# BOLTED

A MAGAZINE ABOUT BOLTING TECHNOLOGIES

ISSUE 1 - 2021

## DESIGNING FOR A SAFER WORLD

NORD-LOCK GROUP

www.bolted.com

MANAGING EDITOR
Alexander Wennberg
alexander.wennberg@nord-lock.com

ASSISTANT EDITOR
Ariane Osman
Jörgen Lindström

ART DIRECTION & DESIGN
Gabriel Jacobi

CONTENT PRODUCTION
Nord-Lock Group
Spoon Agency

TRANSLATION
LanguageWire

COVER IMAGE
Layer 1

PRINT
Exakta

Bolted magazine is published by Nord-Lock Group and strives to increase knowledge about secure bolting and engineered solutions. Bolted is published twice a year in ten languages, including Chinese, English, Finnish, French, German, Italian, Japanese, Korean, Spanish and Swedish.





Feel free to contact us with any comments at **info@nord-lock.com**

Fredrik Meuller
CEO Nord-Lock Group

# *To invest in a safe infrastructure is to invest in the future.*

COVID-19 put us all to the test, individuals as well as businesses and societies. Yes, we faced tragedies and losses — but we also proved once again that we as humans can move forward and achieve great things when we are committed and put our minds to it, together.

This is a comforting insight for the future. Because there will be many more challenges to come. In this issue of Bolted Magazine we meet with experts and talk about how a growing number of both natural and human-made disasters are increasingly putting critical infrastructure under a severe strain. Now more than ever, structural and mechanical engineers need to plan for unexpected events.

It is our mission at Nord-Lock Group to safeguard human lives and customers investments. For many years, we have been truly committed to playing an essential role for a safer world, and we are therefore particularly proud to be part of demanding and critical engineering projects such as the new bridge in Genoa, Italy.

The city's famous Morandi Bridge collapsed suddenly during a rainstorm in 2018. The feature on this tragedy is yet another reminder of these challenging times. But also a great example of what we can achieve together in cooperation. Indeed, a new bridge has been designed and constructed in record time, and it is secured by Nord-Lock washers.

Safety is also about the fun things in life. Accordingly, we visited the amusement park Gröna Lund in Stockholm, Sweden, to talk about thrills and safety — buckle up and enjoy the ride!

You can also read the inspiring story of how a new generation of coupling bolts — designed to avoid all risk for catastrophic accidents — was developed, get insights from The Experts, and much more.

I wish you happy reading — stay safe, and stay in touch!

# REBUILDING THE GENOA BRIDGE

*Constructing a new bridge in record time to replace the one that collapsed in Genoa in 2018 was a high-profile project. All companies and suppliers were scrutinized as nothing was allowed to go wrong.*

**Text** Claudia Flisi **Photos** Luca Rei/Shutterstock and Nicolò Campo/Getty Images

## GENOA SAINT GEORGE BRIDGE (VIADOTTO GENOVA-SAN GIORGIO)

**INAUGURATED**
AUGUST 3 2020

**ARCHITECT**
RENZO PIANO

**TOTAL LENGTH**
1,067 METERS

**WIDTH**
30.80 METERS

**NUMBER OF LANES**
4 (PLUS 2 EMERGENCY LANES)

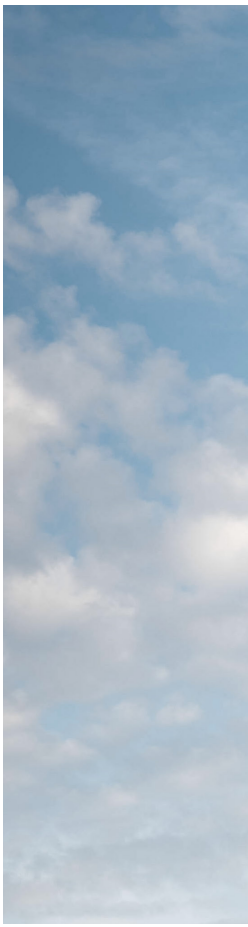
## FINCANTIERI INFRASTRUCTURE

**THE COMPANY**
FINCANTIERI INFRASTRUCTURE IS A SUBSIDIARY OF FINCANTIERI S.P.A., THE FOURTH-LARGEST SHIPBUILDING COMPANY IN THE WORLD.

**OPERATING HEADQUARTERS**
VERONA, ITALY

**PRODUCT LINES**
SUSPENSION BRIDGES, VIADUCTS, ARCH BRIDGES, CABLE-STAYED BRIDGES, RAILWAY BRIDGES, TOWERS, BUILDING STRUCTURES, AIRPORTS, MARITIME WORKS, FLOATING MODULAR SYSTEMS

Lorenzo Sartori
**HEAD OF THE TECHNICAL OFFICE FINCANTIERI INFRASTRUCTURE**



Tragedy struck Genoa, north-western Italy, on the morning of August 14, 2018. During a torrential rainstorm, the city's Ponte Morandi (Morandi Bridge) collapsed so suddenly that some thought it had been struck by lightning. The disaster killed 43 people, destroyed homes and businesses, and exposed infrastructure problems that had existed for decades.

Videos taken at the time of collapse reveal a flexing of the bridge deck followed by the detachment of cables, breaking of a cross-beam, twisted girders, falling towers and finally, the buckling of the 210-meter central bridge section. All punctuated by the screaming of spectators as the occupants of more than 30 cars and three trucks plummeted 45 meters to their deaths.

### Warning signs were unheeded

Technically, Ponte Morandi was a viaduct, not a bridge — a cable-stayed structure 1,182 meters in length, spanning Genoa's Polcevera Valley. It connected two areas of the city and formed part of the road network linking Italy to France. When it was completed in 1967, its innovative design by engineer Riccardo Morandi — making use of pre-stressed concrete encasings for its steel cables — was a source of national pride.

But traffic in 1967 was about six million transits annually. By the early 2000s, that amount had quadrupled, and the bridge began to show the strain. Warning signs were unheeded due to technical ignorance and political neglect.

In the aftermath of the disaster, the government vowed to dismantle what remained of Ponte Morandi and replace it with a new, safe and reliable viaduct. Renowned Genovese architect Renzo Piano offered his services for free, and the construction contract for what was to become Viadotto Genova-San Giorgio (the Genoa Saint George Bridge) was awarded to PERGENOVA, a consortium created ad hoc for the project.

### Construction faced many challenges

To save time, there was no bidding process but PERGENOVA's credentials were impeccable. Its three participants were Fincantieri Infrastructure, a subsidy of Fincantieri SpA, Italy's largest shipbuilding company, WeBuild SpA, Italy's largest engineering and general contractor group (then called Salini Impregilo), and Italferr, a state-owned engineering firm focusing on transportation-related infrastructure.

Fincantieri Infrastructure specializes in complex engineering, procurement, and construction projects using steel, such as bridges, port facilities, or stadiums. Its expertise draws from the long-established shipbuilding heritage of its parent.

Safety is always the major consideration in bridge construction, but the circumstances of the Genoa project underscored its absolute priority for PERGENOVA. Suppliers and sub-contractors were chosen based on stellar credentials, but also competitive cost and speed of implementation.

They faced challenges both foreseen and unexpected. The former included the tight timetable and a restricted construction site. Demolition of the remains of the old bridge continued through late June 2019, having to take into account the residents living nearby. Unforeseen complications included more than 100 days of rain – the most in a century – beginning in late 2019. Then in early 2020, COVID-19 struck.

### Many innovative solutions

Lorenzo Sartori, head of the technical office for Fincantieri Infrastructure notes:

*"The bridge was designed to be conceptually simple and safe, fast and easy in production and assembly."*

It is 1,067 meters long and consists of 19 steel-concrete spans supported by 18 reinforced concrete piers. The design deliberately suggests the hull of a ship, a nod to Genoa's role as a port city and the symbolic importance of this project. Sartori adds that his company's collaboration with Renzo Piano represented "the chance of a lifetime to work with an architectural genius."

Among the innovations of this project:

- the elimination of many bureaucratic obstacles, thus accelerating completion,
- photovoltaic panels to produce the energy used by lighting, sensors, and other systems day and night, lowering the environmental impact,
- a special dehumidification system to avoid the formation of saline condensation that could weaken the structure over time,
- four robots that run continuously along both sides of the lower surface of the deck. They inspect, identify, and signal any anomalies to a control center operated 24 hours a day.

### Cooperation key to success

The Saint George Bridge was inaugurated on August 3, 2020, a mere 15 months after construction began. It is too soon to judge the structure's performance over time but its beauty, functionality, and symbolic importance are unassailable. Sartori observes that the project was "a personal and professional experience for a very large group of people from many backgrounds who gave their all and showed what can be done when everyone is working together toward a shared goal."

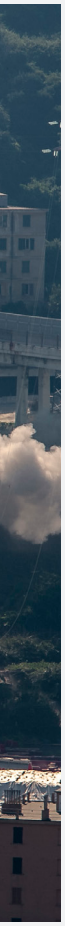
Remains of the old bridge had to be demolished for the construction of the new one


## TECHNICAL INSIGHTS

# A WINNING WEDGE FOR A SYMBOLIC BRIDGE

Luca Gheddo
GENERAL MANAGER
NORD-LOCK GROUP ITALY

Frank Götz
INDUSTRY MANAGER
NORD-LOCK GROUP



The challenge was daunting for Luca Gheddo, general manager of Nord-Lock S.r.l., and Lorenzo Sartori, head of the technical office for Fincantieri Infrastructure, when they met in August 2019.

*The new bridge that was planned for Genoa needed bolts that would not loosen under stress, including dynamic loads and traffic vibrations.*

Moreover, these bolts, once installed, could not be inspected – much less tightened – continually. So, the washers had to be reliable in an elevated setting with difficult access in a saline environment. The solution, they decided, lay with Nord-Lock wedge-locking washers, which utilize tension instead of friction to secure each bolted joint.

These washers provide high corrosion resistance, confirming their durability in the harsh environmental conditions of Genoa, Italy's busiest port. These results are proven by more than 1,000 hours of ISO 9227 salt spray testing.

According to Frank Götz, EMEA industry manager for building and steel construction at Nord-Lock Group, some engineers hesitate to use them for fear they do not meet the exacting standards of European construction regulation (EN 1090-2).

But in fact, Nord-Lock washers do meet these standards, while also increasing safety and decreasing life cycle cost.

Sartori was convinced, and Nord-Lock washers were chosen based on specific functionalities. One series helps secure the frames of the deck edges as well as the bridge ramp, with a wedge design ensuring that the bolts they reinforce cannot loosen on their own, despite exposure to the strong vibrations and dynamic loads characteristic of the bridge and ramp.

Separately, a series of steel construction washers are specially designed for use on steel constructions and HV/HR sets (high strength structural bolting assemblies for preloading). They can be found on the bridge platforms where the VDC (vehicle dynamic control) robots patrol the lower surface of the deck to spot and report on anomalies.

Fincantieri Infrastructure was pleased not only with the technical specifications of the washers but with Nord-Lock's speed in providing necessary certification, technical assistance, and product delivery in a timely fashion. The first orders were delivered in January 2020, recalls Gheddo.

# CAN RESILIENT INFRASTRUCTURE SAVE US FROM DISASTER?

*A growing number of both natural and man-made disasters are increasingly putting critical infrastructure under severe strain. Engineering can play an essential part in making it more resilient, benefiting societies around the world.*

**Text** Ulf Wiman **Photo** TerenceLeezy/Getty Images

The International Disaster Database (EM-DAT) is not for the faint-hearted. It is an endless litany of human suffering, ecological catastrophes and economic sinkholes. The database lists and describes the occurrence and effects of more than 22,000 mass disasters globally, starting in 1900 and counting. There are natural disasters, including floods, typhoons, landslides, droughts, earthquakes, heat waves and wildfires.

There are also the "man-made" disasters, such as shipwrecks, plane crashes, fires and explosions as well as mine collapses and rail accidents. You will even find things like a disco stampede.

## The number of disasters is growing

Unsurprisingly, given the abundance of disasters, there is an International Day for Disaster Risk Reduction. Organized by the United Nations to "promote risk-awareness and disaster reduction", it has been celebrated yearly on October 13 since 1989.

In connection with this event in 2020, the United Nations Office of Disaster Risk Reduction (UNDRR) published the report Human cost of disasters: An overview of the last 20 years, 2000–2019. In the foreword, Mami Mizutori, Special Representative of the Secretary-General for Disaster Risk Reduction and Head of the UN Office for Disaster Risk Reduction, together with Debarati Guha-Sapir, Professor, Centre for Research on the Epidemiology of Disasters, Institute of Health and Society, UCLouvain, Belgium, write:

"We are twenty years into this new century, and disaster risk is taking on new shapes and sizes with every passing year. Disasters have never waited their turn, and increasingly risk is interconnected. Risk drivers and consequences are multiplying and cascading, colliding in unanticipated ways."

Mizutori and Guha-Sapir continue: "While this report focuses primarily on the staggering rise in climate-related disasters over the last twenty years, it is also a commentary on the need to strengthen disaster risk governance for the entire range of natural hazards and man-made hazards including related environmental, technological and biological hazards and risks."

### Essential to strengthen disaster resilience

The climate-related disasters include meteorological, climatological or hydrological disasters. During the first two decades of the 21st century, these have all but doubled. The majority of the 7,348 reported disaster events were floods, followed by storms. The disasters are calculated to have caused 1.23 million deaths and affecting some 4.03 million people. The estimated global economic losses were 2.97 trillion US dollars.

Along with UNDRR, many initiatives and organizations around the world are committed to turning this around. One example is the UN Sendai Framework for Disaster Risk Reduction 2015–2030.

It aims to "Prevent new and reduce existing disaster risks through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience."

Four priorities for action are outlined:

1. Understanding disaster risk,
2. Strengthening disaster risk governance to manage disaster risk,
3. Investing in disaster reduction for resilience,
4. Enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction.

*While safeguarding human lives, livelihoods and health is the top priority, reducing disaster damage to critical infrastructure and services is also extremely important.*

### Critical infrastructure holds society together

Critical infrastructure is the glue of modern society, holding it together and making it work. It is easy to imagine the utter chaos if we didn't have functioning roads, railways, bridges, tunnels, water and wastewater management, or electrical grids. And imagine a world without access to the internet or telecommunications. How about that for disruptive potential?

**4:1**

A quadruple return is estimated for every 1 US dollar invested in infrastructure adaptation.

**470 million**

The number of people in 45 cities that are expected to face extremely high water stress by 2030, up from the current 255 million.

**$94 trillion**

The global infrastructure gap means there is a need to secure an estimated USD 94 trillion of global infrastructure by 2040.

**$650 billion**

Climate-related disasters have cost the world over USD 650 billion over the last three years.

**Resilience**

The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.

**Infrastructure resilience**

The ability to withstand, adapt to changing conditions, and recover positively from shocks and stresses.

**Source:** resilienceshift.org and undrr.org

The Resilience Shift — an initiative created by Lloyd's Register Foundation and professional services firm Arup — states that, "More people than ever before depend on the critical services provided by infrastructure systems due to the growth of the world's population and its transition from rural to urban areas. If any of these systems fail, consequences can be catastrophic for public safety and wellbeing, the environment and the economy."

*It is estimated that by 2050 almost 70 percent of the world's population will live in cities. So, it is an escalating challenge.*

The Resilience Shift points out that climate change and cyber-attacks also pose genuine threats, making it hard to predict or avoid shocks and stresses on critical infrastructure. "It is essential for infrastructure to be prepared for the threats we can anticipate, and to be able to respond to the unexpected so that it continues to provide the essential services on which society depends."

### Engineering plays a crucial part

Creating resilient infrastructure is a multifaceted area, including planning, financing, design, operation and maintenance. Various sub-disciplines of engineering – such as structural and mechanical engineering – can play a vital role in both creating and retrofitting safe, sustainable and resilient solutions.

When planning and designing for critical infrastructure, engineering must take into account a broader perspective, from potential hazard to responding and adapting when disaster strikes to bouncing back in its aftermath.

The Resilience Shift advocates a shift "from thinking about infrastructure in terms of what it is, to what it does." Subsequently, "Instead of creating fail-safe systems at specific design thresholds, we need to develop and operate systems, so they fail safely with limited consequences and recover quickly."

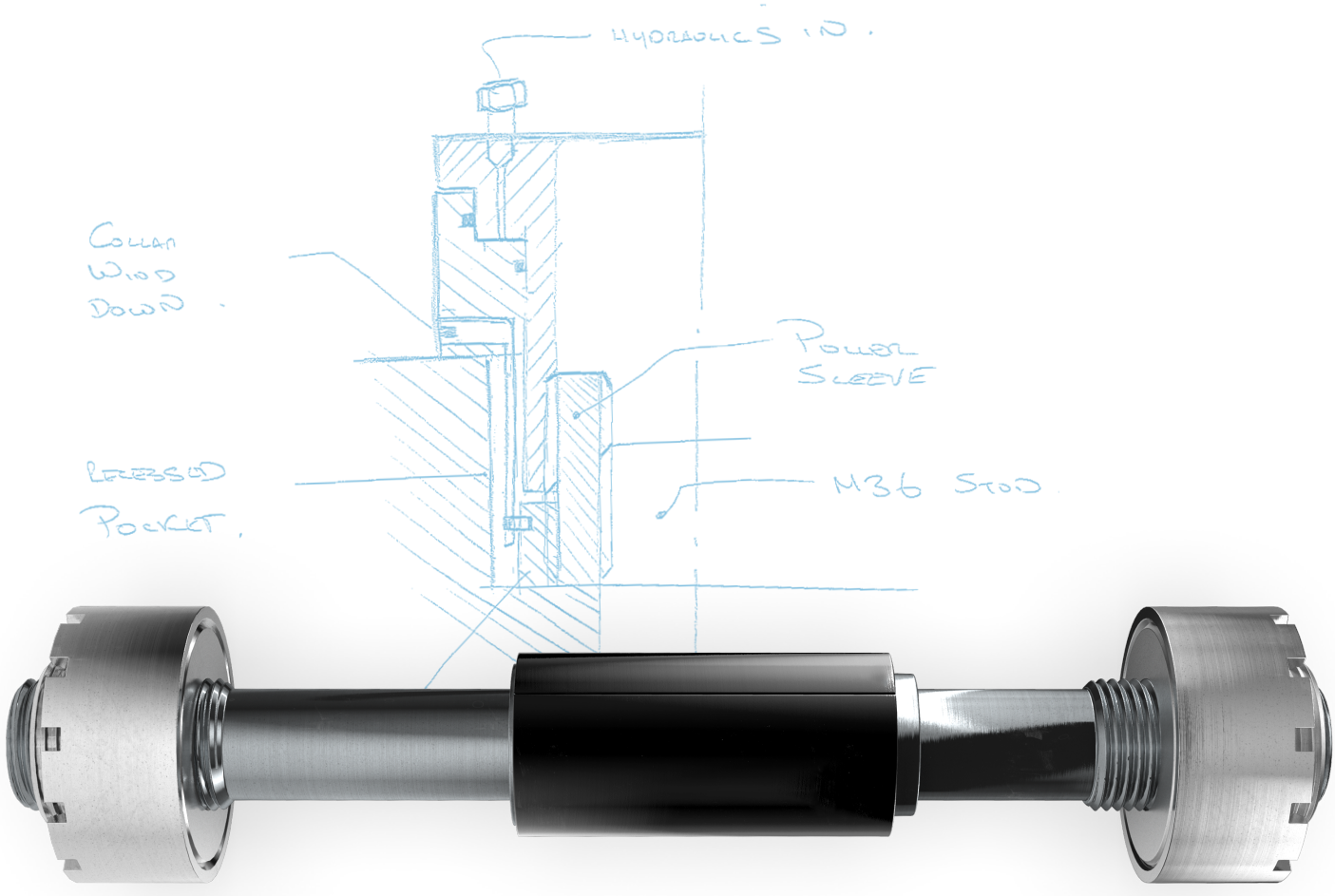
### A foundation for future generations

As we advance, engineers will play an increasingly important part in designing, producing and maintaining sustainable, safe and resilient critical infrastructure. In doing so, they will help create and safeguard the foundation of a well-functioning society for future generations. They will also contribute to sustainable development across the world.

You can read more about designing for resilience in the theme article on page 14.


# FROM A BLANK PAPER TO A NEW GENERATION COUPLING BOLT

*Steve Brown started his career working with coupling bolts for a company in his hometown outside Manchester in the UK. 30 years later, he has come full circle with the design of a new generation coupling bolt that solves several safety issues.*




*"How would you do it if you didn't know how it's done now?"*
*That was the mindset when a team of experienced engineers set out to design a new generation of hydraulic actuated coupling bolts.*
***The outcome? Superbolt HyFit.***

**Text and Photo** Jörgen Lindström

"We had many ideas right from the start, but then said: No, we're not going to do it that way. It's already been done before. Let's start with a blank page," says Steve Brown, Global Product Manager, Expansion Bolts, Nord-Lock Group.

The primary goal right from the outset was to design a hydraulic actuated coupling bolt that makes the procedure not only easier but also much safer for the user.

"When you see a seized coupling bolt and what it requires for it to be removed, you realize the headache and stress it causes for the people involved. We really wanted to find a solution to alleviate that," Steve Brown says.

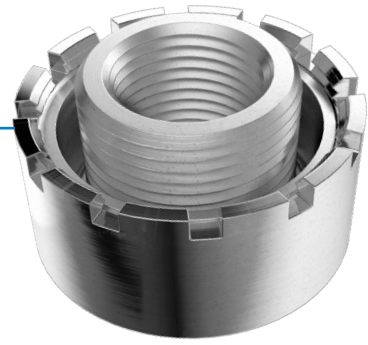
He and his engineer colleagues were fully aware of the major challenges for hydraulically actuated coupling bolts in general. One is that you cannot have an extended length of thread sticking outside of the nut on high-speed applications.

"A steam or gas turbine rotates at either 3,000 or 3,600 RPM, so there would be a tremendous amount of turbulence if anything is sticking out of the coupling when the machine operates," says Steve Brown.

Traditional methods use a puller, an extra bolt that is temporarily screwed into the main bolt itself, to solve the problem of not having any threads to engage the hydraulic tensioner. Of course, this screwed-in component is of smaller diameter than the main bolt and therefore needs to be highly loaded for its size.

*"We wanted to avoid that traditional internally threaded puller because of the risk for it to be stripped from the bolt, causing catastrophic accidents."*

**The solution was to design a nut with an external thread, making it possible to attach the hydraulic tensioner onto the outside, not the inside, of the nut.**



"Because of its bigger diameter, we can reduce the length of the engagement of the thread as we still have the same cross-sectional area of contact. There is far more thread engagement than is necessary, so we can safely apply full load onto the nut knowing there will be no safety issues," Steve Brown explains.

Even though he was satisfied with this solution he felt that the procedure could be even safer. Traditional methods use two different operating pressures — one pressure for sleeve expansion and another for axial tensioning. The same tensioner head is used for both procedures.

"We wanted to find a way to prevent anyone from using the wrong pressure at the wrong time. Then it suddenly hit me: If we have two separate, dimensionally different tensioning heads, it will be possible to use only one operating pressure."

**The key was to use a Boltight hydraulic nut to expand the sleeve into the hole and a Boltight hydraulic tensioner to load the bolt axially.**


Because the tensioner has a larger hydraulic pressure area than the hydraulic nut, the same pressure can be used for both operations.

*In other words, one operation pressure only, and two differently designed heads to make it clear, which goes where.*

"It sounds so simple now, but I guess no one thought of it before. I'm happy we came up with the idea because it provides absolute safety in the procedure. There is no risk whatsoever of someone mixing things up," Steve Brown says.

Indeed, for removing the coupling bolt, there's no need for any internal puller or even oil injection. That's another significant improvement from a safety point of view, compared with traditional methods. Engineers from Nord-Lock Group's sites in St. Gallenkappel, Switzerland, Walsall, UK, and Pittsburgh, USA, have been involved in the project.

"There's been lots of meetings in Switzerland and the UK, and a lot of iterations of the design. Of course, COVID-19 put a stop to that. So to get to this final stage of the product design, we've spent many hours discussing, calculating, and analyzing in online meetings," Steve Brown says.

Steve Brown is an Englishman based in Australia, who recently entered his 31st year of bolting. He started his career working with coupling bolts for a company in his hometown outside Manchester in the UK.

"I feel like I have come full circle now. I started with a hydraulic coupling bolt — and now I've had the honor to be involved in designing a totally new generation of coupling bolts. It does feel quite fulfilling."

# DESIGNING FOR A SAFER WORLD

# *How reliability helps engineers balance competing demands*

Natural disasters will likely be seen as defining features of the 21st century. From heatwaves in Australia to wildfires in the western United States, hurricanes in the Caribbean, and floods in South East Asia, the impact on humanity is grim. And it can potentially be worsened by unreliable buildings, installations and infrastructure.

Structural and mechanical engineers need to plan for these kinds of unexpected events but, at the same time, face demands for cheaper, lighter and quieter products. Can we realistically expect engineers to find a space for reliability in the middle of these pressures?

It is essential to take a step back and understand that there is nothing new about engineers facing conflicting requirements. Demands may appear to be greater than ever, but this is not necessarily a dramatic change.

## Better, faster, cheaper

Fred Schenkelberg is a reliability engineer and consultant, who has spent over 20 years working with and teaching about reliability. As he explains, this situation is not such a radical departure. "'I want it better, faster, cheaper!' That has never changed. However, you could argue that it has accelerated."

*"But that's the art of engineering: to make trade-offs and meet competing needs."*

"A design team will likely have a cost target, a date that they want to launch the product and functionality goals. These get a lot of measurement and priority during the design process. As a reliability professional, I want to make sure that the consideration of reliability performance is also visible at all stages of design."

One of the ways in which this visibility has been encouraged is through Design for Reliability, which brings together many of the tools and methodologies developed in reliability engineering.

## Reliability throughout the life cycle

Design for Reliability (DfR) is a stepwise process to support reliability throughout the entire life cycle of a product, from conception to obsolescence. This means that DfR is not the exclusive remit of reliability professionals. Devised and applied at an organizational level, it guides the design, manufacturing and maintenance of a product, so it can potentially involve every part of a company.

If there is a fundamental principle that underpins DfR, it is that reliability occurs at the point of decision. With that in mind, reliability must be taken into consideration long before physical production takes place.

## Design for Reliability key activities


To do this, you need to have a good understanding of what reliability is. In mechanical engineering, reliability is the probability of an item performing its intended function for a specific period in specific conditions.

Equipped with this general understanding of reliability, you can then identify and define the reliability requirements of your product – these are likely to be similar or identical to your customers' expectations. Only once the requirements are clear, should you begin designing a product that can meet them.

### Not a one size fits all

There is no universally accepted model for DfR, but any outline is likely to involve the following basic steps illustrated in the chart aside.

However, is not a one-way process. It is expected that the design, analyze and verify stages are repeatedly revisited before the product is fit to be sent to market. Within these stages, there can be any number of tools, tests and processes that uncover the product's vulnerabilities, tolerances and robustness. Schenkelberg provides a concise summary of DfR:

*"It is a set of rules, guidelines and activities that enable the people making decisions — the technicians, the engineers, the managers — to understand the ramifications of reliability fully."*

"But it's not a fixed set of tools or activities. Every situation, product, and application is different."

### Stepping back to add value

These differences are crucial because treating DfR as a box-ticking exercise can lead to problems.

"One trap is for organizations to say, 'Our last product was really good. It met our reliability expectations and our customers' expectations, so let's do everything we did last time.' That's dangerous because the next product might have different applications, a different aim, and could be for a different customer," Schenkelberg explains.

"You can end up with a checklist mentality: 'We'll do these two tests, we'll vibrate it for 2 hours, and then we're done.'

Fred Schenkelberg
RELIABILITY ENGINEER AND CONSULTANT

But are you actually adding value by doing that? You have to step back and think about what tests are going to uncover possible problems that might occur in the future." And to uncover future problems, you may have to do something that designers often avoid – embrace failure.

### The benefits of failure

Testing a product to the point of failure can be a useful tool for investigating reliability. However, it is an approach that can clash with typical design principles.

"Designers and engineers usually design away from failure – that's often in their mind during the process of creating an item." Schenkelberg says, and continues:

*"What reliability engineering can do, is make failure more visible."*

"It's important to have the ability to learn from failure. Too many people want to do a test to show that a product works. They run tests in conditions where they're expected to pass but if you're trying to find out something you don't already know, then you really need to run it to failure."

"That way, you find out the nature of the failure, how it manifested itself, and what sets of stresses combine to create that failure. There are different ways to do it, but you have to be willing to look for failures."

One way of drawing out potential failures is through a highly accelerated life test (HALT) . You can use it as part of the verify and validate stage of DfR.

### Understanding the true reliability

"I like to think of HALT as a discovery process," Schenkelberg says. "You use a range of different stresses that are meaningful for your application, and you step up stresses until you force it to fail. You learn if the product is failing at the stress level you expect, and you can make decisions about the margins based on that. Just as importantly, you also learn about the nature of the failure: how it failed."

Academics and practitioners have drawn up lists of the potential stresses that buildings, installations, and infrastructure may face as a result of climate change and other catastrophic events. Although these events make new demands on engineers, the thing that changes is the magnitude and combination of stresses that they will face.

By seeking out failures, as Schenkelberg suggests, you can understand the true reliability and robustness of your product and have a fuller understanding of its capacity to withstand unexpected events.

**Text** Brian Cloughley **Photo** NTaenk/Shutterstock

# DESIGNING RELIABLE BOLTED JOINTS WITH NORD-LOCK GROUP

Discovering potential sources of failure is one of many testing procedures that Nord-Lock Group do, explains Cyril Cadoux, technical manager for the Europe region.

"For a bolted connection, we rarely run tests to failure, because we have the right knowledge to determine root cause from damaged parts. Simply looking at the first thousands of cycles gives us the right indication on the trends. It gives us the knowledge and confidence in our products' reliability to offer a lifetime warranty," he says.

Cyril Cadoux
TECHNICAL MANAGER
FOR THE EUROPE REGION
NORD-LOCK GROUP

*"But it's not enough for us to look at our products in isolation and confirm that they're robust and reliable. We test our bolts and washers in the environments where they are used."*

"We talk to our customers, find out the applications and do a more in-depth analysis based on that. We get as much data as we can from them, then reproduce scenarios. Sometimes you can't get everything from 3D drawings or plans, so where necessary we visit their workplaces in person."

"It means that we're not just testing Nord-Lock products but are actually testing their bolted connections. We can bring our analysis and simulation, our internal tools, to advise our customers properly," concludes Cadoux.

Curious to learn more? Read our white paper on the design principles behind safe bolted connections at **www.nord-lock.com/safe-bolts**

*We all expect our roads to be smooth, our pavements unrutted, to have running water, electricity, gas, and telecommunications in our homes and offices and yet many of us probably pay little attention (except to get annoyed because of the noise!) to the excavators that lay the roads and these vital underground networks.*

# EXPANDER SYSTEM ENSURES LONG-LIFE FOR EXCAVATORS

Montchanin, a town about two-thirds of the way down from Paris to Geneva in the French region of Bourgogne, is home to a successful family-run SME with 250 employees: Pascal Guinot TP (which stands for Travaux Publics or public works). The company, founded in 1993, not only digs the trenches but also lays dry networks (electricity, heating, telecommunications) and wet networks (water and sewerage) inside them and then fills them in and repairs the road. It also does earth-moving works, lays roads and pavements, builds outdoor parking lots and will do work for individual customers who want to organize a courtyard, for example.

## Costly and time-consuming repair

"Our clients are municipalities, SMEs, industrial groups and, occasionally, private customers." says Thomas Desmerger who is responsible for the company's maintenance workshop.

Pascal Guinot TP has about 800 different machines with which do this work. These include 70 excavators and mini-excavators "which are in use 45 weeks a year," says Mr. Desmerger. "We outright own about half of these excavators of various different brands such as New Holland, Liebherr, Caterpillar, JCB and Mecalac," he explains, "whilst the others are on a rent-to-own basis with a maintenance contract. So by the time we own them, these vehicles are about mid-way through their 10-year average lifespan, and are no longer covered by the maintenance contract so that's when we have to start maintaining them ourselves. And because they're five years old they start needing major repairs!"

The boom, arm and bucket are the parts that most suffer from wear-and-tear on these excavators but the pivot pin on the arm is the principal problem. "When the arm becomes a bit wobbly it makes it hard for the operator to control and then he can't dig or scoop precisely," Mr. Desmerger explains. The wobble comes because the pivot pin has become worn and so no longer fits snug and tight in the lug ears. "In the past we would have to dismantle the part, do some welding, have some line boring done, and then put it all back together... which usually meant the machine was out of action for at least a month. And if a machine is down then it's not earning us any money," he adds. "The most expensive part of this operation was the machining because that was something that we couldn't do ourselves and it was costing us a small fortune, sometimes €2,000 for a single pivot pin," he remarks.

## Shortening the downtime

Before Mr. Desmerger joined Guinot TP he was already familiar with the Nord-Lock Group Expander System. "I've been in this business for more than 20 years so I knew about Nord-Lock products," he smiles. So he suggested that Expander System pivot pins might be a solution to shortening the downtime of these excavators. "I contacted Nord-Lock Group and discussed our problem and got a solution."

His workshop does a lot of predictive maintenance so that during the two principal periods when work is slow (January and February because of the weather and August when many are on holiday), the excavators can be fixed quickly. "So, when the operator begins to feel that the pivot pin is getting a bit loose then we take all the necessary measurements, communicate them to Nord-Lock Group and they supply us with a fix. We've been using the Expander System for about three to four years and we always get an answer and a follow-up from Nord-Lock Group, they're very professional," he says.

*"Our aim was to prolong the life of our machines and to reduce their costs," he says.*

"Today, thanks to the Expander System the downtime of our machines has been divided by three, down to around 10 days, so the money is very well spent," Mr. Desmerger stresses.

**Text** Christina Mackenzie **Photos** Olivier Gaillard

# TECHNICAL INSIGHTS

The boom, dipper arm, bucket and hydraulic cylinder interconnections on an excavator are extremely susceptible to lug wear. Traditional repair methods are costly, time-consuming and must be repeated multiple times over a machine's life span. Expander System is a permanent solution to this problem.

Expander System consists of a pivot pin tapered at both ends, two expansion sleeves, two tension washers and two fasteners. Upon tightening the fasteners, the washer presses the slotted expansion sleeve up the tapered ends of the pin. The sleeves expand, conform to the lugs and lock the system in place. Once re-torqued, the system locks from both sides and significantly increases stability. The tapered axle makes it easy to remove and reinstall compared to traditional straight pins.

### A wide product range to suit any machine

Because Pascal Guinot TP's excavator fleet is supplied by various manufacturers, the pins are not all uniform. When a pin needs replacing, all the workshop manager does is fill in the pivot data on an online dimension sheet available on the Expander Webshop. A Nord-Lock Group engineer then contacts them with a suggested solution. In 2019, Guinot placed eight orders for more than 30 pins and spare parts.

**CUSTOMER**
PASCAL GUINOT TP

**LOCATION**
MONTCHANIN, FRANCE

**BUSINESS**
PUBLIC WORKS AND CIVIL ENGINEERING

**APPLICATION**
EXCAVATOR ARMS

**THE SOLUTION**
NORD-LOCK EXPANDER SYSTEM

**THE RESULTS**
PROLONGING THE LIFE OF THE MACHINES, COST REDUCTION, SHARP REDUCTION OF DOWNTIME

Thomas Desmerger
**WORKSHOP MANAGER**
**PASCAL GUINOT TP**

# *What affects pivot wear?*

Email your questions about bolting technologies to experts@nord-lock.com

Mathias Olofsson
PRODUCT MANAGER,
EXPANDER DIVISION
NORD-LOCK GROUP

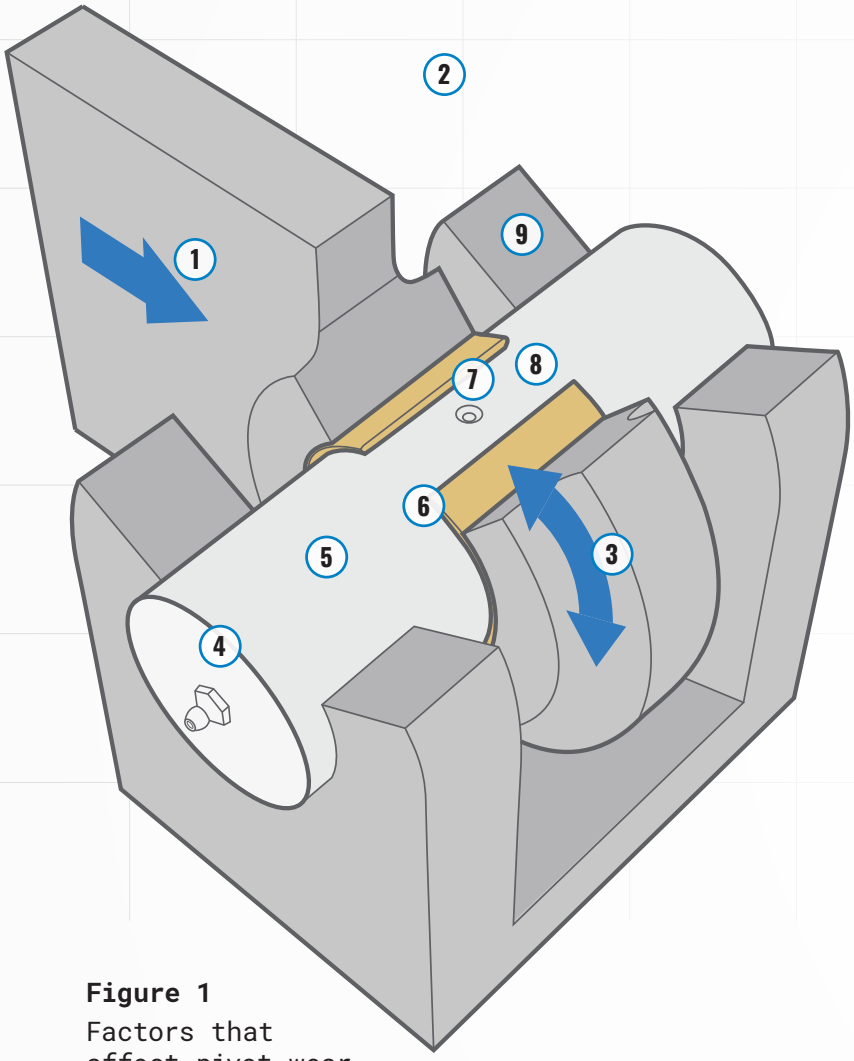
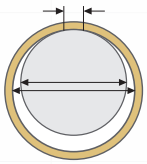


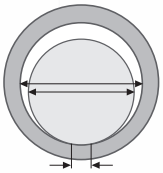

**Figure 1**
Factors that affect pivot wear

1. **Load**
   - Duration
   - Frequency
   - Direction
2. **Environment**
   - Temperature
   - Particles size & type
   - Humidity
3. **Rotation motion**
   - Velocity
   - Length
   - Frequency
4. **Axle (pin) material**
   - Metallurgy
   - Mechanical properties
   - Size
5. **Axle (pin) surface**
   - Hardness & depth
   - Roughness
   - Metallurgy
   - Corrosion properties
6. **Bearing (bushing)**
   - Metallurgy
   - Mechanical properties
   - Lubrication distribution
   - Size
7. **Lubrication**
   - Composition
   - Viscosity
   - Amount
   - Frequency
   - Solid lubrication inlay



Pin-bushing contact area

8. **Motion contact area**
   - Load area
   - Hole & pin tolerance/gap



Pin-lug contact area

9. **Lug**
   - Mechanical properties
   - Load area
   - Hole & pin tolerance/gap
   - Size

*For a machine manufacturer there are many factors to consider to minimize pivot wear over time.*

Pivot wear is the sum of bushing, axle and lug wear and there are many factors that influence it. While the machine manufacturer have multiple design options to minimize this wear, there are less options for the end-user who, would like to optimize uptime and service costs in an easy cost efficient way. At this point, one can seldom do anything about the load, size of the pivot, velocity and frequency of the motion or the environment where the machine operates. What can be changed however is:

— If and how lubrication is used,

— Type of material, hardness and surface finish used in the axle and bushing,

— Fixation of the axle in the lugs.

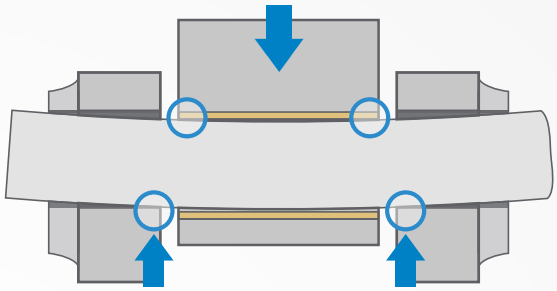


**Figure 2** Traditional straight pin

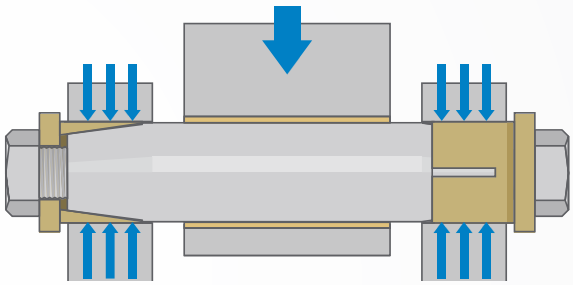


**Figure 3** Expander System

## As little bending as possible

The factor that affects pivot wear the most is the load area in relation to the load/force, the surface pressure. If the pressure is high enough, there is no lubrication, material or hardness in the world that can prevent permanent damage to either the bushing, axle (pin) or lug. If the load remains the same but the area on which it acts is made smaller, the pressure increases. When loading a pivot, the axle (pin) will bend ever so slightly but enough to alter the contact area between the axle/bearing and the axle/lug. When there is low load on the pivot, the load is distributed over the full length of the bearing and lugs. When the axle bends as load increases, the areas will change and the pressure will increase (Figure 2).

How much the pressure changes depends not only on the load, length and diameter of the pin but also on the bushing's mechanical properties. A more elastic bushing will help distribute the load to a certain extent after which it will either become plastic (permanent) deformation and/or force redistribution.

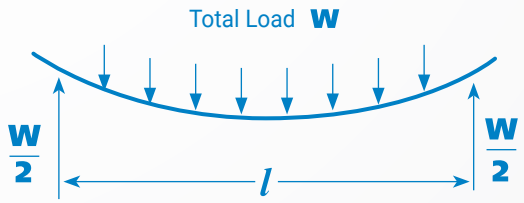
## Benefits of axle fixation

How much the axle (pin) bends is also dependent on whether it is fixed or loose at the ends. A traditional straight pin, which is only supported from the bottom of the lugs, is loose and will bend like a beam with simple supports. Expander System (Figure 3) is fixated in the lugs and will bend like a beam with fixed supports.

Depending on load case, a fixed supported axle will bend up to 5 times less as one with simple supports under the same load (Figure 4).

Approx. **Traditional straight pin**
Load case: **Simple supports**

The axle ends are only supported from the bottom due to the play needed during installation

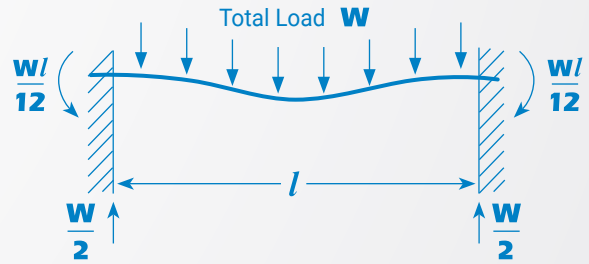



Maximum Deflection at $l/2$

$$\delta_{max} = \frac{5\,W l^3}{384\,EI}$$

Approx. **Expander System**
Load case: **Fixed supports**

The axle ends are fixed in the lugs by the expanding sleeves




Maximum Deflection at $l/2$

$$\delta_{max} = \frac{W l^3}{384\,EI}$$

**Figure 4** Initial load case examples

The fixation of the axle ends will also limit the pin's free radial movement to only be the clearance between bushing and axle. This helps to limit the acceleration of the mass and high impact forces on the bushing and pin. Expander System eliminates lug wear and reduce bushing/axle wear.

# AMUSEMENT PARK SAFETY: LEAVING NOTHING TO CHANCE

*When it comes to amusement park attractions, safety is absolutely crucial. However, maintenance can both be expensive and time-consuming. But there is a solution for worn-out axles and bearings that can solve the problem.*

*Permanently.*

Some people love them and can't get enough. Others, not so much. When it comes to thrills — or outright fright — amusement park attractions cover much ground.

Whether you want to take a free fall from 80 meters height, go at high speeds upside down then into a hairpin curve, or generally expose yourself to crazy G forces, you've got it. But let's face it. It would be taking it too far if you couldn't depend on safety.

Most attractions move much mass at high speed, so there are tremendous forces at play. It can put extreme loads on the, mostly, steel structures and the carriages. Safety and reliability are paramount to avoid incidents or accidents.

**Strict demands throughout the value chain**

Even though the number of accidents remain relatively low in Europe, the European Committee for Standardization, CEN, introduced a new European standard, EN 13814 "Safety of amusement rides and amusement devices", in May 2019. It covers everything from the design of an attraction to operation and maintenance to monitoring and inspections.

The standard puts heavy demands on manufacturers and on the companies that operate amusement parks. According to Peter Andersson:

*"Safety is a fundamental part of our business and covers the visitors as well as our staff. We never compromise on that."*

He is the Ride Maintenance Manager at the Gröna Lund amusement park in central Stockholm and at Parks and Resorts Scandinavia, the group that owns and operates Gröna Lund as well as some of Sweden's most popular theme parks.

Parks and Resorts' local maintenance departments perform meticulous daily controls of both rails and carriages, looking for any wear or damage. Yearly, the carriages are dismantled, and all parts are X-rayed. According to licensing authority rules, in-depth checks are carried out every five years, where attractions are dismantled into small pieces.

### Often enough to change washers

As in all engineering, loosening bolted joints are a safety hazard. For example, the Gröna Lund attraction Eclipse is made from 910 tons of steel and concrete and involves 80,000 bolts. That is a lot of potential problems.

"If we detect any bolt loosening, we often perform root cause analysis. Generally, it is enough to switch to Nord-Lock washers," says Andersson who first learned about Nord-Lock wedge-locking washers back in 1998, when they were used to secure the rails on one attraction after visual inspection.

*"When I saw how well that solution turned out, there was no going back," he says.*

"Since then, if we find loose bolts, we immediately order Nord-Lock washers." Many attraction manufacturers specify Nord-Lock washers already at the design stage. They generally find use in large bolted joints, in applications such as the rails and steel structures, but also for moving parts in wagon brakes.

### A solution that saves time and money

Apart from using Nord-Lock washers, Parks and Resorts is also partial to the Expander System to counter lug wear. This has saved a lot of money and minimized downtime compared to traditional repairs, such as line boring. But it has also significantly prolonged attraction lifespans, which translates into serious savings, given that a new big-sized attraction can cost upwards of 900,000 euros.

Andersson first learned about the Expander System back in the late 1990s too: "We had tried various reparation solutions, but the feeling was always, 'there must be something better'. Then we found the Expander System."

Peter Andersson
**RIDE MAINTENANCE MANAGER GRÖNA LUND**

**CUSTOMER**
PARKS AND RESORTS SCANDINAVIA AB

**NUMBER OF VISITORS**
APPROXIMATELY 3 MILLION EACH YEAR

**APPLICATIONS**
SEVERAL, INCLUDING SECURING RAILS, BRAKES AND STEEL STRUCTURES

**BUSINESS**
OWNS AND OPERATES FOUR OF SWEDEN'S MOST POPULAR THEME PARKS, SKARA SOMMARLAND, GRÖNA LUND, KOLMÅRDEN AND FURUVIK

**THE SOLUTION**
EXPANDER SYSTEM AND NORD-LOCK WEDGE-LOCKING WASHERS

Since then it has been used on numerous attractions at Gröna Lund, including Octopussy. In 2009, Expander System was installed on all arms of the attraction, which has worked flawlessly since then. Another exciting attraction is the Flying Carpet – the oldest at Gröna Lund.

"It has a historical value, and it is difficult to find a replacement," Andersson says. "About eight years ago, we noticed wear on a critical stay. Attending to this would traditionally have meant doing new calculations and finally a complete inspection, which would probably have meant that the attraction would have been put out of commission." Expander System replaced the worn-out axles and bolts, and the Flying Carpet is still used safely.

## The use is spreading

The use of the Expander System has spread within Parks and Resorts. When the maintenance department at the Kolmården wildlife and amusement park contacted Andersson about installing the Expander System on their attractions, he was happy to recommend it.

The wheel bogie suspensions on attraction wagons are usually a weak spot as they are under the most significant strain. Due to wear and tear on the axles, chassis hole tolerances get enlarged, sometimes in just a couple of years.

Fredrik Johansson, a mechanic at Kolmården, says: "If you've been at it for 30 years like me, you know that if something is loose, you've got a problem. And given our high safety standards, we don't put together any makeshift solutions. If it costs a bit more, then that's okay."

## Saving money in the long-term

At first glance, the Expander System may seem expensive but in a life cycle perspective, you can save money, Johansson explains. "Comparing the purchasing price of the Expander System to dismantling an entire attraction and sending parts away for line boring, the latter is both more costly and time-consuming."

As a mechanic, Johansson appreciates how easy the Expander System is to install. There is no line boring or welding involved, you can perform it at the site, directly in the worn mountings.

*"It's a brilliant solution," he says. "We have used it for a season now, and it just works. Problem solved."*

**Text** Ulf Wiman
**Photos** Justin Garvanovic/Parks and Resorts
Gröna Lund/Parks and Resorts
Magnus Glans/Parks and Resorts

# SUPERBOLT TOOL
## BEST PRODUCT DESIGN 2020


**For many years, it was considered too difficult to design a device that could turn multiple jackbolts to the correct load simultaneously. But a group of engineers at Nord-Lock Group made the impossible possible.**

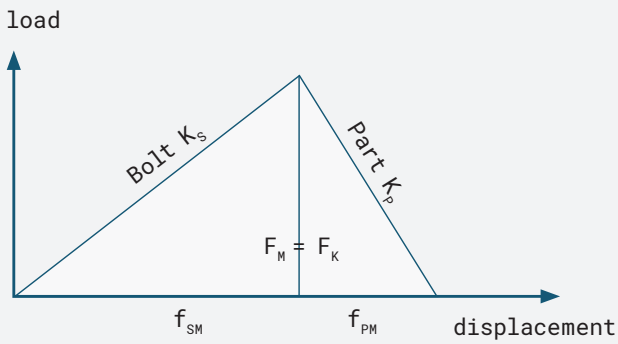
---

In fact, their innovation, Superbolt Tool, has made such an impression that it's been awarded one of the world's most prestigious design awards: **Red Dot Award**. Superbolt Tool won the **Best Product Design 2020** in the **Innovation** category.

reddot winner 2020

# *What happens to preload and clamp force when external loads are applied?*

Email your questions about bolting technologies to experts@nord-lock.com




$K_S$ : Bolt stiffness ($F_M$ / $f_{SM}$ = $1/\delta_S$)
$K_P$ : Parts stiffness ($F_K$ / $f_{PM}$ = $1/\delta_P$)
$F_M$ : Preload
$F_K$ : Clamp load
$f_{SM}$ : Bolt displacement elongated (+)
$f_{PM}$ : Part displacement compressed (-)

We generally apply torque via a wrench to the bolt or nut to generate the required tightening load. This tightening load is called preload. Preload is defined as the tension created in a fastener when it is tightened. Its function is to prevent the slippage and opening of construction parts. Clamp force, in response to preload, is the force acting on the parts.

When external forces act on the joints, each element that transmits force must be analyzed. One can predict the behavior of the joints by seeing how they react to external forces.

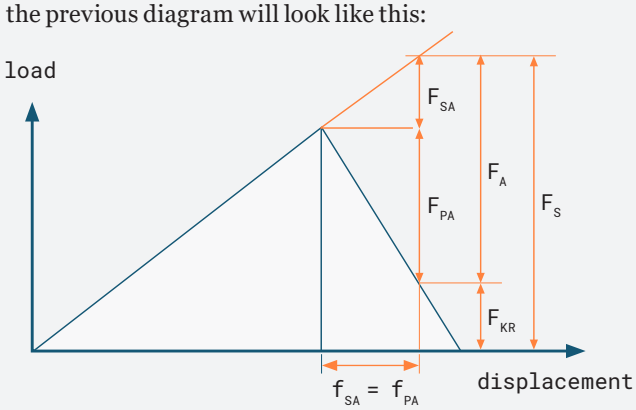
Hence, the calculation of a single bolted joint is based on the elastic behavior of the joint in the bolt axis. This region has a considerable effect on the deformation and the loading of the bolt.

During joint assembly, a preload $F_M$ is produced, which creates a clamp load $F_K$ at the interface. The stiffness factor should be defined first. This is how much load is required to stretch 1 mm of the material.

$K = \Delta F/\Delta L$, opposite of Flexibility (resilience $\delta = 1/K$)
Referring to the joint diagram (Rötscher Diagram).

Then, an axial working load $F_A$ , introduced via the clamped parts and acting on the bolt, is transmitted via the clamped region and via the bolt. The proportion of the working load that goes into the bolt, in addition to the preload, is designated as bolt load $F_{SA}$, the $F_{PA}$ is the reduction of the preload due to the external working load. The proportion of this distribution depends on the elastic behavior of the joint.

The forces and displacements which occur in the bolted joint can be illustrated by means of the joint diagram. Accordingly, the previous diagram will look like this:




$F_S$ : Max. Bolt load
($F_S = F_A + F_{KR} = F_{SA} + F_{PA} + F_{KR}$)

$F_A$ : Axial external load

$F_{SA}$: Axial additional bolt load
$= n \times \{\delta_P / (\delta_S + \delta_P)\} \times F_A$
$= \lambda \times F_A$ using $\lambda$,
load factor $\lambda = n \times \{\delta_P/(\delta_S + \delta_P)\}$
(n: load introduction factor for describing the effect of the introduction point of $F_A$)

$F_{PA}$: Reduction of the preload
$= (1 - \lambda) \times F_A$

$F_{KR}$: Residual clamp load

$f_{SA}$: Elongation of the bolt due to $F_{SA}$

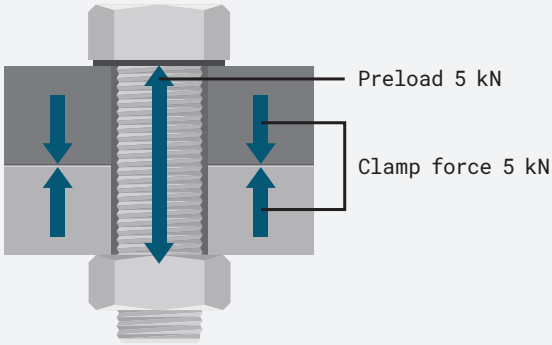
$f_{PA}$: Elastic linear deformation of the clamped parts due to $F_{PA}$

Luke Jun
APPLICATION ENGINEER
NORD-LOCK GROUP KOREA

Masato Takenaka
ENGINEERING MANAGER
NORD-LOCK GROUP ASIA PACIFIC

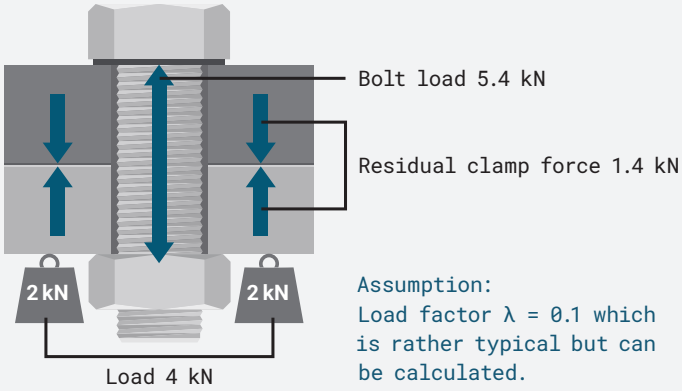
## The previous formula can be verified with the following example

**Step 1**
The bolted joint is tightened to 5 kN. No external load is applied.



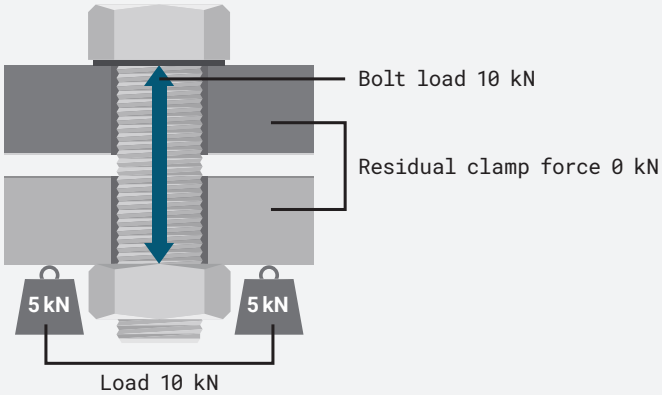

**Step 2**
External static loads (4 kN ) are applied but less than the preload. The initial preload now becomes the residual preload. The bolt load is calculated to 5.4 kN but the clamp force is reduced down to 1.4 kN.

$F_A = 4$ kN, $F_{SA} = \lambda \times F_A = 0.4$ kN
$F_S = 5.4$ kN $= F_A + F_{KR}$
$F_{KR} = 1.4$ kN




Assumption:
Load factor $\lambda = 0.1$ which is rather typical but can be calculated.

**Step 3**
Additional external loads are applied, more than the initial preload. Since the external load is much larger than the preload, the parts are separated and the load in the bolt increases up to 10 kN. (100% of external loads)




In conclusion, the elastic behavior of each component was reviewed when the axial forces were generated on the joint. In addition, there are other external factors to be considered for accurate prediction of the required preload, such as shear forces, temperature, vibration and dynamic loads. For further information, please contact your closest Nord-Lock Group office.