Interior, Exterior & Structural Applications
Design Considerations

- Is the environment
  - Interior controlled climate?
  - Sheltered exterior environment?
  - High or low traffic?
    - Scratching, denting, graffiti, urine
- Type 304 - most interior applications
- Type 316 - coastal and polluted exterior locations
- Use an appropriate finish and visual standard
- One supplier per finish
DG Bank
Headquarters
Berlin, 2001
Type 304 conference room exterior and structural components
Architect: Gehry Partners
Bibliothèque
François Mitterrand

Woven stainless on walls, draped from ceilings and over windows
Bibliothèque François Mitterrand

Woven stainless steel mesh on the building exterior
September 11 Museum Building, New York

- Situated between the sites of the two towers
  - Perforated Type 316 roof and wall sunscreen cladding
  - Two finishes to create texture
    - Glass bead blasted and mirror polished
- Other park applications
  - Type 316 park benches, water feature components, lighting, subway station canopy
  - 2205 walkway gratings
Type 304
Vibration finish on wall panels and ceiling
Softly diffuses light and hides scratches
Hyatt Center
S. Wacker Dr., Chicago
Pei Cobb Freed
Type 316 exterior/ Type 304 interior panels
Soft embossed finish highlights
British artist Keith Tyson’s art
New England Aquarium

Overlapping Type 304 shingles

Ground finish simulates fish scales
Sears Tower lobby, Chicago, DeStefano & Partners Architects
Hairline and swirl finishes
Custom stainless steel table

David Curry, designer
ferromobius innovative designs
Mean Bacteria Count After Cleaning
10 Seconds - Abraded Sink Surfaces (x $10^4$ cfu/cm²)
Stainless Steel Kitchen Cabinets & Custom Table Base
Corrosive Indoor Public Transit

• Corrosiveness increased by
  – Exposure to coastal or deicing salt
  – Urine exposure
• Type 316 and smooth finishes for locations with salt or urine exposure
• Fire safety also important

Southwark Station, London
Washington National Airport elevators
Embossed and polished column cover Miami International Airport

Etched Column covers Tokyo International Airport, 2nd terminal
Column Cover Details

1. STEEL COLUMN
   - STUDS AS REQ'D
   - ATTACH STUDS TO COLUMN WITH CLIP ANGLES AS REQ'D
2. PANEL "A"
   - STAINLESS STEEL STUD FASTENED TO PANEL "A" (TYPICAL)
3. STEP 3
   - ANCHOR CLIP FASTENED TO PANEL "B" (TYPICAL)
4. STEP 4
   - FINAL ASSEMBLY
   - USE MULTIPLE RATCHET STRAPS WITH CLOTH PADS UNDERNEATH RATCHET TO UNIFORMLY SEAT THE S/S STUDS INTO THE ANCHOR CLIPS
Petronas Towers
Kuala Lumpur, Malaysia

Cesar Pelli & Assoc.

Stainless: Type 316
Height: 88 stories
1,483 feet (452 m)

Flat panels:
0.098 in., (2.5 mm),
Cambric finish

Tubular panels:
0.118 in. (3.0 mm),
No. 4 polish
One Canada Square, Canary Wharf, London

Cesar Pelli & Assoc.

Type 316
HyClad Cambric finish
Fine No. 4 finish details
Examples of Traditional Wall Panel Joints and Attachment to Concrete Wall
Ray and Maria Stata Center for Computer, Information, and Intelligence Sciences

Massachusetts Institute of Technology, Boston

Type 316 overlapping shingles
Non-directional finish
Gehry Partners
Peter B Lewis Building
Case Western Reserve University, Cleveland
Peter B Lewis Building Details

Overlapping, interlocking shingles in a predetermined design
University of Texas, Natural Science & Engineering Research Building

Type 304, electrochemically colored stainless shingles

Design for 50+ year life to sustainable design standards
Maggie’s Cancer Center
Dundee, Scotland

Gehry Partners
Flat lock seam roof
A small entrance that makes a big design statement
Illinois Institute of Technology, Chicago

Architect: Rem Koolhaas

Corrugated wall panels and perforated patio screens
Nippon Sheet Glass Building

Osaka City, Japan
Type 304 with black electrochemical color
Scratching damage is visible at ground level
Neiman Marcus Store
Electrochemically Colored Stainless Steel
Custom color variation creates wave pattern
41 Union Square

Perforated stainless steel sunscreen panels
Installed over poured concrete building and windows
Screens reduces building energy consumption
Sun Screens

University of Chemistry, Physics, and Electrical Engineering (CPE), Lyon

Installation of perforated sunscreens over an existing glass wall dramatically reduced heat gain.
Kuala Lumpur International Airport
Stainless Steel Plant Support Sun Screens
Residential Photo Studio
Salzburg, Austria
Electrochemically colored stainless
Deliberate color variation
Shaped like camera lens
Stainless Doors Provide Long-Term Durability & Security

Toronto Stock Exchange 1932

Cast disks

Tiffany & Co. Solid vault-like doors
100 Summer Street, Boston
Type 316, No. 4 Finish

Renovation
First floor of a weathering steel building
Design

• All standard metal designs are possible in stainless steel

• There are differences in
  – Thermal expansion
  – Strength
  – Appropriate thickness
  – Weight/square foot
Chrysler Building

Completed 1930

Type 302, 2B finish

Stainless replacement masonry angles and wall ties
Wind Uplift Resistance

- Design
- Material strength
- Strength retention over time
  - Minimal corrosion

Stainless roof, private residence, Florida
Both roofs exposed to 257 km/hr gusts
Impact Resistance

Increased strength = Increased impact resistance

- UL 2218 Class 4 impact resistance
- Resistant to:
  - Hail damage
  - Damage from walking on roofs
  - Perforation by falling tree limbs and wind blown debris
- Best performance - stainless steel or carbon steel

Copper hail damage
Roofing Finishes

- Low reflectivity
- Most common finishes
  - 2D
  - 2B
  - Terne-coated (tin, zinc/tin)
  - Rolled-on abrasive blasted look finishes
- Other finishes
  - Electrochemical color
  - Nickel oxide coated
  - Zinc coated “spangled”
  - Paint (plastic resin) coating
  - Embossed and colored
Bending Characteristics Annealed Stainless Steel

R = bend radius, T = metal thickness

<table>
<thead>
<tr>
<th>Type</th>
<th>Free Bend</th>
<th>V-Block</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austenitics</td>
<td>180°R = 1/2 T</td>
<td>135°R = 1/2 T</td>
</tr>
<tr>
<td>Ferritics</td>
<td>180°R = T</td>
<td>135°R = T</td>
</tr>
</tbody>
</table>

Standing seam roof detail with very tight bends
Standing Seam Roofs

Thickness and pan width comparison (mm) and profiles

<table>
<thead>
<tr>
<th>Pan Width</th>
<th>Stainless Steel</th>
<th>Galvanized Steel</th>
<th>Copper</th>
<th>Aluminum</th>
</tr>
</thead>
<tbody>
<tr>
<td>430</td>
<td>0.38</td>
<td>0.61</td>
<td>0.55</td>
<td>0.81</td>
</tr>
<tr>
<td>580</td>
<td>0.46</td>
<td>0.61</td>
<td>0.69</td>
<td>1.02</td>
</tr>
</tbody>
</table>
Reform Later Day Saints Temple Complex

Hellmuth Obata Kassabaum Architects

Standing seam roof, 4,500 roof panels, Type 304, 2D finish
‘s-Hertogenbosch Apartment Block, Netherlands

1 mm thick, 2B finish, Type 304
Adjoining fresh water artificial water course
Doha International Airport
Under construction – estimated completion 2012

Roof: Duplex AL2003 and 2205
Interior: Type 304
Kowloon Station, Hong Kong

Batten cap design, Type 316, proprietary dull rolled finish resembling abrasive blasting
Stainless Steel Roofing Fasteners

- All metal roof types
  - Stainless steel
  - Aluminum
  - Painted galvanized steel
- Wood shingles, tile, slate

San Francisco Type 316 bay-side sine-wave roof design represents rolling hills, ocean waves, movement.....
Stainless Steel Wire Ties for Tile or Slate
Recommended by FEMA in coastal areas
Should be considered for any corrosive high wind area

Hurricane damage
Gateway Arch

First large stainless steel structural application

Architect: Eero Saarinen

Completed: 1965

192 m (630 ft.) high

Exterior: Type 304, 6.3 mm (0.25 inch) plate, No. 3 polish

Interior: Carbon steel, 9.5 mm (0.375 inch) plate
Stainless Steel’s Advantages

• Corrosion resistance
  – Sustainability/long term performance
  – Avoid coatings and see structural detail
  – Reduce maintenance
  – Long term security
• Seismic performance
• Impact resistance
• High temperature strength & stiffness retention
• High strength stainless steels
  – Reduce section sizes & minimize visibility
Stress-Strain Behavior

Stress, $\sigma$

Strain, $\varepsilon$

Type 2205

Carbon steel

Type 304
Japanese Structural Demonstration Building

Osaka, Japan

Photo taken after major 1995 earthquake - No damage
Pio of Pietrelcina Church, Italy

Type 316 used in seismic design

Stainless mesh ties stones in arches together to allow movement during earthquakes

Roof supports above arches are stainless steel
Fire and Thermal Radiation Resistance

• Aluminum is least resistant
  – Aluminum’s strength decreases above 100°C
  – 6061-T6 tensile strength decreases 60% at 200°C

• Carbon & weathering steel are normally fire proofed
  – Carbon steel limited to 370°C under continuous loading
  – Carbon steel tensile strength drops 30% at 500°C
  – Weathering steel tensile strength drops 50% >540°C

• Stainless steel has better strength and stiffness retention
  – Stainless steel used for heat treating furnaces for other metals
Fire Testing Video
Darchem Engineering
Fire Resistance Testing Summary

Test: Loaded structural cable supports exposed to 1,000 – 1,050 °C (1832-1922°F) flames

Requirement: Retain structural integrity for 5 minutes

<table>
<thead>
<tr>
<th>Metal</th>
<th>Result</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless Steel</td>
<td>Passed</td>
<td>Test extended to 45 minutes when gas ran out. No failure occurred. Deflection was 80.5 mm (3.2 inches) after 45 minutes.</td>
</tr>
<tr>
<td>Galvanized Steel</td>
<td>Passed</td>
<td>Deflection was 166.5 mm (6.6 inches) after 5 minute test, some molten zinc observed</td>
</tr>
<tr>
<td>Aluminum</td>
<td>Failed 26 seconds</td>
<td>Collapsed</td>
</tr>
<tr>
<td>Fiberglass</td>
<td>Failed 30 seconds</td>
<td>Collapsed and started to burn, releasing fumes</td>
</tr>
</tbody>
</table>
Darchem Engineering
2-Hour Radiant Heat Testing

Loaded structural supports exposed to radiant heat from cabinet

Requirement: Retain structural integrity until temperature stabilizes

Summary: Carbon & stainless steel maintained structural integrity. Carbon steel stabilized faster and had 3 times the deflection

<table>
<thead>
<tr>
<th>Metal</th>
<th>Result</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless Steel</td>
<td>Stabilized in 3 hours</td>
<td>Average temperature at end of test = 556 C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Stainless had 1/3 the deflection of carbon steel</td>
</tr>
<tr>
<td>Galvanized Steel</td>
<td>Stabilized in 2 hours</td>
<td>Average temperature at end of test = 552 C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 times the deflection of stainless steel</td>
</tr>
<tr>
<td>Aluminum</td>
<td>Failed 12 minutes</td>
<td>Average ladder temperature at failure = 238 C</td>
</tr>
<tr>
<td>Fiberglass</td>
<td>Failed 6 minutes</td>
<td>Average ladder temperature at failure = 185 C</td>
</tr>
</tbody>
</table>
Stiffness Retention at Elevated Temperature

7 times the stiffness retention of carbon steel at 800 C (1472 F)

Graph showing stiffness retention values at different temperatures for stainless steel and S350 carbon steel.
Toughness vs temperature

[Austenitic 304-type]

[Duplex 2205]

[A36 Steel]
700 KG Ball Impact
Carbon Steel Reinforced Concrete
700 KG Ball Impact
Type 304 Stainless Reinforced
Stainless Steel Reinforced Concrete

- Concrete slab connections in seismic zones
- Impact and blast security
  - Building walls, security barriers
- Buildings with sensitive electronic equipment
  - MRI facilities, government buildings
San Francisco ground anchors

Salt = corrosive soil

After >50 years, unprotected stainless ground anchors had no significant corrosion

Triple protected carbon steel deterioration after 15 years

Stainless initial cost is lower
New Bangkok International Airport

- Type 316 sun screens over skylights
- One the world’s largest low profile stainless steel and glass curtain walls - 37 m high, 441 m long
New Poly Plaza, Beijing
Skidmore Owings & Merrill

Type 316 cable
2205 tension
bars and spiders
Apple Cube, Manhattan

Glass supported by high strength 2205 duplex,
Points of light created with highly polished Type 316
US Air Force Memorial

Pei Cobb Freed

Structural: Arup

Type 316 plate
0.75 in (19 mm)

3-step dull finish

66 - 87 meters
(218 to 284 feet)
South Bank Arbour, Brisbane, Australia
Type 316 plate and wire support plants over a curving walkway
New York City
New 2nd and 7th Avenue Subway Lines
Both lines will extend up the sides of Manhattan Island
Extensive use of Type 316 in 23 stations and tunnels

The new 2nd Avenue subway along the east side of Manhattan
Some section open including Fulton Street station
2020 completion

2nd Ave Entrance design
Hanover Square/Ferry Station
Type 316 structural components and glass
Conclusions – Stainless Steel

- Very sustainable construction material, particularly for
  - Long building service lives
  - Corrosive locations
  - High traffic/low maintenance
- High level of design and finish flexibility
- Contact ISSDA or the Nickel Institute for free literature and technical assistance
- Questions?