PROSPECTS FOR NO-DIG TECHNOLOGY IN HONG KONG CONSTRUCTION INDUSTRY

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ABSTRACT: The no-dig technique has been proven in Europe and Japan as a successful means of constructing underground utilities and drainage works through densely populated areas without causing unacceptable disturbances, by eliminating the conventional open-cut method. Although this conventional method causes detrimental impacts on traffic flow, pedestrians and motorists, as well as on the environment, it is commonly employed in Hong Kong for various utility activities. Despite this, the advanced no-dig technique, which can tackle the problem, remains unpopular. Past records reveal that in Hong Kong the technique had only been applied to the construction and maintenance of utilities to a very limited extent. It is useful to identify the factors impeding its widespread application. This paper reviews the causes that preclude the extensive applications of no-dig technique to utility works in Hong Kong. The prospect of promoting such a technique in the territory in the future is also investigated.

INTRODUCTION

The no-dig technology, which is an innovative and less disruptive method of the installation of utility work without employing the conventional open-excavation method adopted in many major cities, is relatively new. The techniques can be broadly classified by nature of work, namely, new works on renovation works. Pipe jacking, directional drilling, impact moling, pipe bursting, tunnel-boring machine, minitunneling, microtunneling, and thrust boring are under the heading of new works. Sliplining, inversion lining, spiral liners, in situ coatings, and grouted sliplining are renovation techniques. Details of various techniques are given in Chau (1992). Following are brief definitions of the terminology.

Pipe jacking is a method of lining insertion whereby pipe lengths are lowered into a pit and jacked forward into the tunnel. Directional drilling is the drilling of holes on a curved vertical alignment to pass pipes beneath rivers or roads. Impact moling is the use of a remote controlled mole, which forms an opening in soft ground by being hammered through the soil and effectively compacts an annulus around the opening. Pipe bursting uses a remote-controlled expanding mole to burst the existing pipe from the inside and compress the debris into the surrounding ground. A tunnel-boring machine is a fully mechanized rock-tunneling system that normally uses pick cutters to cut soft rock and rotary disc cutters to cut hard rock for installation of temporary supports prior to the subsequent construction of in situ concrete lining. Minitunneling are small cross-section tunnels that require special equipment during construction, because of space limitations, but which

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still allow man entry. In circular tunnels, diameters of 900–2,000 mm are defined as minitunneling. Microtunneling are circular section tunnels or pipes where the techniques are related to tunneling techniques but where man entry is not possible or not intended. Thrust boring is an excavation method whereby a cutting head or machine advances through the ground by virtue of a thrust exerted by hydraulic jacks.

Sliplining is the insertion of a new polyethylene or pvc pipe, with diameters reduced by mechanical rolling or by passing through a preheated die before being towed through, into the old. Inversion lining uses a polyester or acrylic felt bag coated with a polyester or epoxy resin that is unrolled into the pipe via a manhole using water pressure. The curved liner can be made to form a full structural lining. Spiral liners are formed by winding the lining from ribbed pvc strip with a machine and continuously feeding it into the old pipe from a manhole. In situ coatings are numerous, but are usually either mass concrete, reinforced concrete, resin or opc-based. Grouted sliplining is similar to sliplining, but the towed pipe is not reduced in size before insertion. Instead, a smaller pipe is used and the annulus subsequently grouted.

The no-dig technique has been proven in Europe and Japan as a successful means of constructing underground utilities and drainage works through densely populated areas without causing unacceptable disturbances. The Tokyo Metropolitan Government Sewerage Bureau has adopted the pipe-jacking method to renew pipeline ("Existing" 1990). Microtunneling was used to construct sewers across the Trent and Mersey Canal, which crosses the country from Nottingham to Liverpool in the U.K., as part of a major sewerage improvement scheme (Smith 1989).

CURRENT BACKGROUND IN HONG KONG

Hong Kong is one of the most densely populated big cities in the world due to the scarcity of land. The 1,074 km^2 of available land, which includes a number of undeveloped outlying islands, have to accommodate a growing international commercial and financial center, expanding light industries, and an incessantly growing population (currently six million). To further worsen the situation, there was no systematic planning for the road network in the existing urban districts from the early eighteenth century to the early twentieth century. As a result, any extension and improvement of this road network in highly populated areas must be limited. The solution can only be made possible by means of overpass, elevated roadways, or expressways on reclaimed lands to cater to the ever-increasing traffic flow of a rapidly expanding city like Hong Kong. In most cases, such solutions are impracticable in the crowded hub of the city, and traffic congestion is accepted as one of the special features of the daily life of the Hong Kong citizens. Similarly, the extensive network of utilities in the urban districts, which underlies the road network, has to closely follow its alignment. In general, this network of utilities is installed unsystematically in confined spaces underneath the road surfaces and pedestrian walkways.

In Hong Kong, the network of utilities embraces the systems of storm drains; sewers; water, power, and gas supplies; and other service and communication cables. Under such circumstances, it is inevitable to have repairs on damaged portions, realignment and diversion of parts of the existing system, and refurbishment and expansion of the existing system in conjunction with each utility network by the individual utility undertaker. There are incessant open-excavated operations carried out daily in roads and pedestrian walkways in connection with the drainage, water services, and other utility works. No matter what activities are being carried out, the conventional open-cut excavation method is generally used to expose the underground utilities. It was manifested that such a method causes not only significant inconvenience and disturbance to motorists and pedestrians, but also gives rise to adverse impact on the environment, such as noise pollution. Among the aforementioned activities, repairs on utilities are the most frequently dealt with and they can occur unforeseeably anywhere at any instant of time. On many occasions, the repairing activities are carried out exclusively by each utility company at his own convenience. It is not surprising that the same area on road surfaces or pedestrian walkways can be open excavated and backfilled several times within a short interval of time, e.g., a week, by different utility undertakers. A joint schedule for any foreseeable major or sizeable new work involving more than one utility undertaker can seldom be agreed on. It is likely that the degree of impact to the traffic flow, the pedestrians, and the environment will be magnified as a consequence of the foregoing activities. In fact, many, if not most, major cities in the world have the same problems as Hong Kong.

In view of the preceding information, it is advisable to identify qualitatively the depth of impact on the traffic flow, the pedestrians, and the environment due to the utility activities before any remedial policies can be developed in the context of Hong Kong. Prima facie, the no-dig technique, which has been widely adopted in Japan and Europe during the past decade, seems to be a sensible solution (Ishibashi 1988; Smith and Jameson 1987; Szczupak 1989; Tohyama 1985; Watson 1987). In using this technique, the cause of disruption to the traffic flow and pedestrian movements on roads can be reduced to a minimum. However, despite the various disturbances, it is observed that such a technique has not been commonly employed in the territory, and there seems little indication that it will be widely adopted to handle drainage and utility activities. The only significant example of such a technique being used was in the construction of Fanling trunk sewer. In this project, excavation was successfully carried out by using the Iseki Unclemole minitunneling method (McFeat-Smith 1990). By virtue of this, it is noteworthy to study the causes for low use in terms of cost and ease in operation. It is also hoped that strategies can be developed under which the no-dig technique will be favorably used, subject to local constraints.

IMPACTS OF CONVENTIONAL OPEN-CUT EXCAVATION METHOD

Despite the advent of sophisticated technologies, the conventional open-excavation method is still popular among the major utility undertakers and their contractors. The main reasons may be due to the cost problem and conservatism in the construction industry. The impacts of using conventional methods can be broadly classified in three areas: traffic flow, pedestrian movement, and the environment.

Regarding the impact of conventional excavation methods on traffic flow, it may cause not only inconvenience to the motorists but also increase the occurrence of traffic accidents. The inconvenience stems from undesirable temporary traffic diversions during the period between the excavation and the final reinstatement of the road surface. This traffic diversion, which may require the closing or narrowing one or more existing traffic lanes, causes adverse disturbance to smooth, normal traffic flow. This certainly reduces the speed of the traffic flow, and traffic congestion is to be expected to a certain extent, depending mainly on the volume of traffic. Time delays will

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probably result for individual motorists to get to their respective destinations. Similarly, traffic accidents will be increased due to impatient motorists competing for the road, frustration of motorists resulting from traffic congestion, poor road-surface conditions after temporary reinstatement, inadequate arrangements for traffic diversion, and insufficient traffic signals. This adverse effect will be further magnified in inclement weather when there is rain and fog. Besides, as a side effect, the loss of trade to shops in the vicinity of the traffic diversions can be serious.

In general, the conventional excavation method causes more injuries to pedestrians than inconvenience. The inconvenience only affects the movement of the pedestrians by creating bottle necks in the pedestrian walkways and causing detours. In contrast to this, the poor conditions of the temporarily diverted pedestrian walkways is the main cause for pedestrians to get injuries when they walk along the temporary route provided, especially in crowded situations. On many occasions, pedestrian traffic will compete with the vehicular traffic for the use of the road if there is no clear demarcation between the temporary pedestrian walkway and the diverted traffic lanes. This probably causes traffic accidents and injuries to pedestrians. This situation will be compounded if the excavated areas are not properly fenced and lighted at night.

The environmental impact resulting from the conventional excavation method are threefold. The open-cut method is likely to produce harmful fumes and dust from the excavation operation, noise nuisance from the construction plant, and damage to the road surfaces in their reinstatement. The main source of harmful fumes and dust comes from the air compressors and pneumatic drills when they are used to open up the road surfaces. In general, there are hardly any protective screens erected to protect the passers-by when the excavation is in progress. This causes harmful fumes and dust to contaminate the air in the surroundings. Similarly, noise nuisance is usually generated from the operation of the mechanical parts of the air compressors and the pneumatic drills in breaking through the road surfaces. The tranquility of the surrounding is inevitably ruined by the nerve-racking noise created. Undoubtedly, the combination of the air and noise pollutants results from the conventional equipment used to perform open-excavation, and will be detrimental to the health not only to the pedestrians, but also to people in the surrounding neighborhood. Another impact to the environment is the frequent damage to the surface conditions or even the structural parts of the roads and pedestrian walkways due to the alternate excavations and reinstatements at relatively frequent intervals. In this case, the most common minor adverse effect to both motorists and pedestrians is the unpleasant surface conditions of the roads and pedestrian walkways as the result of uneven patching up by different utility undertakers and their contractors.

Table 1 summarizes categories of the impacts of the conventional open-excavation methods. Despite the various detrimental impacts on traffic flow, motorists, pedestrians, and the environment by using the conventional open-excavation method, there is still no sign of a trend towards a better substitute, e.g., no-dig technique, in solving the problems. In view of this, the various causes for such reluctance will be the next aspect to be studied, and Table 2 summarizes various impediments to application of the no-dig technique.

IMPEDIMENTS TO APPLICATION OF NO-DIG TECHNIQUE

The principal impediment of using this new technique to deal with the excavation aspect (in both the new and maintenance works for utilities)

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TABLE 1. Impacts of Conventional Open Excavation Method

Traffic flow	Inconvenience to the motorists Increases traffic accidents Time delay to traffic destination Loss of trade to shops in vicinity
Pedestrian movement	Injuries to pedestrians Inconvenience to pedestrians
Environmental impact	Produces harmful fumes and dusts Noise nuisance from construction plant Damage to road surface

TABLE 2. Various Impediments to Application of No-Dig Technique

Higher construction cost	Insufficient plant utilization Initial training of operator
Conservatism in construction industry	Government not enthusiastic to promote change Local contractors not investing in research and development of advanced technology Utility company does not want to bear the higher risks
Site conditions	Overcrowded condition of various underground utilities Nonhomogeneous substratum of soils

originates from their cost and effectiveness. As this technique involves special plant, the capital outlay for its ownership is quite considerable. On top of this, additional expenses are required for the training of each operator and the provision of sufficient stocks of spare parts for the proper maintenance of the plant. Such plant will probably not be obtained through plant-hiring firms because it is unpopular. Furthermore, the special problems of the equipment involved in the no-dig technique generally involve decisions of a design nature, resulting in a problem of attaining plant utilization to an acceptable level. In the event that a no-dig technique is considered appropriate by a particular contractor, his tender price will be raised accordingly to cover the higher costs incurred in using the special plant. In doing so, the competitive capability will subsequently be reduced. On the whole, a contractor is confronting the problem of achieving cost effectiveness if a no-dig technique is used in a project.

In a review of trenchless construction techniques carried out for the Hong Kong Island South sewage master plan (*Technical* 1989), estimated costs were provided for trench excavation and a variety of techniques. Although each case must be judged on its own merits, it is evident that trench construction was generally cheaper at that time. However this comparison is rapidly changing due to the availability of more appropriate plant, both internationally and locally.

In Hong Kong, the cost for the use of no-dig technology is high, due to a lower utilization rate. The conservatism in the construction industry renders the utilization rate of these special plant far below the usage capacity. It is reasonable to believe that the construction cost will be lowered if the capital outlay for the plant are shared by more usage. This can explain why major municipalities in the U.S. have found it to be less expensive, provided the utilization rate is sufficient.

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In Hong Kong, the application of advanced construction technology to the construction industry proceeds slowly, compared to the manufacturing industry. Furthermore, most of the local contractors seem not to invest in the research and development of advanced construction technology. This is compounded by the Hong Kong government not being enthusiastic to promote change. There also seem to be very few training courses promoted by the government to train technical staff in this area. Consequently, most of the transfer of advanced construction technology is accomplished through joint ventures between the local and foreign contractors, in which the latter provides the impetus. Coupled with the conservatism prevalent in the local construction industry, there are other hindrances in the promotion of no-dig techniques.

The inevitably greater risk factor associated with more advanced no-dig technology means that, even where a contractor can justify the method on the basis of cost, he is unlikely to propose it. Where the technique is specified by a utility, it is bound to bear any risk that is not otherwise attributable to the contractor. This sharing of risk may lead to tendered costs being lower but, when difficulties are encountered, liability may be contested, and this may to some extent discourage utilities from promoting the advanced technique. Thus, the question of whether the method of construction should be specified by the utilities or proposed by the contractor in contractual terms is very crucial.

Another hindrance precluding the wide application of no-dig techniques comes from the overcrowded condition of the various underground utilities. In many cases, there are no detailed records of the most recent utility alignments made by individual utility undertakers. To solve the problem, the utility contractor concerned has to dig trial trenches or pits to locate the exact alignment of the utility in question. The interwoven pattern of these underground utilities gives rise to extreme difficulty for the special equipment of the no-dig technique to operate efficiently, even though the true alignment of the utility has been located. Sometimes, the nonhomogeneous substratum through which the special plant of the no-dig technique has to go induces further hindrance. In this case, either the advancing speed of the excavation plant has to vary or a frequent change of cutter is needed to cope with the different nature of soils encountered. This inevitably reduces the productivity of the excavation method in terms of cost effectiveness.

PROSPECTS IN PROMOTING NO-DIG TECHNIQUE IN HONG KONG

After reviewing the detrimental impacts of the conventional open-excavation method on traffic flow, pedestrians, and the environment, one can be convinced to a great extent that the no-dig technique can be a better substitute method to reduce the detrimental impact from utility work. Besides, the no-dig technology has the added advantage of enabling utility repairs to be performed at night, without causing intolerable noise in the environment. This can be considered an important feature to handle emergency works because urgently needed remedial work can be carried out in the nick of time. In promoting this technique, the most important aspect is to increase its cost effectiveness. This can be accomplished by increasing the utilization of special plant so that its unit cost can be substantially reduced. Besides, higher utilization of such special plant will, in turn, provide incentives for suppliers or manufacturers to give more effort to develop plant with higher efficiency as well as cost-effectiveness.

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The participation of the government in promoting this technique is needed. At present, utility undertakers in Hong Kong are required under the Crown Lands Ordinance to obtain an excavation permit from the authority before making or maintaining an excavation within a public road for the installation of maintenance of underground services. The highways department, the party exercising power to control and manage the vast amount of utility works, imposes a restriction on road opening on newly constructed or reconstructed roads for a specified period of time (i.e., five years for highways, one year for footways on newly constructed road, and one year for newly resurfaced flexible roads) (Teague and Lau 1990). This has an indirect effect in forcing the utility undertakers to carry out works in conjunction with road works or to adopt no-dig construction technique during the restriction period. However, it is believed that the government can play a more active role by issuing mandatory direction to individual utility undertakers to use no-dig technique to carry out their utility work when both the condition of subsoil and work environment allow. Such provision, as an extension to the existing legislation, could be enforced in such a manner that open-excavation for utility work is generally prohibited in densely populated zones, commercial districts, and on busy trunk roads, unless otherwise approved by the government.

In addition, the government, the utility undertakers, and consulting engineers should take the lead. These three parties should form a tripartite group in drawing up a set of guidelines under which the no-dig technique is most favorable for application to utility works of different types. In reducing the impact of high capital outlay in the acquisition of the special plant in connection with the no-dig technique, the government could assist by issuing grants to the utility contractors or undertakers for procuring the plant. Alternatively, the government could buy all such plant and set up a rental centre for the utility contractors of undertakers to make the plant available to them when required.

It is generally agreed that the risk of damage to existing services is another major disadvantage of the no-dig technique that should be overcome before it can gain popularity. The obvious solution to this problem of adjacent services is the accurate location, which could be achieved by two means. Better and more accessible records of existing services are certainly required. In this respect, it appears that the government should be the one at the right position to promote cooperation between the various public utilities, including the rapid exchange of reliable information on existing services. The government could collate a central computerized record of the various utilities, which could be accessed for updating and interrogation at all the utility substations. As a supplementary measure, the economic application of some accurate and nonintrusive methods of detecting existing services should be encouraged.

On the other hand, if various utility undertakers realize or are persuaded of the seriousness of the impacts in using the conventional open-cut excavation method to perform utility work, they may take the initiative to instruct utility contractors to employ the no-dig technique in lieu of the conventional technique through mandatory clauses in the specifications. For example, the drainage services department instructed the contractor to use no-dig technique to construct a cavern sewage-treatment works at Stanley, Hong Kong (Siu 1991). Such a technique has been proven successful in minimizing the interference to traffic in that area. In view of this, the Hong Kong government should take the leading role in promoting the use of the no-dig technique in drainage works. This is most practical, since more detailed records of the alignment of the drainage works exist, and such works are carried out along or across the highways where utilities are less congested. Since the construction cost of underground services is a function of the depth of the services, for services of greater depths, the construction cost by employing no-dig technique will become less expensive compared with the conventional open-excavation method. Sewers are often laid at considerably greater depths than other services to avoid other services or to achieve the required gradients, and they have to be laid to tight tolerances with regard to level. The depth of a sewer may be as much as 5–10 m. Construction of deep sewers in congested areas without significantly lowering ground-water levels entails the slurry-shield microtunneling machine (i.e., for an underground conduit smaller than will allow man entry or 900 mm in diameter). This method is designed to provide support at the face by applying to the ground a degree of pressure and, in this way, settlement or heave is minimized even in unstable ground.

Owing to the advent of more stringent enactments for environmental protection in terms of air and noise pollutants, together with the complaints of environmental protectionists in the territory, the no-dig technique can be considered as a sensible solution to minimize substantially the production of harmful fumes and nerve-racking noise from the construction operations of utility work. Furthermore, the growing public concern about traffic delays, social costs, and damage to roads has led to an increasing tendency to try to recover damages from the utility. There are recent instances in other parts of the world where third parties, such as bus companies and others, have sought to obtain compensation for these additional costs from the utility installing the services. The increasing importance of providing safety for site workers and the noticeable successes in claims by motorists and pedestrians for injuries caused by the conventional excavation methods provide another impetus to adopt the use of a no-dig technique as the best alternative. In many cases, it can be postulated that the higher cost incurred in using the no-dig technique is well-balanced by the direct and indirect losses in relation to time and monies when the conventional excavation method is adopted. Previously acceptable methods for carrying out utility operations are now entirely intolerable, and alternative methods to trenching should be considered and adopted wherever economical and feasible.

It is difficult to evaluate the indirect or social costs incurred in the open-excavation method. Nevertheless, an economic model is presented that could be used by governmental agencies to properly evaluate this aspect.

indirect or social cost = function (nature of road, time delay, population characteristics, accident frequency, and building density)

Different weighing factors should be imposed on different factors contributing to the indirect or social costs. Among them, the importance or the nature of road will be of principal value. If it is a trunk road, the disturbance will be much more serious than that on a side street. Based on the local population characteristics and the statistics on the traffic volume on the road concerned, the loss of individual productiveness in terms of costs due to the traffic time delay caused by the open excavation can then be calculated. According to surveys and deduction from roads of similar nature, the increased frequency of accident due to the excavation can be inferred. The losses arising from accident can then be converted to monetary values.

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Besides, the health hazard to the pedestrians and residents in the vicinity, as a result of the environmental impact, can also be converted to loss of production and then to cost term. The devaluation of adjacent property value due to dust emission can also be assessed.

Nevertheless, it is too radical to say that it is time to completely replace the conventional open-cut method. The greatest potential for no-dig construction in the near future will be for sewers to be laid at greater depths, where a conventional trenching method becomes more costly, where lowering of the ground-water level may have an adverse effect on adjacent structures and for utilities to be laid across busy roads. For new utility works, microtunneling is most appropriate for sewers, and moling is suitable for other utilities crossing the roads. In regard to renovation activities, pipe bursting and sliplining are the most common events. When the cost of no-dig construction can be lowered to a competitive level with that of its counterpart, and the problem due to the risk of damage to existing buried services can be kept under strict control, this innovative technique will become the norm of all underground activities.

CASE STUDY: FANLING SOUTH TRUNK SEWER

This contract called for the construction of 370 m of 1,350 mm internal diameter sewer located 6–14 m below ground level. The alignment passed beneath new roads, footpaths, a cycle track, a pedestrian subway, the embarkment of a recently constructed expressway and many existing services. The geological sequence of the area consisted of fill and alluvium deposits overlying moderately to completely decomposed volcanic rock (mainly silt). The water head above the tunnel soffit ranged up to 7 m.

Owing to the embargo imposed by the highways department prohibiting excavation in the newly constructed road for five years, trench excavation was not permitted. The Iseki Unclemole minitunneling was recommended as the only feasible solution in spite of its relatively high cost, the possible time constraints to import the plant from Japan, and some uncertainty about the maximum size of boulder to be encountered. The average production per day was 3.5 pipes (10.4 m/day). Besides, the average settlement recorded was only 0.5 mm. It was found that the use of this technique can substantially avoid settlement to adjacent areas.

CONCLUSIONS

After a careful study of the no-dig technique, it can be seen that this innovative excavation method has merits not only in pollution control, but could also minimize chaotic impacts on the traffic flow and the movement of the pedestrians when utility works are in progress. It can be observed that cost incurred and the risk of damage to existing services in using the no-dig technique are the main hurdles to be overcome before it gains popularity. These can probably be solved, to a certain extent, by increasing the technique's degree of application to execute as many types of utility works as possible, and by the coordination of the government to assemble an accurate, updated, and centralized record of various public utilities. It is strongly believed that there is a definite prospect for the no-dig technique to gain popularity in performing utility works, provided that the government takes the initiative in promoting such a technique. This can further be reinforced if the attitude of the utility undertakers goes for the idea so that the no-dig technique is a first priority to be considered and adopted in

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performing their respective works, wherever economical and feasible. Finally, future research effort in this field should be concentrated in two directions, i.e. the development of less expensive plant as well as the development of economic, accurate, and nonintrusive methods of detecting nonmetallic underground services.

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