

# ITATECH

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**PEOPLE LIKE TO** talk about the 'big tunnelling family'. It's an idea that makes sense in a relatively small industry where everyone knows each other – well, almost.

But the thing about most families is that the older relatives are usually in charge. And sometimes new ideas from younger members can take a while to be accepted.

So it is interesting to see how the rest of the family is reacting to ITAtech, the industry group within the International Tunnelling and Underground Space Association (ITA) which was set up just over two years ago. At an open meeting of ITAtech at the World Tunnelling Congress (WTC) in Geneva in June, some appeared slightly anxious about this new kid's ambitions.

Already ITAtech's Activity Groups (AGs) are

technical knowledge, helping countries where tunnelling is developing and bringing in best practice from other industries. Activity Groups on the other hand provide a forum where industry can come together to promote innovation which is relevant to the industry at that time. We have always been missing this type of forum."

Ruckstuhl is a confident public speaker and diplomat, who is well-suited to making

need to produce results. No company wants to pay for membership, pay for travel to meetings and give its employees' time for no return. As Ruckstuhl told fellow ITAtech members at the open meeting, "We all have to fulfil the expectations of our shareholders."

ITAtech's purpose is to speed the uptake of new technologies, primarily by coming together to agree on what decision-makers



**“Working Groups see representatives from member nations coming together to share technical knowledge, helping countries where tunnelling is developing and bringing in best practice from other industries. Activity Groups on the other hand provide a forum where industry can come together to promote innovation which is relevant to the industry at that time. We have always been missing this type of forum.”**

Daniel Ruckstuhl

living up to their name (see Table 1). Where Working Groups typically take on larger subjects that might require several years' work, the AGs have already produced guidance despite having been formed just 18 months ago, some even more recently. You can read reviews on both these documents at the end of this article.

Speaking to TJ after the meeting, Daniel Ruckstuhl, chair of the ITAtech steering board and vice president of MEYCO Global UGC, BASF, acknowledged that there are some maybe feeling anxious. "To a certain extent, there may be a misunderstanding and a fear. But there is a distinct difference between Working Groups and Activity Groups.

"Working Groups see representatives from member nations coming together to share

ITAtech's case. "When I reported in the General Assembly I reached out to both parties and said 'let's work together'," he says. "'Lets invite each other and be very clear that we are not duplicating work, that we are complementing each others' competencies and that we learn from each other'."

ITAtech Activity Groups certainly are different from Working Groups. For a start, companies have to pay to be involved in them. If you want to chair a group and have a seat on the steering board, your firm has to be a prime sponsor, paying Euros 15,000 a year. Or a firm can be a supporter for a much more modest Euros 1,500 a year, which allows them to sit on a group.

What this means is that Activity Groups

should know and what current best practice is. The output from the Activity Groups is likely to be guidance, in the form of published documents, which ITAtech will be looking to share freely with anybody and everybody.

In Geneva, two of the Activity Groups, Excavation, and Lining and waterproofing, were able to unveil guidance documents on main bearing life and spray-applied waterproofing membranes respectively.

This first 18 months of activity haven't just been about getting the guides out. Companies which usually compete have willingly come together in order to find common ground, and to set the right level of detail and information to promote the technology without favouring any particular

Industry group ITAtech may be the little brother in the ITA family, but it is already making its presence felt. Kristina Smith reports from the World Tunnelling Congress in Geneva whilst two industry experts readers review the group's first two guidance documents.

# headway

manufacturer.

In defining and explaining to the world about bearing life, for example, some of the leading TBM manufacturers have almost formed a treaty. Now like can be compared with like, and if anyone tries to misrepresent what they are offering, the guidance can be referred to.

There must have been some heated debates around the sprayed waterproofing

table too. But the group managed to overcome their differences – and even to stand side by side to deliver a seminar on the subject, a live illustration of what they are trying to communicate with three products all being applied next to each other.

Many lessons have been learned, some of which were highlighted at the meeting and as a result, some changes will be made. But that isn't a problem for people who come

from a commercial environment.

"I want to have an organisation that can review what it's doing and adapt to the needs of that organisation," says Ruckstuhl.

"Because we all come from industry, we all know what it's like to change organisations in order to meet new challenges."

## You pay, you play

ITAtech was formally born in April 2011 (For more details about its origins, see TJ Oct/Nov 2012 p10-14). Suppliers see it as their chance to take a more constructive role in the ITA: rather than only have the opportunity to promote their own products through exhibition stands, advertising and branding, they hope to answer some of the big questions that consultants, contractors and

## Seeing is believing

There was enthusiasm all round from those who attended ITAtech's first seminar on spray-applied waterproofing membranes. Some 58 people (suppliers, consultants and contractors) spent a day at the Hagerbach Galleries in Switzerland, with presentations and demonstrations of three waterproofing systems from BASF, Mapei and Normet.

"I believe seeing is believing," said Normet president Tom Melbye, who heads up the ITAtech Activity Group which organised the seminar. "There are some

people who have written a lot, argued a lot about these technologies but have never actually seen them in practice."

Though ITAtech would have liked to attract more people to the seminar, says ITAtech steering board chair Daniel Ruckstuhl of BASF, the event did set out what it aimed to do. "When you are looking to establish common ground, if you are able to grow the pie, your slice of that pie will be larger. That was the idea of this seminar."

The seminar gave a unique opportunity to attend both lectures and practical demonstrations at the Hagerbach Galleries





## **“We burn for this!”** Tom Melbye

clients might have about existing but not well-established technologies.

ITatech isn't a suppliers only club; consultants, contractors and academics are equally welcome, but they too must pay for membership. Ruckstuhl would like to attract more contractors. "This is a big challenge for us, and for the ITA generally. Contractors are key people in the industry."

There are some contractors who see the benefit from getting inside information on emerging technologies through ITatech.

Already five contractors have joined up, one as prime sponsor and ITA executive director Olivier Vion reports two or three more may also sign up.

All-in-all there are 14 prime sponsors and 51 supporters, with eight in the process of joining after the WTC in Geneva. Some smaller firms see ITatech as a good way to punch above their weight, contributing their position to industry-wide guidance and making connections with other professionals in their field.

There are currently five Activity Groups, some of which have sub-Activity Groups. The output of the AG Lining and

waterproofing, under the leadership of Tom Melbye, president of the Normet Group, has been impressive.

At the meeting in Geneva, Melbye said of ITatech: "We burn for this!" And he meant

it. He must have been driving his group hard because not only did it produce a 64-page guidance document on spray applied waterproofing membranes, it also organised the seminar which was held at the Hagerbach test galleries in Switzerland, just prior to the WTC.

Melbye had a few words of wisdom to pass on to leaders of other AGs and sub-AGs. Getting agreement on anything at meetings was difficult, he said; leaders should set strict timetables, ask for comments from everyone, compile those comments, and move on.

Forging ahead, too, is the Excavation AG under Robbins CEO Lok Home, which has produced the guidance on main bearing life and has now moved on to look at best practice in backfilling. The purpose of the bearing life document was to try and explain why standard specifications calling for 10,000 hours' bearing are totally meaningless – unless the loading on the bearing during its lifetime has been taken into consideration.

Home addressed the issue of potential conflict with Working Groups head-on during the Geneva meeting: "We are cognisant that there are a couple of Working Group leaders we are bumping up against," he said. "We are conscious that we don't want to step onto your ground. We are not putting ourselves up as a theoretical group, we are just trying to say: this is out in the industry, we want to set best practice and to clear up things that bother us all."

Under the Monitoring AG, headed up by Felix Amberg president of the Amberg Group, there are three sub-activity groups all tackling issues which are most definitely

A second sub-AG is trying to tackle the issue of information overload in monitoring. Its goal is to define what an information and communication system which takes and translates all the information should look like; what information is valuable and what is not.

Finally a third Monitoring sub-AG is producing draft guidelines on how to use and tender some of the new technologies on the market. The document will focus on three – reflectorless measurement, laser scanning and InSAR – and also set out how these new technologies can work with existing ones.

The Support AG, led by Gustav Bracher, corporate key project manager for Sika Services, has been working to produce guidance on fibre reinforced precast concrete segments through one of its sub-AGs. This is an important subject, because many consultants and clients are reluctant to consider this technology because of a perceived lack of track record.

Clearly there have been plenty of discussions between members of the sub-AG on fibre reinforced segments, but discussion is an important part of the whole process, says Ruckstuhl. "It's not always easy to agree on what is best practice," he says. "It can take time, lots of discussions, but this is a big part of what ITatech is about. It cannot be about promoting a single technology or company because if we allow this, we will lose credibility."

Another Support sub-AG has been looking at the topic of sustainable sprayed concrete, but this has proved to be too large a topic to tackle. "This was too big a fish to catch," comments Ruckstuhl. "Having worked on it,



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Lok Home

topics of discussion in the industry right now. One sub-AG is providing advice on how often measurements should be made and defining 'active zones' and 'vigilance zones' around tunnels and station excavations.

it became clear that this was not a tangible enough subject."

At the Geneva meeting there was plenty of discussion about the need to tackle topics in small, manageable chunks. The conclusion

was that though every process is connected to another and part of the bigger picture, those producing guidance must draw clear and tight boundaries in order to produce something specific and useful.

Ruckstul told the meeting: "If we want to keep momentum going and deliver results, it is sometimes important that we limit what we are doing and focus on getting what we are doing to the market."

With many tunnels now in need of refurbishment or upgrading, guidance on rehabilitation will be welcomed by many clients. The Rehabilitation AG had just kicked off on the day of the ITAtech meeting in Geneva, but leader Enrico dal Negro, director of Mapei UTT, had already managed to map out with his group how they would tackle this topic.

"The first thing we want to do is a diagnostic activity – to understand where we are," dal Negro told the meeting. "Then we want to put together a big family of



**"The language of persuasion was coming out of the guidance document," Knights told the open meeting. "We felt there had to be a level playing field to allow designers to make up their own minds objectively."**

Martin Knights

**Table 1 - What ITAtech groups have been up to so far**

Activity Group	Sub-Activity Group	Progress so far
Excavation	Mechanical	Guidance on defining life of main L10 bearing published.*
		Working on best practice guidance for backfilling – publication expected mid-2014
		Working on agreeing standard nomenclature for machines and their applications
	Flexible excavation	First meeting due in second half of 2013
Support	Fibre reinforced concrete segments	Working on best practice guideline – publication expected June 2014 at WTC in Brazil.
	Bolts & anchors	Subject for guidelines yet to be decided
	Sustainable sprayed concrete	This subject proved difficult to tackle and is under review as an activity group
Lining and waterproofing	Spray applied waterproofing membrane	Guidance already published.*
		Deminar created and delivered.
		Now working to set up accredited training scheme.
Monitoring	Frequency of measurements	Draft guideline setting out frequency of measurement, distances and zones is ready. Final publication later this year.
	Communication systems	Defining what a plug-and-play system should look like. Draft due June 2014 at WTC in Brazil.
	Remote monitoring	Working on guidelines on how reflectorless measurements, laser scanning and InSAR should be used and tendered – expected publication late 2013
Rehabilitation		First meeting held in June at WTC in Geneva
Design		Providing peer review function for guidance issues; may also provide design input to guidance where appropriate.

\*you can download the two published guidance documents at <http://www.ita-aites.org/en/wg-committees/committees/itatech/publications>

problems and solutions." The plan is to split the group into two, one to tackle problems, the other solutions. "We want to find a common philosophy for the correct rehabilitation approach," said dal Negro.

The last person to speak at the ITAtech meeting was Martin Knights, tunnelling leader at Halcrow and former ITA president who has been a strong supporter of the ITAtech concept from the earliest stages. He is heading up the Design AG.

Knights reported that the Design AG has discussed whether it should be producing guidelines, perhaps outlining what industry best practice on design should be for emerging nations. But the group decided it should take an overarching role: "We felt we could be a bridge between the Activity Groups, to ensure some kind of consistency."

In fact, it seems that the Design AG has become the self-appointed upholder of the ITAtech brand. Asked to review the first guidance on spray applied waterproofing, the group suggested some substantial changes, along with a standard format which might be applied to guidance generally.

"The language of persuasion was coming out of the guidance document," Knights told the open meeting. "We felt there had to be a level playing field to allow designers to make up their own minds objectively."

The Design AG did improve the report, confirmed Melbye: "I want to recommend the work we did with the design group. It was a critical review but a really good intervention. And they were able to do a

review of a big document in under one-and-a-half months."

Ruckstuhl commended this approach: "The work we produce in this forum needs to be unbiased and professional. It cannot be promotional, exclusive or specific. This is not a promotion platform, this is a platform for all of us to find a common ground for advancing technology."

#### Investing for the future

One thing that impressed at the WTC in Geneva is the amount of money that some of the ITAtech prime sponsors are putting into the industry through the ITA. These firms were paying for exhibition space and branding at the WTC; they are providing their top brains to work on guidance; and paying into the ITA for their membership of ITAtech.

Some of the prime sponsors came together to host an ITAtech Industry Reception on the Monday evening of the WTC, held in a beautiful old power station building on an island in the River Rhône. The event was a celebration of ITAtech's formation and progress so far, and also a demonstration of the new entente cordiale which allows competitors to entertain their customers together.

All this investment is worth it, insists Ruckstuhl: "Our industry suffers from two things: it is conservative in its uptake of new technology and it does not attract enough new talent. If you are not ready to invest to change these things, then you are only hurting yourselves down the road."



**ITAtechs very first report from its Activity Group Excavation addresses a thorny issue for some TBM manufacturers: how to define the main bearing life. We asked specialist TBM consultant Richard Lewis for his thoughts on the document.**

## Review of ITAtech Report no. 1 TBM Main Bearing Life

**IF YOU TALK** to any tunnel engineer about TBM's and ask him which is the most important and crucial part of a TBM, nine times out of ten he will say "the main bearing". Of course there are many parts of a machine that are essential and important, - without cutters the ground will not be excavated, without a drive motor the head will not turn, and without thrust rams it will not move forward - but still the bearing is considered the heart of the TBM. Why is that? I suppose it is primarily because if it fails during the drive it is a catastrophic occurrence. Smaller components can usually be changed if necessary, and in many cases the machine can limp forward with one of the motors or rams inactive, until such time as it can be replaced. But changing a main bearing underground is a different story altogether, and the machine will not move until it is changed. Replacing the bearing is possible, and has been done on several occasions, but it is very time consuming and very costly. It is important therefore to try to ensure that the bearing will not fail, and that it is designed for the anticipated work it has to do, with sufficient life to ensure that it will last for the duration of the tunnel construction anticipated - and beyond.

Most TBM specifications these days define this by demanding a certain minimum Bearing L<sub>10</sub> life to be designed into the machine. In many case this is set at a figure of 10,000 hours and in the case of the Channel Tunnel Project a figure of 20,000 hours was demanded.

But do all engineers know exactly what this means - what an L<sub>10</sub> life is, - and how many understand how much and in what way the life depends on the loading applied to the bearing.

It is admirable therefore that the ITA, through their new grouping called ITAtech, have published a short and simple booklet entitled "ITAtech Guidelines on Standard Indication of Load cases for Calculation of rating Life (L<sub>10</sub>) of TBM main bearings".

This should serve two main purposes - To clarify what the phrase L<sub>10</sub> means, and to explain about the importance and assessment of

the load cases which are used to assess the bearing life. For the most parts these objectives are achieved in general terms, but the words of explanation are quite brief and in some areas perhaps some more detailed and accurate explanation and warning could have been given.

### Definition of L<sub>10</sub>

The definition of L<sub>10</sub> is provided by ISO R281 - (Rolling bearings - Dynamic load ratings and rating life). This document emphasises that the L<sub>10</sub> life is that reached by 90% of group of the same bearing - working under the same load conditions. This last condition of the life is not made clear in the guidelines leaflet.

However the guidelines do point out that the L<sub>10</sub> life is based primarily on the number of revolutions that the bearing will survive. This is logical since the calculations are based on fatigue analysis. Despite this, most TBM specifications define the life as a number of hours to be expected but do not refer to the speed or load cases which are the basis of the calculation. The difference between the life in revolutions and life in hours is given in the guidelines.

### Calculation of the L<sub>10</sub> life

One look at the formula quoted in ISO R281- (and the explanatory note PD ISO/TR 1281-1:2008 which is available on the internet) is sufficient to be thankful that no attempt is made to describe the detailed method of calculation of the L<sub>10</sub> life. The complicated and involved stress and fatigue analysis is well beyond the ken of this reviewer and it is



sufficient to quote the end result stated in Chapter 3 of these guidelines that the Rating Life Equation is:

$$L_{10} = (C/P)^K$$

Where  $L_{10}$  = Rating Life in [ $10^6$  revolutions]  
 C = Dynamic Load Carrying Capacity of the Bearing in [kN]  
 P = Applied Load in [kN]  
 K = for Roller Bearings = 10/3

i.e. the life is defined as the ratio of the designed capacity (as calculated by the manufacturer) to the applied load – all increased to the power of 3.333.

It is essential that these calculations are left to the specialist bearing manufacturer and are not attempted by the TBM user.

Nevertheless this formula, and the simple one for converting life in revolutions to life in hours, tell us two things.

**1** For any given bearing, the life in hours will vary inversely with the speed at which the TBM is operated

**2** The life will vary inversely with the applied load – to the power of 3.33

Clearly it is vitally important that the TBM designer provides the details of the load cases that have to be used in the design of the bearing, and/or the calculation of the  $L_{10}$  life.

$L_{10}$  life should be calculated for the maximum possible head speed for which the TBM is designed, and this information should be passed to the bearing manufacturer.

More importantly the applied load on the bearing affects the life to a factor greater than the cube of the load. These days more and more tunnels are designed to pass through a mixed face, going from soft ground where the loading is relatively light though a face of partial rock where impact loading is a danger through to a full face of rock where the maximum thrust loading that the discs can stand will be applied.

Some actual figures from a project which passed through soft ground, a mixed face and into a full face of rock and back again ended up with the following average figures for each ground type

Type of Ground	Head speed - rpm	Contact load on head - kN
Soft	3	1637
Medium	4.5	2600
Hard	4.75	4100

It can be seen from these figures that the relative  $L_{10}$  life of the bearing in the hard and the soft ground will differ by the following factor

$$(4.75/3) \times (4100/1637)^{10/3} = 33.7$$

The conclusion is that it is essential that the load cases given to the bearing manufacturer do not under-estimate the

amount of hard or mixed ground that is to be expected and that for variable speed TBMs, which are just about universal these days, the maximum head speed is used for the life calculations.

**TBM Bearing loads**

The bearing manufacturer can only design a bearing for the loads that are supplied to him by the TBM manufacturer. It is his responsibility after being advised of the geology by the contractor to assess and determine what load cases are given to the bearing supplier and what proportion of the total excavation time will apply to each load case.

anticipated ground conditions.” This is of course absolutely correct. However in the annex giving typical examples, general figures of 90% and 10% are used as if these are the normal amount of load case distribution. This could be misleading.

**Annex – Typical examples with different TBM types**

There is little explanation of how the eccentricity of  $F_e$  should be assessed. For machines driving through rockheads, from full face rock conditions into soft ground, the eccentricity can be large and an assessment of the average has to be made depending on the amount of mixed face encountered. As



suggested above, it is essential to err on the high side.

In the typical example for the rock gripper TBM, the maximum static load, which correctly does not have a % time allocated to it, is given as  $F_{CH}$ . This is stated to be the disc cutter capacity, e.g. 40 discs at 267kN = 10,680kN. For an occasional maximum static load, this seems low, since the maximum thrust installed in the thrust rams could inadvertently be applied by the operator whilst the machine was stationary.

In the typical example of the earth pressure Balance TBM, it is stated that  $F_t$  is the total equipped shield thrust, and is defined as  $120 \times (\pi/4) \times D^2 \times 9.81$ . This indicates a general load of 120 Tonnes per sq metre of face. This

The table for presenting these load cases is well set out in the guidelines document, showing the various loads and eccentricities that may occur. What is less apparent from the guidelines are how to select the different load cases and how to select the time differences.

In the remarks listed on page 7 it is correctly stated that “the number and setting of the load cases should ....take into account the

ignores face pressure, tunnel depth and geology. Whilst this may be a reasonable 'rule of thumb' average for some general cases and for early planning, - in a guidelines leaflet like this, it is not really accurate enough for detailed bearing design and it would be better to provide a more accurate method of assessing the load on the cutterhead and bearing. This would not be the total equipped shield thrust. The total thrust installed has to allow for skin friction, friction from the tail seals, towing load of the backup and include a factor for steering allowance. Of course none of these loads would be seen by the bearing, and so are not relevant in the bearing calculation.

In the typical example of the Slurry TBM, the loading due to the support pressure has been allowed for, although the formula assumes that the central area of the bulkhead is static and fixed to the main shield. In fact in many mixshield, this central area is fitted to the cutterhead and rotates with it. In this case, the face pressure will act on this area also and the formula for this element of thrust on the bearing is  $F_{FP} \times (\pi/4) \times D_1^2$ .

The diagrams and formula used in these examples are also confusing because nomenclature is not consistent. T represents both Thrust (Force) (in the slurry example and also Torque. F is normally used to represent thrust, or force, but in the slurry example, this letter is also used for pressure. Pressure is also represented by P. This inconsistency should be eliminated.

**Conclusion**

In conclusion, the Excavation Activity Group are to be commended for producing an important leaflet on a very complex, but important subject and trying to present it in a format that is easily understandable. Such documents can only improve the general awareness of the complexities of the machines we use, both within and outside the industry. However there are some aspects of the subject which have been, perhaps over-simplified. It is believed that most tunnel engineers who are likely to read and use these guidelines, would be able to cope with a more comprehensive approach to some of the assessments of selecting load case and the time to be associated with each load case, and with the assessment of loads on the bearing. These simplified rules do not appear to be consistent across the different types of TBM.

There are also some omissions. Little mention is made of the fact that many bearings used in TBM's have integral gear rings, either external, or more usually internal to the bearing. The cutterhead torque and drive motor configuration is important in establishing the tooth loads and gear design. This does not affect the

bearing life or raceways, but is important for the bearing manufacturer.

No mention is made of the re-use of bearings in second hand TBM's. When a TBM is to be re-used it is clear that the previous use must be taken into account when assessing the life of the bearing that is remaining. What perhaps is less clear is that the  $L_{10}$  life of the bearing will need to be recalculated based on the new load cases in the new project, which may be more arduous, reducing the  $L_{10}$  life from that anticipated at the start of the first

project.

Finally, it is worth noting that although bearing failures are fortunately not a common occurrence, they do occasionally occur – but they are more often due to seal failures allowing contamination in to the bearing cavity rather than to a design fault in the load assessment of the bearing design. This is more true now, as three axis rollers are the norm, rather than the cross roller bearings where the thrust and radial capacities were interdependent and not independent of each other.

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THE QUEEN'S AWARDS FOR ENTERPRISE: INTERNATIONAL TRADE 2011



**The second report to come out of ITAttech, the new industry-led group within the ITA, is a substantial 64-page document all about sprayed waterproofing membranes. We asked Mike King, Crossrail head of underground construction, Halcrow (CH2M Hill) to cast his eye over it.**

## Review of ITAttech Report no. 2 Design Guidance for Spray Applied Waterproofing Membranes

**WHEN WE WERE CHILDREN** (and had not put away our childish things), and before we started mucking around in dark holes in the ground, we were taught that it was charitable to share our childish things. And now that we are no longer children it is always encouraging to see that practice applied to the new currency of power – information.

This type of document takes a great deal of time and effort to assemble and this document is informative, straight-forward and an easy read, everything we are looking for in our stress packed lives. Although I may quibble about some minor phrasing and possible overstatement of the advantageous features of a sprayed membrane, I only have complaint about one word – and that's on the front cover.

Sprayed waterproofing membranes are likely to be a relatively new, if not novel, approach to excluding water from structures for some people, and guidance on the use of a new product is very welcome indeed. It is here that the ITA document is successful, taking the reader through the background of the system to give an appreciation of the benefits and restrictions of planning to embark upon its use on a project.

The example specification in particular will be of benefit to anyone starting from scratch, and captures the majority of issues that need to be considered, measured and recorded. As always with this type of generic specification, project specific needs will still need to be considered to ensure that over or under specification does not materialise because of direct copy. In particular, the user will need to understand the difference between long-term and short-term testing results for a particular product to ensure that the correct bond requirements are specified if the long term design relies upon this value.

But let us consider the caveat emptor moment. Do any of the documents of this

form put enough emphasis on the "design" aspect of the title? This is certainly not the easiest thing in the world to achieve, particularly when dealing with a material with varying properties and requirements. So why does the industry insist on claiming "Design Guidance" rather than just being a Guidance document.

It may seem churlish to complain about a document that provides a pretty broad spectrum of information, but to truly be a guide for the design of the system further information is required. Examples of useful material for inclusion are: information on the change in properties with time or with speed of testing; and data so that the "quasi" aspect of the "quasi-monolithic" structure can be evaluated.

Shrinkage of the secondary lining, and the impact of the bond (possibly whether the designer wants it or not), will also take on a whole new life of its own in the designer's mind, having spent a life-time thinking of cunning schemes to reduce bond to prevent shrinkage cracking. Guidance on this and other secondary aspects would be welcome. And yes, I know that this may not be part of the membrane "design", but it is a serious consequence of adopting bonded sprayed membranes.

It is a fact of life, and an unfortunate complication with this type of document, that the different materials and formulations



available will behave differently and data from the supplier will be required to undertake a full design. But as "Design Guidance" rather than "Guidance", shouldn't the designer, specifier and user be fully apprised of all the issues and pit-falls and trends of the material behaviour even if actual numbers for the real comprehensive behaviour of every material available can not be provided?

So, a "must have" read for anyone new to the subject... but please change the title.