There's always a solution in steel.

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Course Description

Designing Structural Stainless Steel: Part 1
Presented by Catherine Houska
March 13, 2014

The history, performance, sustainability and applications for stainless steel as a structural material will be introduced, with references to specific projects. The families of stainless steel used for structural sections and available product forms will be reviewed. The mechanical and physical properties will be compared with other metals. Guidance on material selection for a range of environments (atmospheric, salt water, soil, swimming pools, industrial) and design factors that influence durability will be presented. The appropriate ASTM specifications and AWS codes will be reviewed.

Learning Objectives

- Gain familiarity with stainless steel in structural applications.
- Learn and understand about the different stainless steel structural sections and material properties.
- Become familiar with the design of stainless steel for different environmental situations.
- Gain familiarity with the ASTM and AWS codes for stainless steel structural material.

There's always a solution in steel.

Part 1: Designing Structural Stainless Steel

Catherine Houska

structural STEEL

Topics

- Applications, history, performance and sustainability of stainless steel
- Structural stainless steel families
- Physical and mechanical properties relative to other metals
- Available product forms
- Specification
  - For corrosion performance
  - ASTM and AWS

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Gateway Arch Design Inspired First Structural Research

- Completed 1965, 630 ft. high
- Structural components
  - Exterior triangle: Welded stainless steel plate Type 304, 0.25”
  - Interior triangle: Welded carbon steel plate, 0.375”
  - Stiffener rods between layers
  - Concrete between layers first 300 ft
- Started stainless structural design research & lead to SEI/ASCE 8

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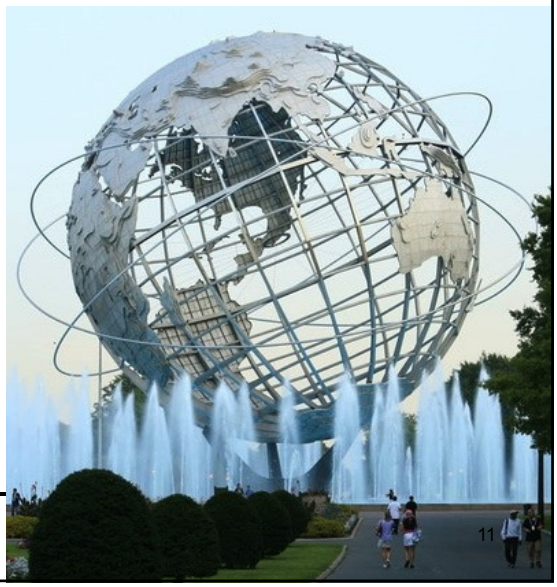
Unisphere, New York City, 1964

- 1964 World's Fair
- Used same structural research
- Highlighted structural product forms
- Type 304L



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Canadian National Archives

- First large building framing application, 1995
- 500 year design life
- 2,800 tons types 304 and 316, Designed to withstand earthquakes, tornadoes, and a corrosive environment

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European & Japanese Demonstration Buildings

- Structural standards based on SEI/ASCE 8 Cold Formed Design
  - Adopted Australia, Japan, South Africa
- EuroCode 3
  - Hot or cold rolled
  - Welded structural stainless steel

Residence Finland

Japanese Lab

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AISC DG 27 Structural Stainless Steel

- DG 27, Structural Stainless Steel
  - Issued September 2013
  - Free PDF for AISC members
  - Fasteners & tension bars
  - Austenitic & duplex hot rolled or welded structural sections
    - Thicknesses ≥ 0.125” (3 mm)
    - I-beams, channels, angles, hollow sections etc.
- SEI/ASCE 8 - cold formed sections

Gateway Arch
Completed 1965

Courtesy Catherine Houska

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DG 27 versus AISC 360

- Not everything in AISC 360 Specification for Structural Steel Buildings is covered
- DG 27 includes most common structural shape and load scenarios
- Some stainless and carbon steel rules are identical
- Where there are differences, standard carbon steel equations are adjusted with multipliers for stress-strain curve differences
- Structural design covered in Part 2

Photos Courtesy Outokumpu

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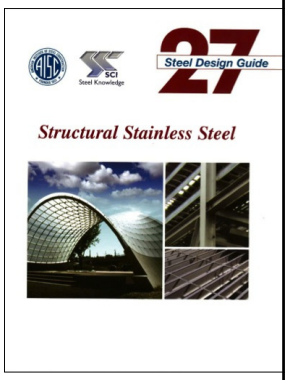
DG 27 Covers

- Stainless steel properties, specification, & selection
- Design in
  - Tension,
  - Compression,
  - Flexure, and
  - Shear
- Various other loading conditions
- Mechanical & welded connection design
- Fire Resistance
- Fabrication & erection



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Stainless Steels Families in Guide

- Austenitic (structural sections, fasteners)
  - 300-series numbers (304/304L, 316/316L)
  - Strengthened by cold work, easy to weld, tighter bends
  - Nonmagnetic
  - Use low carbon (304L & 316L) for welding
- Duplex (structural sections, fasteners)
  - Austenitic/ferritic microstructure (UNS32101, 2304, 2205)
  - Higher strength & magnetic
- PH - Precipitation hardened (tension bars, fasteners)
  - 630/17-4 PH
  - Highest strength, least corrosion resistant & magnetic

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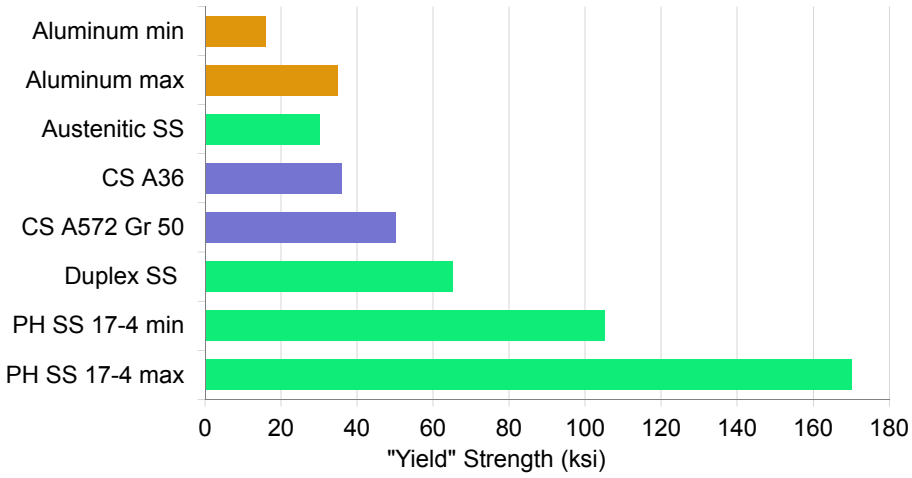
Minimum Design Strength



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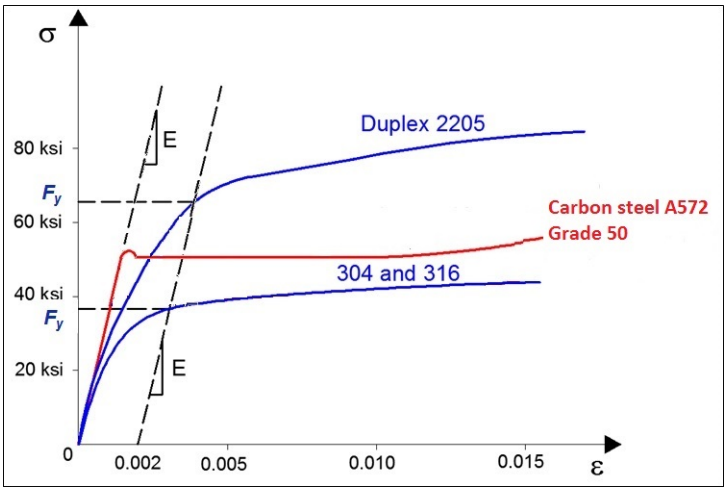
Stress Strain Characteristic Differences

Nonlinearity……..leads to some design differences



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Common Stainless Steel Structural Section Applications

- Food, beverage and pharmaceutical industries
  - Corrosive and coatings are contaminants
- Highly corrosive industrial environments
- Water treatment & processing
- Moderate to high coastal & deicing salt exposure
- Cryogenic applications
- Seismic, blast & high impact concerns
- Aesthetic applications
  - Memorials & monuments
  - Highly visible architectural

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Industrial Environments

- Largest application for structural stainless steel >90% of the market
- Stocked sizes in typical industrial sizes and finishes

Photo Courtesy Outokumpu

Stainless Structurals

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New Poly Plaza, Beijing

Skidmore Owings & Merrill

- Completed 2007
- Type 316 cable
- 2205 tension bars and spiders

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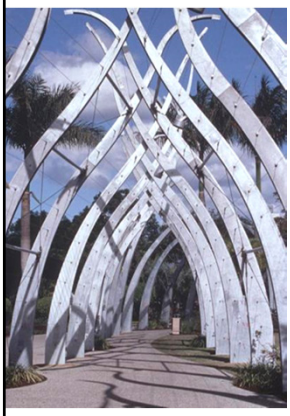
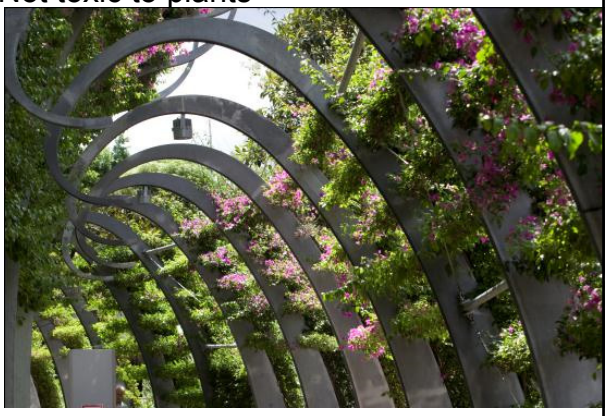
South Bank Arbour, Brisbane, Australia

Type 316 plate and wire support plants
Long term performance in coastal environment
Not toxic to plants





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US Air Force Memorial

- Designed by Pei Cobb Freed
- Structural engineering Arup
- Completed 2006
- Height 218 to 284 feet
- Primary structural materials
  Type 316L, 0.75” welded plate
  Type 316L rebar spacers/stiffeners
  Concrete in lower half

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San Diego Harbor Dr. Bridge

- Completed 2011, 2205 is primary structural material
- One of world's longest self-anchored, suspension bridges 550 ft long, 16 ft wide
- Architect Safdie Rabines
- Structural Engineer T. Y. Lin

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Sustainable Construction Characteristics

- Design for long service life
  - USGBC LEED (60 years)
  - Avoid replacement, repair or protective coatings
- Minimize material use, waste & impact
  - High recycled content or high recapture rate
  - Reuse components
  - Reduce material requirements
- Preserve natural resources & building environment
  - Extend life of other materials (wood, stone, masonry)
  - Minimize toxic run-off and other environmental impacts

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Life Cycle Cost Analysis

- Stainless premium over carbon steel
  - 4 to 5 x Rolled Shapes (angles, channels, etc.)
  - 6 x Duplex stainless welded structural sections
  - 8 x Type 316L welded structural sections
- Potential cost reductions
  - No galvanizing, painting and possibly fire proofing
  - No maintenance coating reapplication
  - Section size reduction with duplex stainless
  - No premature replacement in severe environments
  - Avoid liability concerns
- Fabrication & erection costs are equivalent

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Life Cycle Cost
Coastal Piers, Progreso, Mexico

- Installed cost difference 2 – 12% higher for stainless rebar
- Functional pier
  - Completed 1941
  - Stainless rebar
  - Core samples confirm performance
- Non-functional pier
  - Failed < 30 years
  - Carbon steel rebar

Photo courtesy of the Nickel Institute

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Railings Coastal Splash Zone

- New York City
- Painted carbon steel railings failure 8 – 10 yrs
- Hudson River Park used stainless steel 316TI

- Canary Islands park
- Painted carbon steel railings failure 8 years
- Duplex stainless 2205 after 30 years

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Pulp Plant Structural Framing

- 2205 Duplex stainless I-Beams in a pulp mill
- A very severe environment

Photo Courtesy Outokumpu

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Recycled Content vs Recapture Rate

- Recycling = % of scrap used in material production
- Recapture Rate = % of the material that is recaptured at the end of service and reused without loss of its initial characteristics (i.e. down-cycling)
  - Much better measure of natural resource retention
- Metals are infinitely recyclable resources
  - Metal refining dates back to 6,000 BC
  - Metal has always been recaptured at the end of life and reused to make the same high quality product
  - Metal producers use as much recycled content as possible to reduce costs

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Average Rates (%)

	Recycled Content	Recapture Rate
Carbon Steel		
Sheet/strip	25-35 **	70
Structural	≤90 **	98
Stainless Steel	70 - 90**	92*
Zinc	23 **	33
Copper		
Electrical wire	0 *	>90
Other products	70 – 95 *	>90
Aluminum		
Sheet	0 *	70
Extrusions	Varies *	70
Castings	≤100 *	70

* ABC Industry ** All Applications

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Stainless Steel Specification

- Determine level of corrosion resistance first
  - There are numerous property combinations available at each level of corrosion resistance
- List the ASTM Specification(s)
- And specific alloy by UNS number
  - "304" is a common name
  - It is UNS S30400

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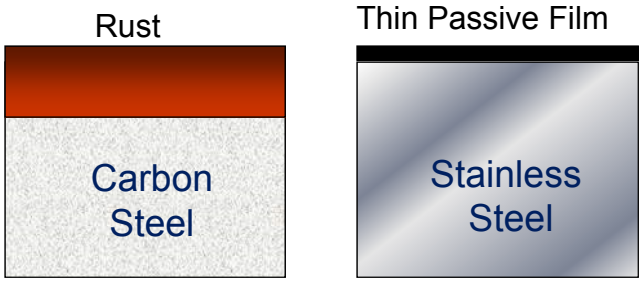
How Does A Stainless Steel Work?

Stainless steel = iron + ≥10.5% chromium + low carbon

Name means "stain – less" not "stain – free"

Corrosion resistance = chromium, molybdenum, nitrogen

Formability & weldability = nickel



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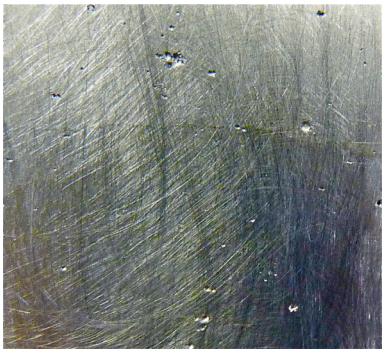
Typical Carbon vs Stainless Corrosion

- Carbon steel has uniform rapid thickness loss without protection
- Layered appearance

- Stainless steel corrodes by pitting – small round pits



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Chemistry & Corrosion Resistance

(Nominal Chemical Composition, Wt. Pct.)

	Cr	Ni	Mo	N	PREn
Martensitic 630/17-4PH	15	3	---	---	15
Austenitic 304/304L	18	9	---	0.06	18
Duplex 2304	23	4.8	0.3	0.1	24.5
Austenitic 316/316L	17.5	11	2	0.06	25
Duplex LDX 2101	21.5	1.5	0.3	0.22	26
Duplex 2205	22	5	3	0.15	35
Duplex 2507	25	7	4	0.28	43

PREn (Pitting Resistance Equivalent number) = %Cr + 3.3(%Mo) + 16(%N)

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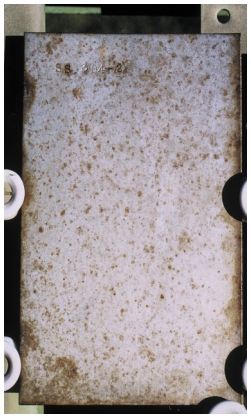
Kure Beach

250 m (800 ft) from the ocean never washed

57 years exposure



Type 304

Type 316

48 years exposure

Carbon steel
60 Zn, 20 Al, 20 Mg coating

Photos courtesy of TMR Consulting

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20-Year South African Exposure Data

Average Annual Corrosion Rate (mm/yr)

Metal	Severe Marine**	Severe Marine*	Marine**	Rural*
Type 316	0.0003	0.0001	0.00003	0.00003
Type 304	0.0004	0.0001	0.00008	0.00003
Type 430	0.002	0.0006	0.0004	0.00003
Al 3003	0.019	0.005	0.005	0.00028
Copper	0.025	0.04	0.009	0.00559
Zinc	0.111	NA	0.023	0.0033
Cor-Ten	0.810	1.15	0.212	0.0229
Mild Steel	2.190	0.846	0.371	0.0432

* Low pollution, ** Moderate pollution
National Building Research Institute, South Africa

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What Factors Influence Atmospheric Corrosion?

- Pollution (acid rain, sulfur dioxide, particulate)
- Coastal and deicing salt exposure
- Weather conditions
- Maintenance
- Design/specification
  - Finish topography, roughness & application method
  - Crevices between materials
- Crevices from surface accumulations dust, sand, debris
- Handling & post fabrication cleaning

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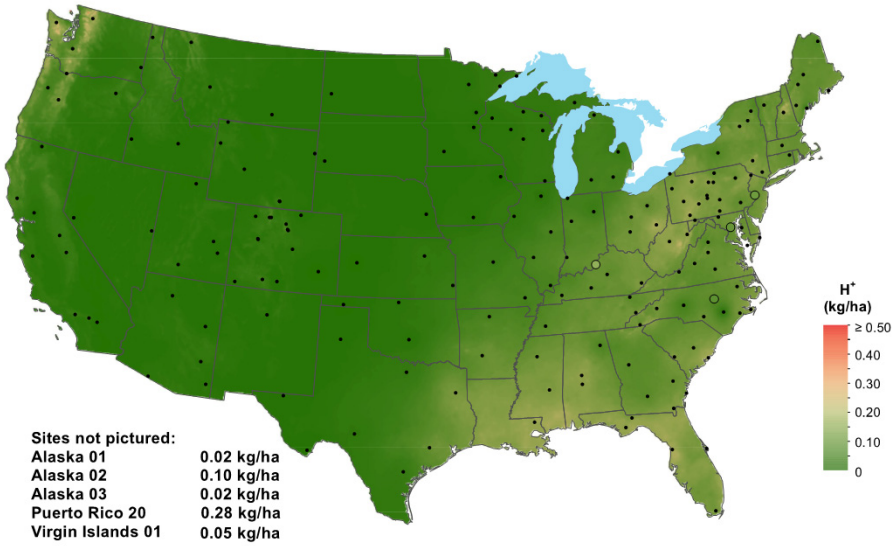
Rain Deposition pH (Acidity) - 2012



National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

Rating Pollution Levels

City	Pollution Level	Suspended Particulate $\mu gm/m^3$	Sulfur Dioxide $\mu gm/m^3$
Rio de Janeiro	High	139	129
Beijing	High	377	90
Calcutta	High	375	49
Moscow	High	100	109
Tokyo	Moderate	49	18
New York	Moderate	27	26
Chicago	Moderate	35	14
Stockholm	Low	9	5
Paris	Low	14	14

World Health Organization Data

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Critical Temperature/Humidity Combinations Salt (Chloride) Corrosion

Above these critical temperature and humidity level combinations, hygoscopic salts absorb moisture from the air creating concentrated highly corrosive salt slurries on surfaces

Critical	**Critical Humidity Level, %**		
Temperature ° F	Sodium Chloride	Calcium Chloride	Magnesium Chloride
77	76	30	50
50	76	41	50
32	---	45	50

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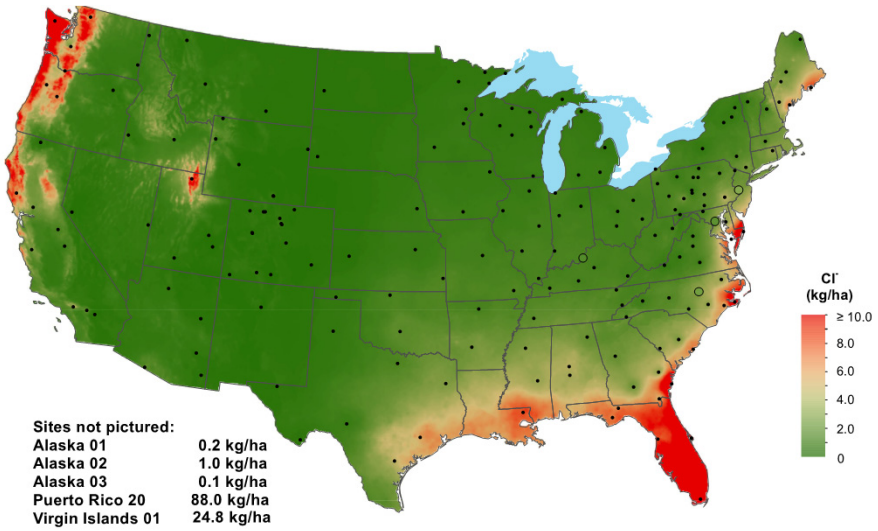
Salt (Chloride) Deposition (kg/ha) – 2012

Data varies from year to year and multiple years should be reviewed



Sites not pictured:

Alaska 01	0.2 kg/ha
Alaska 02	1.0 kg/ha
Alaska 03	0.1 kg/ha
Puerto Rico 20	88.0 kg/ha
Virgin Islands 01	24.8 kg/ha

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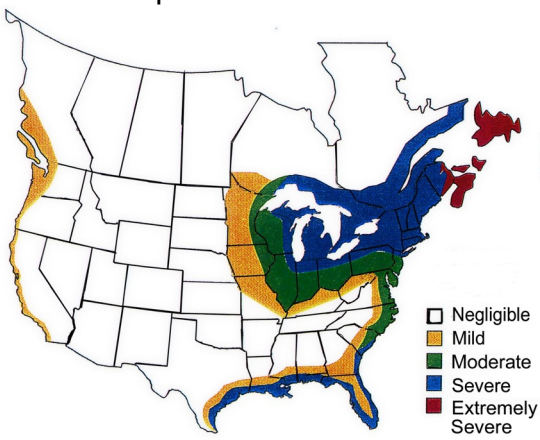
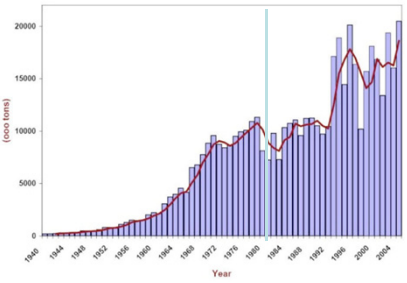
National Atmospheric Deposition Program/National Trends Network
http://nadp.isws.illinois.edu

1980's US & Canadian Corrosion Map

Samples placed near roadways
No samples in some known severe areas





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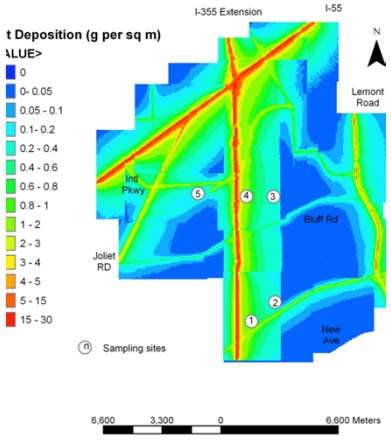
The Deicing Salt Corrosion Threat



- Multi-year study Chicago area highway intersection
  - IL DOT, NADP & Argonne National Lab
- High seasonal salt accumulation
- Splash zone (≤ 49 ft.)
- Dry particles
  - ≤ 1.2 miles downwind from roads
  - ≤ 59 floors in downtown Chicago
  - Stays in the air for days

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Aesthetic Specification

17-4 PH

- Interior or protected from environment

interior stair, 304L

Select Type 304

- Rural/suburban low/moderate pollution
- Climate controlled interior

Select Type 316/316L

- Pollution
  - Moderate to high urban
  - Low to moderate industrial
- Coastal and deicing salt
  - Low to moderate exposure

Houston Galleria arches, 316L

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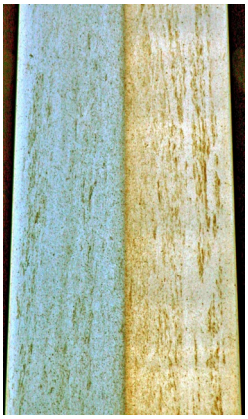
Stainless Steel Corrosion Differences

2nd floor, 3 Pittsburgh buildings
Factors: salt (chlorides), sulfur dioxide

Type 430 = 17-4PH



Type 304

Type 316

Photos courtesy of TMR Consulting

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Select More Corrosion Resistant Stainless Steels

- Duplex 2205, 2507, etc.
- Moderate/high industrial pollution
- Coastal or deicing salt
  - Salt water splashing, spray or immersion
  - Sheltered unwashed applications
  - Significant deicing salt
- High particulate (dust) levels with pollution or salt

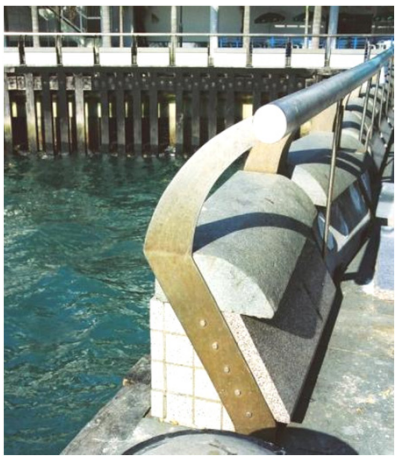

Photo courtesy of the Nickel Institute

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New Franklin D Roosevelt Memorial

- Roosevelt Island, New York City, Louis Kahn
- Grand opening October 2012
- 2205 selected, 100-year storm surge design
  - Handrails, doors, and structural components for granite
- Immersed in seawater (Hurricane Sandy) shortly after opening
  - No corrosion after debris removal

Courtesy CMPI

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Dubai Beach Site Corrosion Rates Predict Perforation - Standing Seam Roof Example

Metal	Corrosion Rate Dubai Coastal Inch/year	SMACNA Thickness Inch	Time To Perforation, Yrs
2205 Duplex*	0	0.015	50+
Galvanized steel**	0.02	0.024	2.2
Aluminum	0.002	0.032	16
Zinc***	0.035	0.028	Less than 1
Copper	0.004	0.022	5.5

* Type 304/316 guidance was used. Lighter gage maybe possible.
** A G140 coating (0.001 inch) was assumed to have delayed carbon steel corrosion by 1 year based on zinc corrosion rates, this may not be accurate.
*** Zinc thickness for a double rolled standing seam per Rheinzink Applications in Architecture

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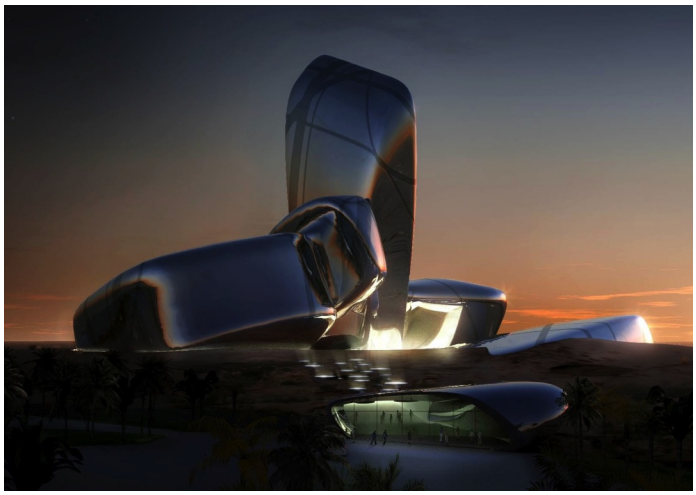
Near Dubai Site
King Abdulaziz Center for World Culture



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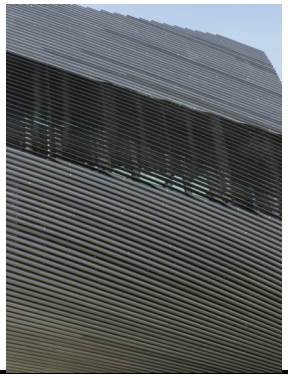
Duplex 2205 Stainless Steel Selected

- Corrosion testing documented severity of location
- Paint would have failed & not been repairable
- Less highly alloyed stainless steels would have had a corrosion problem



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Soil Environments

- Most corrosive
  - Low pH, high chloride & sulfide levels, poor drainage
- Stray currents can accelerate corrosion
- Aluminum and carbon steel are not suitable
- Cast iron can provide reasonable life – low/no chlorides

Stainless Steels	Soil Environment
Austenitic 304, 316 Duplex 2304	Cl < 500 ppm, resistivity > 1,000 Ω-cm, pH > 4.5
Austenitic 316, duplex 2304, 2205	Cl < 1,500 ppm, resistivity > 1,000 Ω-cm, pH > 4.5
austenitic 6% Mo alloys duplex 2507	Cl < 6,000 ppm, resistivity > 500 Ω-cm, pH > 4.5

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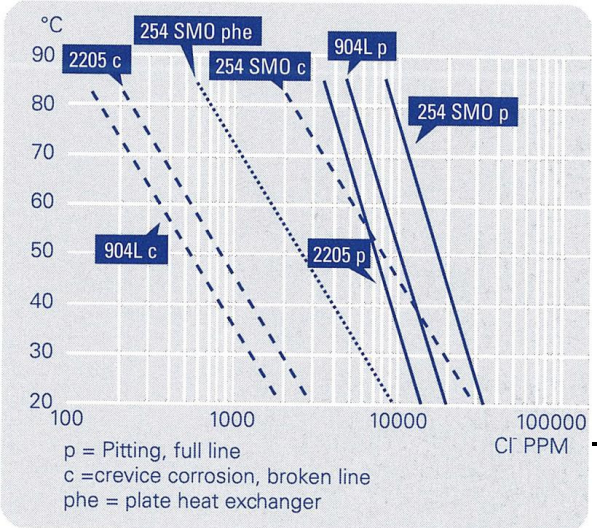
Immersion In Sea & Brackish Water

- Requires seawater grade stainless steels & expert analysis of service environment



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What Makes Indoor Swimming Pools Corrosive Environments?

- Preferred free chlorine range in water
  - Pools , 1 - 3 ppm
  - High temperature pools/spas, 3 – 5 ppm
- High water chloride levels
  - Calcium chloride use without dilution
- Pool shocking can raise levels to 20 – 25 ppm
- Above pool level
  - High chloramine levels
  - Inadequate air replacement
- Inappropriate bromine application for algae
  - 1% concentration can cause corrosion

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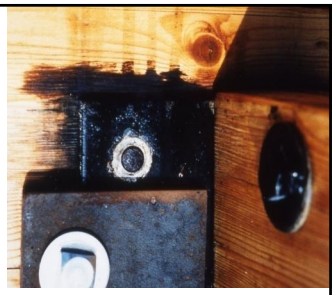
Swimming Pools

- Pool deck & immersed - 316
- Ceiling load bearing – no cleaning
  - Stress corrosion cracking (SCC)
  - Do not use 201, 304, 316, 321
  - Best choice
    - 6% Mo austenitic stainless
    - Super duplexes like 2507
  - Acceptable for many applications
    - 904L, 2205, 317LMN
  - Replace or inspect regularly if the wrong stainless was used



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Specification in Industrial Environments

- Determine all characteristics of environment
  - Temperature, pH, chemical/acid exposure, chlorides, particulate, aeration, biological growth, chemistry
- Review corrosion handbooks, papers, producer & industry association publications
- Obtain advice from stainless steel corrosion expert

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Galvanic Corrosion Requires...

- Dissimilar metals
- Electrical connection between metals (i.e., metal-to-metal contact)
- Moisture is present and connects the metals on a regular basis

Solution

- Prevent direct contact
  - Inert washers
  - Paint
  - Other non-conducting barriers

Surface area ratio is important!

Stainless steel plate/galvanized steel fasteners

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Galvanic Series
Metals and Alloys in Sea Water

Magnesium
Zinc
Aluminum Alloys
Mild Steel
Low Alloy Steel
Cast Iron
Muntz Metal
Yellow Brass
Red Brass
copper
Aluminum Bronze
Silver
Stainless Steel
Monel
Gold

Anodic
More Likely to corrode

Paint failure eliminated metal separation

Galvanic corrosion of carbon steel support

Cathodic
Less likely to corrode

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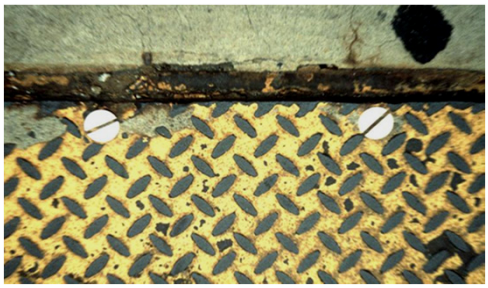
Surface Area Ratio & Corrosion Potential



Good ratio = no impact on corrosion

- Stainless steel fasteners in carbon steel

Photos courtesy of Nickel Institute

Bad ratio = rapid corrosion

- Galvanized fasteners in stainless steel

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Statue of Liberty Restoration

Completed 1886, Restored 1986

- Original cast iron frame separated from copper by wool felt which rotted away
- Iron corrosion damaged the copper and threatened structural integrity
- New framing – duplex stainless steel

St Mary's Cathedral, Tokyo

Completed 1961, Type 304, 2D, near coast

- Galvanic corrosion of carbon steel framing caused stainless failure

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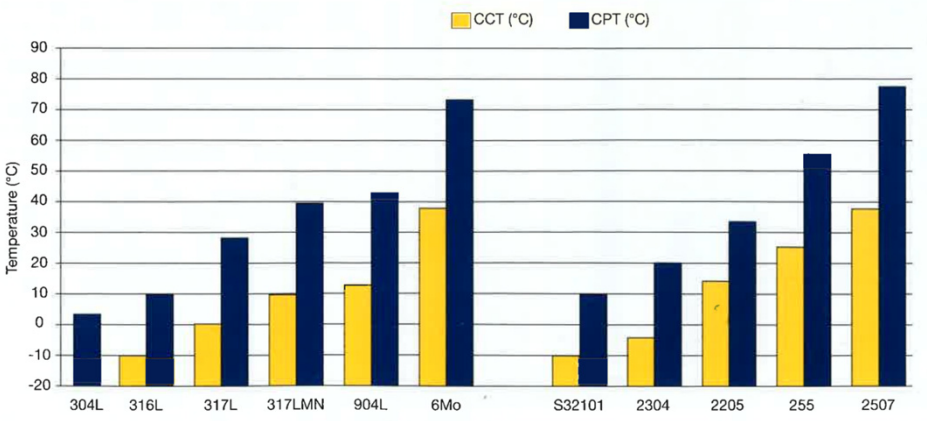
Critical Pitting (CPT) vs Critical Crevice (CCT) Corrosion Temperatures



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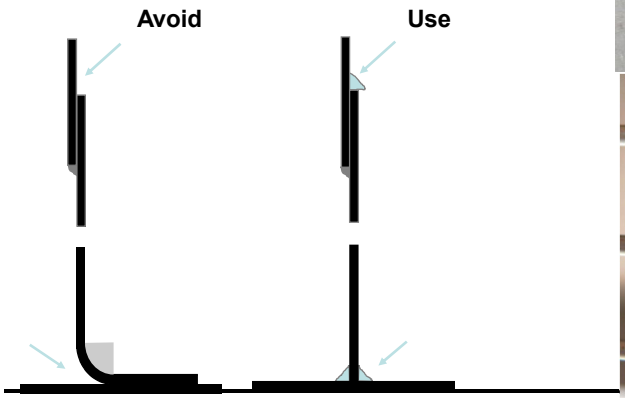
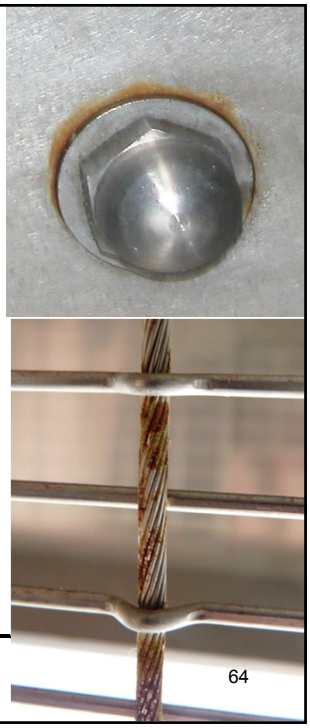
Sites for Crevice Corrosion

If the design will be exposed to salt (chlorides) and moisture, avoid crevices or seal them to prevent corrosion





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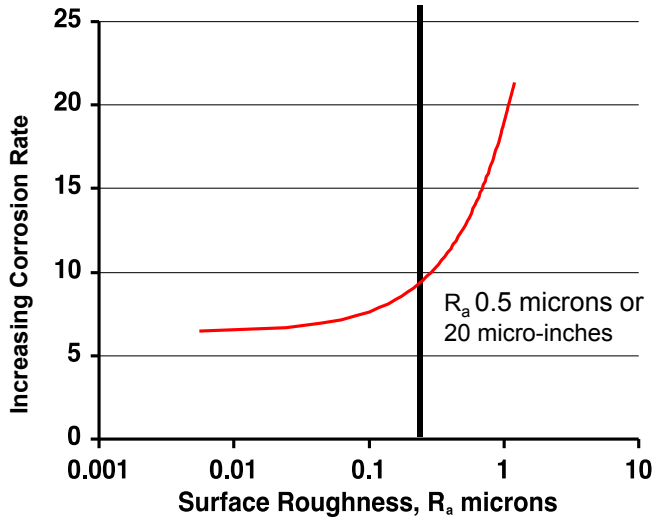
Surface Finish Critical To Corrosion Performance



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Type 316 Bollard Düsseldorf, Germany

- 100% Type 316 – Same pipe
- Splashed with deicing salt
- Corrosion difference due to surface roughness
- Specifying the correct surface roughness is as important as selecting the right stainless steel.

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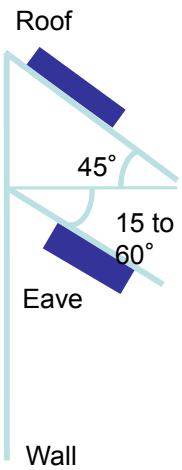
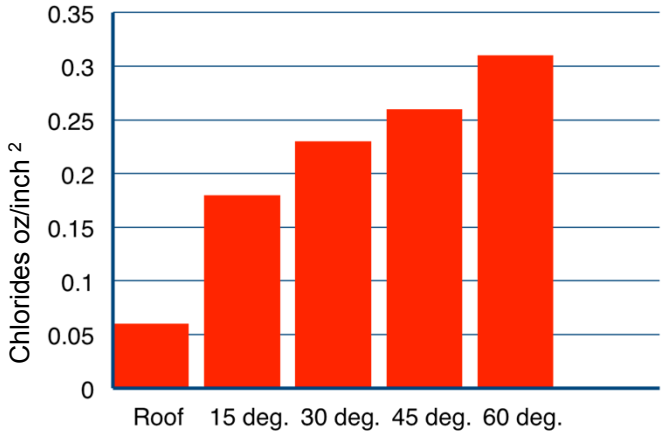
Higher Chloride Accumulation In Sheltered Locations





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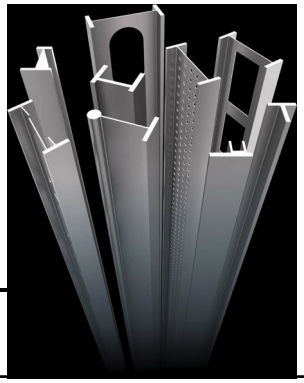
Product Forms

- Bar and concrete reinforcement
- Structural shapes
  - Extrusions
  - Hot & cold rolled
  - Welded
- Structural tubing & pipe, welded
- Castings
- Fasteners



Stainless Structurals Inc.

Availability of Stainless Structural Shapes

- All of the common carbon steel structural shapes available can be obtained in stainless steel
  - Stocked sizes are more limited then carbon steel
  - Generally only 304/304L and 316/316L are stocked
  - Custom fabrications & short runs readily available
- Sources
  - Directory in structural section of SSINA website
  - Stainless steel service centers (distributors) stock basic angles and channels
  - Stainless steel steel producers

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Stainless Steel Specification Basics

- Terminology, Grade = chemical composition (alloy)
- Stainless steel gauges are not defined in any standard
  - Specify thickness (minimum, maximum or range)
  - Select based on corrosion resistance first **then** mechanical and physical properties
- Stainless steel specifications list minimum strength
  - Representative of very heavy plate not lighter sections
  - Standards can be tightened by agreement between supplier and purchaser– never loosened
  - Exception – concrete reinforcing bar

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Flat Rolled Product Specifications
(Plate, Sheet and Strip)

Primary Specifications
- ASTM A240 - chemistry & mechanical properties
- ASTM A480 - finishes & dimensional tolerances
- ASTM A666 – cold rolled to higher strength levels for structural applications

Do not use
- ASTM A167 – replaced by A240

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Bar and Structural Shapes
(includes tees, channels, angles, etc.)

- Bar & hot rolled and extruded shapes
  - ASTM A 276
    - Chemistry/mechanical properties
- Structural sections with filler metal
  - ASTM A240 & AWS D1.6
- Laser welded structural sections
  - ASTM A1069
- Use ASTM A 484 Dimensional tolerances/finish

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Tube Specifications

- Most cost effective to order tube not pipe
- Structural tubing, welded not seamless
  - Dimensions based on the OD
  - Standard structural product
  - Light and heavy wall available
- Austenitics
  - ASTM A 554 up to 16” OD
    - Light or heavy wall
  - Larger OD use ASTM A269
- Duplexes use welded ASTM A 789
  - ASTM balloting to add to A554

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Pipe, Concrete Reinforcement & Castings

- Pipe – pressure rated (extra cost)
  - Pipe transports fluids & dimensions based on **inside diameter**
  - ASTM A 312 Austenitic pipe
  - ASTM A 790 Duplex pipe
- Most common casting specifications
  - Austenitic ASTM A 351/A351M
  - Duplex ASTM A 890/890M
- Stainless rebar ASTM A955/A955M

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ASTM Fastener Specification

- Most common standards - Duplexes are not covered
  - F 593 bolts/hex cap screws/studs
  - F 594 stainless steel nuts
  - F 738M metric bolts/screws/studs
  - F 836-a Specification for stainless steel metric nuts
- Special applications & diameters above 1.5 inch or 36 mm
  - A 193/A 193M Stainless Steel Bolting High Temperature or Pressure Service & Special Purpose Applications
  - A 194/A 194M matching nut standard
- A1082 high strength precipitation hardened & duplex stainless bolting – all sizes

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Property Comparison

Metal	Thermal Expansion ºC x 10^{-6}	Thermal Conductivity *(W/m-C)*
Type 304/316	16.9	0.16
2205	13	0.23
Carbon steel	12	0.54
Alloy 400	13.9	0.26
Copper	16.9	3.86
AA 3003	23.2	2.04

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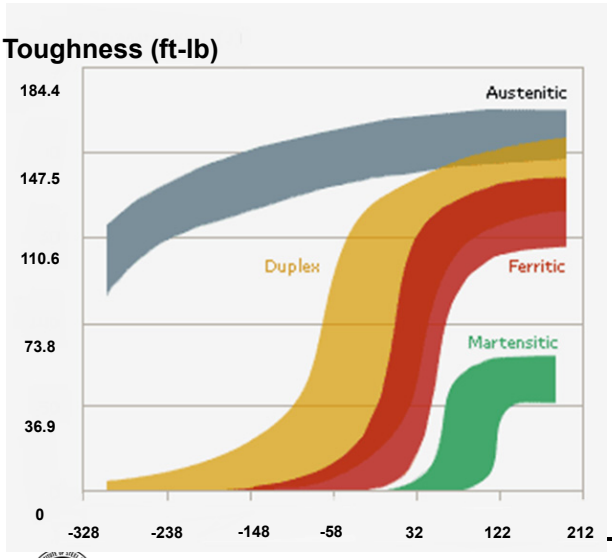
Low and Ambient Temperature Toughness



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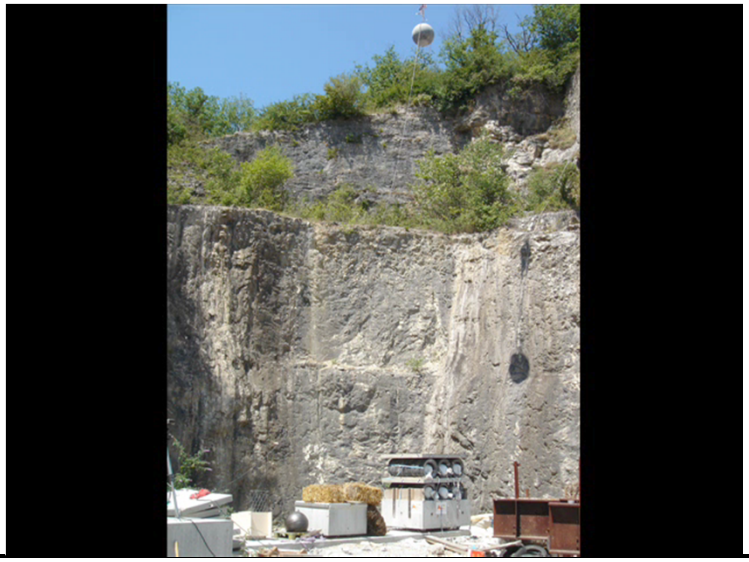
700 KG Ball Impact – Carbon Steel Reinforced Concrete



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700 KG Ball Impact – Carbon Steel Reinforced Concrete

VIDEO

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700 KG Ball Impact – Type 304 Stainless Reinforced

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700 KG Ball Impact – Type 304 Stainless Reinforced

VIDEO

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Welding Structural Applications

- Use AWS D 1.6 Structural Welding Code – Stainless Steel
- Includes:
  - All welding methods
  - Welding all stainless steels
  - Welding different stainless steels to each other
  - Stainless to carbon and alloy steels
- Different stainless steel product forms

US Air Force Memorial welded 0.75 inch plate

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AWS D1.6 Contains

- **Do not preheat austenitic or duplex stainless steel**
  - Precipitation hardened grades – possible exception
- Stainless family differences
  - Austenitics 304L, 316L– easiest, most forgiving
  - Duplexes– more challenging then austenitics
  - Martensitic and PH – special challenges
  - Higher alloys (all families) a little more challenging
- Design of welded connections
  - General requirements, weld length/area, structural details
  - Stainless steels & welding to carbon & alloy steels

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Welding methods

- SMAW (Shielded Metal Arc)
- GTAW (TIG)
- GMAW (MIG)
- FCW (Flux cored Wire)
- PAW (Plasma Arc Welding)
- SAW (Submerged Arc Welding)

- Others (Laser, Resistance welding etc.)
- Not oxy-acetylene

- AWS D1.6 also provides
  - Stud welding - technique, mechanical requirements

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Filler Metals

- Listed in AWS D1.6
  - AWS specs
    A5.4 – coated electrodes; A5.9 – bare wire;
    A5.22 – flux cored wire; A5.30 – consumable inserts
- Generally “matching” filler metals are used
- 304L, 316L, lean duplexes can be welded without filler
- Higher alloys like 2205 should (almost) always be welded with filler metal
- See D1.6 Table F.1 for different base metal combinations, cast grades, stainless/carbon and some alloy steel combinations

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Welding Stainless Steel & Carbon Steel

- Stainless is regularly welded to carbon & alloy steels
  - Remove any coatings from the carbon steel near the weld
  - If the carbon steel has been galvanized, it must be removed from the weld zone to prevent zinc embrittlement
- Painting joint plus to prevent galvanic corrosion

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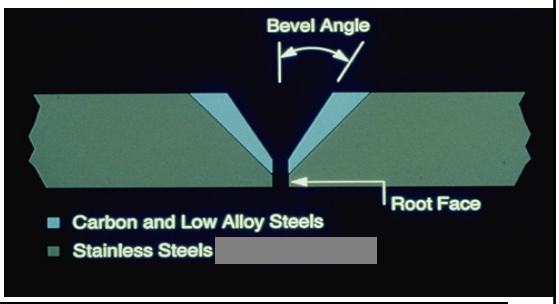
Welding Stainless Steel & Carbon Steel

- Post weld heat treatment maybe needed for higher alloyed stainless
- Relative to carbon steel, stainless joints have
  - Wider angles
  - Smaller root face
  - Allow a root gap
  - More tacks



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AWS D1.6 Contains

- Prequalification
  - Welding processes, base metals, filler metals/fluxes/ gases, weld sizes, joint details, plug & slot welds
  - Reference tables
  - Joint designs with welding processes
- Qualification
  - Welders & welding operators
  - Testing requirements & acceptance criteria
  - Tables WPS qualification variables
  - Essential variables for each type of welding
  - Thickness, number of test specimens

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AWS D1.6 Fabrication

- Strength / Ductility
  - Weld metal is always less ductile than parent material
  - Annealed duplex grades and austenitics, no major effect;
  - For hardenable grades (e.g. PH) the strength may be affected by welding. Consult a specialist.
- Corrosion Resistance
  - Require low carbon 304L & 316L
  - Duplexes have higher risk if improperly welded

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AWS D1.6 Inspection

- Inspection
  - Requirements vary with structure
  - Personnel qualification & procedure
    - Use AWS certified welding inspectors
    - Directory on AWS website
  - Contractor obligations
  - Non-destructive testing
    - Visual, radiographic, ultrasonic, & other testing
  - Interpretation of problems, rejection/acceptance criteria

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AWS D1.6 Design

- Contract plans & specifications
- Eccentricity of connections
- Allowable stresses
- Weld length & areas
- Structural details provided
  - Lap joints
  - Transitions
  - Connections/splices
  - Built-up members in statically loaded structures
  - Non-continuous beams
  - Cyclically loaded structures, etc.

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Remove Weld Heat Tint & Contamination

- After welding require
  - Restoration of weld corrosion resistance per ASTM A 380
- After all fabrication/welding, require chemical passivation (ASTM A967)
  - Improves corrosion resistance by removing surface sulfides
  - Does not restore corrosion resistance after welding or heat treatment
  - Removes lighter surface contamination (free iron, oil, etc.)

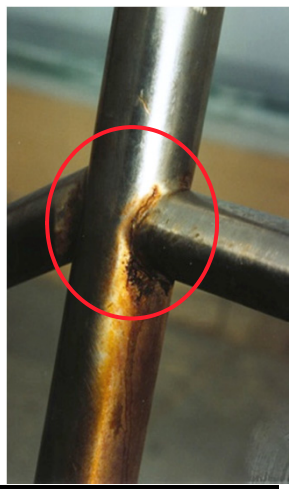

Photo courtesy of ASSDA

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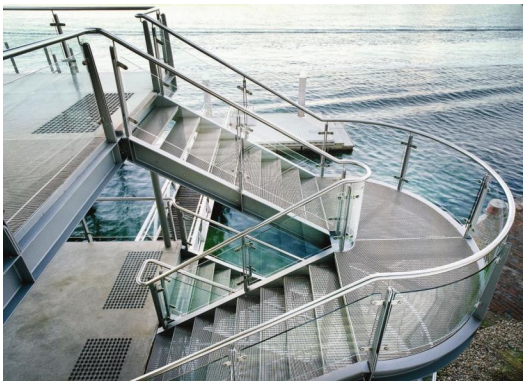
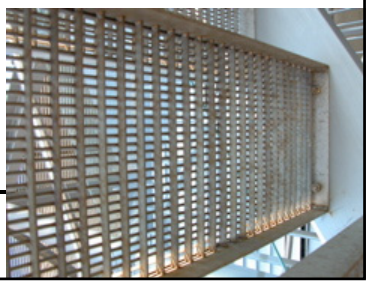
Sydney Australia Swimming Club Stairs





Type 316L stainless steel stairs adjoin harbor

Clean Before Welding

- Stainless steels are considerably more susceptible to contaminants than carbon steel
  - Hydrocarbons (oil, grease, lubricants, etc.)
  - Marking crayons, paints, etc.
  - Other metals – zinc, copper
  - Road salt
  - Shop or on-site dirt
  - Moisture
  - Contamination from carbon steel
  - Contamination of shielding gases

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Fabrication Considerations

- Use experienced stainless structural fabricators
  - Welding light gauge is not the same thing
  - Many experienced industrial fabricators
- Use fabricators experienced with the alloy family
  - Duplex ≠ austenitic ≠ precipitation hardened
  - Require current AWS certifications for alloy with bid
- Require dedicated stainless steel fabrication areas
  - If carbon steel has been fabricated on the same equipment, thorough cleaning is required
- Never allow carbon steel brushes, wool, abrasive blast media used on carbon steel

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There's always a solution in steel.

THANK YOU FOR YOUR TIME!

QUESTIONS

structural STEEL

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- Completely fill out online form. Don't forget to check the boxes next to each attendee's name!

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