G. Rolfe, Hampshire County Council

I was one of the Resident Engineers for the trial works at Portsmouth.

80. At Portsmouth all the material excavated was classed as suitable. It was therefore loaded on to the belt continuously with no hold-ups, apart from those arising from the systems used. If there is unsuitable material mixed with suitable material, does one load the unsuitable material on to the conveyor system when it is encountered, and then dispose of it on to some spoil tip? Does one stockpile it somewhere? Does one suspend operations, extend one's conveyor past the area of unsuitable material, be it large or small, and then move it later, possibly with the conveyor, bringing the conveyor back to that point, or alternatively by running a conventional muck-shifting operation parallel with the conveyor system? This might have a bearing on the selection and running of future jobs.

81. If one accepts that obtaining land outside the limits of the motorway is an ideal solution but unlikely in practice, the belt must then run along the formation of the motorway. Once it does so, because of the normal curves on motorways and the straight alignments there have to be with conveyor systems, each conveyor will cross from one side of the route to the other. At Portsmouth this sterilized vast areas of the site which might otherwise have been used by other trades on the motorway. One would normally operate a cut and fill operation, and as soon as possible one would put in drainage gangs. This needs to be borne in mind when considering the conveyor system. The job must be planned to operate one concentrated earthwork operation and then bring the subsidiary operations in afterwards.

82. At Portsmouth there were difficulties in getting vehicles and people from one side of the belt to the other. It formed a barrier down the length of the site which was overcome only by bridging operations. Wherever one needed to get Land-Rovers for maintenance, plant for subsequent operations or such like, a bridge had to be provided. There also had to be numerous small bridges for the workmen. The workmen had the habit of climbing across the belts and this is extremely dangerous.

83. These minor costs could together form a significant part of the cost of a conveyor operation.

84. A final point that I would like to raise is that of site safety. On a muck-shifting operation with conventional plant there can be a few controlled crossing points for the public and they can generally be kept under control. Each piece of machinery, dump truck and scraper has a driver who can see unauthorized people and take the necessary action. However, with the conveyor system, there is a continuous exposed piece of machinery which is an attraction to members of the public, particularly children. There needs to be constant vigilance or constant fail-safe devices to cater for unauthorized persons interfering with the belt anywhere along its length.

Mr M. Milne, Department of the Environment

It is not easy to say that the economic case for using the belt conveyor has been proven, or that it has been disproven.

86. I think there is no doubt that, with the attitude of the wider public towards the building of motorways and any major constructions which have an impact on their lives, it is going to be increasingly difficult, unless one pays proper respect to this, to be able to build these things. A great deal of people's attitude towards motorways stems from their experience during construction and adverse feeling towards motorways persists for a long time afterwards. I have little doubt that the attitude of people affected spreads to the wider public.

87. The Department of the Environment would like to see what it believes are economic possibilities explored by the industry. This will require a considerable amount of further work. In the light of the experience on the M27, I would say that there are undoubted environmental gains to be had from the use of belt conveyors in appropriate sites but whatever method is used excavation must be noisy. Much work on this site was remote from the more noise sensitive areas. The use of a belt conveyor does not automatically mean that all the problems of noise, dust and so on have been solved. However, it seems that there will be some way in which the undoubted gains, in environmental terms, from the use of the belt conveyor can be exploited to the benefit of everyone.

Dr A. P. K. Tate, Howard Humphreys & Sons

I would like the Authors' comments on a project that appeared ideal for a conveyor system yet had actual bill rates for conventional plant that were appreciably less than the cost estimates given in the Paper.

89. Essentially the project involved excavating about 1·65 million cu. yd of Oxford clay overlaid by sand concentrated in an area of about 50 acres.

90. The upper layer of the Oxford clay was mainly wetter than 1·2 × plastic limit. Since the earth balance was favourable, this material was placed in two landscape areas; one taking approximately 70% of such 'unsuitable' material had a haul of about 4 km. The other had a less suitable haul for conveyors of only 1 km but was adjacent to the area of compacted fill and thus useful for 'selection' of material. The compacted fill area took about half a million cu. yd of material.

91. One possible cause for the very low bill rates were that at time of tender thirteen 657s and various smaller motorized scrapers were standing idle. With such a fleet it had been intended to move the 1·65 million cu. yd. between July and September. Unfortunately a very wet summer occurred and during these three summer months the plant stood idle for over 50% of the time. It would appear that conveyors would have avoided such standing time.

92. Referring to the comments of other speakers in relation to noise and public relations, I have recently experienced considerable pressure to restrict the working hours due to noise arising from two scraper boxes and D8s. Undoubtedly in urban areas, the environmental factor is of major importance in any decision irrespective of direct cost comparison.

Mr Lewis and Mr Parsons

Mr Elbourne mentioned the difficulty of handling the chalk, and in particular he made the criticism that vibration during transit down the conveyor turned it into an unmanageable pudding. There is no doubt that as the chalk passed over the conveyor system there was a redistribution of the excess water created by the crushing of the chalk by the excavation plant. This redistribution was brought about by compaction of the chalk on the belt, giving the appearance of a deterioration to a wetter condition. Nonetheless, the chalk would have achieved a similar weak condition upon compaction in the fill, whether or not it had been compacted previously on the conveyor belt. In the early stages of the Contract some chalk was stockpiled in the cutting to form a minor embankment. Although it had not been transported by belt conveyor, it appeared to be as weak as the chalk in the fill area.

94. With regard to control of the rate of loading, Mr Elbourne is right in that a number of overload occasions resulted from the stopping and starting of the system. The manufacturers have recommended that in any future scheme all sections of the conveyor system should stop simultaneously to avoid the overrun of material at each transfer point.

95. Mr Elbourne commented that it would be better to have a conveyor system made of more massive units, but one has to form the right balance between the portability of the system and other considerations, such as robustness and reliability. In the full-scale trial the portability of the lightweight system used appeared to provide a considerable advantage. In the fill area, in particular, where embankments were formed for a complex interchange, the conveyor had to be constantly moved, requiring frequent dismantling and re-erection. A more massively built conveyor would have restricted these operations, and the equipment used at Portsmouth was probably the right type from that point of view.

96. The all-round practicability of the scheme shown in Fig. 5 is certainly debatable. This was a first attempt at planning the loading of a conveyor from a bucket-wheel excavator within a road construction scheme. However, a mobile system connecting with a trunk conveyor located outside the earthwork area is probably the best way of avoiding the interruptions to production associated with extensions of belt conveyor. It is not always possible to extend the conveyor outside the shift periods; one of the advantages of the conveyor is that, because of its low environmental impact, it can work very long hours.

97. Several comments have been made on the impracticability of using land outside the road limits for the location of the trunk conveyor. In the basic feasibility study we considered plans of sites, and these showed that the belt conveyor was not always outside the fence line. In fact the total additional land usage on one of the sites would have been as little as 300 m^2/km. In the feasibility study it was concluded that an extra 5 m width of land along one side of the site, designated as temporary working space, would cover all circumstances. Nonetheless, Mr Elbourne was right in saying that the number of transfer points are increased when the conveyor is located outside the area of the earthworks. This would possibly result in a slight increase in cost which would have to be compared with the practical and economic advantages of locating the conveyor in that position. This is very much a decision for the contractor. One could imagine a combined scheme where the belt conveyor is only put outside the area of the earthworks in the areas where excavation and filling are carried out with the conveyor system, and elsewhere the conveyor could be nearer the middle of the site.

98. Mr Elbourne asked about electrical consumption of a belt conveyor in comparison with the gas oil consumption of conventional earthmoving methods. The data in the basic feasibility study show that, provided the belt conveyor can be powered by mains electricity, gas oil consumption can be reduced by 30–55%, depending on haul distance, in any earthwork operation where belt conveyors are substituted for conventional earthmoving methods. However, there is no evidence that the total energy consumption is reduced.

99. **Mr Taylor** emphasized the problem of controlling the rate of feed of material to the belt conveyor. There is evidence in the results of the full-scale trial that the utilization of the system improved if the rate of loading was reduced. In further analyses we shall determine the optimum rates of output for the particular conditions at Portsmouth which gave maximum utilization and minimum operational costs.

100. Mr Taylor proposed the use of crawler-mounted, radial-spreader units for distributing material in the fill area. This may be a better system than the method of spreading the fill originally envisaged and given in Fig. 6. Clearly the use of crawler-mounted units adds to the flexibility and avoids the need to construct rails associated with equipment such as the travelling radial stacker used in the full-scale trial.

101. Mr Taylor asked for confirmation that the size of equipment as used in the

full-scale trial and its rated capacity would be adequate for future applications. The computer program we use for assessing future demand for the belt conveyor is based on the use of that size of equipment, transporting 400–500 m^3 (bank volume) per utilized hour. Experience at Portsmouth confirmed that this output can be achieved. On schemes where the computer analysis indicates that economic benefits can be gained from the use of belt conveyors, the equipment could be in use on each site, on average, for about a year. This indicates that equipment of that size and rated capacity would be suitable where a combination of conveyors and conventional plant is used, with the conveyor applied to the longer haul distances.

102. Mr Taylor also mentioned the failure of the belts and the idlers in the full-scale trial. Experience at Portsmouth has shown that one must over-design idlers to cater for occasional overloading and for large boulders which could possibly be conveyed on the system. The British Standard for idlers (BS 2890:1973) requires idler bearings to have a minimum design rated life of 25 000 hours. Clearly this life was not achieved in the full-scale trial.

103. **Mr Banks** disputed the nine-month period for delivery of conveyor equipment, and stated that it could be reduced to three to six months. Any reduction in the delivery period must be helpful. With a three-month delivery period, and with the duration of usage on site averaging about one year, a contractor could consider ordering the conveyor subsequent to winning a contract. In addition, the hiring of the conveyor may be attractive to the contracting industry.

104. It is useful to learn from **Mr Worrall** that the complaints and third party claims were virtually non-existent. This supports our view that in the full-scale trial the belt conveyor proved its many environmental advantages.

105. **Mr Harris** also mentioned the environmental advantages, and I agree that, had we considered in detail the possible application of conventional plant within the full-scale trial situation, one might well show a considerable increase on the 78p/m^3 quoted in the Paper as the estimate of the cost of conventional operations, based upon our simple cost model. In the light of Mr Harris's comments we may consider these aspects in our more detailed appraisal of the full-scale trial.

106. **Mr Rolfe** raised the question of handling unsuitable material in a conveyor scheme. The method chosen would depend on the circumstances, but there could be three basic possibilities. One would be a conventional muck-shifting operation running in parallel (this would be the most feasible method if the unsuitable material occurs at the upper surface of the cutting). A second method would be to have a conveyor system with two discharge points, one in the fill area and one in the spoil area; material would be diverted to one or other area depending on its suitability. A third method is whether, with vertical-face excavation and the ability to mix material during the process of loading the conveyor, a suitable mixture of the material can be produced, thus avoiding the need to convey any unsuitable material to spoil.

107. Mr Rolfe made the point that the belt conveyor can isolate certain areas of the site. Presumably this comment is based on experience in the full-scale trial, which was a very special job. On most schemes the conveyor would not remain at any one point on the site for the length of time that it was in use within, say, the Paulsgrove housing estate. Within the sites analysed by computer, the conveyor would not be expected to remain in one spot for longer than about six months.

108. **Mr Milne** mentioned the environmental advantages and these must be considered. Excavation is a noisy operation and it seems that the noise cannot be reduced at present. However, if one consideres excavation at a vertical or near-vertical face, the duration of the disturbance at any one location on the site is considerably shortened. It would be only a week or two before the excavation process moved out of range of a particular dwelling, whereas transportation of material through an area can go on for six months.

109. **Dr Tate** posed an interesting problem of earthwork logistics. A computer analysis on this scheme would almost certainly indicate that economic savings could

be achieved by the use of conveyors if about ¾ million cubic yards or more had to be moved over the distance of 4 km.

110. Dr Tate also said that rates quoted in the Paper were higher than those quoted for this scheme. This may be explained by the fact that the scheme which he mentioned was carried out in 1968 and the rates in the Paper are based on 1972 estimates.

111. It is interesting that two scraper boxes and D8s can give rise to complaints about noise, and it shows how conscious the public is becoming of construction noise. Perhaps the solution is the wider use of belt-conveyor systems.

112. The civil engineering construction industry is in some ways one of the most conservative industries in the UK. Perhaps in 20 years' time techniques which are now novel will be commonplace in the construction of roads. Perhaps what is now needed is a new conception of road construction in which one would use the advantages of new techniques at an early stage of design. The contributors seem to be thinking of building roads by existing techniques and trying to superimpose the belt conveyor system on to them, whereas it is necessary to think afresh in the construction phase and also in the planning phase. If there is a system which can move large quantities of material cheaply, perhaps one's whole philosophy of road construction should be changed. One might consider much more the utilization of large waste heaps and moving such material over long distances to construct roads, at the same time clearing up public eyesores. The environmental issues are the key factors in all this.

113. The economic case is neither proven nor disproven; it seems fairly evenly balanced. If we had shown that belt conveyors were likely to be cheaper, it seems that costs of earthmoving by conventional plant might well come down to match the cost for conveyors. Competition between different systems is a good thing and is likely to help reduce the cost of road construction.

114. When we started the study of the possible use of belt conveyors we were concerned with the economic side. As a spin-off the environmental side became more apparent, and it seems that this is going to be the major issue in future. Limitations are undoubtedly going to be placed on contractors on noise levels. Whether with existing conventional plant these limitations can be complied with is not certain. It may be that costs of earthmoving by conventional plant will increase if the plant has to be modified to reduce noise levels.

115. Belt conveyors provide a very efficient haulage system if a lot of material has to be moved a long way. However, the system lacks flexibility. If there is a breakdown of a single unit the whole system comes to a halt, whereas with conventional earthmoving plant if a single machine breaks down it is not usually very serious and the progress of the work is hardly affected. Consequently the attitude to the maintenance of belt conveyors must be different from the present attitude to the maintenance of conventional plant. More attention will have to be paid to preventative maintenance if belt conveyors are to be used successfully.

116. Mr Harris said that he did not believe that large types of bucket-wheel excavator would be appropriate to road works. The type of machines we have in mind are surprisingly small and quite mobile. Such equipment certainly could be used on roadworks. Perhaps the possibility of hiring equipment will help to encourage the greater use of belt conveyors.

117. Safety was one of our fears at the beginning of the M27 project. However, Mr Worrall has said that third party claims were virtually non-existent. This suggests that despite all the apparent safety difficulties belt conveyors were in fact not particularly dangerous. There had to be special provision for crossing the conveyor at various points, but the cost of this was taken into account and was included in the figures in the Paper.

118. In urban areas noise may be more important than costs. With regard to the earthwork project which Dr Tate described, where costs using conventional plant

were lower than the rates quoted in the Paper, it is important to realize that low rates did not necessarily mean that the actual costs were low. As the contractor was only able to work for 50% of the time he probably experienced a loss which he would have to retrieve on some other job or by making some big claim. Contractors can make mistakes and underprice work. Earthmoving is a very competitive business and some of the low rates quoted may not be real costs. What matters in the long term are the average prices which have to be paid for road earthworks.

119. We are not advocating that belt conveyors should be used indiscriminately. However, we feel that there will be a number of projects where belt conveyors can be used with significant savings of money. There could also be important environmental benefits.