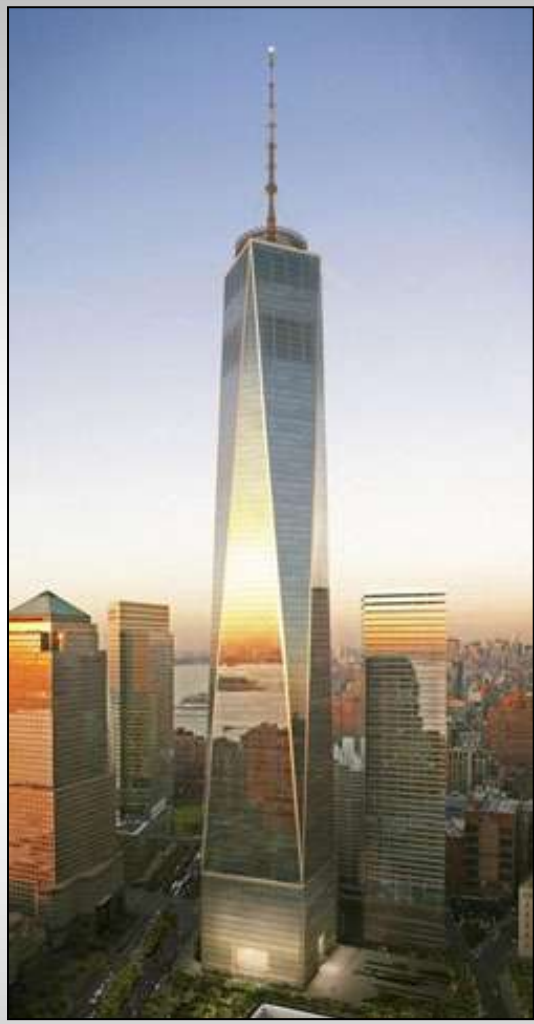
Stainless Steel Architectural Design

Sponsors:
Nickel Institute
Indian Stainless Steel Development Association

Speaker: Catherine Houska

Why Should You Consider Stainless Steel?

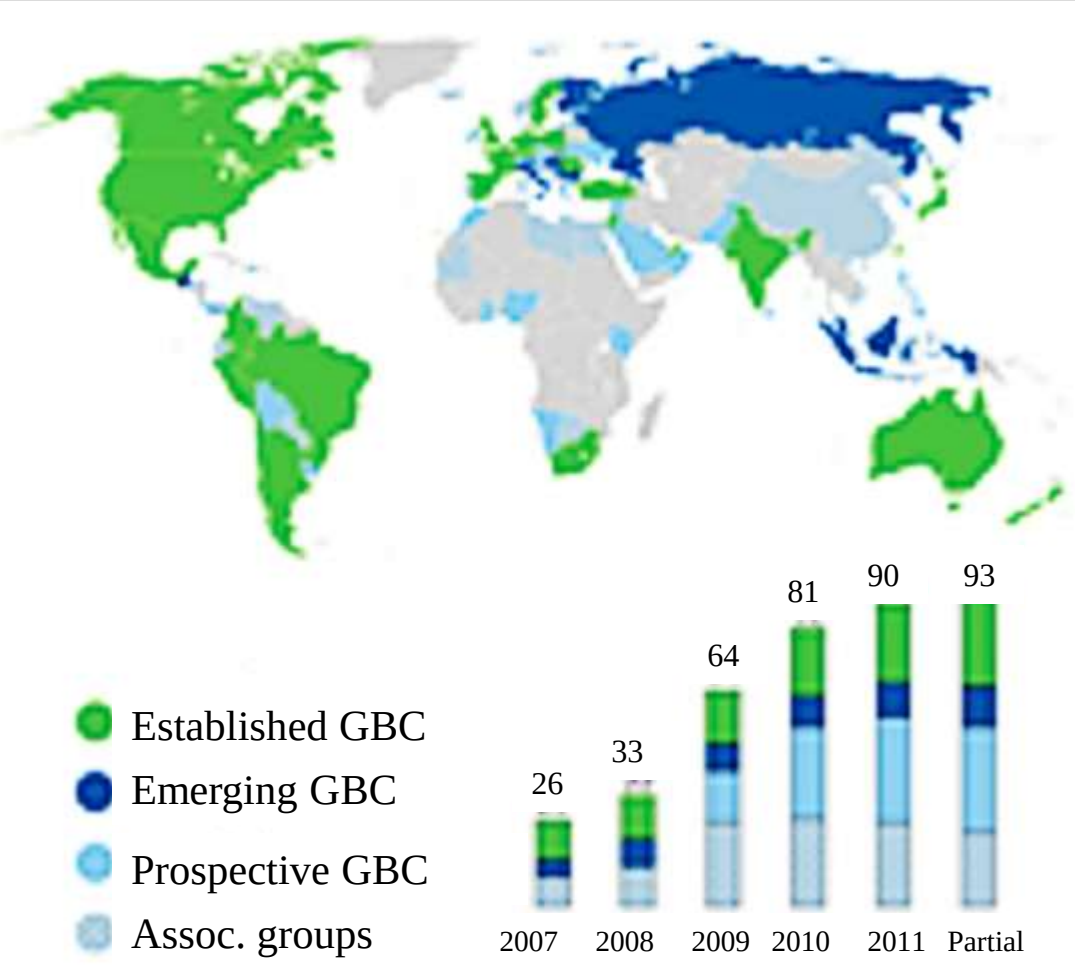
- Sustainable
  - Longevity, energy savings, no VOCs
- Attractive & provides design flexibility
  - Wide range of finishes on sheet and strip
  - Any metal design is possible
- Structural benefits include
  - Enhances safety & security
  - High strength
  - Reduces section sizes
  - Seismic performance



1 World Trade Center
Type 316 Linen & spire
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

Defining Sustainability

- Voluntary scoring systems
  - Most widely used
    - LEED, Green Star, BREEAM
    - Development of global versions
  - India GBC LEED and Green SEZ
- International specifications and guides
  - ISO, ASHREA, ASTM E60, ENs, etc.
  - Defining sustainable manufacturing, business and construction
    - Example: ASTM E60 standard on sustainable dentistry

Environmental & Economic Benefits

- Energy & water reduction provide both economic and environmental benefits
- 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
    - Indefinitely recyclable into the same high quality product
  - High scrap content
  - No emissions unless you coat it
  - Helps to reduce energy requirements
  - 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	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

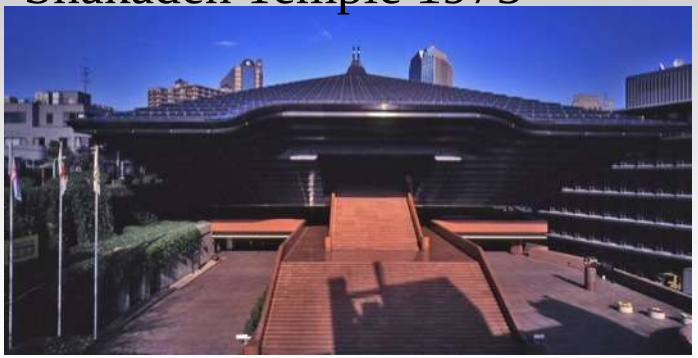
* ABC Industry ** All Applications

Stainless Steel Provides Long Life

Chrysler 1930

Savoy Hotel Canopy 1929

Shakaden Temple 1975



Empire State 1931

Thyssenhaus 1956

Gateway Arch, 1965

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
- 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

Reducing Energy Use & Heat Islands

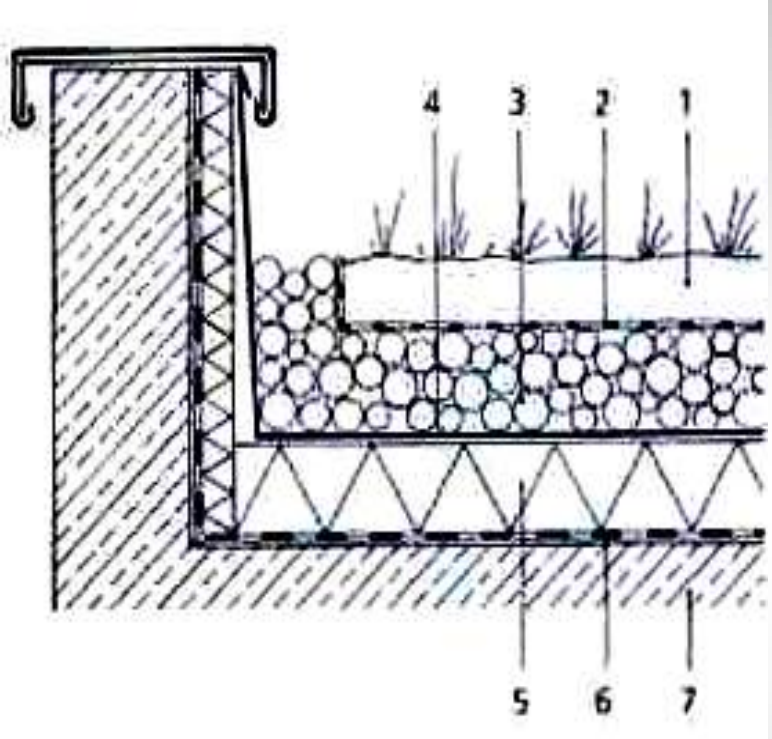
- Material and finish choice affects energy performance
- Solar Reflective Index (SRI)
  - Calculated based on ASTM E1980
  - Solar Reflectance & Emittance
    - Varies with material & finish
  - Roof slope (1:6) & exterior walls ≥ 39
  - Low slope roofs ≥ 82
- In 3 years, SRI values can not deteriorate 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

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

Welded Stainless Green Roof Liners



1 Plants in soil

2 Filter membrane

3 Drainage layer

4 Welded molybdenum-containing stainless steel

5 Thermal insulation

6 Vapor barrier

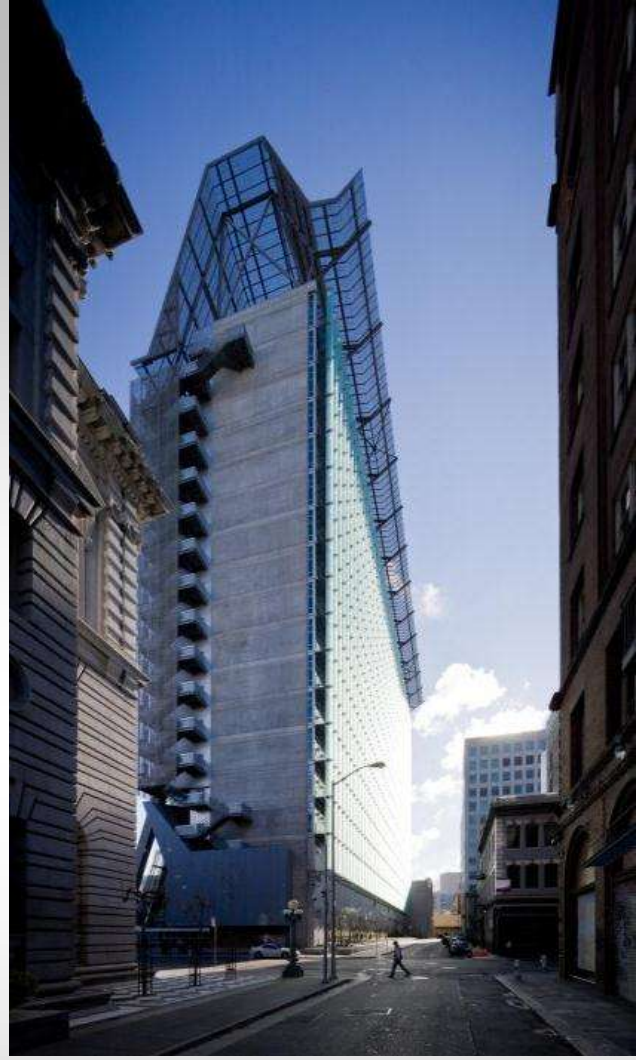
7 Roof deck

Paul Klee Center, Berne

- Renzo Piano Building Workshop
- Undulating shape mimics the hills
- Type 316 roof trays are used to create vegetated roof

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



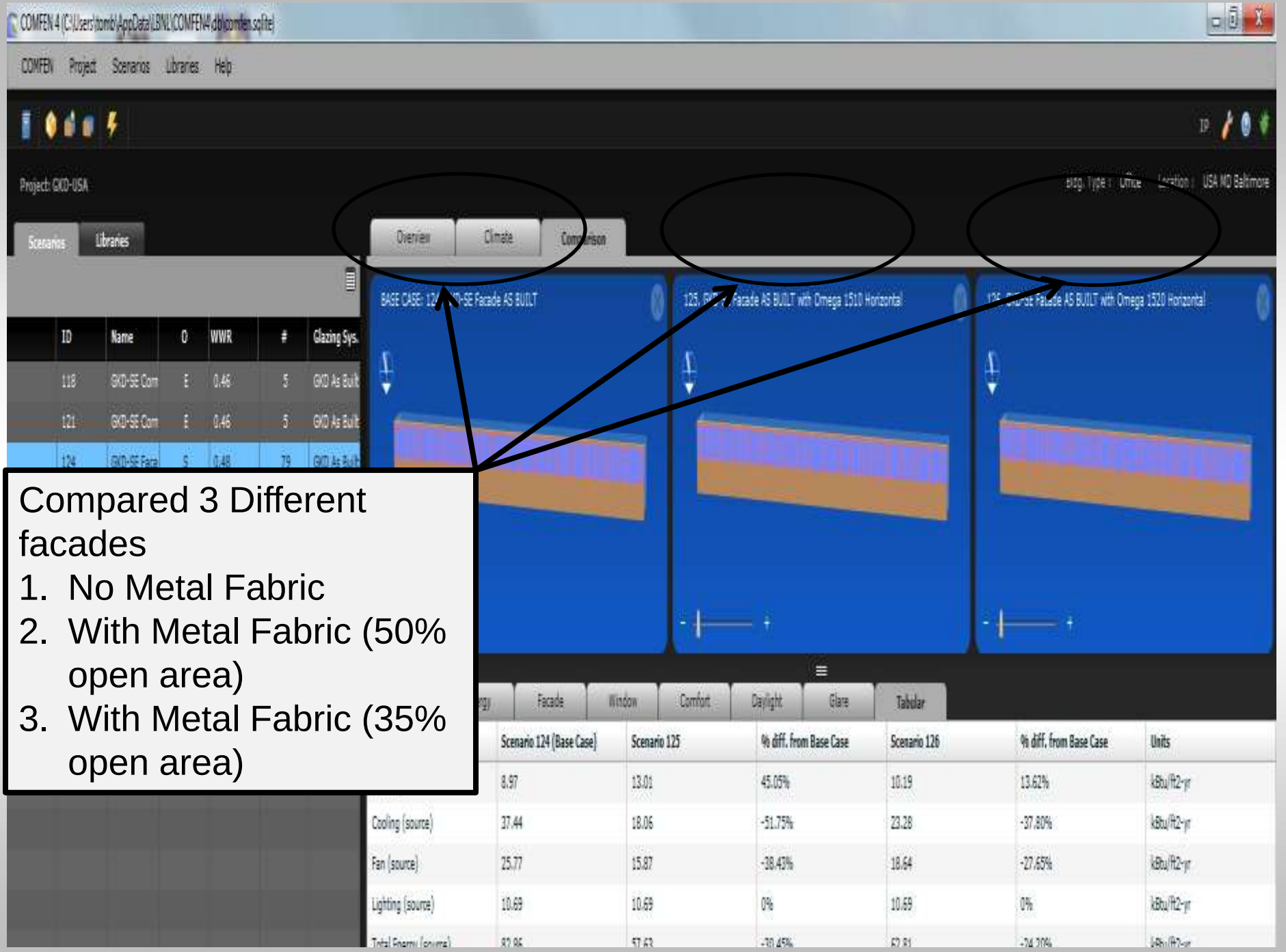
San Francisco Federal Building

Type 316 perforated sunscreens

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

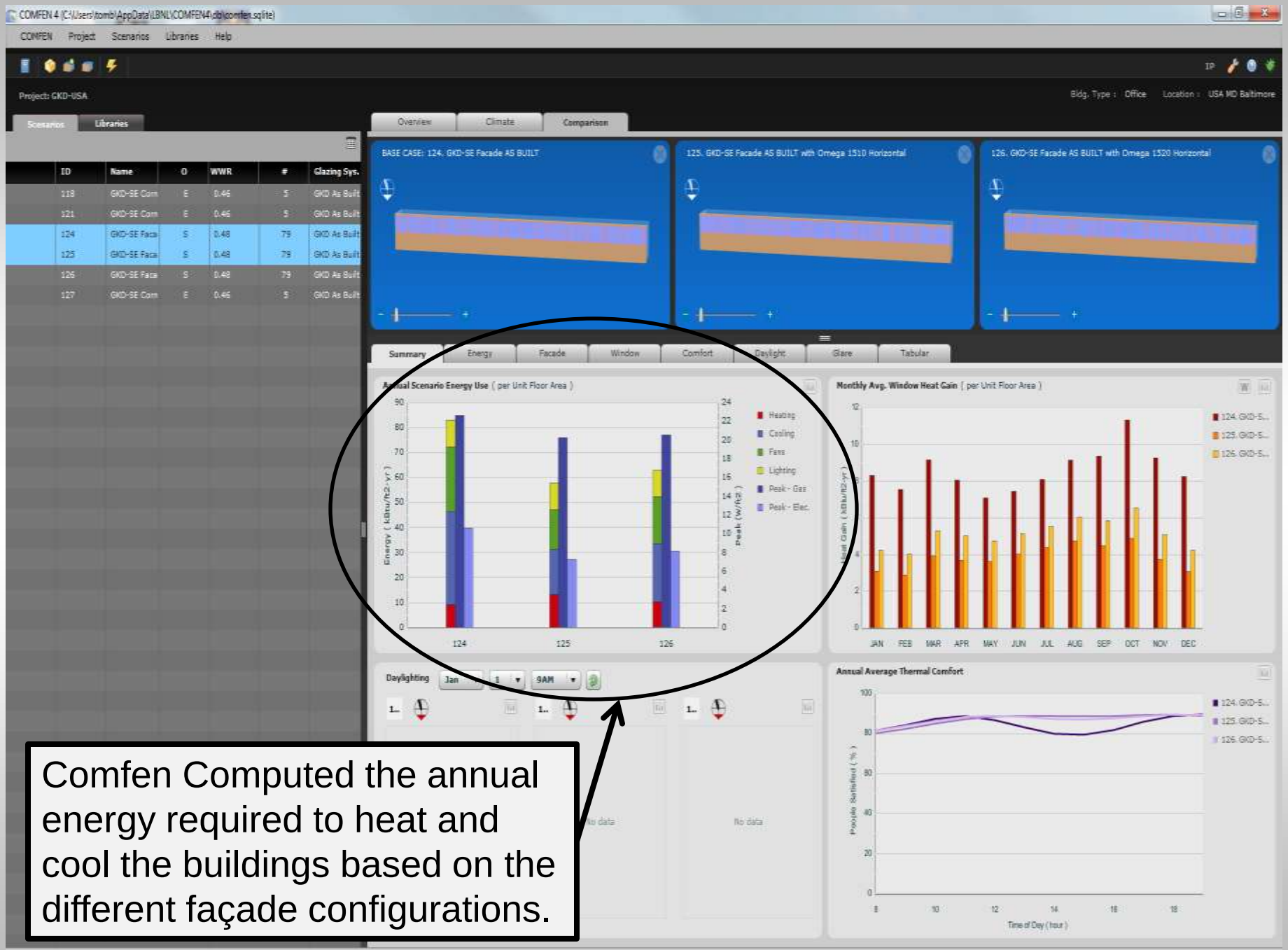
COMFEN Building Example
Eastern Michigan University, USA

- 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



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
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
Peak Demand Electricity	10.60	7.25	-31.62%	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			-10.57%	20.52	-9.27%	W/ft2
Peak De			--	MAR 1 06:15 AM	--	
Avg. Day			-76.83%	85.85	-69.40%	fc
Avg. Disc			1.12%	10.57	8.45%	Index
Avg. The			0.09%	83.52	1.44%	PPS
CO2 emi			-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

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

Stainless Steel Green (Plant) Sun Screens

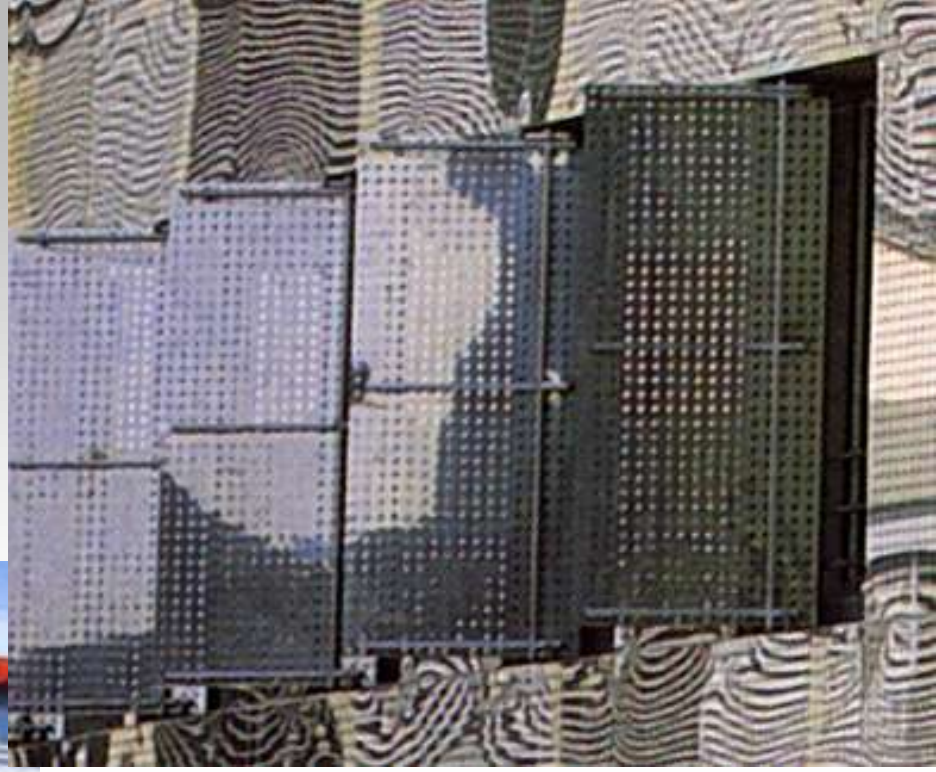
Council House 2, Australia, Green Star 6

Just Announced KPF – New Exterior Petersen Automotive Museum, Los Angeles

Ribbons of vibration polished stainless steel will wrap the existing building in light

Sun Screens

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



Installation of perforated sunscreens over an existing glass wall dramatically reduced heat gain

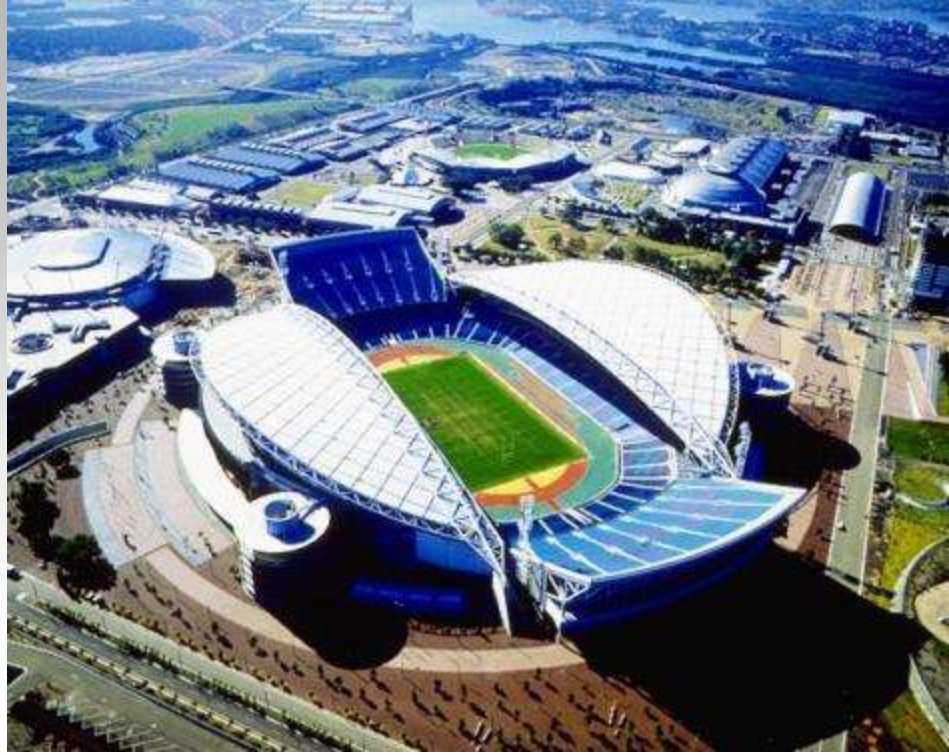
Metal Roof Run-Off Averages (mg/m^2)

	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

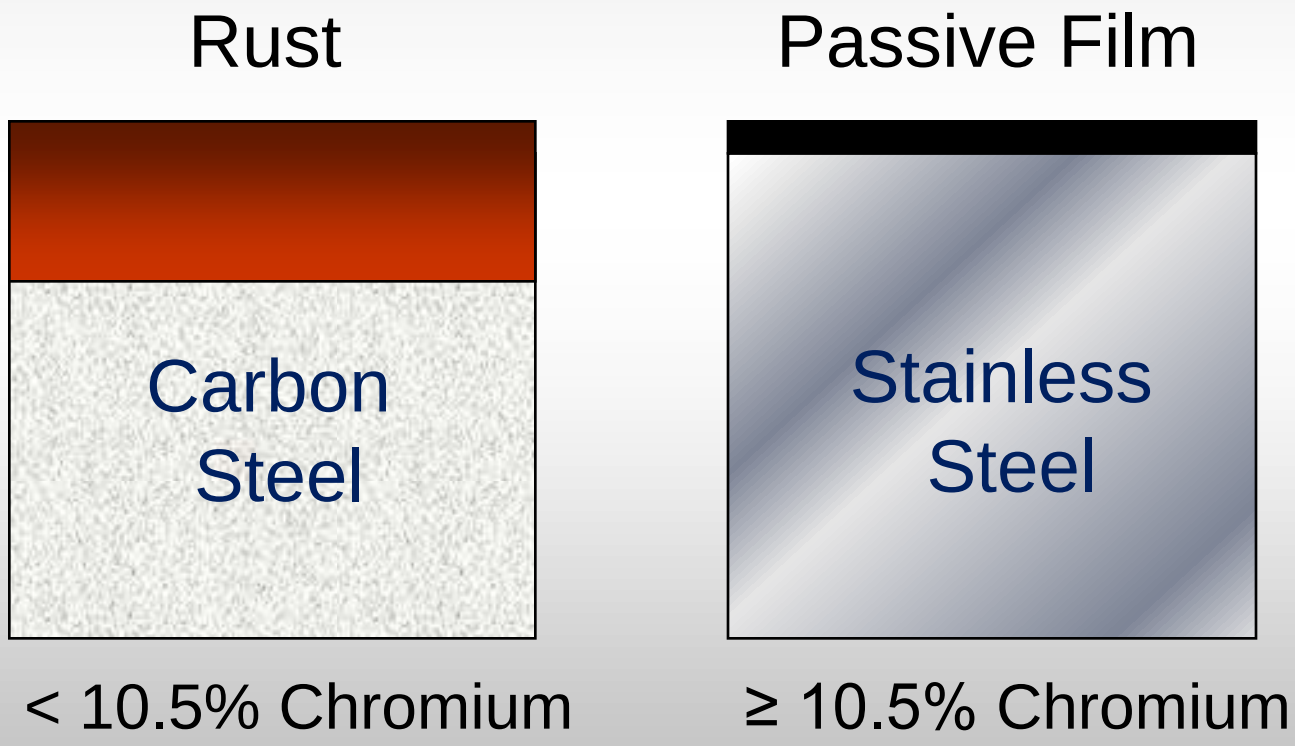
Stainless is also used for in-building water treatment plants

Scottish Parliament

- 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

How Does A Stainless Steel Work?

Stainless steel is iron + at least 10.5% chromium



Families of Stainless Steels

- Austenitic
  - 300-series numbers (304, 316)
  - Strengthened by cold work, easy to form, bend & weld
  - Nonmagnetic
- Ferritic
  - 400-series (430, 447)
  - Magnetic
  - Least formable
- Duplex
  - Austenitic/ferritic (2304, 2205)
  - Cost effective
    - Corrosion resistance
  - Higher strength
  - Magnetic

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

Higher Alloys Like 2205

- High pollution or salt exposure
- High particulate
- No rain washing

More Corrosive Locations

Stockholm Congress Ctr
2205 Sunscreen

2205 Railings, Canary Island 30 years

Some Architectural Stainless Steels

(Nominal Chemical Composition, Wt. Pct.)

	Cr	Ni	Mo	N	PREn
Ferritic 430	17	---	---	0.03	17
Austenitic 304	18	9	---	0.06	20
Ferritic 444	17.5	---	1.75	---	23
Duplex 2304	21.5	3	0.5	0.05	22
Austenitic 316	17	11	2	0.06	23
Austenitic 317LMN	17	13.5	4	0.10	32
Duplex 2205	22	5	3	0.15	34
Super duplex	24	6	3	0.24	38
Austenitic 6% Mo	19.5	17.5	6	0.18	41-43

PREn (Pitting Resistance Equivalent number) = %Cr + 3.3(%Mo) + 16(%N)
Provides a comparison of relative corrosion resistance that is helpful for many but not all service environments

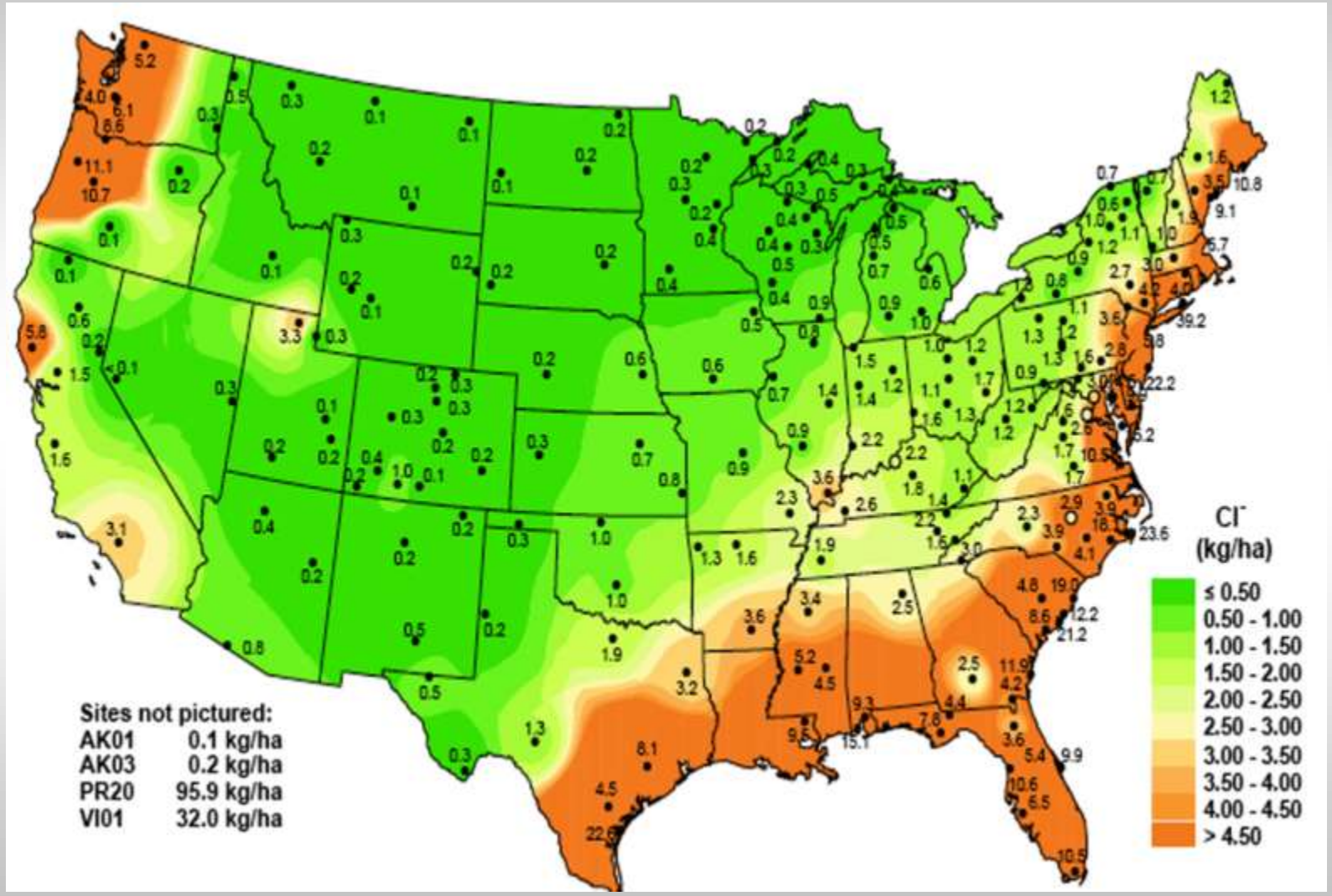
What Factors Influence Corrosion?

- Pollution
  - Acid rain
  - Sulfur Dioxide & particulate
- Particulate accumulation (pollution or dust)
- Coastal and deicing salt exposure
- Weather conditions
- Maintenance cleaning
- Design/specification
  - Crevices
  - Sheltered locations (more corrosive)
  - Surface finish roughness & application method
- Handling & post fabrication cleaning

Rain Acidity (pH)

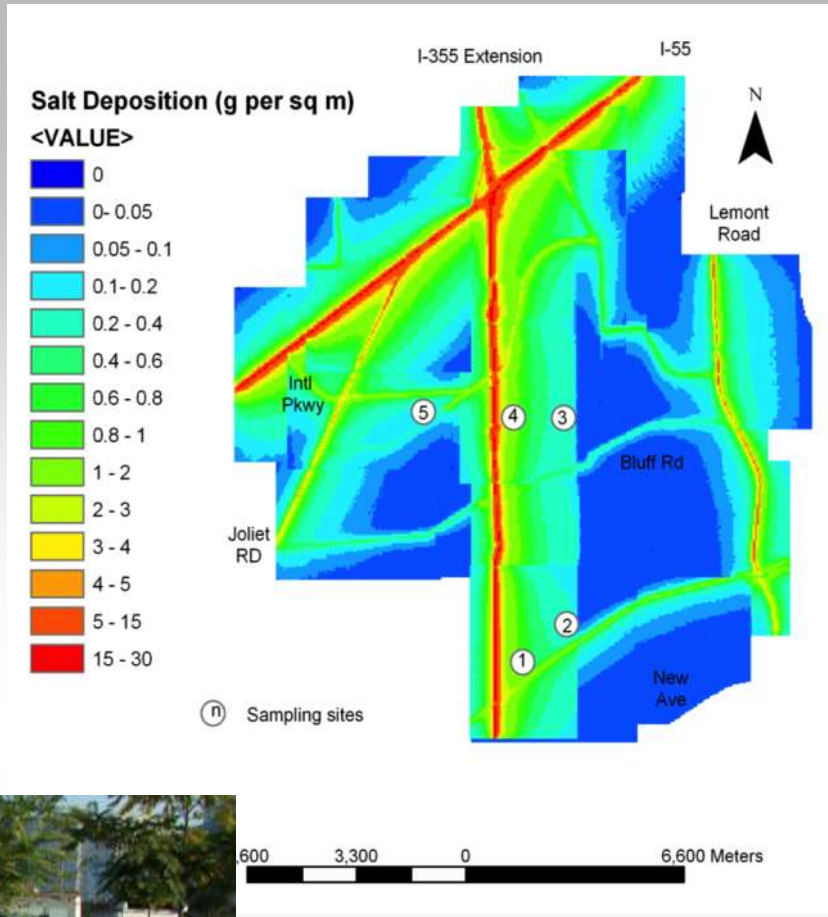
Coastal Salt Exposure

US Coastal Salt Map

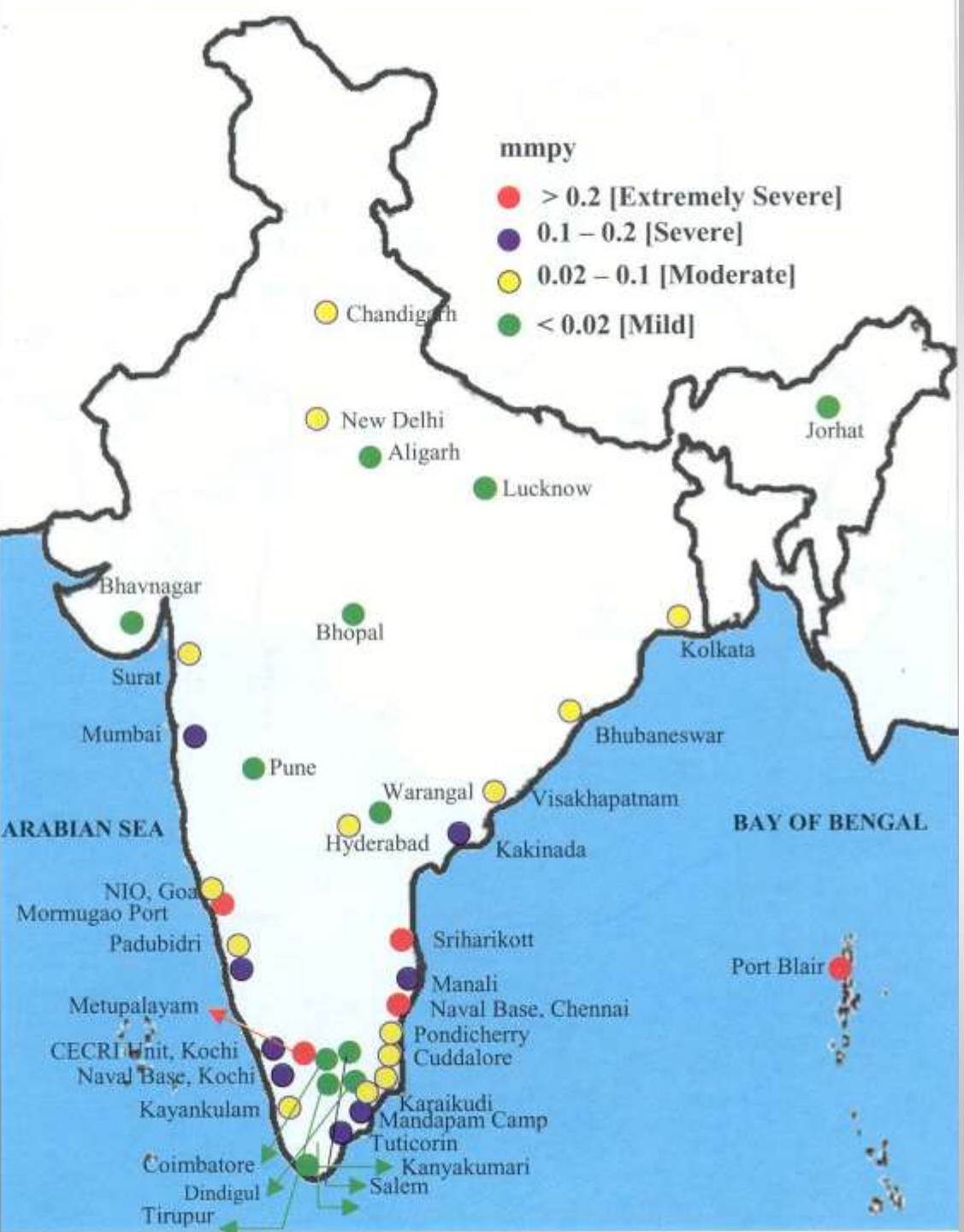


Deicing Salt (Chloride) Corrosion

- Multi-year study
  - IL DOT, NADP, Argonne National Lab
- High seasonal accumulation
- Large saltwater droplets
  - Splash zone (≤ 49 ft.)
- Dry particles
  - ≤ 1.2 miles from roads
  - ≤ 59 floors
  - Stays in the air for days



Deicing salt corrosion in Beijing



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

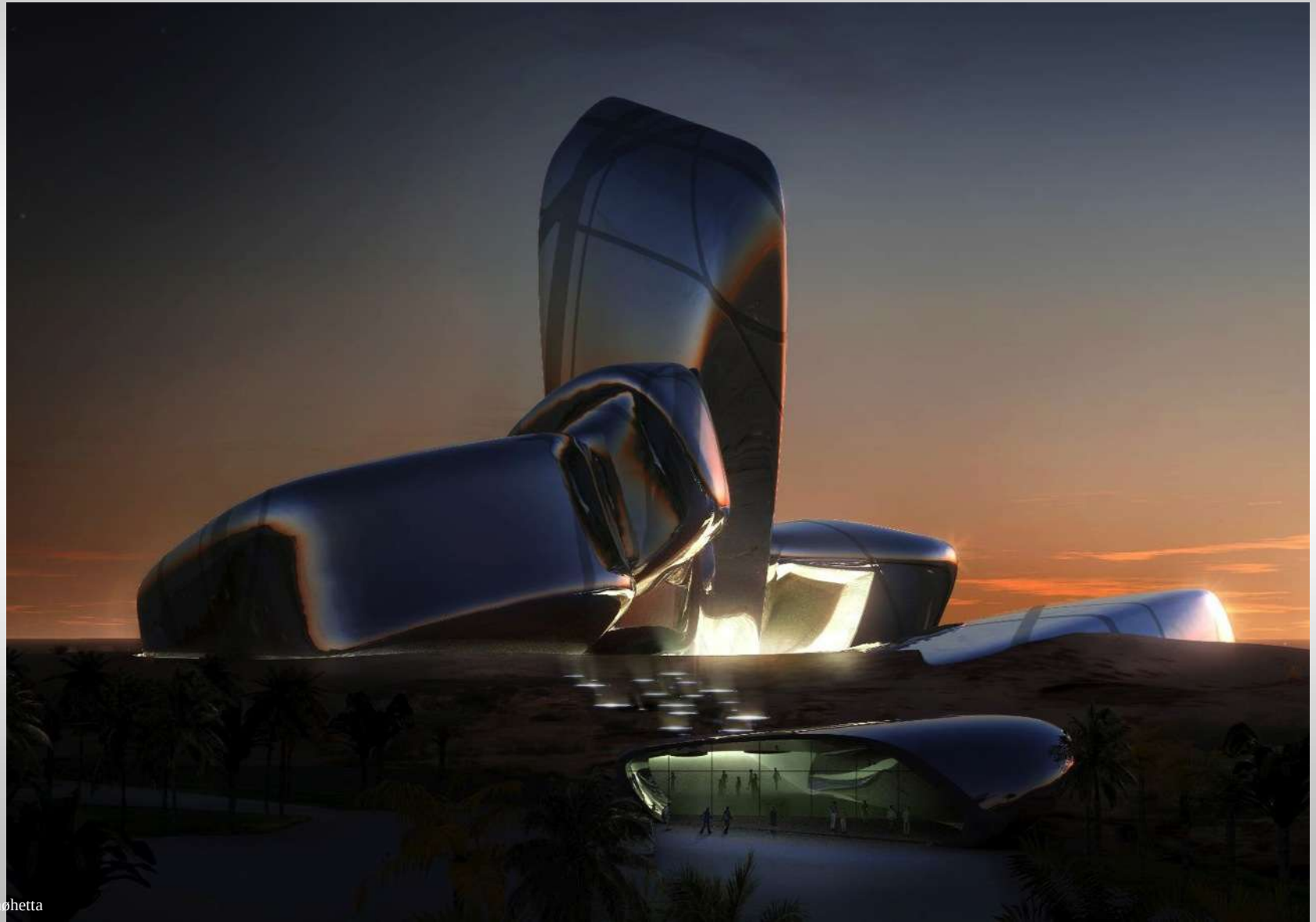
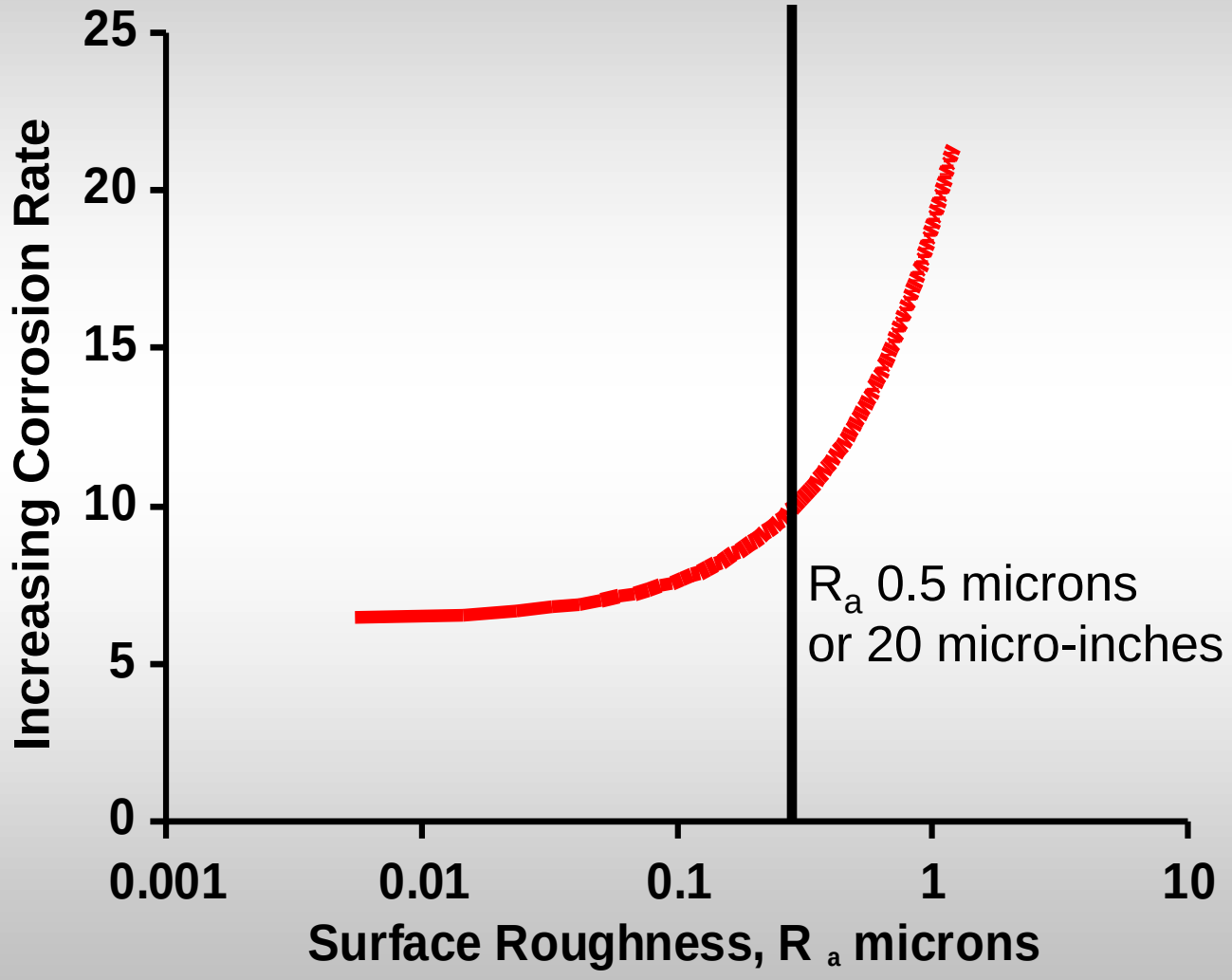


image by snøhetta

Duplex 2205 Stainless Steel Selected

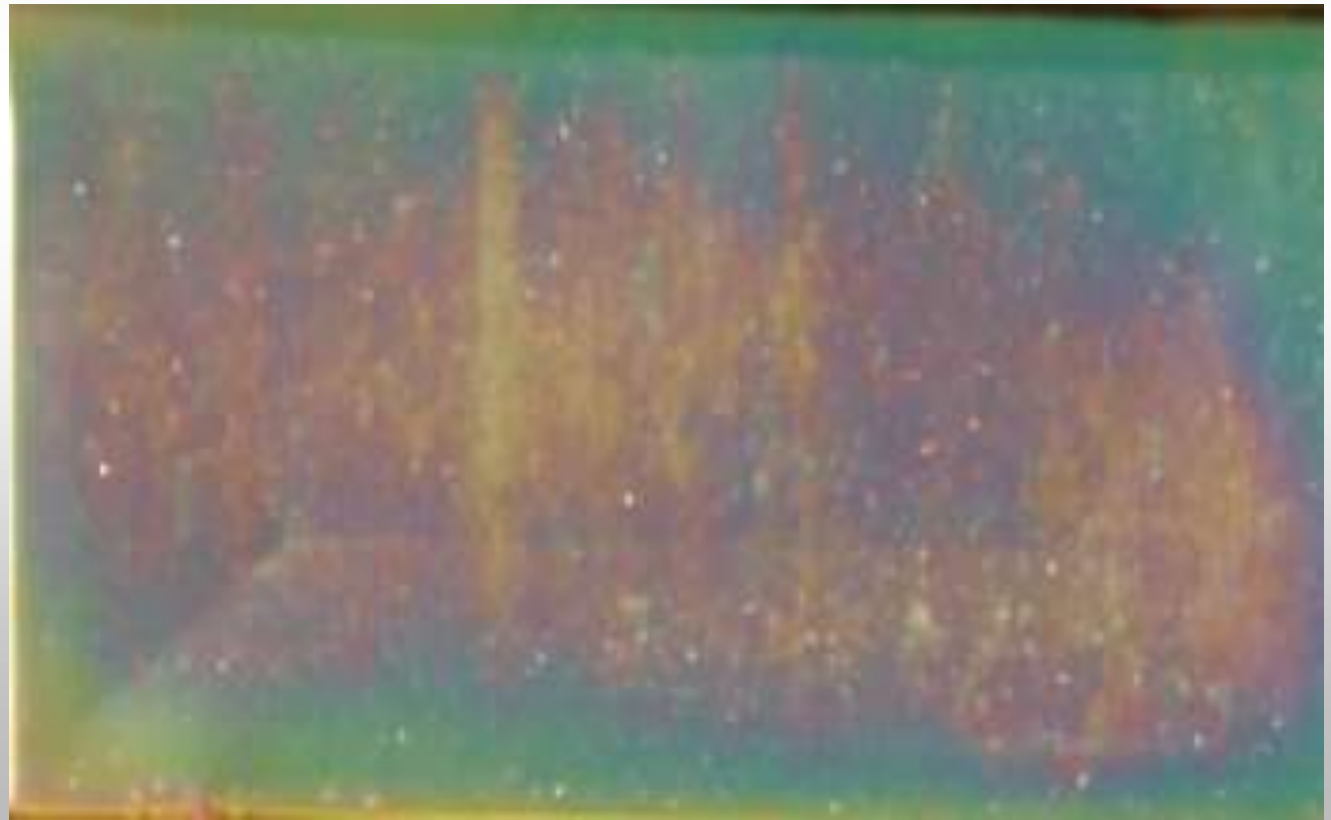
- Corrosion testing documented severity of location
- Paint would have failed & not been repairable
- Less highly alloyed stainless steels would have had a corrosion problem
- High strength allowed lighter tube wall

Surface Finish
Is As Critical As Stainless Steel Selection



Light Corrosion Staining Or Abrasion Can Destroy Some Finishes

- Corrosion or abrasion of colored stainless is not repairable
  - Cleaning leaves bare stainless steel – silver spots



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

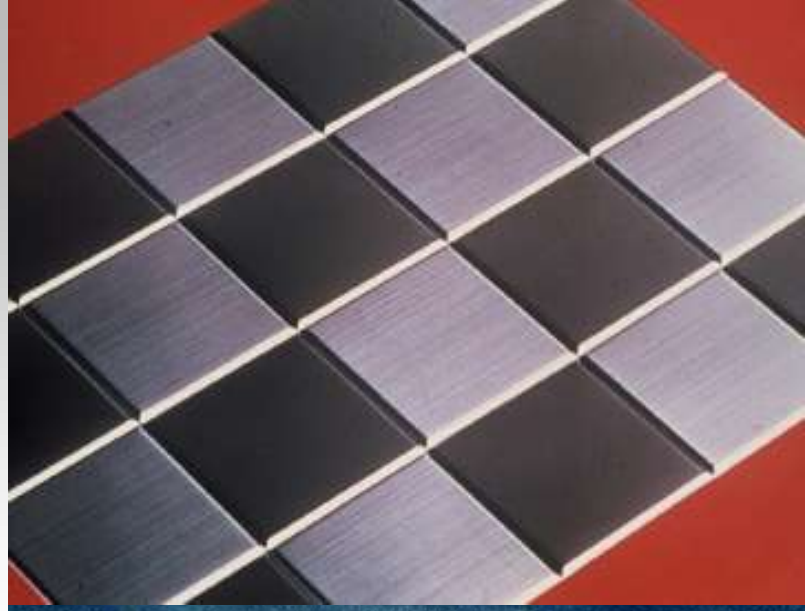
St Mary's Cathedral, Tokyo,

Completed 1961, Type 304, 2D, near coast

- No problems with the stainless steel
  Galvanic corrosion of carbon steel framing made repairs necessary

Obtaining a Uniform Appearance

- Use one coil or consecutive coils from one supplier
- Mark rolling direction and number panels
- Install all panels in the same rolling direction
- Install numbered panels consecutively
- Failing to follow these rules produces a checkerboard appearance



Metal	Thermal Expansion $^{o}C \times 10^{-6}$	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

Flat Unlaminated Panels

Dull or coined finishes look flatter than more reflective finishes and thinner gauges can be used.

Reflectivity	Width-to-Thickness Ratio
High	150 max.
Medium-to-low	200 max.
Coined/Embossed	200 or higher

No. 4 Polish

- Short parallel lines

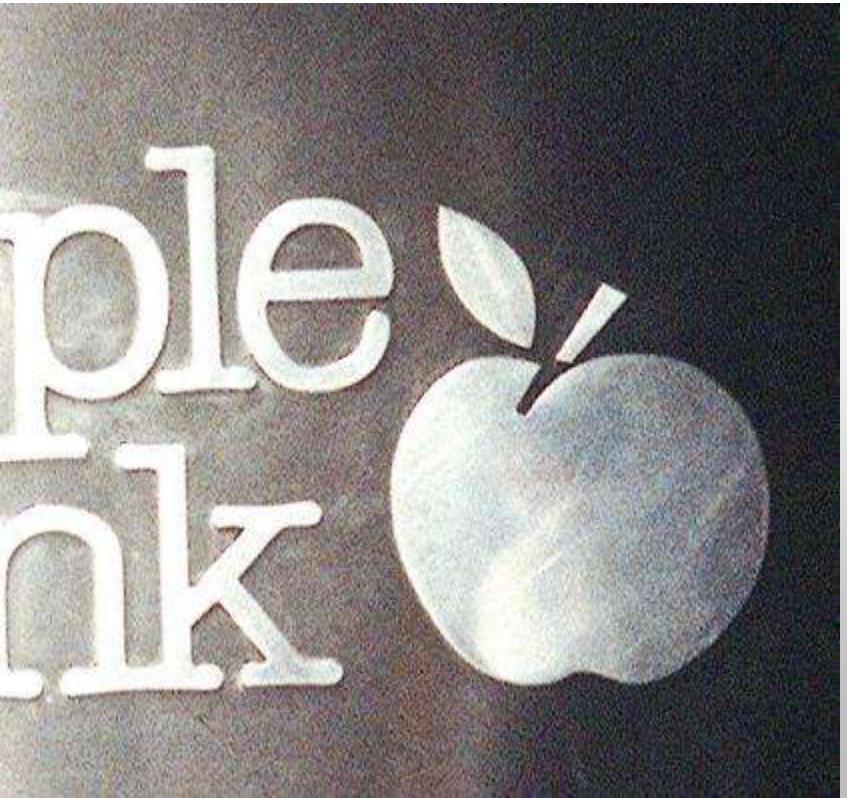
Hairline

- Long fine parallel lines

No. 8 Polish

- Mirror like

Neuer Zollhofs, Dusseldorf, Germany, Gehry Partners



Acid Etching

- Unprotected areas are etched to create the design
- The acid is rinsed off and the coating is removed
- Etched areas are a dull silver color
- Custom and stock patterns available
- Etched areas can have fingerprinting problems

Walt Disney Concert Hall, Gehry Partners

Vibration Finish
(angel hair, suede, non-directional polish)

- Stainless wire brush or non-metallic abrasive pad
- Applied to a mirror polished or bright annealed finish
- Non-directional, fine, random scratch pattern
- Lines are smaller, finer than distressed finish
- Use control samples

Swirl Finishes

- Applied over 2B or 2D finish
- Grinding wheels or stainless wire brushes
- Swirl patterns
- Use control samples

Effect of Abrasive Blast Media

- Non-directional and repairable
- Surface distortion if panels are too thin
- Susceptible to fingerprinting
- Clean surface before and after blasting

Fine sand	Dark, coarse
Silicon carbide	Dark, coarse
Glass beads	Light, smooth, grainy
Stainless shot	Small, curved indentations
Ground quartz	Shiny, coarse, angular indentations

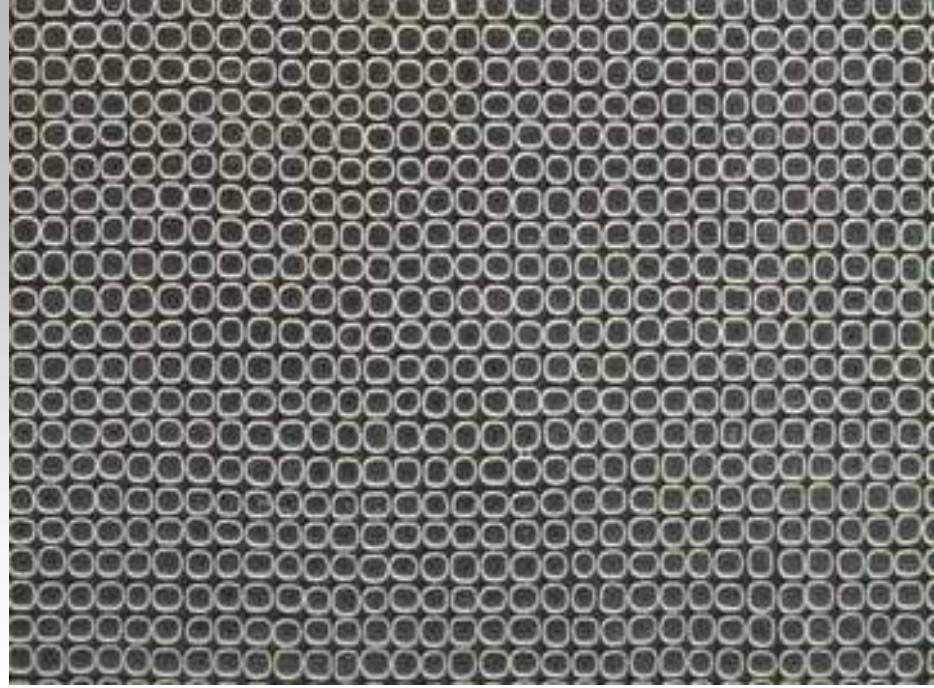
Liner Museum

Appenzell, Switzerland

3 mm thick, glass bead blasted stainless shingles roof and wall panels

Embossing and Coining

- Applied by passing a stainless steel coil between two rolls
- Improves scratch and impact resistance
- Coining
  - One roll is patterned
  - One roll is smooth
- Embossing
  - Both rolls are patterned



Electrochemical Colors

Similar to anodizing aluminum

Color can be uniform or deliberately varied

Bronze	Blue	Gold	Red
Purple	Black	Green	

Sputtering or Plasma Vapor Deposition

- Thin, adherent, abrasion resistant, uniform, non-fading
- Color determined by coating

  Gold (titanium nitride)

  Black (titanium carbide)

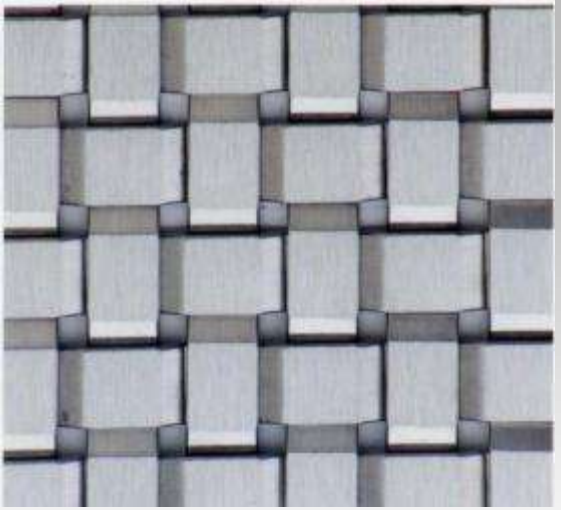
  Brown or Blue (titanium aluminum nitride)

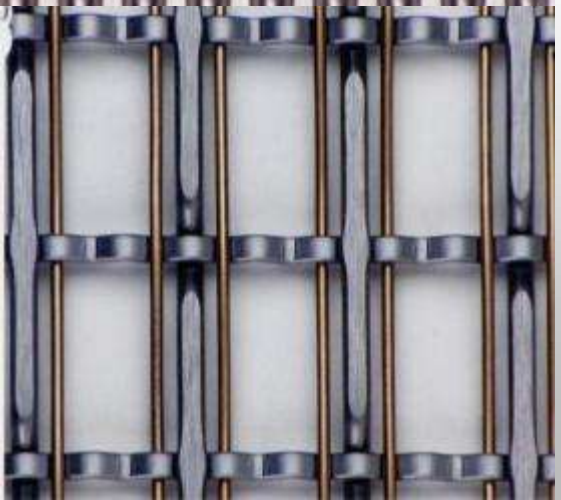
  Others: Rose Gold, Silver Gold, Brass

Perforated Panels

- Decorative, sunscreen, security and safety applications

US court house sunscreens, Type 316 Surpassed energy performance criteria by 50%





Woven Stainless

- Many styles and weights
- Hides scratches and impact resistant
- Interior and exterior applications
  - •Ceilings, walls, room dividers
  - •Sunscreens and sculptural shapes
- Salt crevice corrosion must be considered

Questions?

10 Minute Break Before Applications Discussion