

# Winds of change

How can a building with a roof as thin as paper withstand typhoon force winds? A new airport in Qingdao, China, shows the world how it's done: with molybdenum-alloyed stainless steel. Known for its famous beer, Qingdao is also a major industrial and financial center. With its new infrastructure, the city hopes to attract more air travelers. The star-shaped airport features the world's largest continuously welded stainless steel roof, just 0.5 millimeters thick.

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Standing-seam metal roofs, common in large construction projects, are susceptible to failure in adverse weather conditions such as high winds and heavy rain. A technique known as continuous-seam welding takes the resilience of metal roofs to a new level. Qingdao's new Jiaodong International Airport incorporates this flexible welding method on its ferritic stainless steel roof. Upon its inauguration in 2021, the Jiaodong airport will be the largest in Shandong province.

## Welcoming in all weather

Qingdao is a major seaport, naval base and industrial center in eastern China. Briefly occupied by Germany at the turn of the 20th century, Qingdao features soaring gothic churches alongside a 2200-year-old preserved ancient town. These antique fixtures mingle with modern architecture, including the new airport. The Jiaodong airport will be one of the most advanced commercial airports in China, twice the size of London's Heathrow. It will serve over 35 million passengers annually, with flights taking off and landing as frequently as every 73 seconds – one of the busiest in the country. The airport features two runways, each 3,600 meters long, and a 450,000 square meter terminal building. It is also designed to capture, store and recycle rainwater for later use.

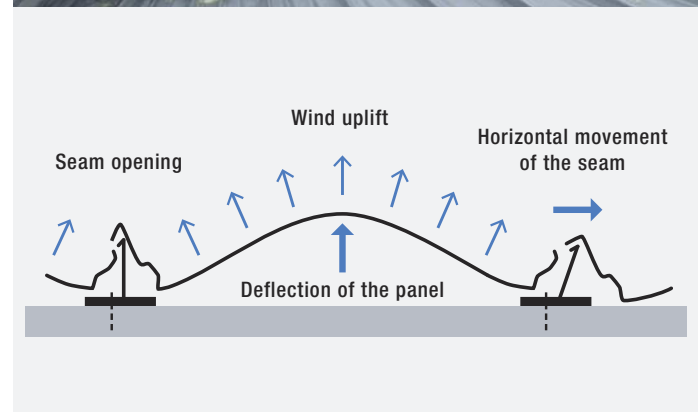
The new airport replaces the existing Qingdao Liuting International airport. Built in a dense part of the city, the original airport had no room to expand to accommodate a growing number of annual passengers. The Jiaotong airport is further out of the urban core, about 60 kilometers from the city center. However, it is only 25 kilometers from the Yellow Sea and even closer to Xiaocha Bay, exposing it to high levels of corrosive salts. The city also experiences seasonal strong rains, high wind pressure and moderate typhoons. To welcome travelers in all kinds of weather, stainless steel, with its excellent ductility, corrosion-resistance and yield strength, spans the entire roof of the building.

## Learning from mistakes

Metal roofs have been preferred for covering large structures, such as airports, stadiums, convention centers, as well as commercial and industrial buildings, for decades. These roofs are light, easily and efficiently assembled, attractive and have low-life cycle costs, making them crucial in large venue construction. Among metal roofs, the “standing-seam” variation, consisting of interlocking metal panels, is most popular. However, because of the need for a minimum slope to allow for efficient rain drainage, this system is not suitable for flat or very low-pitched roofs.

Standing-seam roofing is characterized by roll-forming of coiled metal to form U-shaped panels of the required length, with subsequent joining of the vertical “legs” along their long sides. Depending on the system used, the legs are folded, hemmed, snapped or clipped together. The panels are generally attached to the roof deck with an invisible clip that is fastened to the substructure, without any visible screws punching through the roofing panels.

However, in areas with typhoons and other extreme weather like Qingdao, large roofs can be susceptible to wind uplifts that result in water leakage. The long joints between the panels are particularly vulnerable. These connections work well in most situations, but in a very heavy wind, the lower pressure above the roof panel creates uplift like an airplane wing. The force on the metal sheets causes the joints, that are only mechanically fastened, to loosen, disengage or even pull apart. Such damage often causes leaks or, in extreme cases, the metal cover to rip off.



➤ Strong winds can lead to leakage or even lifting of conventional standing-seam metal roofs, as they are only clipped in place.

Besides the direct cost of roof repair or replacement, any unscheduled construction at an airport is hugely disruptive. Construction not only causes delays but also ripple effects such as increased traffic and congestion in the surrounding areas, as well as compromised travel and freight shipment. Fortunately, continuous-seam welded stainless steel roofing provides a solution to both joint damage and roof uplift from wind.

## A better solution

The continuous welding method for stainless steel standing-seam roofs originated in Northern Europe in the 1960s. However, the method remained more of a niche technology in Europe. It is utilized primarily for flat metal roofs, where other metal roofing systems cannot be used. An emerging need for corrosion-resistant, wind-resistant and waterproof buildings made this kind of metal roofing increasingly compelling in Japan. Introduced in the 1980s, the continuous-seam welding method is nowadays a well-established technology there, as well as in neighboring South Korea. In Japan and elsewhere, these systems are incorporated formally into the “Steel Roof Construction Standard”. For China, where aluminum and galvalume metal roofs dominate, stainless steel roofing represents a paradigm shift.

Thanks to the strength and corrosion resistance of stainless steel, it is possible to design an exceptionally thin roof covering. Using less material is not only cost-effective but also environmentally responsible. Increased strength and corrosion resistance allow stainless steel to withstand a greater variety of environments. Attractive and clean, it

also offers the architect unlimited design possibilities, from the simple to the spectacular. Because it does not require any coating, stainless steel is comparatively low maintenance and saves on operating costs. Without any coating, it is also 100% recyclable, and its reflectivity minimizes solar heat gain, which in turn reduces the need for air conditioning. These features, along with its long service life, make stainless steel a sustainable roofing option.

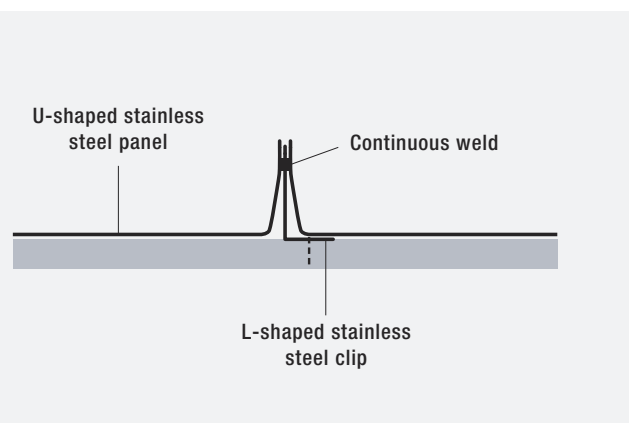
## How it works

With the continuous-seam welding method, metal panels are welded together continuously along their 90° upward bent legs. To keep them from lifting, L-shaped support clips or cleats are fastened into the substructure at regular intervals, their density depending on the expected wind load. Once the U-shaped panels are set in place between the clips, they are tack welded together with a handheld spot welder to keep them from moving during the final welding process. The permanent weld connects the adjoining legs and incorporates the clips. It is applied just below the tack welds, with a self-propelled automatic resistance welding machine or a handheld welding machine at joints and corners. This highly efficient method fully seals the roof skin and dramatically improves the roof's ability to resist wind.

The standing-seam weld is easy to access, inspect and repair if necessary, ensuring a perfect seal. To finish the seam, it is either folded over by a crimping machine or a stainless steel cap is installed, protecting the joint while making it both safe and attractive.



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➤ A fully automatic welding machine joins and seals the stainless steel panels. Clips which are anchored to the roof substructure are simultaneously incorporated into the weld.

Because the stainless steel sheets are only 0.5 mm thick, they can be cut and bent easily with roofing hand tools and welded where necessary to fit custom geometries around skylights, ventilation ducts, roof junctions and others. However, good workmanship involving experienced craftspeople is paramount in ensuring a high quality roof.

## Incorporating the method at Jiaodong airport

The continuous-seam welded stainless steel roofing technology makes its debut in China at the new Qingdao Jiaodong Airport. Its location near the sea is highly corrosive and experiences both seasonal torrential rain and typhoon-level wind loads. The China Southwest Architecture Design and Research Institute Co. (CSWADI) in Chengdu and Beijing Qixia Architectural Technology Co. in Beijing conducted comprehensive studies beforehand, to develop the custom solution. They included wind

tunnel measurements and a study of corrosion resistance, thermal expansion and mechanical properties. Not only the roofing but also the substructures had to be extensively analyzed and optimized.

In the end, an ultra-pure ferritic stainless steel 445J2 produced by TISCO was chosen, with a thickness of 0.5 mm. This is substantially thinner than most metal sheets used for roof coverings. The U-shaped panels have a width of 400 mm. The 445J2 stainless steel grade contains 2% molybdenum and 21% chromium, making it much more corrosion resistant than other standard roofing metals, and even more resistant than Type 316 stainless steel. This translates to both significantly longer service life and lower maintenance costs. Ferritic stainless steels are priced attractively and are popular for roofing because of their higher strength and lower coefficient of thermal expansion compared to austenitic stainless steels. The lower thermal expansion coefficient, similar to that of carbon steel, reduces distortion of the panels as they expand due to solar heating.

➤ With stainless steel roofing systems, connections to skylights, exhausts, gutters or drain pipes can easily be integrated and completely sealed.





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➤ The vast roof of the new Qingdao airport is expected to withstand typhoons and rain storms for decades to come.

The designers chose a shallow embossed surface finish that reduces reflectivity and glare, important for air traffic safety. The embossing makes for a safer roof by improving slip resistance and rigidizes the panels, making them stronger. The embossing also absorbs some of the thermal expansion and contraction from temperature variations, reducing distortion and “oil canning” of the panels. Oil canning describes a mostly visual effect, which makes flat metal panels look wavy.

The installation of the 220,000 square meters stainless steel airport terminal roof, equivalent to 31 standard soccer fields, was completed at the end of 2019. The roof has already proven its excellent performance, withstanding the torrential rains and typhoon winds that occasionally ravage Qingdao. Since then, the same grade of stainless steel has been used for three other large-scale roofing projects in China, including a convention center in Pintan city, Hunan province, a stadium in Shantou, Guangdong Province and the new Zhanjiang airport scheduled to open in 2022, also

in Guangdong Province. This flourish of continuously-welded stainless steel roofing activity signals increasing acceptance of the material as highly cost-effective roofing.

The unique properties of stainless steel roofs greatly expand the possibilities for design and location of new projects. Unlike traditional standing-seam roofs, continuously-welded stainless steel roofs are completely watertight, making them suitable even for flat, low slope and undulating roofs. Securely anchored to the substructure, these roofs can sustain major storm force winds. When an appropriate molybdenum-containing stainless steel is selected, they also resist corrosion, even in marine environments like Qingdao. The incredible thinness and flexibility achieved with stainless steel roofing enable designs once thought impossible to properly function. For the Jiaodong airport and other roof construction with continuous-seam welded stainless steel, the sky is truly the limit! (Gaetano Ronchi, Martina Helzel)