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Managing Risk on Major Tunnelling Contracts

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Synopsis

Risk Management has become increasingly important over the last few years on major tunnelling works. More importantly, as the insurance industry has been hit by a series of large claims due to tunnel failures, there has been recognition that this approach will not be optional and this has been established as part of the Joint Code of Practice issued by the British Tunnelling Society jointly with the principle insurers in the UK. This will have far reaching implications for clients, designers and constructors and some of the principles, procedures and developments relating to this field are discussed.

1. Introduction

Historically, tunnelling as a discipline has always been regarded as an art as much as a science. This has its roots in the fact that tunnel design has never been, and will never be, a deterministic process. There are numerous factors that influence a tunnel lining design and includes the geology, in situ stress regime, material properties of the ground and lining and the construction method, particularly sequential excavation methods. These will all influence the support requirements and it has been understood for many years now that utilising the load bearing capacity of the ground itself, particularly in rock tunnels, is good practice. Practioners of the NATM school have applied this principle to very good effect. Most current approaches to tunnel design accept that if you control deformations to maximise load sharing with the ground, the support requirements can be optimised and in most cases substantially reduced. This has obvious benefits in terms of costs and programme.

There have certainly been many technological innovations in tunnelling in recent years, particularly with regard to soft ground tunnelling and the use of Tunnel Boring Machines (TBM’s), where applying face pressures (EPBM’s and Slurry TBM’s) has been extremely efficient in controlling face losses and hence surface settlements, particularly in high risk urban areas. Such construction methods have moved the industry a long way towards achieving efficient and safe tunnelling. However, it also has to be recognised that the magnitude of cost overruns when problems arise during the progress of tunnelling work can be out of all proportion to the original cost of the construction. One recent example of a TBM driven tunnel in the UK led to a 4200% increase in cost/m to remediate a section of failed tunnel supported using a pre-cast concrete segmental lining. While this is exceptional it is a fact that the cost of replacing new build which fails is at least a factor of 2, and often much more, when compared to the original.

As a result of incidents like this, those at Heathrow Express[1] and, latterly Dulles Airport in the USA, the insurance industry has been looking hard at their risk and liability on major tunnelling projects. This has led to a code of practice recently published in the UK which clearly seeks to limit an insurers’ liability to no more than the equivalent of the original construction cost. This is a tight and extremely onerous limitation but should be seen in the general context of insurers realising that many contractors are using them as a shield. This is borne out by statistics which show that for some years claims and payouts have substantially exceeded income. The response of the insurance industry is hardly surprising but the implications are far reaching. They will be felt worldwide and will affect the way in which clients procure projects, the risks that they will accept and the means by which they will expect their designers and contractors to manage those risks on their behalf.

This paper looks at the Joint Code of Practice[2] and then reviews the subject of risk management and current practice during the design and implementation phases of major tunnelling projects and considers the approach that insurers will now expect clients, designers and contractors to take in order to ensure that cost overruns are kept tightly under control.

2. UK Industry Joint Code of Practice

Current statistics indicate that the leading tunnel insurer's ratio of premiums received to claims and payouts has resulted in losses of between 500-1000% in the last 5 years. The outcome of this was inevitable with many insurers refusing to accept new tunnelling business in the belief that many contractors were simply using this to allow them to accommodate a higher level of risk in their bids and methods of working. It came as no surprise that contractors were forced into negotiations with the insurance industry and the primary aim of the Joint Code of Practice is to improve the management of risk on projects in order to try and control losses.

While this was intended to apply to the UK industry already it is apparent that this is being applied elsewhere. This is inevitable since most of the main insurers involved in preparation of the code operate on a worldwide basis, including India, and could not be expected to accept higher risks outside of the UK. In addition, major funders such as the World Bank and Asian Development Bank, who have an interest in ensuring that their funds are well spent, will also expect this code of practice to be applied.

The questions that arise from this development are therefore:

- What constitutes risk management on major projects
- What impact will it have on clients, including procurement of contracts and acceptance of risk.

3. Managing Risk

It is reasonable to ask what managing risk means. This is the overall application of policies, processes and practices dealing with risk. In reality it means providing an auditable approach to assessing, analysing and managing risk during design and construction to ensure that the works are carried out safely and in accordance with a reasonable programme and budget. If projects are unable to meet a construction programme this could arise from a number of causes some of which are not related to hazards in the conventional sense, e.g. a tunnel failure due to unforeseen local conditions, but more to inexperience on the part of a contractor or designs which may be difficult to construct. However, this only serves to emphasise that in procuring a major contract clients need to be aware that safety and preventing major collapses is only part of a much wider process that should be all embracing as far as the project is concerned. The results of a recent survey in the UK[3] showed that ground-related risks are substantial with groundwater problems accounting for 13% of them, soil properties 20% and ground geometry 22% and these may impact on cost, health and safety, the environment, programme and quality.

The following sections look at how risk should be managed and this is based on knowledge of the systems and procedures implemented in the UK following the Heathrow Express collapse in 1994[1] and implementation of the insurance industries Code of Practice on the new T5 terminal at Heathrow which is currently under construction and has project wide insurance cover. It also reflects the authors own experience of working in India on the design and construction of the Chamera II project and the special difficulties that constructing projects in mountainous and rugged terrain creates.

4. Concepts and Definitions

There is now general acceptance in the UK that risk management is not optional. It took some time for this realisation to sink in but the Construction and Design Management Regulations implemented by the Health and Safety Executive in 1994[4] made it mandatory and enforceable. Therefore it has been necessary to incorporate strategies into the design and construction phases of a project that provide both continuity and a framework that provides an open process that can be adjusted during the progress of the works to suit the actual conditions. The following looks at some of the concepts and definitions that are helpful in this process.

Hazards: The source of risk is a thing or activity with a potential for consequence. Typically the focus is on threats such as unforeseen geological conditions, and in India with complex geological and hydrogeological conditions, especially in the rough terrain of the Himalayas, it is often difficult to investigate and forecast problems for long tunnel drives. However, increasingly it is necessary to evaluate and provide a means for coping with problems that arise. It is often convenient for designers and contractors to consider most problems under the guise of unforeseen conditions but more often than not it is simply a lack of recognition at the advancing face that controlling deformations is essential at all times. In the future this type of claim will be more difficult to reach agreement on with the insurers.

However, there is also a positive side. Hazards can be overcome successfully and turned into an opportunity and very often experienced contractors will work closely with the designers to achieve real benefits that can be passed on to the client. This generally requires a partnering type approach rather than the more traditional forms of contract that can lead to confrontation, particularly on projects where the client and designers seek to pass all the risk onto a contractor.

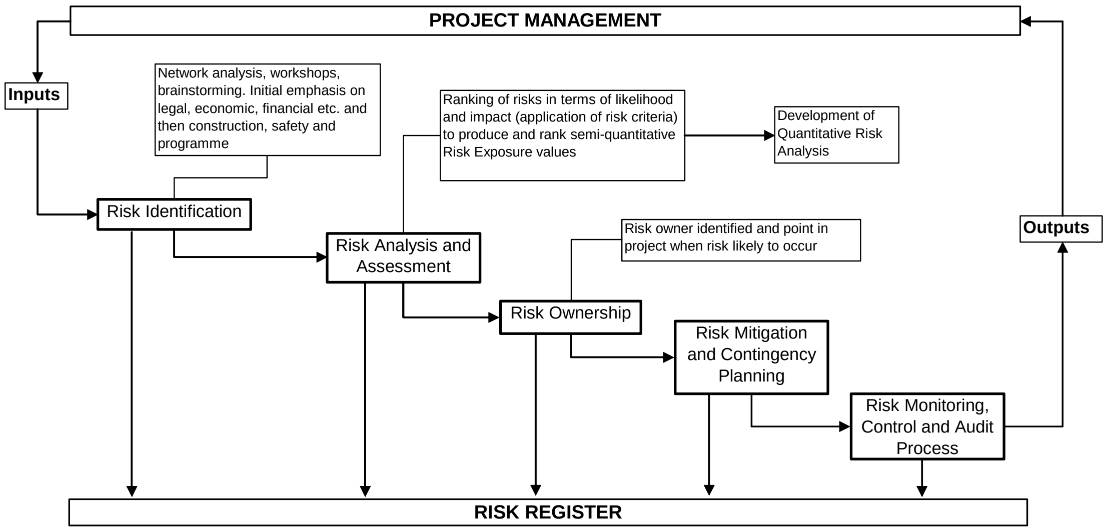
What it is important to recognise is – “if a hazard is not identified then it leads to events that cannot be controlled” – and this is when problems with programmes and budgets, and possibly safety issues, escalate and become difficult to manage on a project.

Risk: Risk is an adverse event having a probability of occurrence and an impact that will affect the achievement of the project's objectives. It is the combination of the chance of an event and its consequences. There will be a level of risk associated with each hazard. The level of acceptable risk will depend on both the probability of an event occurring and the severity of the impact on the project and is obtained using a formal risk assessment. It is the most important tool that the client and designers have at their disposal. This is formalisation of a process that in the past was built into a design or approach to construction using judgement and experience. The risk evaluation can either be quantitative (e.g. Monte Carlo analysis) or semi-quantitative and the level of risk will determine the extent to which measures are taken to mitigate the impact of a hazard on a project. In this context it is also important to note that where risks are “As Low As Reasonably Practical”, i.e. the ALARP principle, and the cost of controlling or eliminating the risk is out of all proportion to the cost of the project, they should be regarded as residual and both acceptable and manageable.

Risk Assessment: This is a formal process that needs to be conducted at the start of the design phase of a project and generally involves a brainstorming session with experienced staff. Involving the client and obtaining his inputs are extremely important at this stage. It is generally best managed using a facilitator but this is not essential if there is an experienced project manager to drive the process

The aim of the process therefore is not only to identify the hazards but to demonstrate that in the design phase, if there are serious concerns, e.g. squeezing ground in carbonaceous pyllite, these are recognised and the measures taken by the designers have reduced the level of risk to manageable proportions. More importantly as residual risks these need to be flagged up with the contractor and considered in his excavation and support methods through a "Live Risk Register". The Register should be part of the contractors Site Safety Plan as well as an integral part of his Quality Control/Assurance System. This is what the insurance industry now expects.

Risk Register: As a live document it is available to all parties involved in construction, built with key inputs from the project management team and providing key outputs to it. It is based on the identification of risks and their ranking in terms of likelihood and impact. This ranking is possible by applying an accepted risk criteria to determine Risk Exposure values and is a quick and semi-quantitative approach that may be refined by means of simulations and using the Monte Carlo approach. Further inputs to the risk register are assigning risk ownership and specifying when in the project the particular risk is likely to occur. This whole process allows risk mitigation and contingency planning strategies to be developed, which in themselves may generate further risks which are entered into the risk register and re-analysed as depicted below:



In this way it is a vital and living tool and subject to modification as the works progress in order to meet safety and other engineering concerns.

Practically it is a document that is a summary of:

- What can go wrong, i.e. hazards?
- How likely are they?
- What means are required to mitigate the chance of something going wrong?
- Who is responsible for managing it?
- Who is vulnerable if something goes wrong?
- When risk management actions needs to be followed through?

Ultimately it is also a communication tool and should be seen by project managers as an important means of controlling and implementing the works.

Site Safety Plan/Contingency Measures: There is little value in assessing risk and developing designs that address key issues if the contingency measures needed to manage risk are not identified. Without these recovering the costs of remediation will be difficult if the measures are not included up front in the design and addressed in the contractors Site Safety Plan. In practice, and this is applied on most rock tunnelling projects, rock support classification systems are developed by the designer to ensure that major changes in ground conditions can be addressed. However, it is also becoming common to include a suite of additional support measures that are able to supplement the support systems. This often includes adjusting excavation sequences to minimise face loss, the use of spiling or canopy tubes to pre-support headings or, in some instances of squeezing ground, face bolts to control deformations and volume losses. These therefore need to be documented by the contractor in his Site Safety Plan where he notes what plant, materials and equipment will be available in the event that a rapid response to an event is required.

5. Project Risk Management

This is the overall application of policies, processes and practices dealing with risk and has to be looked at for all phases of a project. A treatise on the subject has been published that provides a good overview of the subject[5]. The approach used by designers and contractors are different but also interdependent and therefore contractors need to understand the importance of a risk assessment.

Design Phase

The designer at both the preliminary and detailed design phases has to carry out a risk assessment that highlights the main hazards and how these are going to be addressed and/or mitigated in the design (including an assessment of contingency measures). The first part of this process involves risk identification and this can best be done by brainstorming, initially of legal, economic and financial risks and then of construction, safety and programme ones. A pro forma that documents this process is a pre-requisite and this document is important to the client and contractor since it forms the basis on which a contractor can evaluate his risks at the bid stage.

Construction Phase

At the bid stage it is important and vital that the contract documents, which should include the designers risk register, require the contractor to address four particular areas in his bid relating to risk management:

- What organisation and decision making structure will be put in place by the contractor to make sure that the design can be implemented in a robust and structured manner that reflects the needs of the project.
- The level of experience of the staff selected for the project and their ability to make decisions during the progress of the works.
- The procedures and systems implemented by the contactor to manage the works and make sure that residual risks are managed properly or adjustments are made to the design to reduce risks to ALARP.
- What Quality Assurance system will operate to make sure that the above requirements are auditable.

Organisation: An organogram for the management of the project that clearly identifies responsibilities and a decision making structure is essential and once submitted should not be varied if the client or project manager believes that it is not in the interests of the project. It should also clearly detail the decision making structure that will be employed - all the way from the Construction Manager through to the Tunnel Shift Engineers responsible for the day-to-day operations at the face.

This organisation will also be responsible for programme and costs and if there are variations that appear to be uncontrolled then the contractor should be held accountable by the client.

This may lead either to modifications of the design or to supplying additional resources at no additional cost to meet the programme. Only if the lack of progress is beyond the designers and contractors control should an application for an increase in budget be considered.

It should be noted that the main cause of the collapse on Heathrow Express was related primarily to the poor management and decision making structure rather than deficiencies in the design. The same was true of the project on Hull[5] and may prove to be the case on other recent failures.

Experience: It is invariably the case that many problems in tunnelling are people related. Tunnelling is a hands-on practical discipline and without hands-on experience on the part of both the designer and contractor it is extremely difficult to produce designs and manage construction safely and economically. Therefore, it seems likely that the insurers and their representatives will insist on a standard of qualification and experience that will ensure that the works can be managed safely.

The industry will have to consider this carefully. Already there are moves to look at the accreditation of people with tunnels skills and in our view it is only a matter of time before this is implemented.

Systems and Procedures: The framework that a contractor is required to work within is important. No longer is it sufficient that he intends to implement the requirements of the project, it is necessary that systems and procedures are in place to make sure that he complies with the intent of the design and contract documents. This is one of the primary purposes of a Live Risk Register compiled at the start of the construction phase.

Quality Assurance is a particular requirement in many countries, especially the European Union, and companies are not eligible to bid for work if they have not achieved IS 9001 status. This will increasingly become a worldwide requirement. The Site Safety Plan and Live Risk Register are an integral part of this.

As far as procedures are concerned, many of these are now built into the contract documents, especially the technical specifications. The single most important requirement is for the designer and contractor (and sometimes the client's representative) to attend a Daily Review Meeting (DRM). This reviews the previous day's performance and is a meeting that is empowered to make changes to a design where they are clearly necessary and ensures that the contractor is always aware that changes can bring benefits.

An essential part of the DRM requirement is to monitor a series of Key Performance Indicators (KPI's) Typically the KPI's are trigger levels relating to tunnel convergence as well as supporting instrumentation such as extensometers, inclinometers and pressure cells. These are normally plotted to show trends and if adverse trends are picked up provide a means of adjusting progress or the support systems to enhance the stability of the excavations. Other inputs into the DRM relate to the details of any grouting works, progress, support systems, sequences of excavation for multiple headings as well as the frequency of monitoring. While many engineers initially feel that this is onerous familiarity with it has shown that it is helpful and can be used for both drill and blast and TBM driven tunnels. The KPI's can also be progress rates and expenditure/cash flow projections that help the client and project managers to monitor the contractors performance.

6. Client Risk

Acceptance of a formal approach to risk management by all parties has implications that reach beyond the immediate impact on construction and is expected to have a profound impact on contract strategy and procurement. In particular, two endorsements in the Joint Code of Practice will apply to all risk policies and these in brief are:

1. The insured "shall use all reasonable endeavours" to comply with the Joint Code of Practice or any subsequent amendments thereto or any revised edition.
2. It is agreed and understood that otherwise subject to the terms, exclusions, provisions and conditions contained in the Policy or endorsed thereon, the Insurers will not indemnify the insured in respect of expenses incurred for:
   - alterations to the construction method or due to unforeseen ground conditions or obstructions,
   - measures which become necessary to improve or stabilise ground conditions or to seal against water ingress unless necessary to reinstate indemnifiable loss or damage,
   - removing material which has been excavated, or due to overbreak in excess of the design profile and/or for refilling cavities resulting therefrom,
   - dewatering unless necessary to reinstate indemnifiable loss or damage,
   - loss or damage due to breakdown of the dewatering system if such loss or damage could have been avoided by the use of standby facilities
   - the abandonment or recovery of tunnel boring machines
   - the loss of bentonite of any media or substance used for excavation support or as a ground conditioning agent.

Many in the industry feel that this is overdue. As far as designers are concerned this will eventually impact on their Professional Indemnity in so far as the construction method is intimately linked to the support systems. What it will also mean is that it is likely that the risk of failure due to anything other than negligence on the part of the designer will lie with the client. The client therefore needs to be satisfied that all appropriate precautions have been taken at the design stage to minimise risks.

It would be surprising if this does not affect procurement strategies since it is clear that if negligence cannot be demonstrated then the optimum approach for a client is to share rather than attempt to transfer all risk. The current trend and perception with "Design and Build (D&C)" or "Design, Build and Operate (DOB and BOOT)" is that clients can transfer all risk. Another variation on this is the Engineer Procure Construct[6] (EPC) contract which places all the risk on the bidder. On hydroelectric projects in particular, such contracts will be difficult to procure given the higher than normal risks and therefore it will be sensible to expect a move towards "partnering" formats. There are a number of examples worldwide where partnering has worked well, e.g. the LA Metro in the USA, T5 Terminal at Heathrow in the UK and the Amsterdam Metro.

It is now apparent that the only through a properly implemented risk management strategy will it possible to satisfy insurers requirements. This will affect all stages of a project from inception through to the operation and maintenance phase. It is also obvious that the insurers will appoint approved experienced professionals to represent their interests and provide an independent check on appointments that include vetting of designers and contractors.

The outcome is that clients will not be able to divest themselves of all risk and therefore there may be fewer design and build contracts and increasingly a more conventional contractual arrangement where the responsibilities for design and construction are clearly identified. It will certainly require that clients make sure their designers and contractors are well qualified to manage risk on their behalf.

The position is best seen in the context of the tunnel failure at Hull[7]. Insurers intend to limit their liability to between 110-125% of the original construction cost. On Hull this would have led to a reconciliation of £1,125,000 rather than £42 million. If the contractor and client had to bear this cost it would have been catastrophic. Certainly at the tender stage if this situation was known the contractor would not have been prepared to accept the risk and the client would have insisted on an alternative and more robust solution to mitigate the risks. This may have led to increased costs for the client but this becomes one of the penalties of repeated abuse of the insurance system. What it does imply is that when clients procure designers and contractors the contract documents have to be carefully written. Also, if in opinion of the insurer's auditor a designer or contractor has not implemented a proper risk management strategy all risk cover may not be available. To avoid such a situation a pre-qualification process is now seen as an automatic requirement, particularly on projects where the contract award is to the lowest tender. The alternative is to operate a two envelope system with the best two technical bids taken forward for negotiations on price.

7. Managing Projects in India

Many of the most challenging projects in India are related to tunnelling works on hydroelectric projects. In recent years projects such as Naptha Jakhri and the Chamera I and II projects have highlighted some of the problems that can be experienced. Many of these can be resolved by applying risk management but there also has to be increased recognition that partnering between the client, designers and contractors is necessary and will bring considerable benefits. One particular example of this was the Chamera II Hydroelectric project in Himachal Pradesh when a high level of cooperation between NHPC the client, the designer and the contractor Hindustan Construction led to a rapid and successful resolution of a number of difficult excavation and support issues in the underground powerhouse complex. In particular the NHPC Project Manager was supportive in terms of recognising the need for more discipline during construction in terms of sequencing excavation and support and understanding that if additional support measures were required that a framework was developed to compensate the contractor.

While there was a successful outcome to the construction, and recognising that hindsight is a wonderful thing, it is clear that a situation developed that almost led to an uncontrolled situation. How did this arise and what lessons should we take from this?

Firstly, the design was based on what was considered to be good geological and geotechnical information. An adit was put through to the powerhouse area and appeared to indicate that there were excellent tunnelling conditions. The actual conditions proved to be very different because of the presence of an undetected major fault and even with the information from the adit, would not have allowed the designer to predict the problems that arose, i.e. there was a good case for claiming unforeseen ground conditions.

Secondly, the contract documents were not sufficiently flexible to allow for variations in the actual conditions and therefore if the contractor cannot be reasonably compensated for additional work then it is difficult to get his cooperation.

Thirdly, additional support measures were not documented well enough or included in the Bill of Quantities. This could have been avoided to some extent by carrying out a risk assessment and building these in as a contingency.

Lastly, the experience of the staff concerned was an issue. In situations such as the Himalayas where difficult ground conditions should be expected the challenge is to understand ground behaviour, provide designs that can address worst credible cases and ensure that the staff working at the face are able to exercise control and make the right decisions when additional support is necessary. This is not an easy facility to acquire and comes from both a good design background coupled with sufficient construction experience to recognise the patterns of behaviour as they arise.

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