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DIFFICULT GROUND SOLUTIONS:

SPECIALIZED TBM IS KEY TO REVAMPING NEW YORK CITY'S WATER SUPPLY

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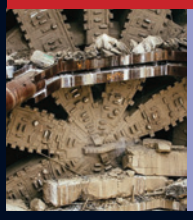

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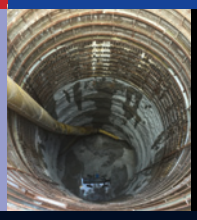

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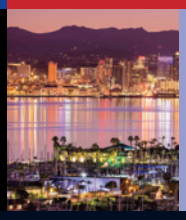

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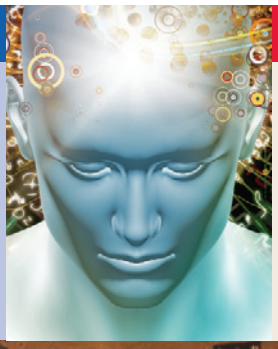

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AUTOMATE DESIGN

A FRAMEWORK IS DESCRIBED THAT COULD BEGIN THE TREND FOR AUTOMATED DESIGN

DELIVERING IN DELHI

Above: A view down London's Lee Tunnel showing the segments being delivered to the deep sewer tunnel (p23)

Left: Drill and Blast techniques still provide solutions for tunnel projects in the correct conditions, unsuitable for TBMs (p56)

Front cover:

At the end of November 2016, the Delhi Metro Rail Corporation (DMRC) successfully wrapped up tunnelling works on one of the largest urban tunnelling projects ever undertaken. With more than double the amount of tunnelling on both Phase I and Phase II combined, overall a total of 30 TBMs were used to bore the 80 kilometres of underground tunnels on Phase III of the metro system.

Among its competitors, TERRATEC received the largest number of new machine orders for Phase III, with eight EPB machines successfully achieving 20 breakthroughs across four separate contracts on the project. In addition to supplying the machines, TERRATEC also provided comprehensive services on site to support the operation and maintenance of the equipment, assisting contractors in their achievements on the project.

Cover photo: One of the two TERRATEC EPBMs that made a double breakthrough on 14th November 2016, marking the end of tunnelling on Delhi Metro's 58.6km Pink Line (Line 7)

contents

SSE Generation Limited

the £130M Collapse at Loch Ness

The recent findings of Lord Woolman attributing the burden of around £130M in rectification works of a brand new hydroelectric tunnel on the Client in a design and build contract has lessons and implications for the tunnelling industry in the United Kingdom and internationally.

The Court placed liability at the foot of the Client in a design and build context, even where the collapse occurred within a short period after commissioning. The way in which the Court dealt with expert evidence as well as legal principles and concepts provides a tangible insight into the management of risk during construction projects. This brief commentary, soley relies upon material disclosed in the Judgement of the Court case and is not the synthesis of 80,000 pages of evidence and argument. ("[x]" in the text is a reference to the key paragraphs of the court case.)

By Professor Arnold Dix, Lawyer and Scientist, and CEO of the ALARP group of companies.

THE GLENDOE HYDROELECTRIC SCHEME suffered a catastrophic tunnel collapse shortly after being handed over to the Client. Its' design life was 75 years and the collapse occurred during the commissioning period. The project reportedly enjoyed an excellent professional working relationship between the Client, its' experts and the Contractors for the duration of the construction period. However, following handover, irregularities were detected within the performance of the hydro scheme ultimately resulting in it being switched off. The tunnels were then drained revealing an area of substantial collapse. Despite the prior excellent relations between the Client and the Contractors a dispute arose about payment for the remediation works and ultimately this resulted in another

against Hochtief –

contractor being employed to remediate the failed section of the tunnels.

Design and rock classification

A review of the Court documents reveals some interesting conclusions of fact. Firstly, and critically neither the Owner nor the Contractor's experts noted any geological or geophysical defects during the tunnelling which demanded rock support in the area of collapse.

Both the "Q System" published by the Norwegian Technical Institute and the Contractors "Observational System" which relies on the skills and experience of the engineering geologist to assess rock mass of the tunnel were relied upon for rock mass classification. The tunnel was built using a TBM. It was contemplated that mostly the tunnel would be unlined, however the Court noted that:

"Most unlined tunnels require some support in section of weak rock and also close to the turbine." [21]

The tunnel diameter was around 5m. The head race tunnel was around 6.2km long and the tail race tunnel was around 1.9km long spilling water into Loch Ness. It was agreed that the design life would be 75 years.

"Although I hold that the collapse was an employer's risk event, I also conclude that any loss suffered by Hochtief was caused by its own breach of the repairing obligation…"

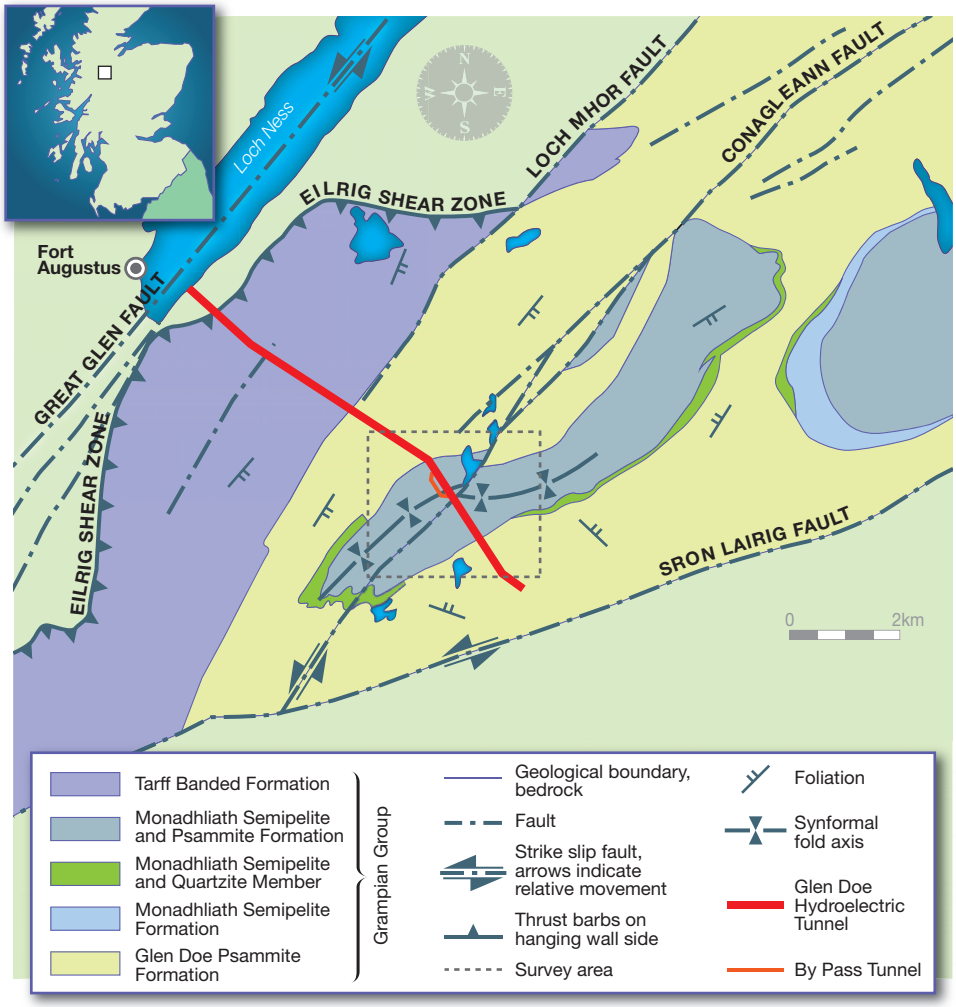

Figure 1: Plan map of the project location and geology

The parties

Interesting about the Glendoe scenario is that the case involves sophisticated contractors, clients and consultants from the mature tunnelling industry. The client, Scottish & Southern Electricity Group (SSE), is no stranger to hydroelectric schemes. Hochtief is one of the most highly regarded contractors in the world, Jacobs (Jacobs Gibb Ltd and Jacobs UK Ltd, together here as Jacobs) as the clients engineering geology consultant and supervisor, Pöyry Energy as specialist designer for Hochtief, and Andritz mechanical and electrical sub-contractor for Hochtief with extensive experience in hydroelectric power station refurbishment. Clearly this was a "top shelf" group with an equally impressive array of teams and individual experts supporting the project. In this context a catastrophic collapse of the tunnel is worthy of particular attention and the courts deliberations of the evidence presented by Senior Counsel (Queens Counsel in Scotland) means the readers can have confidence that this is a case which has been dealt with in detail, professionally and that the lessons to be gained should be considered carefully.

Geological context

The Glendoe Scheme required the construction of the head race tunnel through the Conagleann Fault Zone ("CFZ"). This zone was identified from the outset as posing a risk to tunnel integrity. A noted by Lord Wolman:

> *"While it is apparent on the surface the only means of knowing how the individual fault strands align and intersect with each other underground is to drill bore holes." [26]*

Legal Context - Tender Procedure

During the tender phase SSE told contractors that:

> *"Jacobs expected 97.5% of the excavation to be in "good" rock, but added that there was a plausibility about the ground conditions…" [37]*

Hochtief submitted its tender stating that:

> *"During construction the support requirement will be decided at the face, based on actual conditions …"* [38]

Prior to submitting its tender Hochtief asked SSE to drill a deep bore hole to find out more about the geology of the CFZ.

His Honour found that that request was not fulfilled because:

> *"It would have required the largest drilling rig in the UK. At that stage there was no access road to allow such a rig to be transported by lorry. No civilian helicopter could lift a rig of that size."*

Jacobs prior to tender produced a ground reference conditions report based upon a bore hole examining where it was thought the CFZ intersected the tunnel. Subsequent to the collapse it was determined that this borehole missed the main area of the CFZ. As a result of missing the main area of the CFZ the parties were misled into thinking there were good tunnelling conditions in the CFZ.

Hochtief's method relied on a TBM and initially expected to have only 40% of the head race tunnel lined. The contract price was £126M.

Culture during construction

The Court notes at paragraph 44 (the evidence of Hochtief) that from the outset of this project there was a good relationship between SSE (the Client), Hochtief, Jacobs, Poyry, and Andritz. The Court noted the parties held weekly and monthly meetings to discuss technical issues, which they mainly resolved by agreement. A fact of specific reference is made to the culture of the project and this positive professional attitude onsite is testament to the high calibre of all parties in this case. Indeed the Court case as reflected in Lord Wolman's judgement also reflects the high level of satisfaction of Lord Wolman with the clients in Court (albeit there are some criticisms in detail about the complexity, mass of documents and expert evidence preparation).

The TBM was of a gripper type and there was a probe drilling rig on the TBM. Because the conditions were so dry and there were no gas issues, forward probing was not required by Hochtief. From the TBM excavation perspective the conditions were very dry and there were few sections of weak rock.

Rock classes and mapping

Between the parties experts it was agreed that there would be only 4 classes of rock. Class 1 requiring minimal support; Class 2 involving rock bolts and shotcrete around part of the crown; Class 3 was full circumference shotcrete; and Class 4 prescribe increased shotcrete together with steel arches.

There was also the opportunity for the engineering geologists to specify additional support measure within a class on an as needs basis. [paragraph 53]

Both SSE and Hochtief employed geologists' onsite to continuously agree on rock classification. Lord Woolman noted that the records reflected the fact that the

mapping procedure was conducted jointly and a draft rock excavation classification sheet was prepared with comments from all parties. Lord Woolman also noted that the practice was that Hochtief created a geological database and that as the database was updated an email would be sent to Poyry and Jacobs in the following terms:

> *"The latest rock excavation classification assessment and geological mapping can be found via the following link…. Please advise if the classification or support specification is at variance of your observations or design assumptions." [63]*

The Lord found that there was:

> *"… no evidence that anyone sought to change or otherwise queried the decisions being made onsite."*

Neither Poyry nor Jacobs took issue with the classifications being made. Furthermore Hochtief, Jacobs and Poyry all signed the rec sheets with the Client's expert signing them "approved". His Lord specifically notes that the signing of the rec sheets was "approved" and not "as seen" or "acknowledged". His Lord also noted that:

> The Client's signature *"approved"* was included *"many weeks later, he had ample opportunity to cross check classification ... against the findings of the Q-System"*.

Such a system demonstrates a high level of expertise, professional conduct and confidence in the process. It is further evidence of a sophisticated and mature system for construction on this project and this conclusion is reflected in the tone of the decisions by His Lord.

Predicted and reality - The Rock Conditions

The tunnel conditions actually encountered were much better than predicted. [67]

	Expected %	As Built %
Class 1	58.9	84.3
Class 2	23.1	15.4
Class 3	14.3	0.3
Class 4	3.7	0.0

From this summary it is clearly apparent that the Client received the benefit of significantly better rock conditions and the Contractor was required to do significantly less remediation and structural hardening works than initially anticipated. The client got a lower price, the scheme was cheaper.

The article author - Professor Arnold Dix

The Conagleann Fault Zone

Hochtief was aware of the risks proceeding with the TBM through the fault zone and removed the probe rig in favour of enhancing the ability to install rock bolts and metal arch supports. Warnings were issued to mining personnel about the risk of travelling through the fault zone. This was expressed bluntly, warning TBM crews to take "extreme care" when walking through the area of the tunnel. Other warnings recorded by His Lord include:

> *"You are now in an anticipated fault zone so expect deterioration at any time." [70]*

Observation - There was no indication of poor rock condition in the CFZ. All documentation recorded that the conditions were Class 1. As noted by His Lord:

> *"The TBM has now passed through the predicted zone of the Conagleann Fault but indications of its existence were imperceptible." [71]*

After the completion of the tunnel, joint inspections took place. These inspections were attended by representatives of Hochtief, Jacobs and Poyry and there were only comparatively minor areas identified where strips of shotcrete and mesh were prescribed for very small areas of erodible rock. Tests were conducted in areas identified by Poyry to check for swelling clay minerals, but no potential problem was identified.

At the Handover - His Lord found that other than some small matters:

> "No one expressed any concerns about the stability of the tunnels.

Employer Takeover

SSE issued a Takeover Certificate to Hochtief stating:

> *"… I confirm that I am satisfied that the power station and associated tunnels is now sufficiently complete for operation and is taken over by employer .... The employer also takes over the head raise and tail raise tunnels …" [79]*

There was a two year defects period and it was anticipated that there would be an inspection 2 years later to carry out defect inspections.

Within a few months of opening odd measurements were being received on the head pressure in the system. There were no alarms but some of the indicated pressures and resultant hydroelectric generation were lower than expected. Over the next few months there were issued in the head reading and the scheme took an unusual amount of time to get up to a reasonable generating capacity.

Relationships deteriorate

Once it was decided to investigate the failings in the hydro scheme the relationships between the parties began to deteriorate; most importantly between Hochtief and the Client. Hochtief formed the view that they were being prevented from carrying out remedial works and the Client formed the view that Hochtief did not want to do the works. As one would expect it was a significant dispute over who should pay for them. As His Lord noted the question of who pays for it is a different point to who should actually perform the works. The initial response was that Hochtief did not accept liability but that it was preparing to mobilise. Various inspections took place, the debris pile identified was substantial almost totally constricting the tunnel, there were reports of vibration and the sounds of rocks fall occurring while inspections were being conducted.

Hochtief maintained the collapse was an employer's risk event and SSE asserted it was a contractor's risk event. These views existed through to the Court hearings.

In the time that followed the detection of the complete collapse there was an impasse. Initially discussions were good but later they deteriorated rapidly.

The exchanges became contractual in nature with SSE wanting the recovery project to initiate as soon as possible and Hochtief insisting detailed investigations should take place. There was also growing mistrust between the parties over the nature and extent of the collapse area as initially indications were that it was 270m long but later was thought to be more in the order of 100m long and this was not conveyed to Hochtief for many months.

This meant that when meetings occurred around a year later with suggestions of 50/50 costs sharing no agreement could be reached. Hochtief proposed that both parties and their insurers should nominate an expert panel of engineers to investigate the issue prior to

implementing the fix. SSE was concerned that such a panel was not contemplated under the contract and that it would lead to a stalemate. Hochtief insisted it was an employer's risk event because the Completion Certificate had been issued.

Parties relationship becomes dysfunctional

Following the collapse relationships degenerated rapidly. Hochtief's view was that as the project had been handed over this was the Client's risk financially and that a solution should be found after performing a careful analysis. On the other hand the Client's view was that Hochtief had failed to deliver the project correctly and that therefore they were required to fix it. The result is an impasse resulting in litigation, which took many years and cost countless millions of dollars in fees and wasted effort.

Mistrust grows

Around a year after the collapse the Health and Safety Executive ("HSE") attended the tunnel, conducting an inspection and provided an advise on a mediation strategy. As noted by His Lord:

> *"As a result of a misunderstanding Hochtief was not present at the HSE meeting. SSE believed Hochtief thought it premature to discuss the repair works with HSE. In fact Hochtief had been willing to discuss the investigation works."*

His Lord singled out this event as substantially influencing the attitude of each party towards each other. As noted by His Lord:

> *"… it reinforced SSE's view that Hochtief was not committed to finding an expeditious solution. It underscored Hochtief's view that it was being excluded from the recovery project".*

His Lord found that SSE had a preference for Hochtief performing the remediation because of its knowledge and expertise of the site but that it was frustrated at the staff and resources made available. On the other hand Hochtief was concerned that the necessary technical investigations were not being conducted in order to de-risk the remediation engineering and that it was being treated poorly by SSE.

Hochtief made various proposals such as a 50/50 cost sharing of a technical investigation and repeatedly reiterated its willingness to mobilise to site if paid to do so.

Around 13 months later SSE issued, what His Lord described as, "an ultimatum letter". It demanded Hochtief provide a program of the remedial works within 14 days and agree to a 50/50 cost sharing until liability had been determined. Hochtief refused to comply with conditions, denied it had failed to make progress and suggested a further meeting as a matter of urgency. There was no further meeting.

Jacobs

Jacobs produced an outline of the investigations it thought were necessary for the remedial works including surface mapping, aerial photography, seismic topography and drilling of bore holes at specific locations.

The British Geological Survey ("BGS") became involved in the matter, ultimately taking over four years to complete a fresh geological map of the CFZ.

Ultimately the BGS concluded that:

> *a. "The CFZ is a complex fault structure with multiple zones of fractured rock over a short distance*
> *b. It intersects the HRT at the collapse zone*
> *c. The nature of the rocks in the collapse area is unknown" [135]*

Findings – why did the tunnel collapse?

His Lord provided two findings as a matter of fact as to why the tunnel collapsed.

The first one at paragraph [147] was because there was not enough support, poor rock conditions coincided with insufficient shotcrete and rock bolts.

More detailed findings of His Lord were that the great difficulty in providing a long answer as there has never actually been a full investigation of the cause of the collapse. The reason for this is that once it was decided to build a bypass tunnel the exact reasons for the actual collapse are academic, not really relevant, because the legal focus then turns to the construction of the bypass tunnel.

His Lord notes that the dimensions in the void range from 2,374 cubic metres to 13,000 cubic metres.

In the end His Lord was of the view that it was impossible to determine the cause of the collapse. His Lord was ultimately of the view:

> *"… The most likely explanation, which is neutral on the question of fault, is as follows:*
>
> *1. The CFZ consists of interconnected faults of thin single shears with good rock in between.*
> *2. The weak rock deteriorated and lost its strength when submerged, a process … referred to as slacking.*
> *3. The flowing waters washed out the areas of erodible rock.*
> *4. The erosion progressed and opened up larger seams.*
> *5. The erodible material was progressively deposited as sediment over a significant length of the HRT.*
> *6. The HRT lost stability and the tunnel collapsed.*
> *7. Dewatering caused further erosion." [152]*

The legal dispute

Under the terms of the contract the Client assumes risks for events which include:

> *"Loss of or damage to the parts of works taken over by the employer, except loss or damage occurring before the issue of the Defects Certificate which is due to … a defect which existed at takeover …"*

and

> *"a part of the works which is not in accordance with the works information or a part of the works designed by the Contractor which is not in accordance with the applicable law or the Contractors design which has been accepted by the Project Manager."*

The Client contended that both of the above limbs were satisfied and therefore the scheme could not:

> *"… provide reliable service without requirement for major refurbishment or significant capital expenditure"*

because Hochtief failed to install the level of support to prevent the erosion of erodible rock during operation.

On the other hand Hochtief argued that:

"The Contractor is not liable to defects of the works due to his design so far as he proves that he used reasonable skill and care to ensure that it complied with the works information." [161and 162]

His Lord found that Hochtief did not guarantee the works. Instead Hochtief promised to build the works with "reasonable skill and care". As noted by His Lord:

"Hochtief's assumption of a more limited degree of risk would have been reflected in the contract price and the level of the insurance premiums."

This is a very important distinction between what the Client thought they were obtaining and what Hochtief contractually agreed to provide. This meant that Hochtief could provide a lower cost to the Client.

His Lord rejected the proposition that the support scheme required Hochtief to shotcrete all erodible rock as outlined as the terms in the tunnel support methodology. He rejected the proposition that it should have installed Class 3 or Class 4 support wherever it found erodible rock. [165]

The reason His Lord rejected this approach are outlined in Clause 166 of the determination.

a. The overwhelming body of contractual provisions calling for the exercise of engineering judgement in the tunnel
b. The term erodible rock is vague and required interpretation at the face
c. It was not intended by the parties that a mechanistic process be adopted that responded without engineering judgement and care
d. The price would have been much higher for the Client if this was the criteria actually used
e. It would mean that it wasn't possible to have an unlined tunnel in simple geology and yet it was the unlined tunnel which provided the enormous incentive for this economic construction
f. The provisions sought to be relied upon by the Client were actually designed to deal with water outflow and loss, not the issue of tunnel stability [166]

His Lord therefore concluded that there was no mandatory requirement to shotcrete all erodible rock and that the engineering geologists had to exercise judgement in considering the integrity of the tunnel.

Support system to be employed

The contract documentation clearly provides a joint system for assessment of rock classification at the face. His Lord noted in particular that:

- "Reference ground conditions report: "During construction, the support requirements will be decided at the face, based on the actual conditions".
- Works Information: (i) "Following each excavation cycle, the contractor maps the face, crown and sidewalls to enable the classification of the ground in accordance with the rockmass classification system". (ii) "The contractor agrees the rockmass parameters with the project manager and the support class is agreed prior to its installation."
- Design drawing D201: (i) "Rock supports to be installed to the extent required to meet the rock conditions encountered". (ii) "Rock support and surface treatment may be modified as considered necessary to adapt to the actual geological site conditions at the work site."
- The baseline ground conditions report and the design statement for the tunnel are to similar effect." [170]

His Lord therefore concluded that:

"…the parties clearly agreed the approach to rock classification and support. The engineering geologists should jointly determine both matters within the tunnel. This collaborative approach had great utility. It took advantage of the experience of all involved."

Further the Court noted:

"it was beneficial for all parties for the classification of the ground to be checked as it went along because the consequences of defects being raised at a later date would create difficulties for both parties". [171]

Critically and fundamentally and commercially of great relevance is the fact that this system meant that SSE: "*only paid for necessary support*".

Joint inspections

It was important to His Lord to note that many experienced tunnellers scrutinised the HRT both during and after the TBM drive. They included engineering geologists, tunnel designers, engineering and TBM crews. They were actively looking for problems. None of them saw signs of fault that might threaten tunnel stability. None recommended the installation of a high level of support at particular locations. [180]

Prior to the tunnel going into operation Hochtief, Poyry, Jacobs and SSE inspected the whole tunnel on a metre by metre basis. Only minor issues were identified and these were resolved prior to watering up. His Lord noted with approval a report by what he described as a "distinguished tunneller", there is no recorded evidence of passing through any feature that would potentially cause the catastrophic collapse that has occurred. [181]

His Lord holds that:

"A different classification system would not have resulted in the installation of heavier support".

His Lord noted with approval that eminent experts stated:

"No system could have predicted the correct level of support." [185]

His Honour put great weight on the fact that Jacobs had approved the rec sheets on behalf of the Client and that the collaborative approach had been taken about rock conditions encountered at the rock face.

On this basis His Lord found that Hochtief did exercise reasonable skill and care. As noted by His Lord the Client's propositions are "founded on hindsight". [187]

Hindsight is not, and can never be, the criteria for a determination of a liability. This case clearly supports the underlying fundamental proposition of legal systems in all jurisdictions (not merely common law jurisdictions) that hindsight is not, cannot and never should be the basis for determining liability in a case.

Should Hochtief have returned to site?

Under the contract Hochtief was required to return to site. As noted by His Lord the contract provided that:

"Until the Defects Certificate has been issued and unless otherwise instructed by the Project Manager the Contractor promptly replaces loss of and repairs damage to the works, plant and materials."

In these circumstances His Lord drew a distinction between a requirement to return to the site and perform the remediation and secondly whom is to pay for it. For these reasons a Court held that:

"… Wrangles about liability are postponed. If the damage is ultimately found to be to be an employer's risk event, the contractor is entitled to payment. The repair works will be a compensation event: … If, however, the damage is due to a contractor's risk event then it must bear the costs."

Therefore His Lord found that Hochtief breached its obligations under the contract by linking an agreement to perform the remedial works to an agreement for payment.

Furthermore the Court held that as the collapse was an employer's risk event, the employer has to bear the cost of the recovery project because Hochtief failed to perform the remediation (because it was demanding an agreement for payment) it cannot sue the Client for breach. [191]

The Court found that the client did not contribute to the damage by not recognising the unusual pressure measurement and loss of generating capacity as evidence of a catastrophic failure earlier. Therefore the Court held that there was no contributory negligence.

The Court found that the costs of the remediation were reasonable. The general principle which is applied is one founded in common law almost 100 years ago in Banco de Portugal v Waterlow & Sons Ltd 1932 AC 452, Lord MacMillan stated:

> *"It is often easy after an emergency has passed to criticise the steps which have been taken to meet it, but such criticism does not come well from those who themselves created the emergency. The law is satisfied if the party placed in a difficult situation by reason of the breach of a duty owed to him has acted reasonably in the adoption of remedial measures, and he will not be held disentitled to recover the cost of such measures merely because the party in breach can suggest that other measures less burdensome to him might have been taken."*

The fact that His Lord found that Hochtief refused to perform the remediation measures unless SSE agreed to pay the costs therefore placed a high barrier in front of Hochtief in order to prove that the damages claimed were unreasonable. His Lord finding that it was reasonable and that the costs were reasonable and he took note of the fact that cost auditors were involved in ensuring that the remediated works were correctly costed.

His Lord was particularly impressed by the costs monitoring that took place and that the scrutiny afforded by Gardiner and Theobald as cost consultants provided an appropriate level of scrutiny so therefore the costs were reasonable.

"[251] Although I hold that the collapse was an employer's risk event, I also conclude that any loss suffered by Hochtief was caused by its own breach of the repairing obligation…"

Conclusions

This case provides potential wisdom and lessons on so many levels.

The key lessons are clear:

1. *Despite the best endeavours of highly experienced contracting parties, ground conditions can and do conspire to cause catastrophic failures*
2. *Where clients seek to reduce costs as far as reasonably practicably and manage risks dynamically through such methods as agreed face mapping and risk assessment, to reduce costs, the burden of the lower cost can fall with the client.*
3. *Where contracts are entered into that do not impose absolute liability on the contractor, discharging due care and diligence is a defence to claims of liability against the contractor*
4. *Where obligations exist under a contract to rectify faults and the question of costs for those rectification works is at large, it is a dangerous strategic move to try and couple performing the remediation works to the payment for those works*
5. *It is essential in the event of a dispute that professional relationships be maintained wherever possible*

The benefits of an impeccable working relationship between the parties, during the construction of this project, were entirely lost through a series of misunderstandings between the parties following the detection of the catastrophic failure in the tunnel. Respective blame for collapse can never be the basis for liability.

Had the parties taken up early offers of commercial settlement from the builder, or perhaps an expert dispute settlement process as suggested by the client, it is almost certain the case would have settled long ago without the public airing of the dispute and the huge time and financial costs.