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Demand for water mitigation in rail infrastructure

Top considerations for cable and conduit penetration seals

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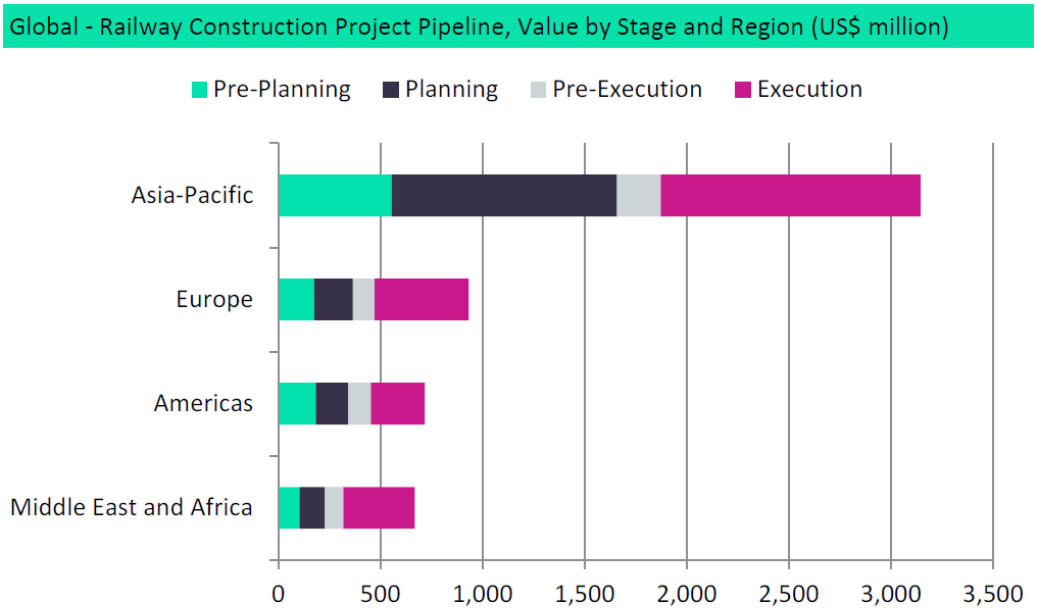
When water leaks in, revenue leaks out

Large investments with massive challenges

Urbanization has been one of the most transformative megatrends of the 21st century. About 60% of the world's population will live in cities within the next decade, up from around 55% in 2018[1]. Mobility in urban areas is not only an important economic factor but also a way of life. Government authorities around the world are recognizing the rising importance and attractiveness of rail transportation as a reliable, efficient and sustainable means of travel.

This optimism is also evident in the global railway construction pipeline, as tracked by the Construction Intelligence Center (CIC), which is worth $5.47 trillion. Asia-Pacific accounts for the highest value of the pipeline at $3.15 trillion, followed by Europe at $933 billion, the Americas at $717 billion, and the Middle East and Africa at $669 billion.[2]



On the other hand, the impact of urbanization and the increasing frequency and intensity of weather events over the last few decades are creating a new risk landscape for the rail authorities as well as for insurance companies, system suppliers and other stakeholders in the railway value chain. Predictions from climate change models indicate that the occurrence and severity of weather events will likely increase over the next few decades. Frequent and unexpected disruptions can wreak havoc for both passengers as well as rail operators.

Railway authorities around the world are looking to mitigate the impact of climate change while ensuring the safety of passengers and employees, longevity of assets, reliability in operations and cost efficiency through the lifecycle of the infrastructure.

Global urban rail transport: Before and after Sandy

Hurricane Sandy proved to be a pivotal test for the rail sector not only in the United States but globally. While the impact of Hurricane Sandy on New York City's iconic railway system is well known, it is important to look at the preparedness of the Metropolitan Transportation Authority (MTA) before the Hurricane struck in October 2012.

MTA had dealt with rain, ground water and seepage from the city's sewer into the railway tunnels during the decade prior to the Hurricane.[3] MTA employed 700 pumps along the railway on a daily basis to drain roughly 13 million gallons of water. These pumps had the capacity to process some level of rainwater each hour but anything in excess would cause flooding and drainage issues. Such flooding events had forced the shutdown of New York City's subway system several times. The shutdowns were necessary to avoid the risk of excess water coming into contact with the electrified third rail, causing the water to boil and possibly setting debris on fire.

According to estimates, Hurricane Irene that hit New York City in August 2011 caused damage to the transportation system worth $65 million.[4] Improvements necessitated by Hurricane Irene and other floods led to the MTA being better prepared to deal with Hurricane Sandy.

Hurricane Sandy led to an estimated $5 billion in losses. $4.75 billion of which was in infrastructure damage and a further $246 million in lost revenue and increased operating costs due to railroad and subway lines, rail tunnels, subway stations and power and signal equipment being flooded with corrosive salt water.[5]

One of the key lessons learned has been that **prior preparations resulted in limiting the damages and losses that otherwise would have been much higher**.

Experts at the World Bank, who visited New York City to learn about the design, operation and maintenance related improvements, also highlight the importance of preparedness to reduce damage to critical assets with respect to mitigating the impact of climate change on urban railways.[6]

An important finding from this group is that the electrical, communication and signaling systems are typically the most critical, vulnerable and expensive assets on the railways and their modernization not only limits losses caused by climate change but also contributes to operational reliability. Along the same lines, delaying inspection and maintenance procedures will adversely affect the resilience of the network against disasters.

Flooding in urban railways and the underground rail infrastructure, however, is not restricted to the United States alone. In 2017, the City of London Corporation commissioned WSP to review the 2012 Strategic Flood Risk Assessment (SFRA) and incorporate latest information on flood risk, which affects the City of London.

In the report created by WSP, it is mentioned, "Flooding is a natural process which can occur at any time, in a wide variety of locations. The speed of inundation and duration of flood events can vary drastically which affect the severity of the impacts. With climate change, the frequency, velocity, depth, patterns and severity of flood events will cause a greater risk of flooding and subsequent damages.

Typically, fluvial and coastal sources are the principal causes of flooding. However, in high-density

urban areas, there are other sources such as pluvial floods, groundwater, sewer surcharge and burst water mains that may result in large flood damages.

According to another report from London Underground funded after Hurricane Sandy, 85 sites are at 'high risk', of which 57 are Tube stations and the rest are shafts and tunnel entrances. Another 68 sites are at 'significant risk', including 23 stations.[7]

London Underground, like other metros around the world, is examining the risk of flooding and other issues that might disrupt the Tube service and how to mitigate their impact.

Another major railway operator, RATP Paris, discusses on their website how they are preparing to protect the rail network should there be another centennial flood of the river Seine.[8] According to RATP, 140 km of the underground network are in flood zones and 70 metro stations need extra protection. The initial investment is about €6 million, which is 4 to 10 times less than the costs linked to the risk of a major flood. They believe this is an indispensable plan of action, in view of the potential damages in the event of flooding.

Parts of Asia are also susceptible to the effects of cyclones, typhoons and heavy rainfall. In October 2017, rainwater flooded Singapore's Bishan tunnel disrupting train services on a stretch of the North-South line for about 20 hours and affecting 250,000 commuters.[9] Post investigation, Land Transportation Authority (LTA) said that all failure scenarios they had come up with could only arise from improper maintenance, audits and supervision by the team responsible for preventive maintenance works on the sump pit and pump system.

The Land Transport Authority (LTA) formed a committee with the National Water Agency (PUB) to look into flood prevention for tunnels. In addition, Singapore has sought Taipei Metro's help to review local operations in improving its Mass Rapid Transit system. Taipei is also sharing its experience with transport operators in China and other countries in Southeast Asia. However, the Taipei Metro has had its share of flooding and delays causing severe inconvenience to commuters and affecting its image.[10]

When Typhoon Nari, a long-lived category 3 storm hit Taiwan in 2001, sixteen underground stations were flooded costing Taipei Metro $76 million. It took three months for the system to resume operations but this incident turned out to be a valuable lesson, according to the transport operator.

The Taipei Metro is nationalized so it is majority-owned by the Taipei city government and headed by Mayor Ko Wen-je. As the metro began its road to recovery in 2003, one of the first things the Mayor did was to set up weekly technical meetings that would look at how and why each problem occurred and how to fix it.

These findings were written into standard operating procedures (SOP) and there is now a database of more than 7,000 SOP documents that are reviewed annually. When a fault develops, the staff can follow the SOPs to keep disruptions to a minimum. Taipei Metro has built the right systems and job culture to better its reliability.

Although ticket fares have not changed in over 20 years, the metro turned a pre-tax profit of $50 million in 2016. Mr. Ko Wen-je said: **"If profit is the only criterion … then very quickly, the public transport will break down."**

When power and water mix

Catastrophic flooding caused by coastal, fluvial and pluvial floods is not an everyday occurrence. The more common and constant source of water intrusion tends to be groundwater making its way into rail systems in critical areas through structural damage and improperly sealed cable and conduit penetrations on walls and foundations. Unfortunately, only limited analysis is available to understand the extent of losses from these sources.

When there is water intrusion into high voltage substations, technical rooms, switching stations, signal and control buildings, tunnels, railyards and railway stations through cable and conduit penetrations, there is damage to the structure as well as the equipment inside. The equipment is stained, rusted, corroded and possibly deformed, so a quick cleanup is not sufficient.

The salinity of the water creates an added challenge in the cleanup efforts because it leaves salt deposits that may not be possible to clean on site, needing offsite cleaning or replacement entirely. Since salt is conductive, improper cleaning of equipment could cause short circuits and fires.

Along with critical buildings, communication and signal shelters need protection from both water intrusion and moisture. Cable and conduit penetrations into signal boxes, junction boxes, communication equipment enclosures and rail heating cabinets must be sealed properly because water also short-circuits electrical signals and switches. In January 2018, the Sixth Avenue subway line was disrupted for more than a day due to water soaking an electrical line beneath Midtown Manhattan.[11]

When ground water accumulates in confined spaces such as underground vaults and manholes, rail transit operators incur costs towards,

- Frequent pump outs
- Cleaning
- Inspections
- Permitting for entry into confined spaces
- On site personnel costs
- Use of specialty safety equipment
- Internal paperwork
- Documentation of following risk reduction programs
- 3rd party certified testers
- Downtime and loss of revenue

According to an article on Railway Technology, around 100,000 train minutes are lost each year due to flooding in Scotland alone, resulting in over £3 million being paid out to dissatisfied customers as compensation.[12]

Floods experienced by the Washington Metropolitan Area Transit Authority (WMATA) infrastructure in 2006 led to the closure of a metrorail station for four days and resulted in millions of dollars' worth of clean up and replacement of critical signaling and communication equipment.[13] WMATA

has also dealt with flooding in 2016 when storms dumped over an inch of rainfall in a very short period leading to station closure.

WMATA has also identified water infiltration as being one of the primary causes of fires and smoke on the track.[14] Federal Transit Administration (FTA) inspectors cite water infiltration as one of the most common problems. In 2017, when the region received over nine inches of rain, the Metro experienced 15 fires, nine of those were caused by arcing incidents resulting from the water.

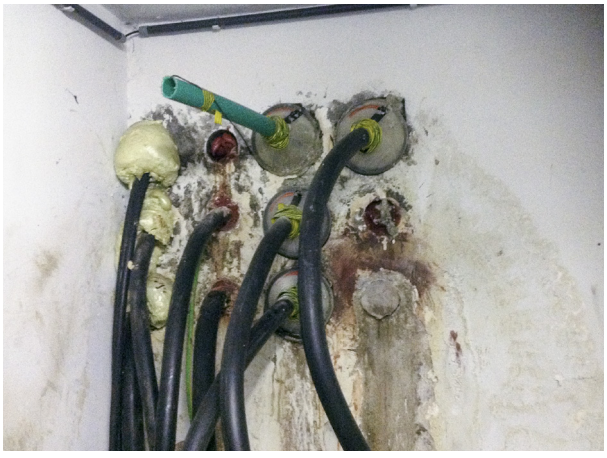
Relevance of cable and conduit penetration sealing

In order to avoid costly remedies in the future, lower operating costs and increase operational reliability, rail operators around the world have undertaken studies to understand the resilience of the infrastructure in coping with floods and ground water intrusion. Rail design standards and operational procedures are being updated to ensure resilience of rail assets for decades to come.

Rail engineers, project managers, maintenance managers, safety managers and systems engineers at rail authorities and consulting firms face an important design challenge with preventing the intrusion of water into rail systems. They are considering various solutions such as floodgates and barriers, installation of pump systems, waterproofing and at times relocating equipment and systems to higher ground.

The railways are also looking to understand where their most vulnerable points are and how quickly water can move through small openings. Taking a very early and clear decision path in all project designs regarding cable, conduit and pipe penetration sealing is an important measure to improve the resilience of Rail infrastructure against water. Design standards are being improved for the sealing of critical areas such as traction substations, communication and signal rooms.

Without standard operating procedures and specifications for sealing solutions, field based decisions are made at each site resulting in various unapproved methods being deployed at the last minute to seal openings. At times cable entries end up not being sealed. This has caused various levels of effectiveness in mitigating water intrusion and created a maintenance nightmare for rail operators.



Cable, conduit and pipe entry seals can no longer be a field decision. Including the specification of sealing solutions in the design and engineering scope allows cables and conduits to pass between separate areas while protecting people and infrastructure against multiple hazards.

Although the overall costs to properly seal cable entries is nominal within the scope of project budgets, when this decision is not taken as a design method or standard practice, the related costs and delays begin to rise quickly near the completion stage of a project. As an example, if civil designs do not properly size apertures in concrete walls, or worse, omit openings for cable entries, the cost to customize product sizing or to modify the opening sizes not only adds costs, but also causes project delays.

Top considerations for cable and conduit penetration sealing

Reliable penetration sealing solutions are also part of the workplace risk-reduction program as they minimize the need for personnel to enter confined spaces. Further value comes in the form of eliminating the need for post pump out inspections, manhole cleaning, confined space entry, reduced on-site personnel costs, 3rd party specialty safety-equipment costs as well as internal paperwork/permitting costs.

The following section provides a simple and effective design method for project owners, engineering and construction firms to approach cable and conduit entry designs for water mitigation along with other top considerations.*

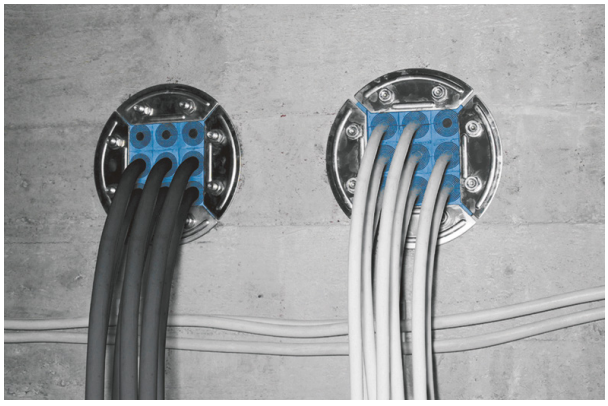
Consider certified and engineered solutions

Multi-cable transits were originally developed in the 1950's to protect against the hazards of water, fire, blast and smoke for marine applications. Early adopters of this technology were primarily naval engineers. The offshore oil and gas industry soon began to recognize the safety features and benefits of having a cable transit that can be opened to add, remove and maintain electrical and control system cabling. As a market leader of multi-cable transits, Roxtec is a standard on many ships and rigs around the world.

Roxtec has further developed the transit technology and successfully introduced it into harsh environments on land including rail infrastructure. Roxtec offers certified solutions as well as the engineering expertise to support the certificates. In addition to certifications, the ability to test products to meet specific design challenges is key to adding longevity to the life of the assets.

Roxtec solutions for rail are tested rigorously for water tightness up to 4 bar/ 58 psi/ 133 feet of water.

* In order to secure the desired protection level, engineers must check the ratings of each selected sealing solution version during the design and specification phase.



While water intrusion into railway systems is the single biggest concern for most rail engineers around the world, it is not the sole design consideration. Providing ample protection through cable and conduit penetrations in the event of a fire requires sealing solutions that not only meet fire ratings, but also shield an area against smoke and gas. Sealing solutions must also fulfil the requirements of non-toxic smoke by meeting safety requirements for flammability, smoke emission and toxicity, which is especially crucial in rail tunnels and railway stations where passenger flow is dense and fire safety is a primary concern.

Vibration damping and cable retention are common requirements given the harsh operating environment around the railway systems.

In the long term, to avoid pulling cables terminating into electrical equipment in cabinets and shelters out of their end-terminals, use cable seals designed and tested for cable retention. Cable retention is also important for aerial deck penetrations and is needed to provide protection against vibrations along the track.

Given these multiple risks associated, it is important during the design process to consider cable and conduit seals that can fulfill other requirements while also fixing a water leak.

With more than 285 registered product certificates and over 430 registered tests and approvals around water-tightness, gas-tightness, fire protection, flammability, smoke emission and toxicity, shock and vibration and other considerations, Roxtec solutions are engineered to protect life and assets. Click here to find relevant products and associated certificates for various rail applications.

Roxtec sales engineers and technical experts know industry specific requirements and application demands and can provide assistance and product advice in order to comply with inspections. As a sealing provider with a global reach, Roxtec can bring in additional knowledge from site assessments in other countries and tap into its knowledge centers across regions to find similarities in requirements and common solutions.

An obvious benefit of using mechanical sealing solutions, such as Roxtec, is that it allows for visual inspections upon installation. Roxtec solutions allow the installer or inspector to check for physical damage and run through a proprietary checklist to ensure the integrity of the installation.

Obtain design support

The adoption of Building Information Modeling (BIM) into infrastructure projects as a digital planning tool wherein all stakeholders have access to the same database is gaining speed because BIM supports in the reduction of risks associated with time and costs. From the end of 2020, Deutsche Bahn, the largest operator of rail Infrastructure in Europe, plans to apply BIM on all new infrastructure projects that are either standardized or complex in nature.

To support the digitalization wave in construction, Roxtec offers its rail product portfolio as BIM Objects in Autodesk Revit family files in release 2016. The files can be downloaded through the following link, Roxtec BIM.

In addition to BIM Objects, Roxtec offers free design tools to navigate through certificates, application areas and sealing requirements. With the Roxtec Transit Designer™ tool, engineers are able to design hundreds of cable, conduit and pipe penetration seals in just a few minutes. Upon entering the cable schedule, sealing requirements and installation preferences, the tool generates manufacturer-approved outputs (dxf, stp, excel) with exact specifications, ordering and installation details. Click here to register.

If there is a need to create a new custom-made solution, the Roxtec team of first class designers, engineers and test technicians are able to develop tailor-made seals according to your needs and requirements.

When writing specifications for sealing solutions, it is beneficial to work with vendors that have acted as technical consultants in shaping up the operating procedures for critical applications requiring water-tightness in addition to other design constraints.

Ask for site assessments and on-site installation training

Service capability of sealing solution providers is almost as crucial as the seals themselves. The experience of a manufacturer's representatives in walking through sites to identify problem areas and then suggesting remedial solutions is of great value to rail operators because not all sites are built equally. Support from sealing solution providers during the design process is critical in selecting the right solution for each application.

Knowing that the quality of installation can make or break a system, training must be provided by cable and conduit sealing providers to share best practices to ensure a tight seal. Roxtec offers onsite installation advice and training all over the world through a network of subsidiaries and distributors to ensure quick and high quality assembly work.

If you are already working with Roxtec and would like to optimize your installation skills, please click here to fill out a form to request training.

Ask about installation in running water and damp conditions

There is often a need for seals to fix leaks in wet conditions meaning that the cable and conduit penetration seals and conduit plugs must meet this requirement as well. Many mastic or compound solutions cannot cope with running water or damp conditions during the installation. Damp or high relative humidity can mean mastics will not cure properly or not at all. Working with a solution provider that recognizes real world installations is crucial to avoiding extended installation times and fixing the leaks over long periods.

The Roxtec portfolio comprises of seals that are ideal for single or multiple cables and conduits entering buildings via foundations and are easy to install even in wet conditions and in environments with running water. Click here to view a video of Roxtec seals installed in running water conditions.

Prevent rodent intrusion

Areas where cables, conduits and pipes enter structures are also common entry points for rodents and pests. Since rodents don't mix well with electrical and signaling systems, seals and conduit plugs must be tested thoroughly and withstand the impact of rodents over extended periods. Third party tests involving rodents are necessary to ascertain the quality of the seals.

Click here to learn how seals can provide a barrier against rodents and help with avoiding costs related to cleaning, rewiring and downtime.

Factor in longevity

The ability of sealing solutions to work seamlessly with the past, present and future of the infrastructure is highly desirable in the railways. Retrofitting seals around existing cables and conduits without having to move them, ensures that there is no damage or disruption to the operations and minimizes downtime caused by scheduled and unscheduled maintenance.

With the Roxtec system, spare capacity is designed into the system during the initial installation. Due to its modularity, flexibility, and ability to allow for a safe re-entry into the system, future expansion of power supply, signal and communication capabilities on the rail line means more cables can be added into the sealing system without the need to drill another hole.

Another element of flexibility with the Roxtec system is Multidiameter™. Roxtec Multidiameter™ is an innovation for flexibility based on removable layers. It makes the system adaptable to single and multiple cables, conduits and pipes of different sizes. Multidiameter™ adds value by ensuring the right solution is always on hand, reduces the number of stock items and helps avoid surprises onsite due to late changes. This adaptability of the seals based on field conditions plays a key role in guaranteeing a quality installation while reducing labor time and costs. Click here to read more about this innovation.

Conclusion

The demand to mitigate flood and ground water from rail Infrastructure is increasing because billions of dollars' worth of infrastructure and millions of dollars in revenue each year are vulnerable to the vagaries of weather conditions. Cable, conduit and pipe penetrations are a key area to address in order to improve the resiliency of rail infrastructure against water intrusion.

Today there are many types of seals used with varying degrees of quality and effectiveness in keeping water out of the electrical, signaling and communication systems, and result in a maintenance nightmare.

The techniques and considerations discussed in this article apply to new construction and existing infrastructure alike. Making design decisions earlier on in the planning process by considering

factors such as longevity, downtime and the total cost of ownership have clear benefits in the long run. Rail owners and engineering firms are increasingly working with manufacturers providing certified and engineered solutions, design support, site assessments and on-site installation training. Design challenges of such magnitude can be mitigated only when engineers work together with their suppliers and demand on quality products supported by world class services.

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