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MOLY REVIEW

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Kindred Spirits in stainless steel

Almost 200 years ago, two tragedies on opposite sides of the Atlantic Ocean gave way to an unforgettable act of kindness. A stainless steel sculpture in Midleton, Ireland, now pays homage to that kindness. Nine eagle feathers, reaching over six meters high, celebrate a gift from the Choctaw Nation of the southeastern United States to the Irish during the Great Potato Famine. The sculpture is a reminder that compassion flourishes in even the darkest hours of history. The corrosion resistance of molybdenum-containing stainless steel helps the sculpture and the legacy it represents endure.

© Irish Times

Following the 1830 Indian Removal Act, several Native American groups living in the southeastern United States were relocated forcibly to make way for agricultural production. In 1831 the Choctaw, native residents of Mississippi, became the first people to walk to designated lands in Oklahoma, over 800 kilometers away. Thousands died along this harrowing march, known as the "Trail of Tears". Nevertheless, when the Choctaw learned that a potato blight hit Ireland during the 1840s, causing one million people to die of famine and another 600,000 to emigrate, they decided to help. Though poverty-stricken and fleeing persecution, the Choctaw collected approximately 170 U.S. dollars, the equivalent of around 5,000 dollars today, and donated it to starving Irish families. At a time when rail travel and telegraphs were bewildering new technologies, these suffering peoples, divided by language, culture, and thousands of kilometers, made a contact that inspires generosity in the 21st century.

Solidarity in stainless steel

A sculpture of eagle feathers in Bailic Park, Midleton, Ireland, celebrates that gift from the Choctaw to the Irish people. Created by artist Alex Pentek, the feathers form a ring representing an empty food bowl, calling to mind the souls lost in the famine. Molybdenum-containing Type 316L stainless steel provides the corrosion resistance necessary for this demanding coastal environment. The stainless steel also provides the structural strength required for the complex high wind-loads associated with its location and Kindred Spirits' delicate design.

Ireland has one of the highest coastal sea salt deposition rates in Europe, with salts traveling far inland and high sulfur deposition levels. Both factors affect corrosion rates. Bailic park adjoins the brackish marsh section of the River Ballynacorra, about six kilometers from Cork Harbour and 12 kilometers from the coast, so at least moderate sea salt exposure must be assumed. Sea salts and higher sulfur levels can lead to corrosion, frequent maintenance, structural failure, and premature replacement of many construction materials. But the two percent molybdenum content in Type 316L stainless steel gives it the necessary corrosion resistance, making it an ideal choice for this location, which, although not subjected to salt spray, is corrosive but receives regular rain-cleaning.

Stainless steel and feathers might seem like total opposites. But the sculpture achieves a delicate effect without compromising durability. The individual veins of the feathers are so thin, they look light enough to keep a bird in flight. The hand-applied, brushed matte surface finish gives the stainless steel a soft glow that contributes to the airiness of the feathers, while avoiding glare and enhancing corrosion resistance by facilitating natural rain-cleaning. With this graceful design, the sculpture has an almost quantum effect; like a ghost that appears only when observed. And as such, Kindred Spirits serves as a modest, though poignant reminder of past losses and overcoming those losses.

Formidable feathers

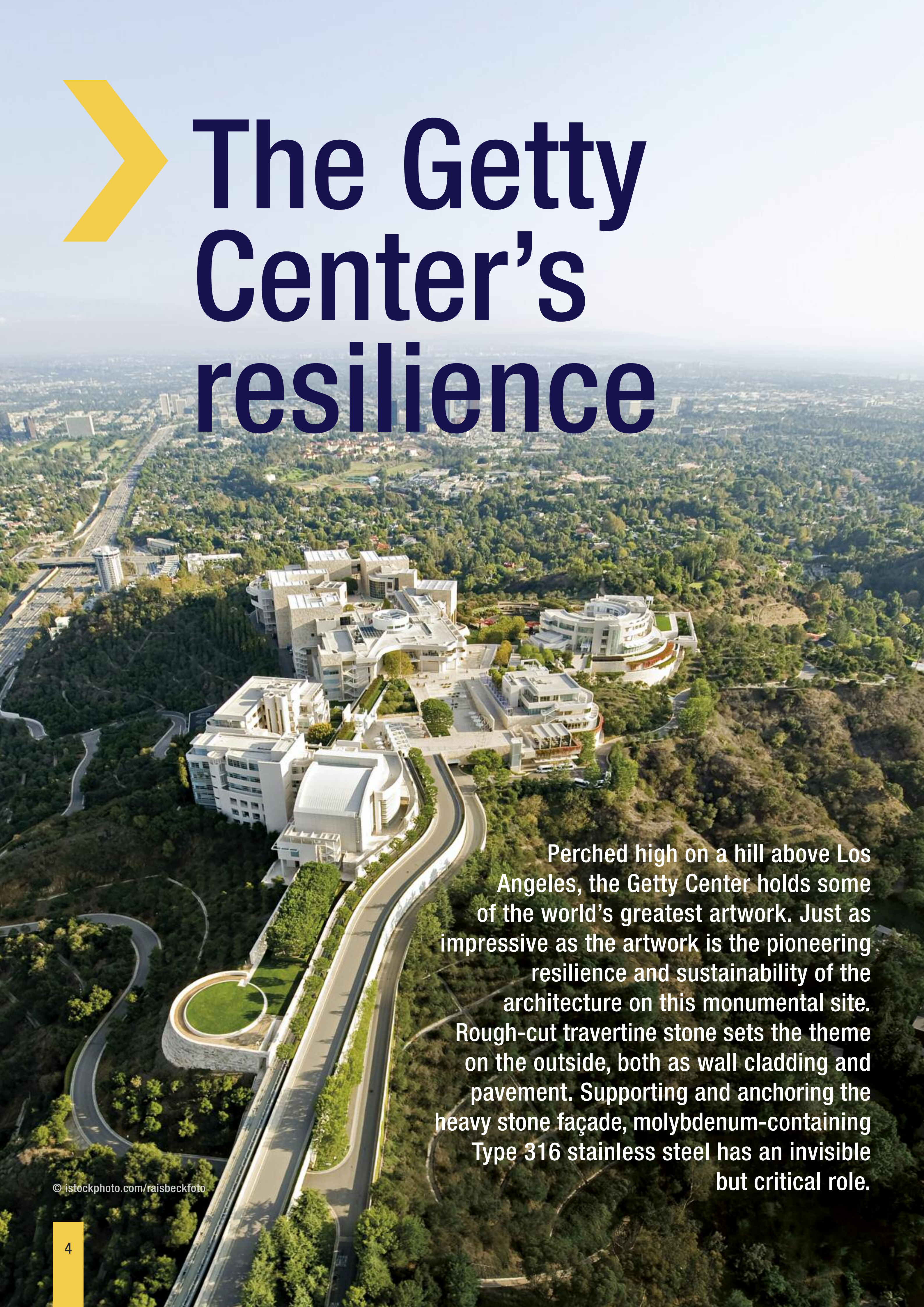
Although it feels weightless, Kindred Spirits was actually assembled on site because it was too large to put together in the studio. The artist formed over 2700 feather veins individually from 10-millimeter square Type 316L stainless steel bar. Using a lever to grip the bar, he cold-bent each vein by hand. The veins were then cut to measure and welded to each feather's central stem, a piece of 150-millimeter diameter stainless steel pipe. The artist gradually removed sections of the pipe and welded them shut while adding the vein to create the tapered effect of a real eagle's feather. Up close, it is apparent that the feathers are creased, imperfect, and organic. Each feather has over 300 veins. Their close 10-millimeter spacing prevents climbing from street level, and the 50% permeability of the sculpture's surface reduces wind loading. In total, there are more than 20,000 welds.

Working at this meticulous level of detail, Kindred Spirits took nearly a year to complete. Once the veins and stems were finished, each feather was cut into three pieces, rolled into shape, and then the sections were welded back together. Finally, the feathers were transported to their final location, bolted down, and concrete was poured over their foundation. In high winds, locals note that the sculpture makes a gentle keening sound, which seems appropriate for this memorial, but the high energy absorption characteristics of stainless steel and its welds help ensure that it will safely weather any storm.

Artist Alex Pentek posing with the nearly-complete sculpture in his studio at the National Sculpture Factory, Cork, Ireland.

Repaying the favor

Almost two centuries later, the Irish have returned the Choctaw's kindness in several ways. In 2018, the Irish Taoiseach created a scholarship program for Choctaw students to study in Ireland. More recently, the Irish people donated more than 1.8 million U.S. dollars to aid two Native American tribes, the Navajo Nation and Hopi Reservations, providing access to healthcare and essential supplies for the Covid-19 pandemic. During the spring of 2020, the Navajo Nation had one of the most severe outbreaks of Covid-19 in the United States. Choctaw tribe leadership expressed gratitude that the Irish have expanded their circle of friendship to others in need. Considering this recent interchange, the Kindred Spirits sculpture nods at enduring and expanding bonds, formed in the face of adversity. These cross-Atlantic ties, like the stunning eagle feathers near the Irish coast, won't be carried away with the wind. (KW)



The Getty Center's resilience

Perched high on a hill above Los Angeles, the Getty Center holds some of the world's greatest artwork. Just as impressive as the artwork is the pioneering resilience and sustainability of the architecture on this monumental site. Rough-cut travertine stone sets the theme on the outside, both as wall cladding and pavement. Supporting and anchoring the heavy stone façade, molybdenum-containing Type 316 stainless steel has an invisible but critical role.

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John Paul Getty was once the richest private citizen in the world and an avid collector of arts and antiques. After his death in 1976, his entire property was turned over to the Getty trust. When the museum outgrew its original location at Getty's former residence in Malibu, California, management of the trust looked for a suitable site that would be more accessible from Los Angeles. The trust also wanted to consolidate all its entities at the same location. They found a large, rugged piece of land, at the top of a hill in the Santa Monica Mountains, with stunning views of both Los Angeles and the Pacific Ocean. The Pritzker Prize winning architect, Richard Meier, was chosen to design the campus in 1984. Thirteen years later, in 1997, the Getty Center opened to the public. The project was so innovative and focused on sustainability that it became the first existing facility in the U.S. to be awarded a U.S. Green Building Council LEED (Leadership in Energy and Environmental Design) certification in 2005.

Picturesque as it is, the Getty's coastal location is subject to both wildfires and earthquakes. In fact, southern California is one of the most seismically active places in the world. The likely impact of such natural disasters, and also of atmospheric corrosion near the sea, must be considered in the construction of the area's buildings. At the Getty Center, Type 316 austenitic stainless steel helps to address all three issues in a variety of applications. For example, austenitic stainless steels in general are very ductile and tough, so they absorb energy from an earthquake or other impacts exceptionally well without breaking. The two percent molybdenum in Type 316 stainless steel adds high-temperature strength in fires and corrosion resistance in chloride containing coastal environments. Therefore, this alloy contributes to a design that is as durable and resilient as it is sustainable. Indeed, over 20 years after it has been installed, the stainless steel shows no signs of corrosion or degradation and looks as good as it did the first day.

Visitors to the Getty Center enjoy panoramic views of Los Angeles.

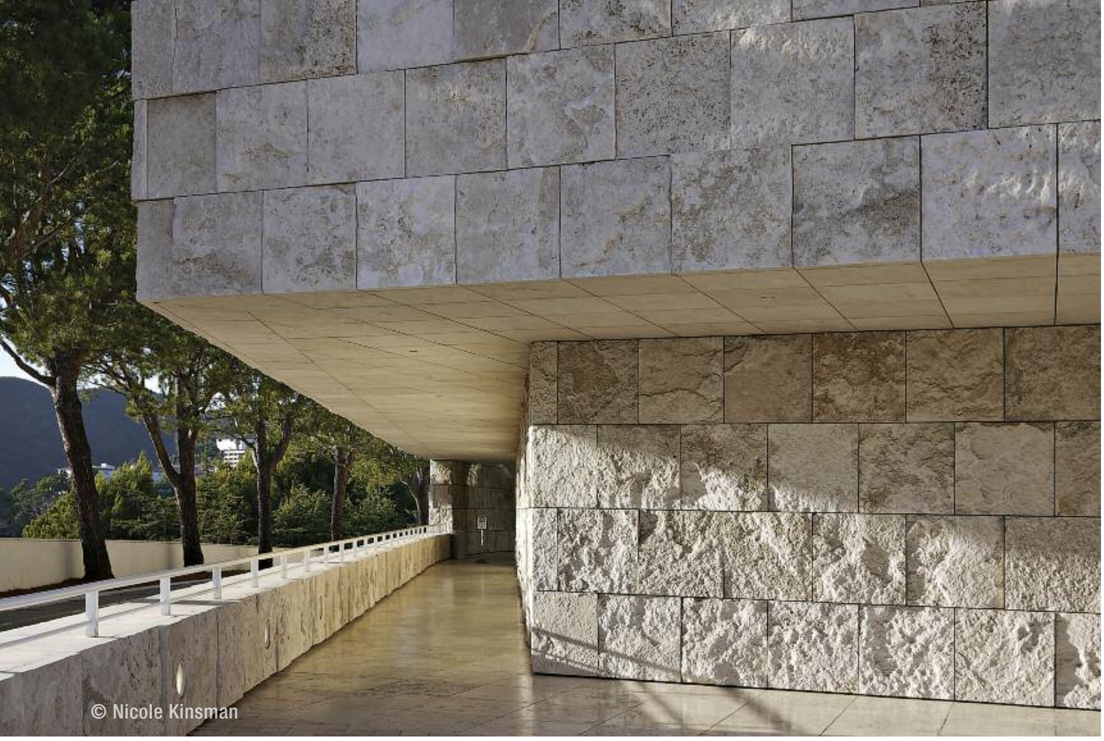
A monumental project

The 1.3-billion-dollar construction covers nearly ten hectares on a 45-hectare site and took over 14 years to plan and build. The complex contains public buildings that house the museum, performance spaces, a cafeteria, and buildings for the different entities of the Trust dedicated to administration, research, conservation, and grant programs. Inside and out of the undulating, sun-bleached buildings, visitors are immersed in countless forms of beauty: artwork, city and ocean views, sprawling gardens, music, fine food, and world-class architecture.

To reduce its visual impact on the city and neighborhood, half of the Getty Center was built below ground. "Hiding" a large part of the complex, combined with gardens and an organic, light-toned color, helps the Center blend in with the surrounding Santa Monica hills. These features also minimize heat absorption. Used in combination with louvered sunscreens and heat venting louvers, they reduce energy consumption.

Set in stone

The various buildings on the site all have different shapes and heights, but they are visually connected by large blocks of cleft travertine. The stone blocks are used as cladding on the retaining walls as well as the lower parts of the buildings and as pavers.



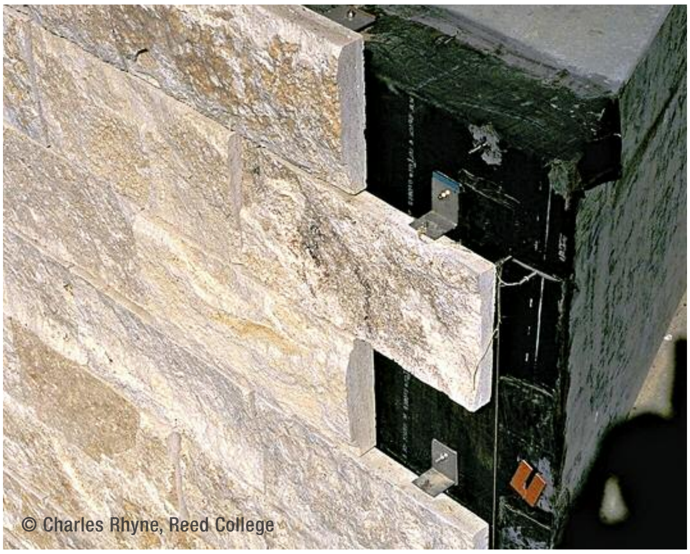
Differing installation methods for walls, facades and ceilings require a variety of special fasteners. One thing they have in common: stainless steel meets the high requirements for building safety.

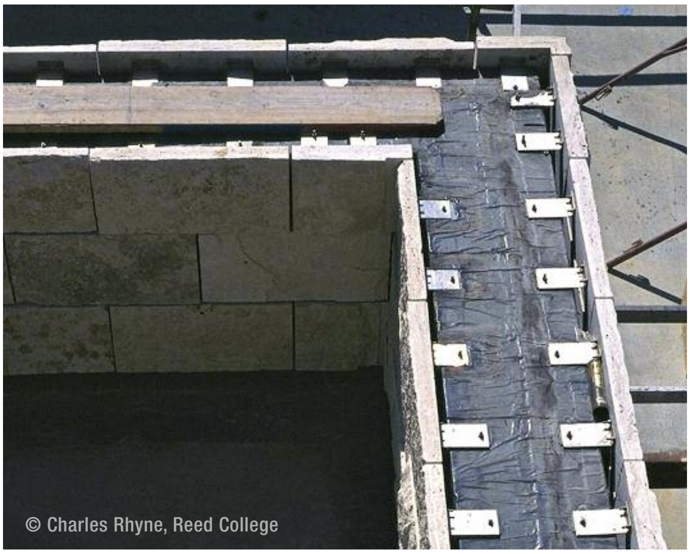
After a lengthy search for a stone that had the right color and was neither too soft nor to hard, the architect chose a travertine from a centuries-old quarry in Italy. Meier and the quarry owner worked for a year to develop a guillotine technique to split the hard limestone, creating the desired rough-hewn surface. As the position of the sun changes throughout the day, the stone's color tone and vibrancy changes subtly with it. All in all, some 110,000 square meters or 375,000 pieces of travertine are installed in the walls and pavements. That translated to the delivery of two containers of stone every day for two years, or roughly 14,500 tons.

Seismic stainless steel

The design of the travertine exterior walls is based on an open joint panel system, instead of the usual technique of sealing the joints with mortar, which requires maintenance and picks up dirt over time. The open joint panel system allows water to drain behind the outer skin, protecting the surface from streaking and ensuring that the building looks as good tomorrow as today. Each individual stone piece is anchored by two invisible Type 316 stainless steel angle clips at the top, which hold the stone to the concrete

The travertine stone is attached to the concrete wall with Type 316 stainless steel stone anchors.





or steel frame walls, and two stainless steel pins at the bottom, which connect the stones to one another, providing stabilization. The top clips are attached using either stainless steel expansion bolts or screws depending on the structural basis.

To protect the steel frame walls from the elements, a Type 316 stainless steel water and air barrier was installed behind the stone façade and the air gap. Similarly, the flashing that directs water outward from the walls and buildings was made from the same material. Thanks to this alloy's good corrosion resistance, even in coastal atmospheres, the stone façade will not suffer staining from corrosion runoff.

The architect's vision required that the stone pieces of the façade look uniform and are precisely aligned. To achieve this effect for the varying contours throughout the building complex, the contractor had to adjust the width and thickness of the custom clips depending on the dimensions of the stones and their positions. More than 250 different clip designs were made to create the unified look. The draftsmen spent over three years creating in excess of 2,500 architectural drawings for the stonework alone. There are some 380,000 stainless steel stone anchors in the entire project. This method allows any stone to be individually removed and repaired, if necessary.

The clip and pin system was designed to resist seismic events. It went well beyond the requirements of the California seismic code at the time of construction. In fact, the system's effectiveness was proven before the building was even completed. The Northridge earthquake occurred in January 1994 while the project was under construction, and many of the stones were already in place. No damage occurred then or during subsequent seismic events. The Type 316 anchoring system provides several advantages in seismic design, particularly its' corrosion resistance, strength and the ability to absorb far more energy during cyclic loading than other steels. Combined with the open joint system, it allows the stones to move independently in a seismic event without cracking.

Fire resistance

The stone cladding and crushed stone roofs were specifically selected for their fire-resistance; indeed, the whole complex was designed with fire resistance in mind. This is crucial considering wildfires in Southern California have intensified in recent decades. For example, in December of 2017, a fire came within a few hundred meters of the priceless Getty collection. Fortunately, the complex's fire-resistance measures were successful. As the fire approached, the sprinkler system soaked the soil surrounding the buildings with over 4.5 million liters of water, deployed from its massive underground water storage tanks, stopping the fire in its tracks.


© Nicole Kinsman


© Nicole Kinsman

Type 316 stainless steel handrails and door frames; more than 20 years after inauguration they look as good as new, despite the aggressive marine environment.

The sprinkler system makes extensive use of stainless steel for both its corrosion resistance and its fire resistance. Stainless steel has very good fire strength performance characteristics. And molybdenum additions increase its stiffness retention well above that of carbon steel when exposed to forest fire conditions. Therefore, the stainless steel anchoring system behind the stone at the Getty helps guard against fires as well as earthquakes; it ensures that the fire-resistant travertine will remain securely in place even during a wildfire. Together, the fire resistance measures at the Getty Center help ensure Van Gogh's Irises and other works will not go up in smoke.

In most architectural applications, stainless steel shines, both literally and metaphorically. Glimpses of this are visible in the form of the beautifully crafted stainless steel handrails, windows and architectural hardware, juxtaposed against the rugged organic stonework of the Getty Center. But the real star here is invisible, behind the façade, holding it all together. The molybdenum-containing Type 316 stainless steel clips and pins, air and water barrier and flashing, will keep the façade clean, safe and secure in the earthquake and fire prone environment of coastal Los Angeles, for as long as the stone lasts. (NK)

Making eco-friendly waves

Building high-performance boats requires strong materials. Typically, stainless steel is not even under consideration for ship construction, but that may be changing. In fact, governments and businesses the world over are starting to take an interest in a new, low-maintenance and environmentally friendly ship hull, built entirely from high-strength, molybdenum-containing super- and hyper-duplex stainless steel, at no additional cost.

Depending on their size and purpose, ships are most commonly made of steel, aluminum or fiber reinforced plastic (FRP). No matter what, ships are generally expensive to keep because they are constantly exposed to water and humidity, which will break down nearly any construction material over time. Steel ships are strong and tough, but steel is heavy and requires corrosion protection and a lot of maintenance. Aluminum is light, but it is very soft, dents easily, has serious fatigue cracking problems, and corrosion is a concern. Carbon fiber reinforced plastic is very light, but it is expensive, can crack when it hits a rock, and can even go up in flames when there is a fire on board. It is also not recyclable at its end of life. Hence, the time is ripe for a better, more sustainable solution.

Keeping fouling at bay

Among the most important design aspects in boat performance are its weight and its hull surface quality. Reducing its weight improves its agility, top speed and fuel consumption. However, if the surface is rough, there is more drag in the water, which slows a ship down and increases fuel consumption. Furthermore, barnacles, seaweed and other marine organisms readily attach to most surfaces submerged in seawater. This process is called “fouling” and it makes the surface bumpy and rough, creating more resistance for a boat moving through water.

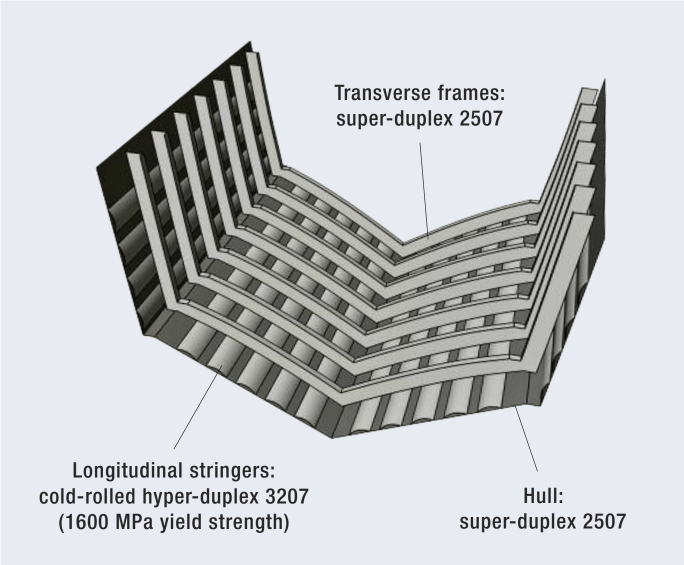
To minimize marine growth, the ship hull under the water line is treated with biocide paint. These paints can be extremely toxic, not only to the target-organisms, but also to aquatic life in general. Even with such treatment, marine growth is only slowed, not eliminated, so it has to be removed by divers to keep it in check. For commercial ships that may be a monthly chore. Anti-fouling paint itself must also be reapplied at least every few years, as it is consumed over time, losing its effectiveness. This takes a ship out of the water, and with that, out of commission. But now, ships built with specialty stainless steel offer an alternative solution.

Lighter, faster, stronger

Realizing the dream of building a lighter, faster and stronger vessel, entirely from stainless steel wasn’t plain sailing for the entrepreneurs Håkan, Petra, and Alistair Rosén of SSY. Traditional stainless steels, such as austenitic Types 304 or 316, are not sufficiently corrosion-resistant in seawater. And while they are extremely tough, they are not that strong. However, when the entrepreneurs discovered the far superior properties of super- and hyper-duplex stainless steels, in particular their great combination of high-strength and outstanding corrosion resistance, a seed was planted. With a stainless steel that is up to three times stronger than the carbon steel traditionally used for shipbuilding, it would be possible to significantly reduce the thickness of the hull, and with that, the weight of the whole ship. But the problem is that thin sheet, no matter how strong it is, buckles easily under wave load when used in normal ship design.

To solve this problem, inspiration finally came from studying the shipbuilding techniques of the seafaring Vikings – over a thousand years ago – and their efficient, strong and flexible wooden hulls. Using a similar design approach in stainless steel resulted in a construction that is both strong and light. The boat glides effortlessly through the water, is very fuel-efficient, and will survive a major impact without springing a leak or losing its structural integrity.

The ductility and energy-absorbing properties of duplex stainless steel even give the hull good anti-ballistic properties, ensuring it deforms to absorb a potential impact without rupturing. Military and law enforcement organizations have shown interest in the vessel due to its enhanced protection against bullets and explosives.

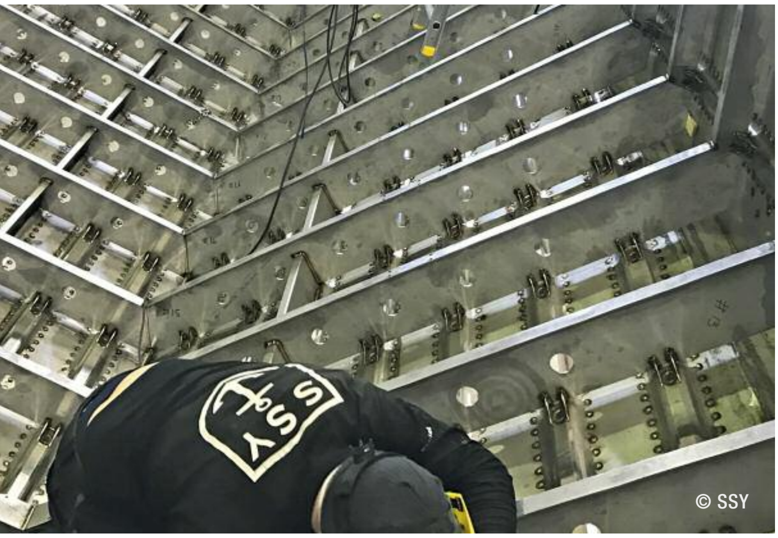


The stringers are spot welded to the hull. The frames, welded to the stringers, are not in direct contact with the hull. The flexibility of the stringers allows them to absorb the wave forces, preventing the hull from buckling.

Corrosion resistant in high seas

While light-weighting was a primary driver for using advanced duplex stainless steels, a further advantage was their ability to resist the severely corrosive nature of seawater without any protective coating. Both duplex stainless steel alloys used in the design contain more than the 2% molybdenum found in Type 316 stainless steel. 2507 super-duplex includes around 4% molybdenum, while 3207 hyper-duplex contains around 3.5%.

These levels of molybdenum significantly increase the corrosion resistance of stainless steel, making it ideal for handling the high-chloride salt levels found in seawater over a prolonged period. Such steels already have a proven track record in offshore oil and gas exploration as well as hydraulic and instrumentation applications in tropical marine environments.



Welding of the interior structure of a ship.

Efficient and eco-friendly

High-strength stainless steel also contributes much to the fuel efficiency of these vessels. Increased strength means that the amount of material required is considerably less than traditional boat construction. For example, high-speed stainless steel patrol vessels that are 15 to 25 meters in length require stainless steel sheets that are between two and three millimeters thick. This is one third to one fifth the thickness of the steel used in a traditional ship. Overall, these agile vessels weigh about 50 % less than a similar carbon steel vessel. Surprisingly, they are also lighter than boats made from aluminum and even what is usually considered the lightest material – carbon fiber reinforced plastic.

Additionally, the hull's mirror-polished finish minimizes drag and friction, which also affords fuel efficiency and reduced emissions as well as greater speed and agility. Moreover, the performance does not deteriorate over time, because the hull is so smooth, it makes it difficult for any performance-reducing marine growth such as barnacles to hold onto the surface. Avoiding the monthly removal of fouling by divers and reapplication of the toxic anti-fouling paint every five to seven years leads to significant operating cost savings.

Stainless steel hull of a prototype at the ship yard.

Besides the direct cost of such maintenance, the ship is not generating any revenue while sitting in a harbor or on a dry dock to apply the paint.

Because super-duplex stainless steel does not corrode, it also will not have to be repaired to replace deteriorated panels. And at the end of its life, stainless steel is completely recyclable. All these benefits add up to huge cost savings over the life of a ship, but maybe more importantly, they significantly reduce emissions and eliminate the impact of biocides on marine life.

Overcoming the welding challenge

Joining the thin-walled super- and hyper-duplex stainless steels with corrosion-resistant, high-integrity welds is part of the core strength of the boat design. SSY worked in partnership with stainless steel producers, a welding supply and an industrial gas company, to develop the specialized welding techniques. The welds have proved to be as strong as the stainless steel sheets and stringers, and the team has been delighted with the consistency and quality of the results. Thanks to the lightweight, optimized design and the efficient welding technique, these stainless steel boats cost around the same as traditional aluminum, steel, or composite boats. In the future, with higher production volumes, stainless steel vessels will cost even less than those made of traditional building materials.

Bigger and better applications

The first 10.8-meter prototype, Elvira, successfully set sail on its maiden voyage in 2014. This revolutionary approach to boat design marked the beginning of a new era of faster, lighter and more agile boats. Two more prototypes, 7.5 and 17.5 meters in length, followed the first vessel, with plans to build another six in the near future. These boats will be displayed at shows and events in the U.S., Europe and elsewhere.

There are numerous other opportunities for marine applications that can benefit from the durable, lightweight design developed by the company. Static floating hulls for solar and wave power generation are among them. The first wave power prototype of a super-duplex stainless steel hull for a Swedish power company is currently being tested. It has been suggested that eventually around 100 of these huge 85-meter floating structures will be used in a single location. By building the hulls out of super-duplex stainless steel, they can remain in the water without any maintenance for the target lifespan of 50 years and beyond.

Other potential applications include the building of much larger ships such as super and mega yachts of more than 100 meters in length. Even bigger ambitions will see the development of giant vessels such as container ships and cruise liners. Reducing the drag and the weight of these vessels using mirror polished, molybdenum-containing super-duplex stainless steel offers a considerable opportunity to reduce fuel consumption and, more importantly, pollution. It has been estimated that one container ship – the length of six football pitches – produces up to 5,000 tons of sulfur each year – the equivalent of 50 million cars. Calculations show that duplex-stainless steel hulls could reduce fuel consumption and emissions by an estimated 20%.

Whether producing a patrolling vessel or luxury liner, the benefits of using molybdenum-containing super-duplex stainless steel are evident. Lightweight ships with an exceptionally smooth hull surface, have considerably lower fuel consumption than traditional ships while maintaining their essential integrity and strength. At the same time, there is no need for regular maintenance cleaning and repainting of the hull with toxic anti-fouling treatment. This adds up to significant operating cost savings as well as much reduced environmental impact. With those benefits, the opportunities for super-duplex stainless steel structures in marine applications are limitless. (ST)

Saving Fallingwater

What was intended to be a weekend retreat for a wealthy Pittsburgh department store magnate and his family, “Fallingwater” now stands as one of the most iconic tributes to architect Frank Lloyd Wright. Molybdenum-alloyed Type 316L stainless steel plays a small but crucial role in preserving one of the greatest buildings of all time.


© iStockphoto.com/Supercel7

As Frank Lloyd Wright's most famous creation, Fallingwater welcomes tens of thousands of visitors each year. In 2015 alone, over 167,000 people traveled to the Laurel Highlands of rural southwestern Pennsylvania to see the legendary home. Fallingwater is defined by its relationship with the waterfall that traverses the property and spills out from beneath the living room. Frank Lloyd Wright famously told the Kaufmann's, the family who lived at Fallingwater, that "I want you to live with the waterfall, not just to look at it, but for it to become an integral part of your lives". Yet, the idea to design a home physically integrated with its natural surroundings was not without structural challenges. By the 2000s, key elements of Fallingwater were at risk of being lost forever. As part of an intensive restoration effort, Type 316L stainless steel was used in the famous staircase that leads from the living room into the river.

The family and the falls

In 1934, global economies were in the throes of the most severe depression of the 20th century. Without jobs to provide economic stimulus, people around the world were struggling to make ends meet. Edgar J. Kaufmann, a department store magnate from Pittsburgh, Pennsylvania, was an exception. Founded in 1871, the Kaufman's Department store grew to become a giant among merchandising businesses in the eastern U.S.. It was a recession-proof staple of the local economy. Fifty miles southeast of Pittsburgh, the Kaufmanns purchased a rundown camp on a stream named Bear Run. Kaufmann loved the unspoiled surroundings, especially the waterfall that cascades from a rock outcropping. This idyllic setting was perfect for the Kaufmann family getaway.

Over the years corrosion weakened the structural steel of the famous staircase.

Close-up image of severely corroded steel hangers and concrete deterioration.

Enamored with Frank Lloyd Wright

Kaufmann's son, Edgar Jr. returned from studying art in Europe in 1934. A friend encouraged him to read the autobiography of Frank Lloyd Wright. Young Kaufmann was so impressed with his organic architecture philosophy that he joined a select group of apprentices at Wright's school, Taliesin, to study the master's principles. There is disagreement as to which of the Kaufmann men contacted the architect to design the country retreat. Whether it was Edgar Sr. or Edgar Jr. is moot. Wright would receive the commission to design the iconic home. At age 67, Frank Lloyd Wright was considered by some to be past his prime. His most notable work before designing Fallingwater was the summer home of an entrepreneur from Buffalo, New York. The Fallingwater commission revived the aging architect's career. He would go on to complete more than one-third of his total work, including the Guggenheim Museum in Manhattan.

The Bear Run retreat was always a playground for the nature-loving Kaufmanns. The falls are the focal point of the property, both aesthetically and recreationally. A staff member who worked at the retreat once observed the Kaufmanns and friends bathing beneath the falls au natural! The Kaufmanns thought that their new country home would be built on the banks of Bear Run with a view of the falls. Wright, however, had a different perspective. After an initial site visit, he would apply his philosophy of organic architecture that promotes a harmonic relationship between the human habitations inherent in the house with the natural surroundings. The home would be constructed atop the falls. Three years after Wright and Kaufmann Sr. first walked the site, Fallingwater was completed.

On the precipice of disaster

Although Fallingwater is an architectural marvel, reinforced concrete design and placement issues coupled with gravity, caused serious structural problems from the outset. A month after the Kaufmanns took up residence, deflection and cracking of the cantilevered portions of the house occurred.

> **"Every Architect recognizes that Fallingwater is a masterpiece"**
> Louis Astorino First Restoration Architect for Fallingwater

The second-floor master terrace contained the largest fissures. Engineers began monitoring and documenting the downward deflection of the cantilevered terraces.

An extensive computer analysis by Robert Silman Associates in 1996 confirmed that Fallingwater's terraces had continued to deflect or sag – one of them nearly 18 centimeters from its original position. These findings lead to a massive restoration effort, headed by Silman's engineering firm, to save the masterpiece before it collapsed upon itself into Bear Run. After extensive evaluation, a system of steel cables or tendons was installed to relieve pressure on both the concrete and the existing steel reinforcement to check the sagging terraces.

Stairway to the waterfall

A unique feature of Fallingwater is a stairway leading from the living room to the head of the falls. It offers easy access to the stream and a plunge pool while providing ventilation for the home when the hatch cover is opened. The original design indicated that the stair treads and landing were to be suspended from the east terrace using steel hangers. However, early pictures document that, in addition to the tread hangers, larger vertical steel members connected the bottom of the east terrace with the riverbed at the landing of the stairs. Over time the steel members have gradually become more substantial, as more vertical structural support was needed for the sagging terrace.

The mild carbon steel used in the original tread hangers of the "hatch" stairs corroded over years of exposure to the moist environment. At times, the staircase would become partially submerged during flood conditions. It also acted as a trap for flotsam and jetsam, adding additional stress to the steel supports. At one point, during a violent storm in the 1960's, the staircase was torn from the structure and had to be replaced.

To prevent the future weakening of the structure from corrosion and the forces of debris-filled storm water, restoration architects replaced the stair hangers and the reinforcement within the concrete treads and landing with molybdenum-alloyed Type 316L stainless steel. The same stainless steel was also chosen for the replacement of the structural columns at the landing that support the east terrace, which can be submerged in the stream after heavy rains. An additional benefit of this alloy is its' impact resistance to flooding debris. A specially formulated "Cherokee Red" paint that Wright claimed reflected both the color of iron ore and the fiery process used in steel-making was applied to blend the new stairs with the existing construction.

The legend lives on

With all its faults, Fallingwater stands as one of the most remarkable architectural achievements of the 20th century. The American Institute of Architects designated it "The Building of the Century." And in 2019, Fallingwater was added to the UNESCO World Heritage List, along with seven other Wright-designed sites. This prestigious recognition is the first designation of modern architecture in the United States. Molybdenum-alloyed stainless steel plays an important role in maintaining both the beauty and structural integrity of this priceless building. (RB)

Fully-restored "hatch" staircase over Bear Run.

© Western Pennsylvania Conservatory

Robots, pigs and pipes

Groundbreaking robots in the UK eliminate the logistical and environmental impacts of gas line excavation by taking measurements from inside the pipe. To withstand the extreme conditions there, 2507 super-duplex stainless steel was chosen for the robots' chassis.

© Synthotech Limited

Understanding the immense value of Project GRAID (Gas Robotic Agile Inspection Device) requires a look back in time. Building the National Transmission System began in the 1960s. By 2030, over 60% of the system will be older than its projected lifespan, raising the risk of both corrosion and leaks. Until now, the only way to assess the condition of pressurized pipe sections inaccessible by traditional Pipeline Inspection Gauges or Pigs was through above-ground surveys and asset life modeling. Such techniques led to costly and environmentally-damaging excavations. Hence, there was a need for a remotely controlled robotic inspection device that could check the condition of these pipes without purging them.

Work on the £6.3 million project started in 2015 with Network Innovation Competition funding from the UK Office of Gas and Electricity Markets. The aim was to design an agile robotic inspection device, capable of surveying the 350 kilometers of unpiggable pipelines that connect the 200 high-pressure installations in the UK Gas Transmission Network. The pioneering robotic platform must operate in extremely demanding physical conditions, including high velocity, live gas, and pressures of up to 100 barg – equivalent to more than five times the maximum pressure experienced by a typical submarine.

This in-line inspection project posed many complex engineering challenges. Once launched into the high-pressure pipe, a challenge in itself, the robot has to negotiate its way through meandering pipe systems. These systems are fraught with obstacles, including sharp bends, inclines, declines and diameter changes. Within this high-pressure labyrinth, flowing with live gas, the robot takes visual and wall-thickness measurements of the deeply-buried pipes. The data is then translated into meaningful pictures for analysis.

Conserving costs and carbon

National Grid collaborated with three companies to deliver the project: Premtech Ltd, who mapped the sites, created a GPS for the robot to follow underground and designed the launch and retrieval device and testing facility; Pipeline Integrity Engineers, who translated the measurements into relevant data via a series of complex calculations and Synthotech Limited, who designed and built the special robots for this world's-first project.

GRAID gives the UK National Grid a detailed understanding of the pipework's condition. It provides reliable data that makes managing, maintaining and replacing pipes more cost-efficient and less disruptive to the community. Now in operation, GRAID is expected to deliver cost savings of more than £60 million over 20 years. In addition to conserving fiscal resources, GRAID also saves an estimated 2,000 tons of carbon emissions annually – equivalent to the emissions from almost 500 UK households.

Extensive testing was carried out to ensure the GRAID robot could operate in the harsh environment experienced within the pipe.

The challenges of developing the robot

Designing the innovative robotic platform took over two years. The final design was influenced by the conditions it must withstand inside high-pressure gas pipework. Natural gas acts like a liquid at high pressure, so fluid dynamics are critical. And when gas flow peaks, an equivalent 200 kilogram force pushes against the robot, so being strong and resilient was also essential.

Project Engineers initially took inspiration from nature – the dolphin – to create the most dynamic form for the robot, with a special skin for use in high flow conditions. However, as the project progressed, the team realized that the agility of the robot was impaired by having one large chassis. Following a re-design, a twin chassis module approach was taken, which allowed all of the electronics to be protected in two custom built chassis. This allowed the device to navigate the tight geometry found on site. The robot uses patent-pending magnetic tracks to adhere to the pipe wall, enabling it to navigate up the side of the pipe, avoiding obstacles, rather than just moving along its bottom.

Project GRAID would not have been possible without the super-strong metal chassis that holds all of the control systems, electronics, and cameras. It was critically important that the robot could withstand whatever conditions it encountered, especially as it was towing a specially-designed 100-meter umbilical cord that contained all the necessary cables to allow it to operate and feedback real-time images. Synthotech's Senior Principal Engineer and Head of Research & Development on the project, John White, explains the challenges of developing the robotic system. He also answers why a super-duplex grade of stainless steel, containing 3.6% molybdenum, was chosen for the chassis.

"No-one in the world has designed a robot for use in an environment where it faces pressures of up to 100 barg, with live gas inside the pipes, so it was a big challenge for us. The strength of the chassis holding the robot was perhaps the key to its success".

"There were many materials out there, but we chose a particular grade of super-duplex stainless steel – 2507 – for a number of reasons. Molybdenum's inclusion in this grade of super-duplex steel also gave it the strength we were looking for. The grade is more expensive, but the benefits justified the additional cost".

The project team considered alternatives, such as carbon steel materials. But in terms of meeting the demanding criteria, the chosen molybdenum-containing duplex stainless steel grade came into its own and performed as expected throughout the extensive testing.

A pipe dream come true

Following the successful testing of the custom-made launch and retrieval vessel in 2017, testing the robot to exacting criteria accelerated. This testing included working under the pressures of 100 barg and traveling distances of 100 meters while collecting visual inspection and wall thickness measurements – definitely not a simple task considering the robot's varied functions. GRAID has sophisticated electronics and control systems, including four individual drive motors, an umbilical management system, seven cameras that transmit live images, and a moveable arm with electromagnetic sensors. It is these sensors on the moveable arm that measure the thickness of the pipe wall and identify any corrosion.

The GRAID robot's front chassis in development.

Specially built test rig, with 90-degree bends, equal tee and reducing diameter sections, and a 45-degree incline.

Also, in 2017, the Project GRAID team reached another major milestone. The GRAID robot successfully navigated a specially built test rig, with 90-degree bends, equal tee and reducing diameter sections, and a 45-degree incline. After every test, the robot was brought back to the launch vessel for visual checks. The robot must return to the launch vessel, sometimes against the flow in the pipe, to avoid any costly retrieval missions involving digging up significant stretches of pipeline. In the latter months of 2018, extensive testing on various transmission sites by National Grid Gas confirmed that the system, especially the robot, was fit for purpose and ready to be put to work.

Project GRAID began as a pipe dream, but through the collaboration of specialist companies and the use of molybdenum-containing duplex stainless steel, this elegant robotic system became a reality. And most importantly, it is helping National Grid to run a safer, more reliable, and efficient gas transmission system. So far, this technology has only been implemented in the UK. However, the robot inspection devices could be used in other installations around the world with unpiggable sections of pipe. The implications for resource conservation in the gas and water industries may be substantial. Wherever these ingenious, pipe-dwelling robots end up, molybdenum will serve an important role in guaranteeing performance in the face of challenging conditions. (ST)

IMOA news

Structural stainless steel workshop

Like so many conferences, the AISC (American Institute of Steel Construction) "NASCC: The Steel Conference" moved online amid the COVID-19 pandemic. Among the speaker line-up selected for the shortened program were IMOA and the Nickel Institute's metallurgical consultant engineer, Catherine Houska, and Nancy Baddoo from the Steel Construction Institute (UK). They delivered a joint webinar to some 1,200 attendees, entitled "Structural Stainless Steel for Corrosive Environments, Resilience and Aesthetic Applications".

Delegates listened to a series of case studies that illustrated the varied uses of structural stainless steel in construction, including those specified for highly corrosive industrial and infrastructure projects. The webinar explored why stainless steel is used increasingly in a wide range of applications, and how the structural properties of stainless steel compare with those of carbon steel and aluminum. The audience also received insights into the characteristics of different stainless steels and guidance on how to select an appropriate alloy for a particular environment and application.

The informative session is available to view online at https://bit.ly/NASCCstainless

Commenting on the session, Nancy Baddoo said "we were delighted that so many people joined us to learn about the benefits of structural stainless steel, particularly in highly corrosive environments. The lively session was attended by structural engineers specializing in buildings, energy, manufacturing, infrastructure and public works, reflecting the diverse and varied use of structural stainless steel today".

In response to a growing need for high performance materials in the built environment, the AISC is writing a new design specification for structural stainless steel, which is due to be published in 2021.

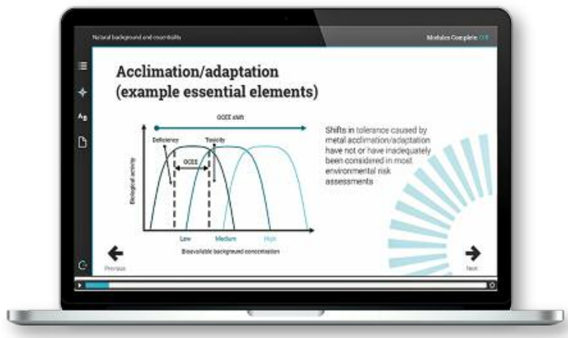
The Garrison Crossing foot bridges in downtown Toronto are built from 2205 duplex stainless steel.

Metals in toxicology and ecotoxicology course launched

Metals are used in almost every aspect of modern society, from transport to energy, housing to healthcare, agriculture to technology. As the amount of metals used increases to keep pace with the demands of modern life, it is important to ensure widespread understanding of their toxicity, management, and impact on the environment.

A new e-learning course about the importance of metals in toxicology and ecotoxicology is now available. The course, written by industry experts from Eurometaux, ARCHE Consulting, and the International Council for Metals and Mining, is being delivered by Chemical Watch. Delegates will develop an understanding of the properties of metals and the impact of their toxicity on humans and the environment. The course focuses on the properties and approaches that are key for the appropriate assessment and management of risks associated with metals.

The new Chemical Watch course will develop an understanding of the properties of metals and the impact of their toxicity on humans and the environment.



The course focuses on the properties and approaches that are key for the appropriate assessment and management of risk associated with metal. © chemicalwatch.com

Regulators in charge of evaluating metals in different chemicals management systems, environmental science professionals, academics, those in charge of environmental regulations related to metals and those new to the metals industry will benefit from this well-designed and informative course.

IMOA's Health, Safety and Environment Executive Sandra Carey commented: "This course will offer anyone with a role in evaluating metals an awareness of the specific properties of metals that impact on their toxicity, as well as the approaches and tools required to properly assess them. The seven online modules draw on expertise from across the metals industry and offer a wealth of information to those who attend".

"Together as an industry we believe it is important to ensure widespread knowledge of the toxicity, management and impact metals have on our lives, particularly among those responsible for their regulation. This course offers an accessible, efficient way in which to access valuable industry knowledge".

More information is available here http://bit.ly/2XUGLeG.

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