Achieving International Stainless Steel Design Success

Speaker: Catherine Houska

Sponsors:

Nickel Institute

Indian Stainless Steel Development Association

Why Should You Consider Stainless Steel?

- Sustainable
  - Longevity, energy savings, no VOCs
- Attractive & provides design flexibility
  - Wide range of finishes on sheet and strip
  - Any metal design is possible
- Structural benefits include
  - Enhances safety & security
  - High strength
  - Reduces section sizes
  - Seismic performance

Defining Sustainability

- Voluntary scoring systems
  - Most widely used
    - LEED, Green Star, BREEAM
  - Development of global versions
  - US Green Building Council (USGBC) LEED
    - 135 countries & 920 mil m^2 construction
- International specifications and guides
  - ISO, ASHREA, ASTM E60, ENs, etc.
  - Defining sustainable manufacturing, business and construction
    - Example: ASTM E60 standard on sustainable dentistry

1 World Trade Center
Type 316 Linen
Gold LEED expected

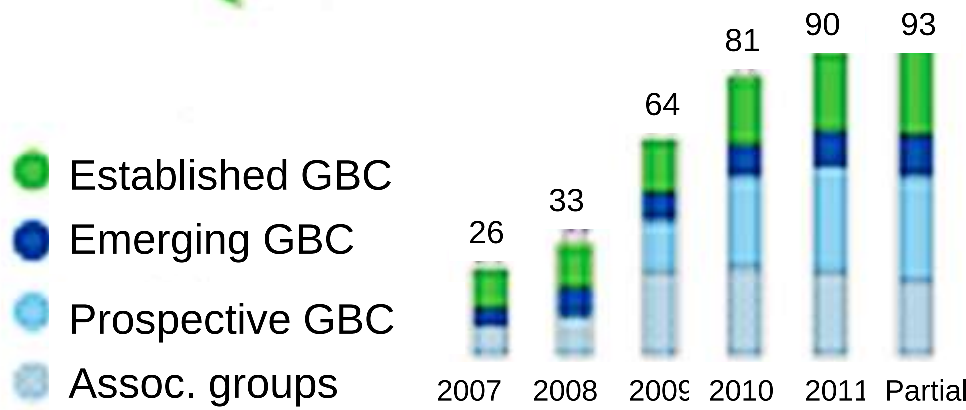
World Green Building Council

Countries & Associated Groups

A rapidly growing international mega trend

WGBC founded by 9 countries in 2002

Now 97 countries and affiliated groups



Environmental & Economic Benefits

- Significant opportunity for decreased energy, water, & material resource use
  - Strategic & environmental advantages
- US statistics for buildings
  - 36% energy use
  - 30% of greenhouse gas emissions
  - 12% of potable water consumption
  - 30% raw material production
  - International averages are higher (>40% greenhouse gases)

Empire State Building, 1931, LEED Gold
Stainless spandrel panels, window frames and spire

Why is Stainless Steel Sustainable?

- Stainless steel's inherent characteristics
  - Long service life
  - Can be restored & reused during renovation
  - Diverted from landfills
    - 92% recaptured at the end of life
    - Indefinitely recyclable
  - High scrap content
    - 60% international average
    - 75 to 90% - European & US
  - No emissions unless you coat it
  - Helps to reduce energy requirements
    - Roofs, exterior walls, weather screens
  - No toxic run off
- Specific products have additional benefits

Before

After

525 William Penn Place, Pittsburgh, Pennsylvania
Completed in 1952, 2002 renovation – Original SS

Average Rates (%)

	Recycled Content	Recapture Rate
Carbon Steel		
Sheet/strip	25-35 **	70
Structural	≤95 **	97
Stainless Steel	60 - 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

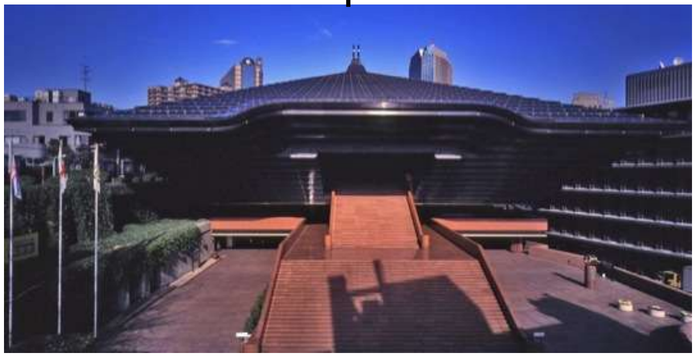
* ABC Industry ** All Applications

Stainless Steel Provides Long Life

Chrysler 1930

Savoy Hotel Canopy 1929

Shakaden Temple 1975



Empire State 1931

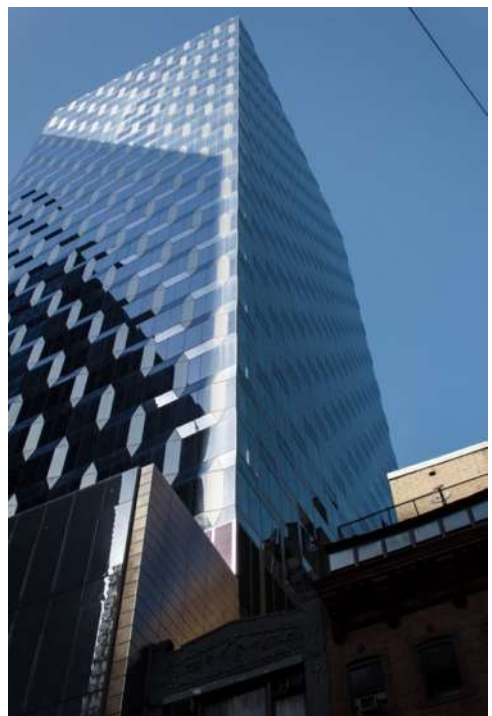
Thyssenhaus 1956

Gateway Arch, 1965

250 West 55th St, 316

West 57th St, 316

7 Bryant Park, 316 facade



Gem Tower, 316

FDR Memorial,

Javits Ctr, 316

Important Trends

- Whole Building Life Cycle Assessment
  - Minimum project life requirements
    - ASTM E60 is using 75 years
    - LEED & BREEAM = 60 years min.
  - Material environmental impact x # replacements
- More corrosive urban environments
  - Population growth/redevelopment
    - High pollution areas & coastal areas
  - Increased & more aggressive deicing salt

US Federal Courthouse
Eugene, Oregon, USA
US Gold LEED, 100 year life

Doha Convention Center
2205 Tower & Convention Center base

Other Metals
Have Shorter Service Life & Require More Maintenance

Peeling painted carbon steel

Peeling painted aluminum roof, 25 years

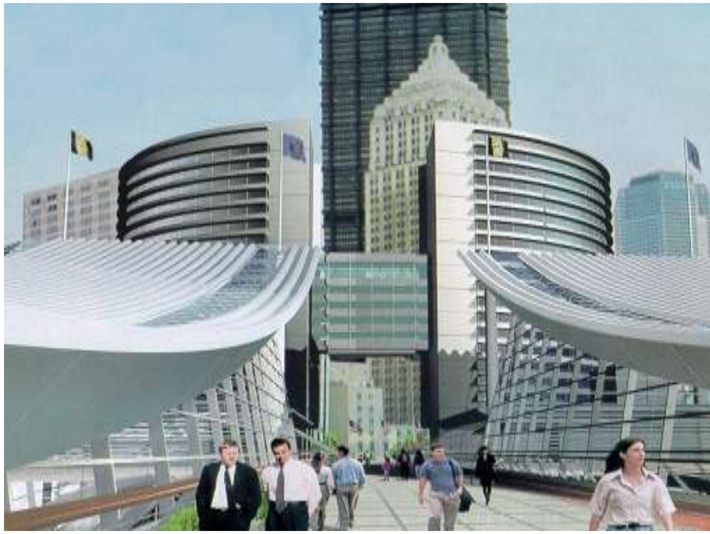
Peeling painted Aluminum Florida, <10 yrs

Product	Temperature Rise, at C (F)	Solar Reflective Index
Stainless Steel, bare	27 (48 F)	39-60
Galvanized steel, new bare	30 (55 F)	46
Aluminum, new bare	27 (48 F)	56
Any metal, white coating	9 (16 F)	107
Clay tile, red	32 (5 8F)	36
Concrete tile, red	39 (71 F)	17
Concrete, white dirty	37 (67 F)	22
Concrete, new white	12 (21 F)	90
Asphalt, generic white	36 (64 F)	26
Asphalt, generic black	46 (82 F)	1
Wood shingle, brown	37 (67 F)	22
Wood shingle, white	6 (10 F)	106

Sources: LBNL Cool Roofing Materials Database
and finish producers

Reducing Energy Use & Heat Islands

- Material and finish choice affects energy performance
- Solar Reflective Index (SRI)
  - Calculated based on ASTM E1980
  - Solar Reflectance & Emittance
    - Varies with material & finish
  - Roof slope (1:6) & exterior walls ≥ 39
  - Low slope roofs ≥ 82
- In 3 years, SRI values can not deteriorate below 32 and 64
  - Unlike other materials, stainless steel SRI values do not decrease over time

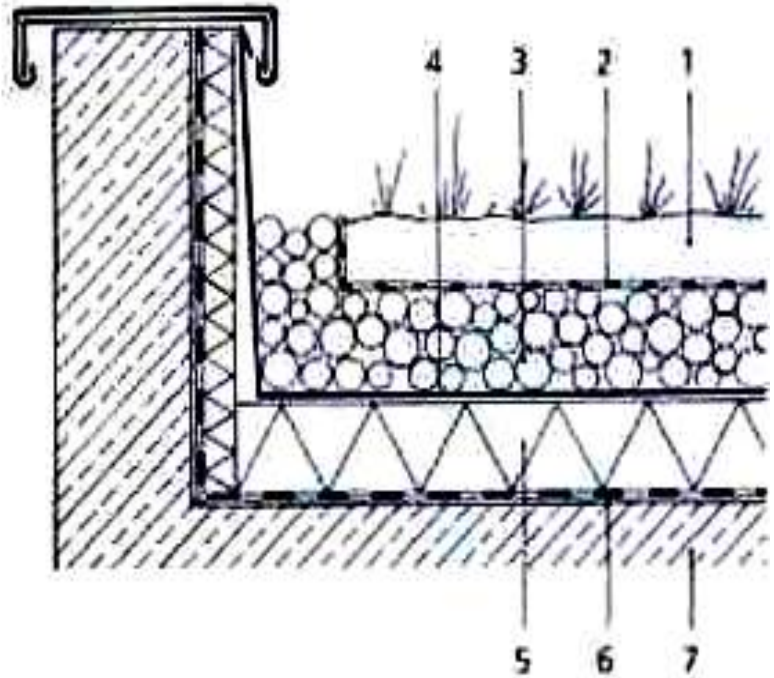


Pittsburgh Convention Center (2003)
Was Gold LEED after construction
Now LEED Platinum Existing Building
2/3% less water, 29%less energy
50+ year life requirement

US Gold LEED Rated
Pacific Lutheran University

Zimmer Gunsul Frasca Architects
100 year design life, Type 304 Roofing and wall panels

Welded Stainless Green Roof Liners



1 Plants in soil
5 Thermal insulation
2 Filter membrane
6 Vapor barrier
3 Drainage layer
7 Roof deck
4 Welded molybdenum-containing stainless steel

Important Trends

- Building energy modeling software
  - US DOE free COMFEN software
    - Large number of buildings analyzed
    - For different design variables calculates energy use/cost, CO_2
  - Exterior sunscreen impact
    - Uses sunscreen solar reflectance & transmittance
    - More relevant than % of open area
    - Sheltered locations are more corrosive application = stainless steel
  - Solar Reflective Index of exterior materials
    - Stainless SRI can not deteriorate over time

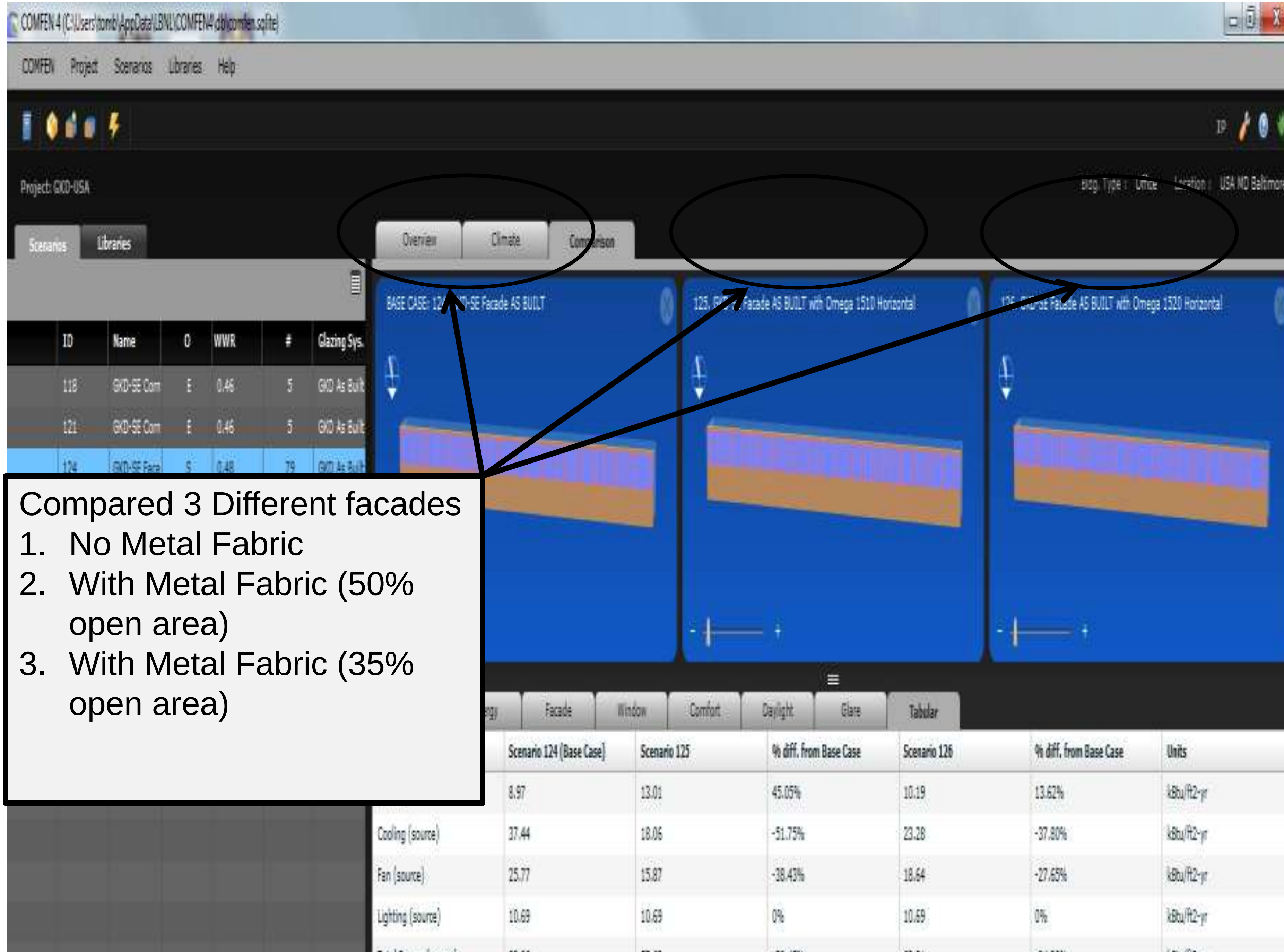
San Francisco Federal Building

Type 316 perforated sunscreens

Surpasses the U.S. government energy performance criteria by 50%

COMFEN Building Example
Eastern Michigan University, USA

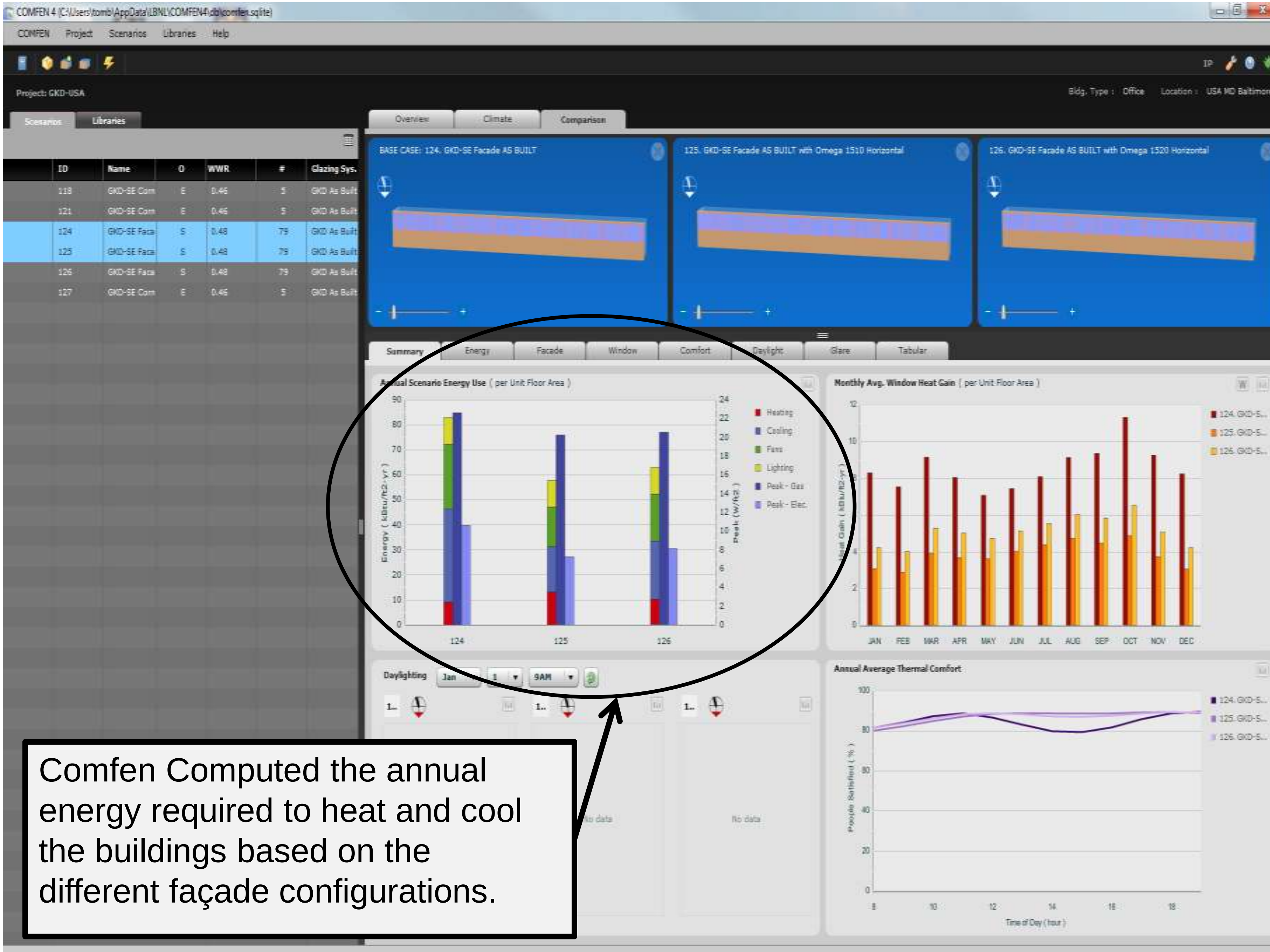
- Woven mesh sunscreens, 35% open area
- US Department of Energy free COMFEN software predicted energy reduction
- Northern climate, air temperature 24 C
  - Building exterior temperature
    - 34.4 C no shading
    - 27.8 C with shading



	Scenario 124 (Base Case)	Scenario 125	% diff. from Base Case	Scenario 126	% diff. from Base Case	Units
	8.97	13.01	45.05%	10.19	13.62%	kBtu/ft2-yr
Cooling (source)	37.44	18.06	-51.75%	23.28	-37.80%	kBtu/ft2-yr
Fan (source)	25.77	15.87	-38.43%	18.64	-27.65%	kBtu/ft2-yr
Lighting (source)	10.69	10.69	0%	10.69	0%	kBtu/ft2-yr
Total Energy (source)	82.86	57.63	-30.45%	62.81	-24.20%	kBtu/ft2-yr

Compared 3 Different facades

1. No Metal Fabric
2. With Metal Fabric (50% open area)
3. With Metal Fabric (35% open area)



Comfen Computed the annual energy required to heat and cool the buildings based on the different façade configurations.

Summary | Energy | Facade | Window | Comfort | Daylight | Glare | **Tabular**

Annual Values	Scenario 124 (Base Case)	Scenario 125	% diff. from Base Case	Scenario 126	% diff. from Base Case	Units
Heating	8.97	13.01	45.05%	10.19	13.62%	kBtu/ft2-yr
Cooling (source)	37.44	18.06	-51.75%	23.28	-37.80%	kBtu/ft2-yr
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Total Energy (source)	82.86	57.63	-30.45%	62.81	-24.20%	kBtu/ft2-yr
Peak Demand Electricity	10.60	7.25	-31.[illegible]2%	8.10	-23.52%	W/ft2
Peak Demand Electricity Date	AUG 17 02:30 PM	AUG 14 01:00 PM	--	AUG 14 01:00 PM	--	
Peak De	[illegible]	[illegible]	-10.57%	20.52	-9.27%	W/ft2
Peak De	[illegible]	[illegible]	--	MAR 1 06:15 AM	--	
Avg. Day	[illegible]	[illegible]	-76.83%	85.85	-69.40%	fc
Avg. Disc	[illegible]	[illegible]	1.12%	10.57	8.45%	Index
Avg. The	[illegible]	[illegible]	0.09%	83.52	1.44%	PPS
CO2 emi	[illegible]	[illegible]	-36.65%	22.34	-27.31%	lb/ft2

% diff. from Base Case compares the total energy savings 35% open area (30.45%) or 50% open area (24.20%) GKD Metal fabric would save versus using no fabric at all.

Recent Stainless Sunscreen Examples

Guangzhou China
2nd Children's Activity Center
Woven mesh

Cooper Union, NYC
Perforated screens, LEED Platinum
40% energy savings

Metal Roof Run-Off Averages (mg/m^2)

	Copper	Lead	Zinc
Rusty galvanized	20	302	12,200
Asphalt	11	10	1,980
Galvanized iron	ND	100	3,600
Concrete tile	ND	90	1,600

	Nickel	Chromium
Type 304 Stainless*	0.3 - 0.4	0.25 - 0.3

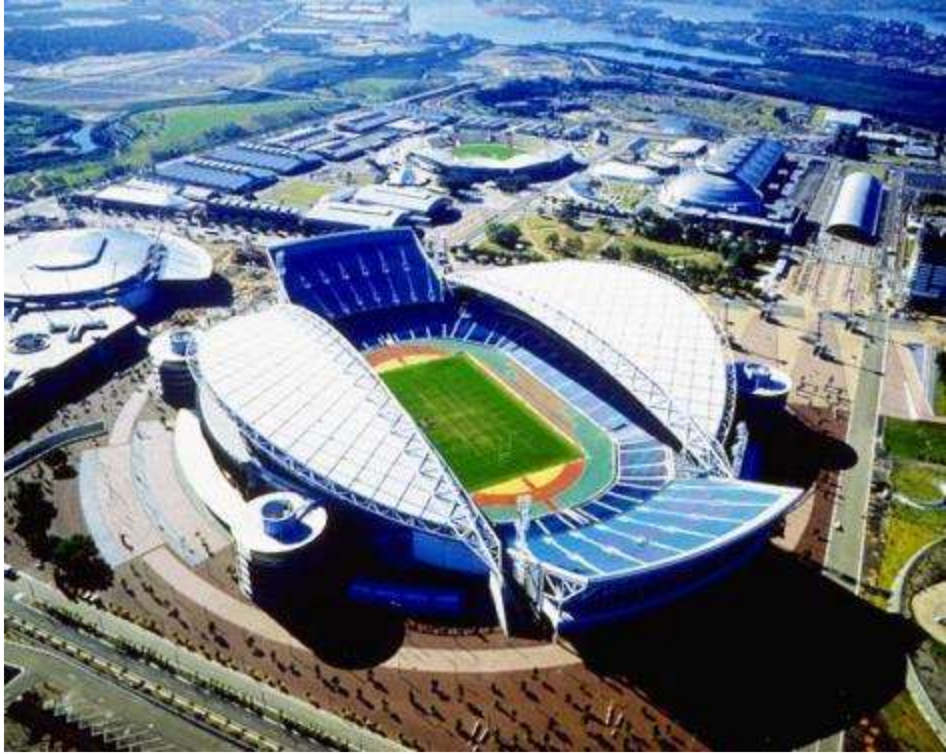
*In many samples, nickel and chromium levels were below detectable limits. The average concentration per liter was well below typical drinking water levels.

Stadium Australia

Type 316 , 2B finish

Drainage system collects water in underground tanks for watering grass and flushing toilets

Stainless is also used for in-building water treatment plants



Scottish Parliament

- Architects AMBT and RMJM, Engineer Arup
- Completed 2004
- Structural supports for wood slats and roofing

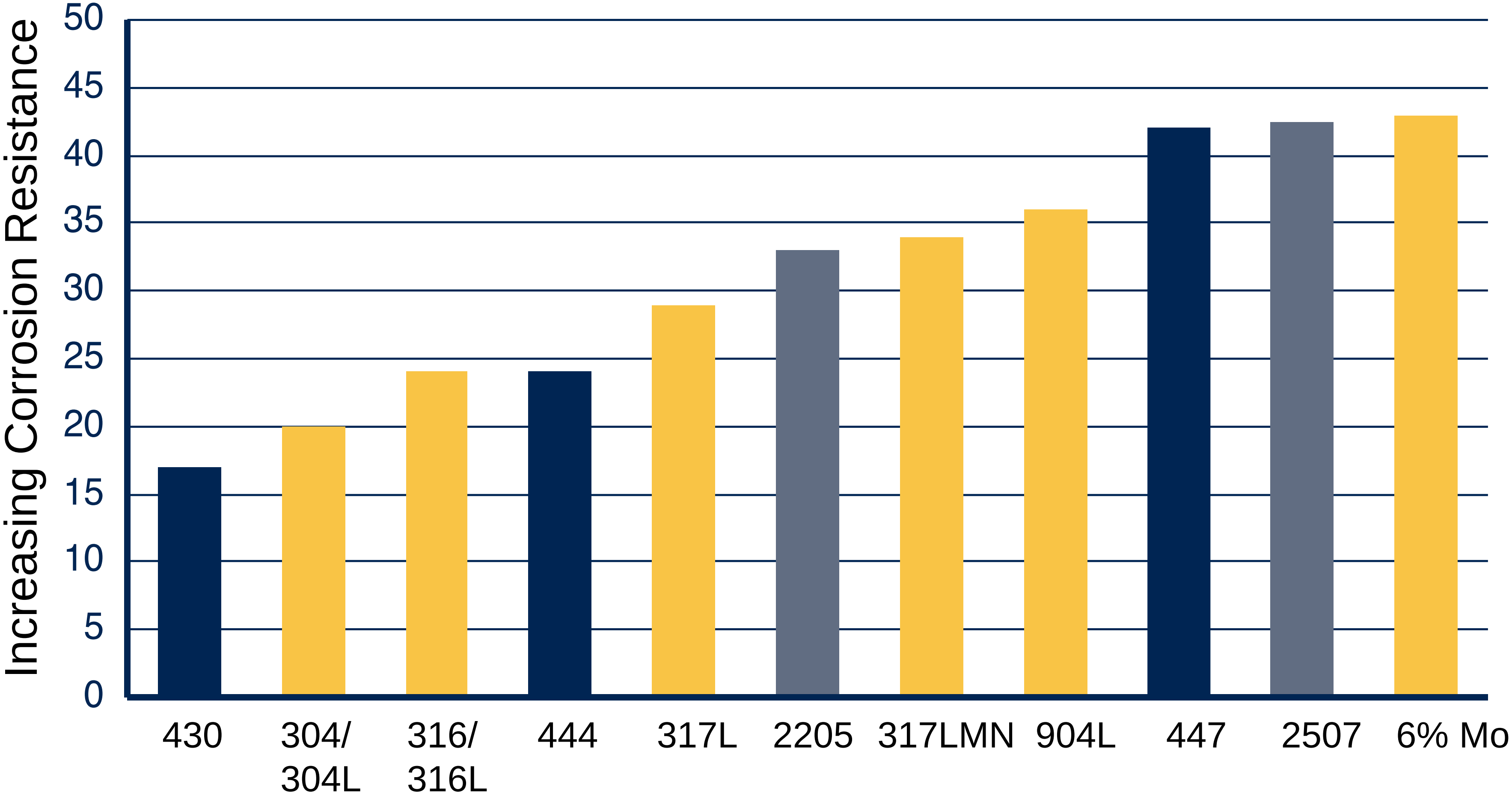
Scottish Parliament

- Many common building materials release emissions
  - Reducing these creates a healthier environment
  - Bare uncoated metal has no emissions
- Stainless, wood and concrete
  - Interior stainless structural supports, wall and ceiling panels

What Factors Influence Corrosion?

- Pollution
  - Acid rain
  - Sulfur Dioxide & particulate
- Coastal and deicing salt exposure
- Weather conditions
- Maintenance
- Design/specification
  - Crevices
  - Finish
- Finish topography, roughness & application method
- Handling & post fabrication cleaning

Stainless Steel
Relative Pitting Corrosion Resistance



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

Kure Beach

250 m (800 ft) from the ocean never washed

57 years exposure

48 years exposure

Type 304

Type 316

Carbon steel
60 Zn, 20 Al, 20 Mg coating

Photos courtesy of TMR Consulting

Two Piers, Progreso, Mexico

- Functioning pier
  - Built over 70 years ago
    (1937-1941)
  - Stainless rebar
- Non-functioning pier
  - Appearance after 30 years
  - Carbon steel rebar
- Significant costs
  - Indirect cost of not being able to use it
  - Replacement

Photo courtesy of the Nickel Institute

Select Type 304

- Rural/suburban
- Low to moderate pollution

Select Type 316

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

Select More Corrosion Resistant Stainless Steels

- Industrial pollution
  - Developing countries
  - High sulfur dioxides levels
  - High particulate levels
- Coastal or deicing salt
  - Splashed by or immersed in salt water
  - Corrosive, sheltered, unwashed applications
  - Significant deicing salt deposits

Photo courtesy of the Nickel Institute

Type 316 railings
Hong Kong Convention Center - seawater spray exposure, rough finish

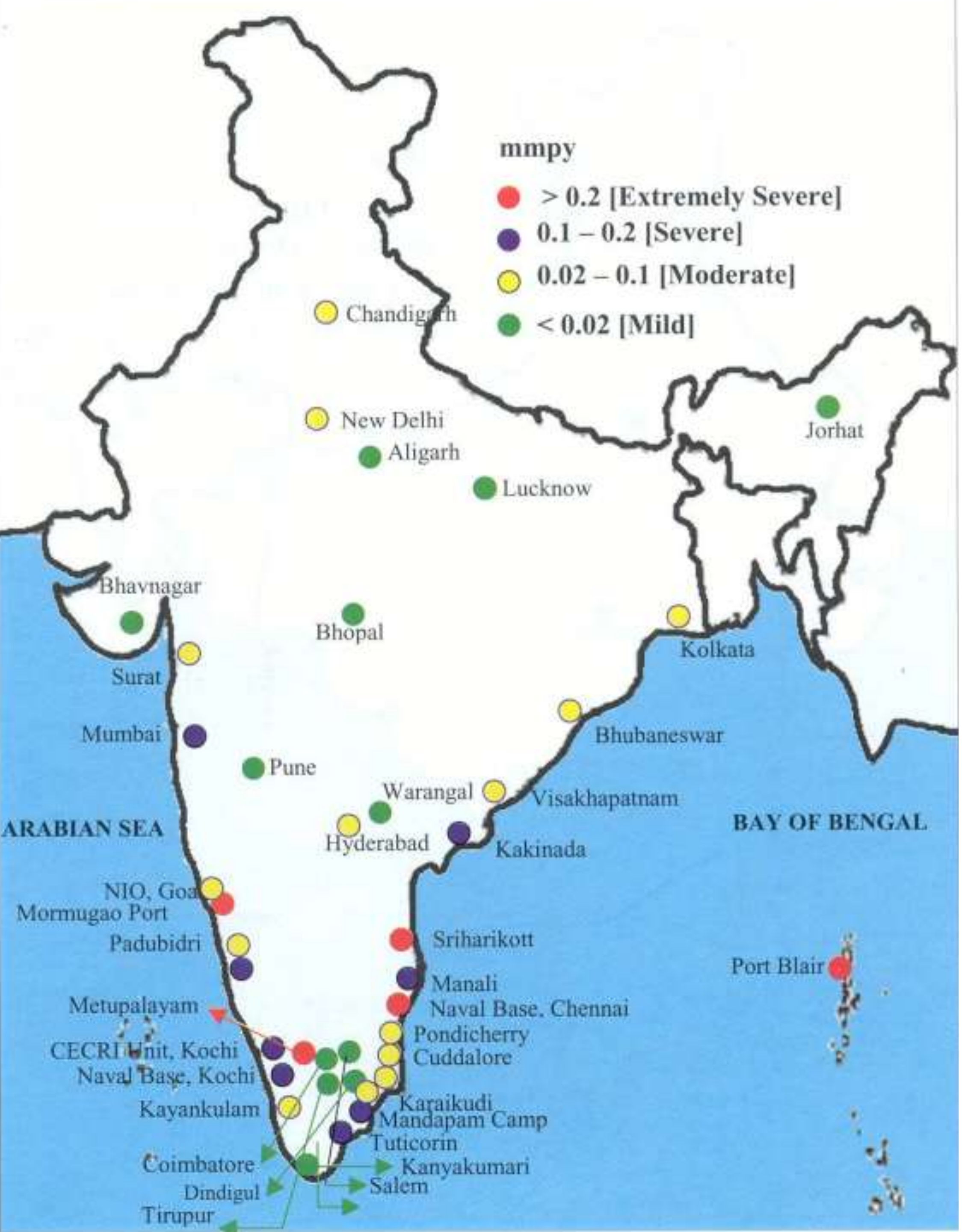
Other More Corrosive Locations

Stockholm Congress Ctr 2205 Sunscreen

Type 316 Bollard
Dusseldorf
Rough bottom finish
Deicing salt

2205 Railings, Canary Island 30 years

New Corrosion Corrosion Map for India



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

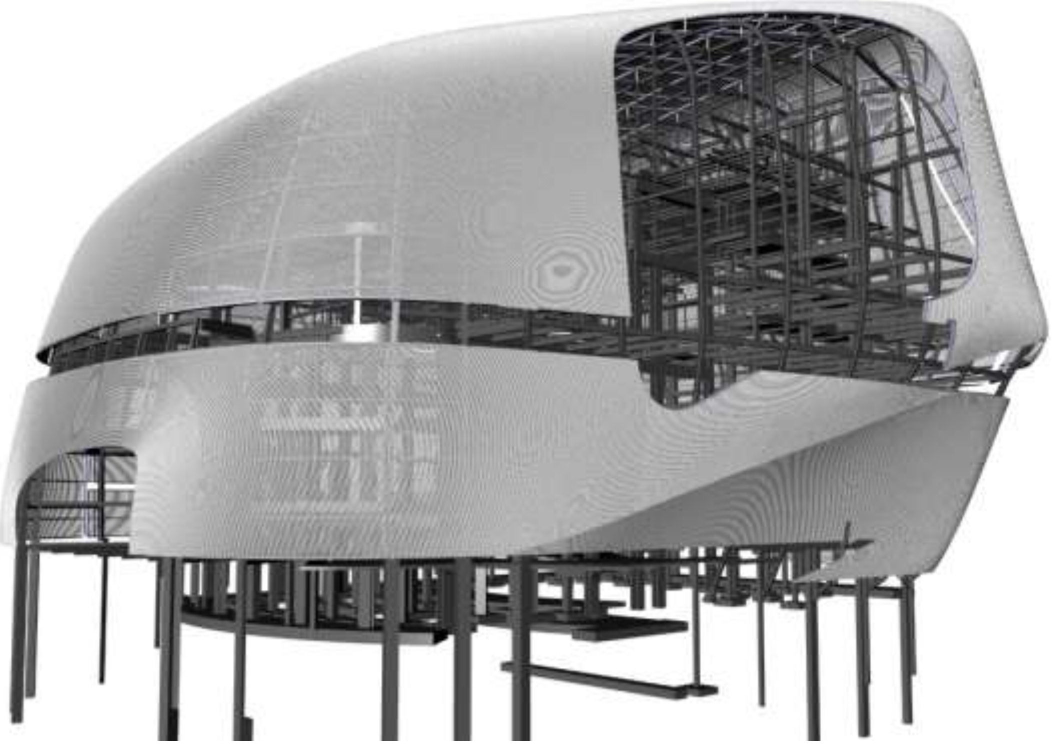
Metal	Corrosion Rate Dubai Coastal Inch/year	SMACNA Thickness Inch	Time To Perforation, Yrs
2205 Duplex*	0	0.015	50+
Galvanized steel**	0.02	0.024	2.2
Aluminum	0.002	0.032	16
Zinc***	0.035	0.028	Less than 1
Copper	0.004	0.022	5.5

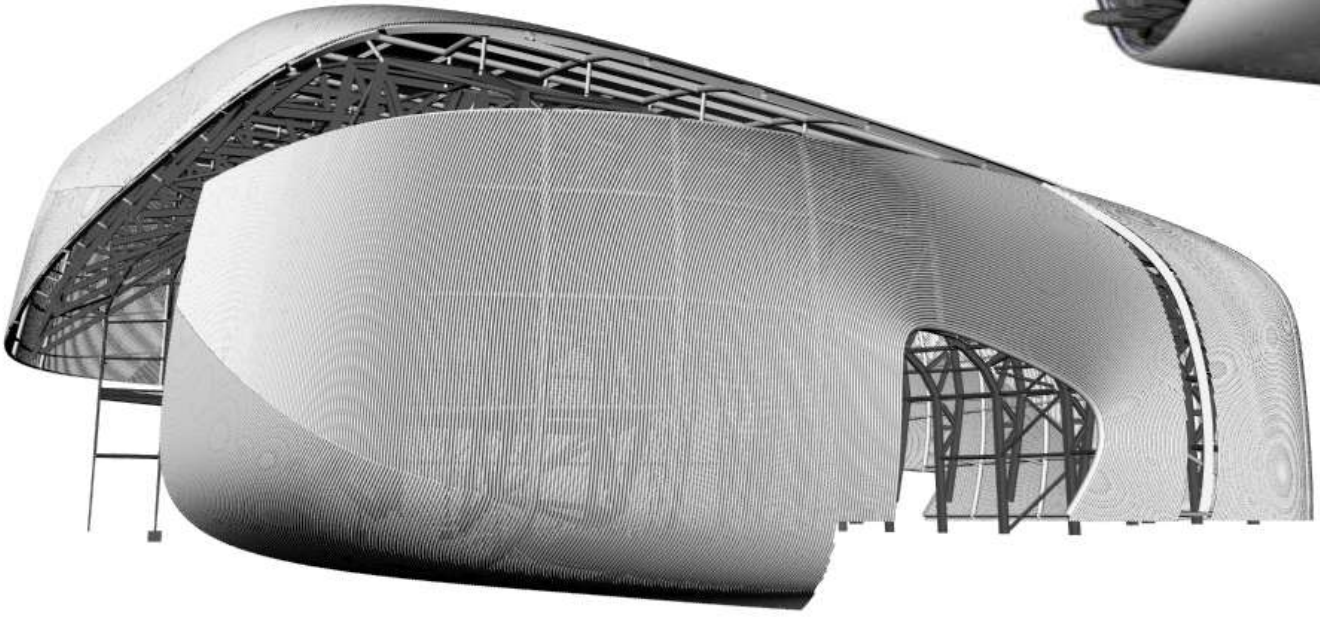
* Type 304/316 guidance was used. Lighter gage maybe possible.

** 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

Near Dubai Site
King Abdulaziz Center for World Culture






JOHNSON

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
- High strength allowed lighter tube wall

When Combining Metals Always Consider Galvanic Corrosion

- 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

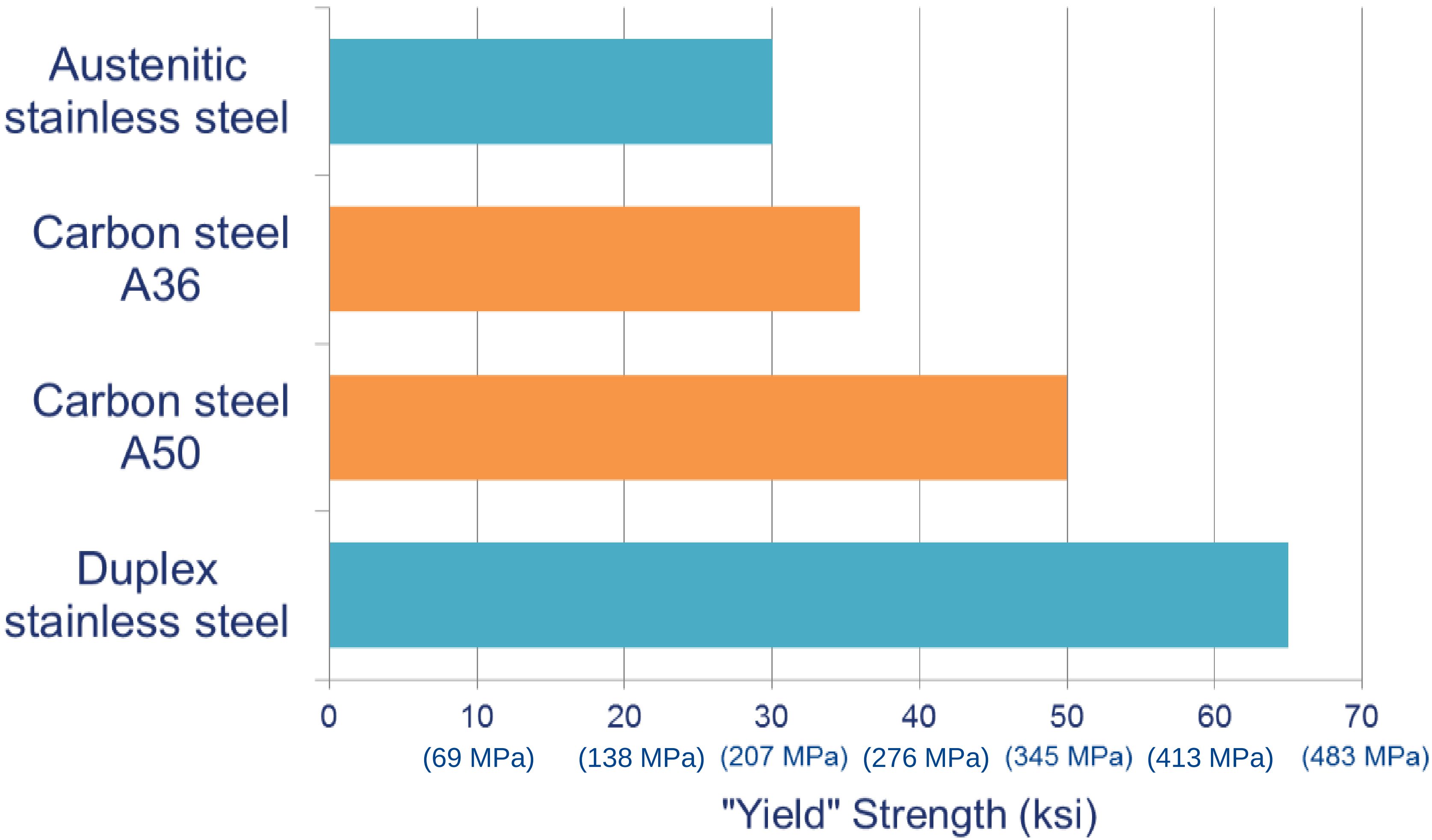
Surface area ratio is important!

Stainless steel plate/galvanized steel

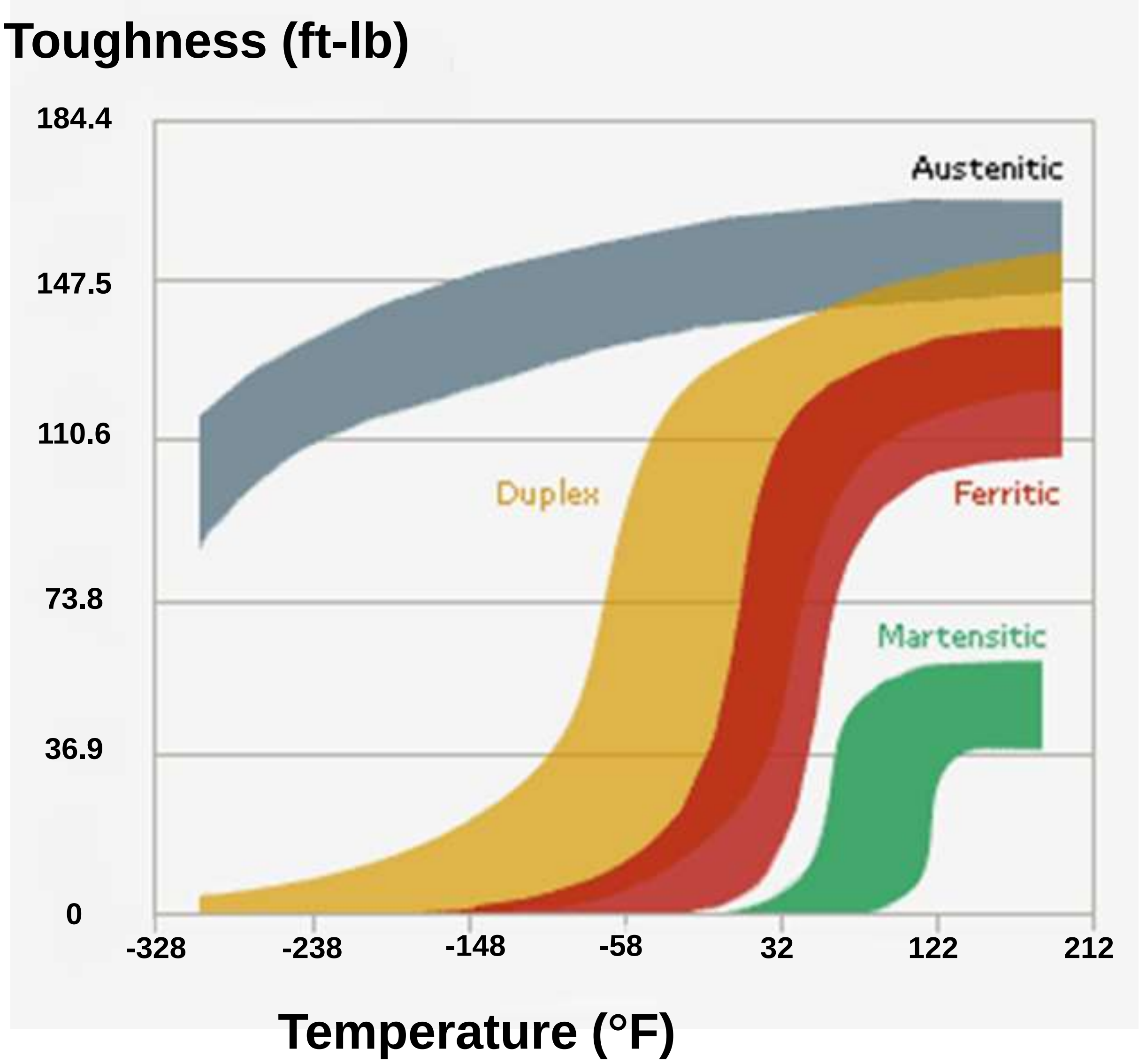
Galvanic corrosion failure

St. Mary’s Cathedral Tokyo

Minimum Design Strength



Impact Toughness at low & Ambient Temperatures

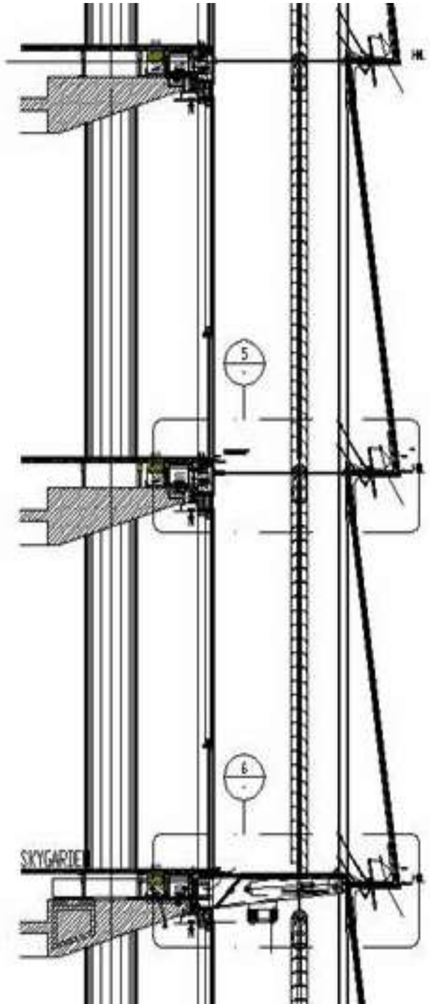


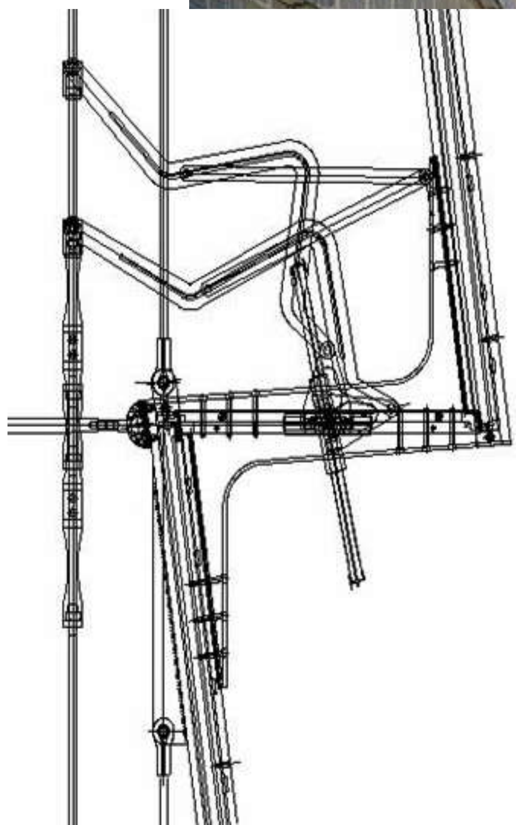
Better intrinsic energy absorption properties than Al or carbon steel due to high rate of work hardening & excellent ductility

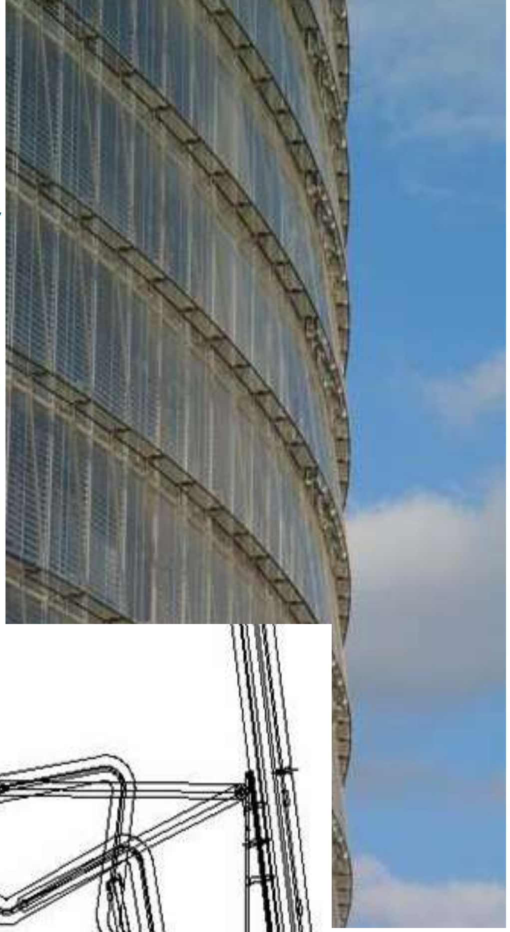
7 World Trade Center, New York

Security: 316 bollards & 2205 structural sections below the canopy

Post Tower
Bonn, Germany
Murphy/Jahn







Apple Cube, Manhattan

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

New Poly Plaza Building, Beijing, SOM

One of the world's largest cable net walls

Supported by 2205 rocker joints and tension rods, Type 316 cable and connectors

Millennium Park Concert Hall and Bridge

Gehry Partners

Type 316 vibration finish selected due to deicing salt exposure

Low Sulfur

- For standard finishes specify "low sulfur"
  - 0.005% or less
  - Improved corrosion performance
  - Finish appearance
- For mirror finishes
  - Specify 0.002% or less
- Low sulfur tube and pipe may not be available
  - Sulfur makes high speed welding easier

Al Hamra Firdous Tower, Kuwait

- Skidmore Owings & Merrill, New York
- When completed in 2010, it will be
  - Kuwait's tallest building at 412 m (1351 ft, 74 floors)
  - Clad in Type 316

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. (now Pelli Clark Pelli)
Type 316 Cambric and No. 4 polished finishes

Jin Mao Tower, Shanghai, China

- Skidmore Owings & Merrill
- Type 316 stainless steel
- Cambric finish
- World's fifth tallest building

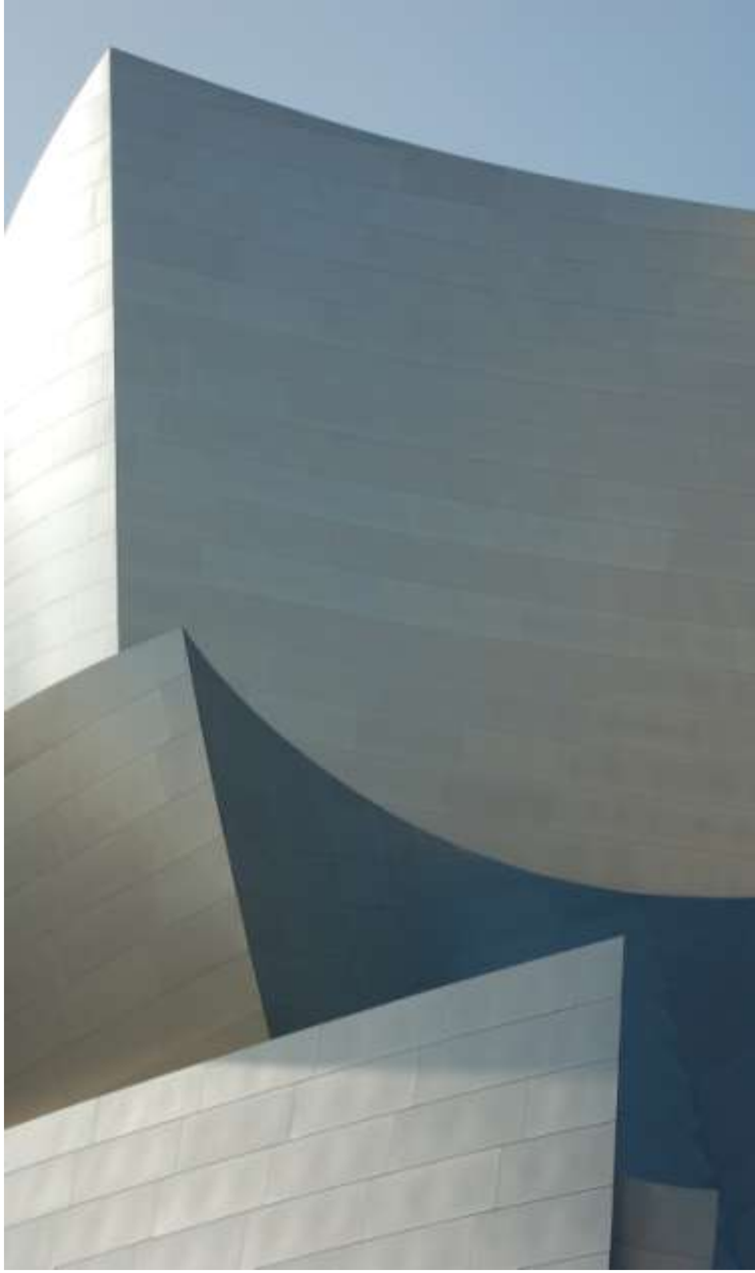
Al Hamra Firdous Tower, Kuwait

- Skidmore Owings & Merrill, New York
- When completed in 2010, it will be
  - Kuwait's tallest building at 412 m (1351 ft, 74 floors)
  - Clad in Type 316

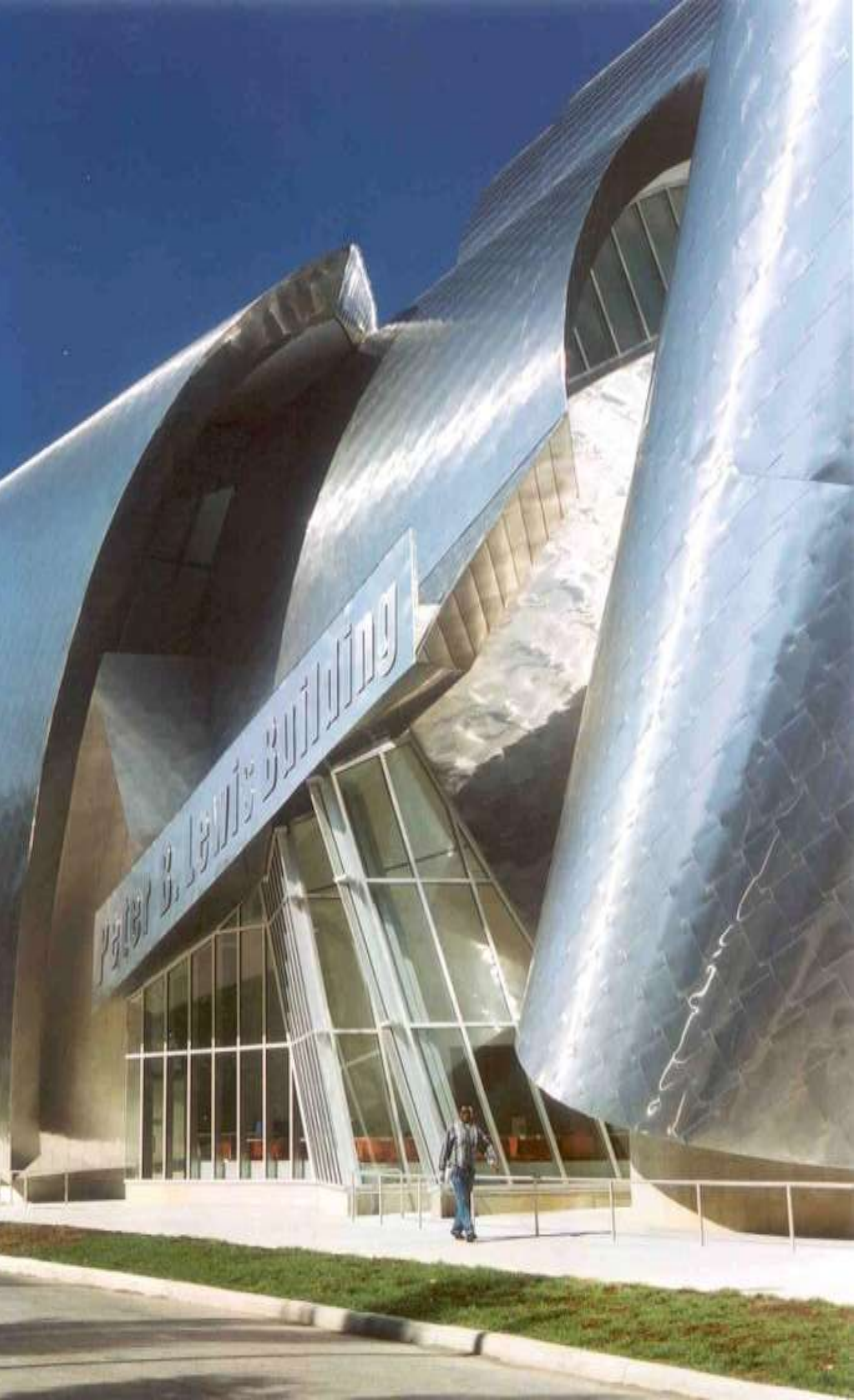
Walt Disney Concert Hall, Los Angeles

Gehry Partners

Type 316, vibration and mirror polished finishes



Flat lock seam stainless steel panels
Disney Concert Hall, Los Angeles



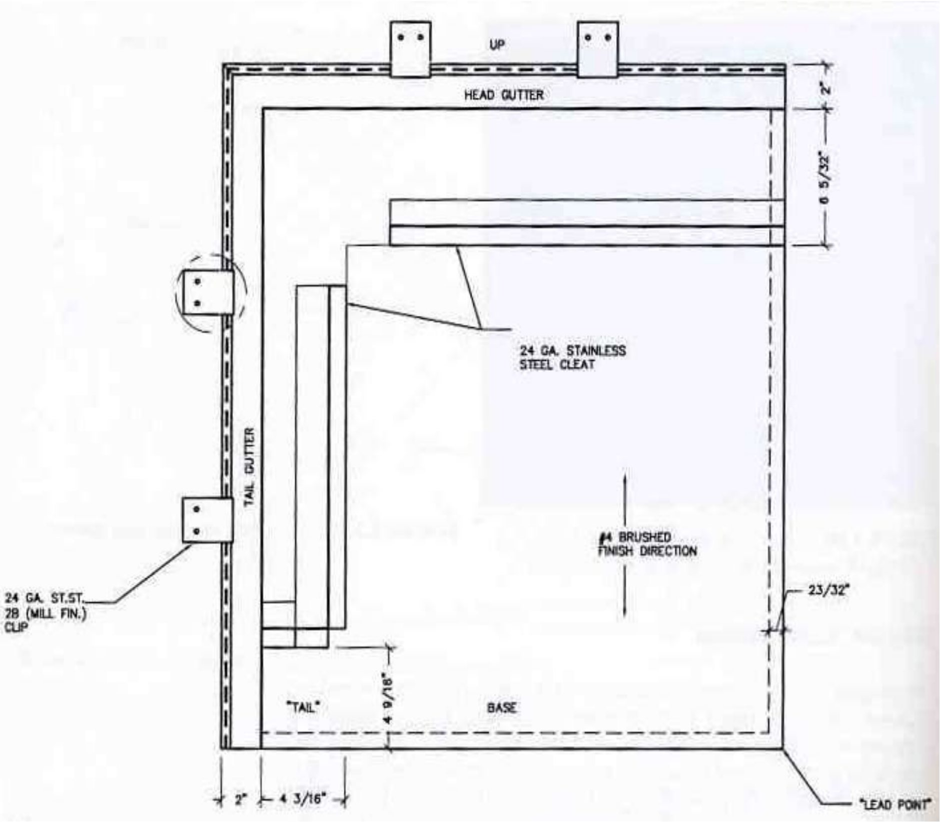
Peter B Lewis Building

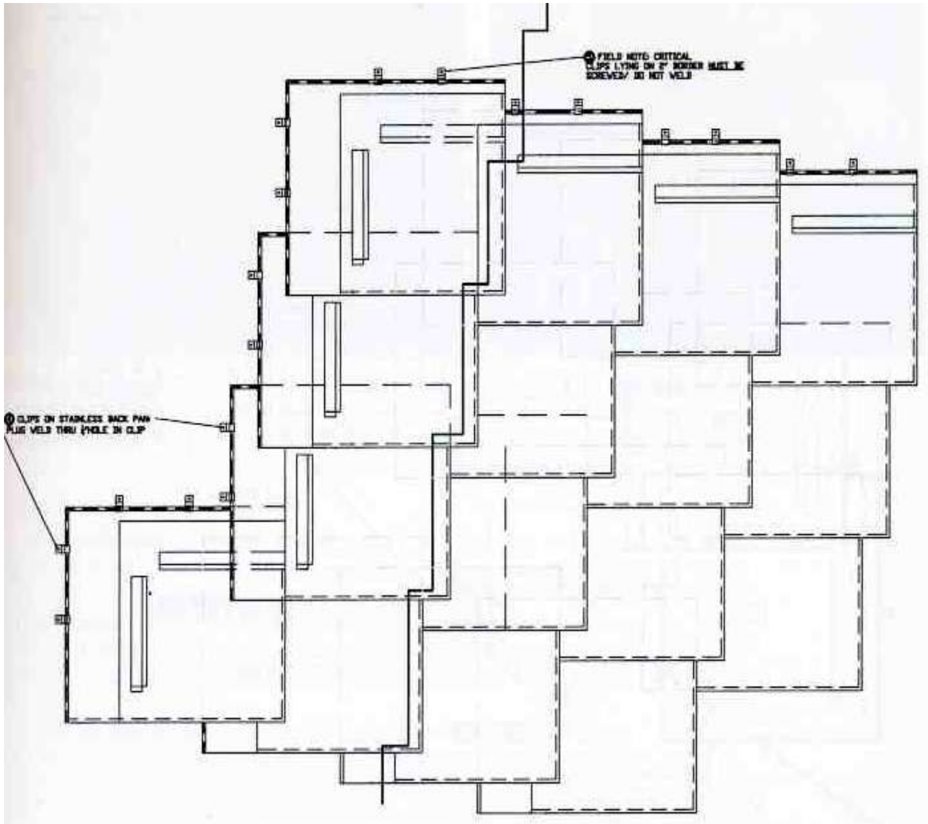
Case Western Reserve University, Cleveland, Type 316

Gehry Partners

Peter B Lewis Building Details

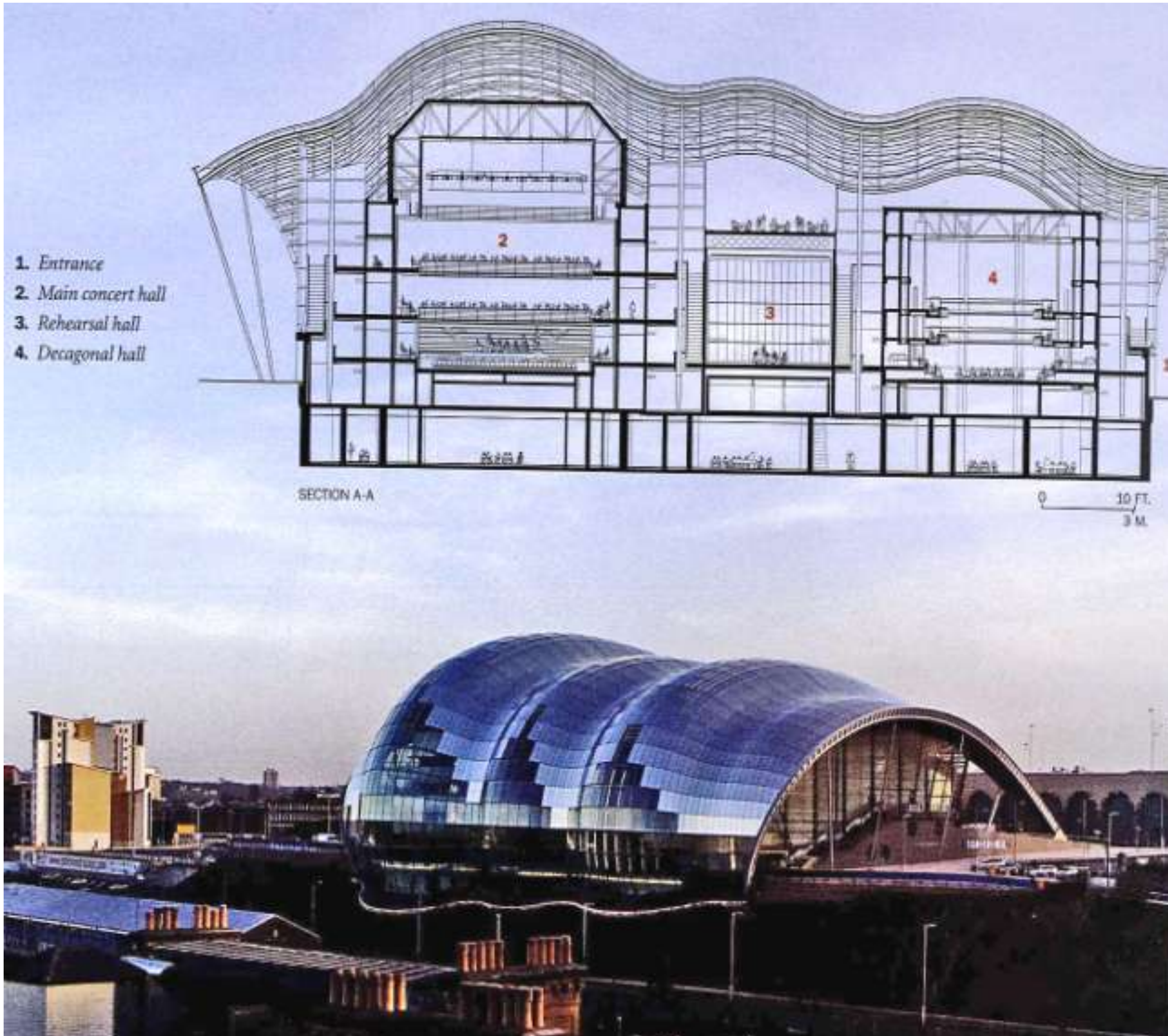
Overlapping, interlocking shingles in a predetermined design





Sage Gateshead, Performance Center

- Tyne and Wear, England
- Foster and Partners
- 2005
- Stainless steel roof



Victorian College of Arts Center
Melbourne, Australia

Minifie Nixon Architects

Horst-Korber Sportzentrum

Electrochemically colored coined stainless steel

University of Texas

Natural Science & Engineering Research Building

Zimmer Gunsul Frasca Architects

Type 304, electrochemically colored stainless shingles

Design for 50+ year life to sustainable design standards

Contemporary Jewish Museum

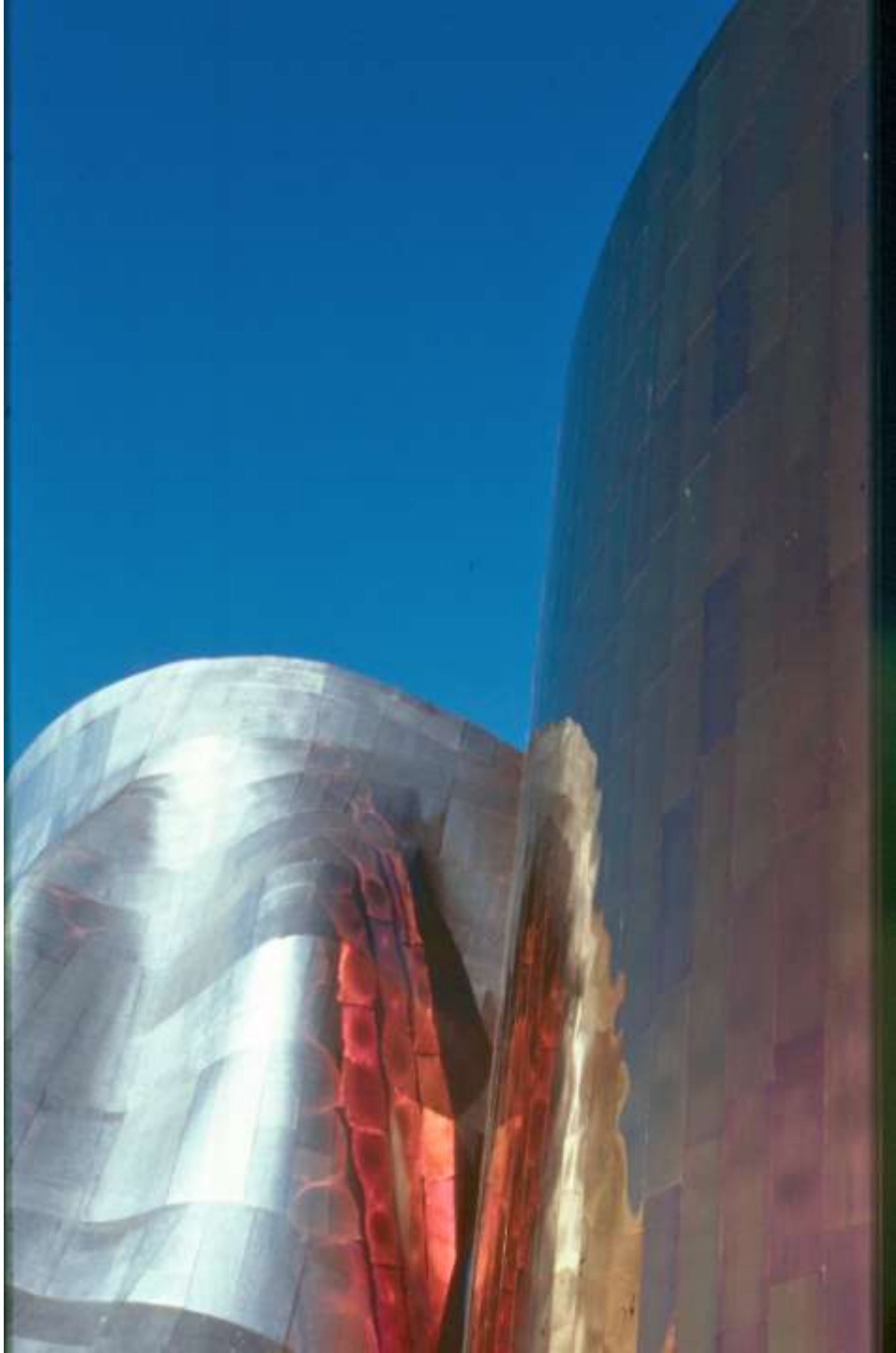
- San Francisco California USA, 2008
- Blue electrochemically colored stainless steel
- Studio Daniel Libeskind

Singapore Residence

Electrochemically colore
stainless steel

EMP, Seattle
Gehry Partners

Electrochemically colored and vibration finishes



Experience Music Project
Seattle, Gehry Partners


Conclusions

- Stainless steel is a sustainable material
- There are endless design possibilities
- It contributes to safety and security
- Evaluate each site carefully & use IMOA and Nickel Institute literature and software to help select an appropriate stainless steel and finish
- If technical questions arise, contact the ISSDA
- In more corrosive environments, have a metallurgical engineer with architecture experience evaluate the site and applications