Case Study 04 Singapore Roofing

Moderate Urban Pollution
Moderate Coastal Salt Exposure

The Singapore Turf Club, Kranji, Singapore, was completed in August 1999. Molybdenum-containing Type 316 (UNS S31600, EN 1.4401, SUS 316) stainless steel was used for the unique roof, entrance canopies, and walkway covers. The curved, 400-meter (1,312 ft.) long grandstand roof design was inspired by the graceful and powerful image of a horse in motion. **(Figures A and B)**

The design architect was Ewing Cole, a Philadelphia, USA firm specializing in racecourse design. The architect of record was Indeco, a Singapore firm. Chadwick Technology of Sidney, Australia was the roofing contractor. The location is coastal and exposed to urban pollution. Singapore's high temperatures and humidity levels make the environment even more corrosive. John Chase of Ewing Cole said, "we did not think twice about using stainless steel, because it is a corrosive, tropical island environment. Stainless steel roofing is widely used in Singapore for that reason." Type 316 contains 2% molybdenum, which improves the pitting and crevice corrosion resistance of stainless steel. Molybdenum is particularly helpful in preventing salt and pollution corrosion.

Figure A The Type 316 stainless steel roof of the Singapore Turf Club's grandstand and covered walkway appears to change color during the day. It reflects sunrises, sunsets, blue skies, and clouds.
(Photo Courtesy of Ewing Cole, Photographer: Erhard Pfeiffer)

Figure B This photo shows the unique roof design and the corrosion-free performance of the Type 316 stainless steel.
(Photo Courtesy of Ewing Cole, Photographer: Erhard Pfeiffer)

A 2D finish was selected for the roof. This finish is dull enough to prevent unwanted glare and smooth enough to provide added corrosion protection.

The standing seam roof on the curved grandstand building appears complex, but it is actually a simple, cost-effective design. Each 6 meter (20 ft) wide, undulating section is a gabled roof made from identical 3 meter (10 ft) long standing seam panels. The gabled sections gradually rise along their length until they reach the top of the grandstand. There are maintenance walkways that double as gutters between the roof sections.

INTERNATIONAL MOLYBDENUM ASSOCIATION

Stainless Steel Selection Criteria

The IMOA publication, *Which Stainless Steel Should Be Specified for Exterior Applications?*, provides stainless steel selection assistance. The site and design scores below are based on the guidelines in that brochure. Copies can be downloaded from www.imoa.info or ordered by emailing info@imoa.info.

Section 1: Environment — Score = 2

In 2001, the Singapore government reported that average annual sulfur dioxide levels were 22 µg/m^3 and airborne particulate levels (PM10) were 29 µg/m^3. Half of the airborne particulate are generated by diesel vehicle exhaust and most of the remainder is from industry and power plants on the other side of the island. This is a moderately polluted urban site.

Section 2: Coastal Salt Exposure — Score = 3

Singapore is a small (640 km^2 or 247 mi^2) tropical island off the coast of Malaysia. The racecourse is on the northern coast near the Straits of Johor, which separate Singapore from Malaysia. It is within 1.6 km (1 mile) of salt water and has a salt exposure score of 3. Generally, salt deposits are found throughout islands making even inland locations corrosive. The salt concentrations will vary with weather patterns and wind direction.

Section 3: Local Weather Pattern — Score = -1

Singapore is close to the equator and has a tropical, humid climate. At night, humidity levels often exceed 90%, and, on dry afternoons, humidity levels are between 60 and 70%. Average annual precipitation is 2,413 mm (95 inches). Even the driest months average almost 178 mm (7 inches) of rain. The heavy afternoon rainstorms effectively wash exposed surfaces. The temperature is usually between 23 and 31°C (73 and 88°F) with recorded temperature extremes of 19 and 36°C (66 and 97°F). Normally tropical climates with regular heavy rain receive a "0" score. Singapore has a more consistent heavy rain pattern, and a score of –1 is considered more accurate for this location.

Section 4: Design Considerations — Score = -1

In the thicknesses typically used for roofing, a 2D finish will have a surface roughness of less than Ra 0.5 µm or 20 µin and the score will be -1. Some suppliers can provide a 2D roofing finish that has a surface roughness of Ra 0.3 µm (12 µin) or less. This very smooth finish would have a score of –2. A smooth finish reduces the possibility for corrosion, because corrosive salt and pollution deposit accumulation is less likely. It is also easier for heavy rain to wash away any deposits. All of the surfaces are boldly exposed, and the finish grain is vertical relative to water flow.

Section 5: Maintenance Schedule — Score = 0

Although the maintenance walkways allow easy access, it is assumed that the roof will not be manually washed. If any debris accumulates after a very bad storm, it should be removed to reduce the possibility of corrosion underneath it.

Stainless Steel Selection — Total: — Score = 3

A score of 3 indicates that Type 316 stainless steel is the most cost effective choice for the application. Pollution, climate, and higher levels of salt exposure increased the corrosiveness of this site. A smooth surface finish and a design that takes advantage of rain cleaning reduced the score and made Type 316 an acceptable choice. If a rougher finish had been specified, regular cleaning would have been needed to lower the score to make Type 316 an acceptable choice or a more corrosion resistance stainless steel would be needed. This roof should provide hundreds of years of attractive service. Stainless steel's corrosion rate is much lower and its functional service life is much longer than that of other common architectural metals.

In contrast, Type 304 (UNS S30400, EN 1.4301, SUS 304) stainless steel does not contain molybdenum and is more susceptible to salt (chloride) and pollution corrosion than Type 316. Corrosion staining would be expected if the roof were Type 304 with a smooth finish (less than R_a 0.5 µm or 20 µin) unless the roof was manually washed at least annually. If a surface roughness of R_a 0.3 µm (12 µin) or less were specified, Type 304 might provide acceptable performance if the environment did not become more aggressive over the building's life. Type 316 is usually preferable in environments with coastal salt and pollution exposure, because it will provide longer service life and require less maintenance.

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