Green Roofs
Dead or Alive?

January 2009

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Karim P. Allana, PE, RRC, RWC

- **Education:** B.S., Civil Engineering, Santa Clara University
- **Registration:** P.E., Civil Engineering, California, Washington, Nevada, and Hawaii
- **Certification:** Registered Roof Consultant (RRC), Roof Consultants Institute, and Registered Waterproofing Consultant (RWC)
- **Overview:**
  - CEO and Senior Principal at Allana Buick & Bers.
  - Former Turner Construction Employee (Project Engineering and Superintendent)
  - Over 37 years experience providing superior technical standards in all aspects of building technology and energy efficiency.
  - Principal consultant in forensic investigations of building assemblies, failure analysis, evaluation and design of building infrastructure and building envelope evaluation and design.
  - Expert in all aspects of building envelope technology.
  - Completed numerous new construction, addition, rehabilitation, remodel and modernization projects for public and private sector clients.
  - Specialization in siding, roofing, cement plaster, wood, water intrusion damage, window assemblies, storefronts, below grade waterproofing, energy efficiency, solar engineering and complex building envelope and mechanical assemblies.

ABBAE Firm Overview

- Allana Buick & Bers (ABBAE) is an Architectural Engineering firm specializing in Building Envelope Systems
- ABBAE is one of the 5 largest building envelope consultants in the country
- ABBAE has over 33 years of experience & over 12,500 projects
- ABBAE is also a leading Forensic Defect firm with hundreds of forensic projects (litigation)
- Locations – 16 offices across California, Nevada, North Carolina, Oklahoma, Oregon, Texas, Virginia, Washington, Colorado and Hawaii

Staff & In-House Expertise

- Licensed Professional Engineers – Civil, Structural, and Mechanical
- Registered Architects
- Building Enclosure Commissioning Process Providers (BECxPs)
- Registered Building Envelope Consultant (RBEC)
- Registered Roofing Consultants (RRCs)
- Registered Waterproofing Consultants (RWCs)
- Registered Exterior Wall Consultant (REWCs)
- Registered Roof Observers (RROs)
- Certified Exterior Insulation and Finish System (EIFS) inspectors
- Curtain Wall Specialists
- ICC Certified Building Inspectors
- Quality Assurance Monitors
- Water Testing Experts
- Leak Investigation and Diagnosis Experts
- Infrared Imaging and Nuclear Moisture Scanning Experts

ABBAE Building Expertise

- Building Envelope Systems
  - Roofing Systems
    - High-Slope/Low-Slope Roofs
    - Green/Garden Roofs
    - Drainage Systems
    - Pedestrian Plazas
  - Exterior Wall Systems
    - Wall Cladding/Siding/GFRC/pre-cast
    - EIFS/cement plaster/stucco
    - Sheet Metal Flashings
  - Windows and Glazing Systems
    - Punched Windows
    - Curtain Wall/Window Wall Systems
    - Sliding Glass Doors
    - Skylights

- Building Envelope Systems (cont'd)
  - Roofing & Waterproofing Systems
    - Deck/Balcony/Lanai Waterproofing
    - Podium Waterproofing
    - Pool/Spa Deck Waterproofing
    - Above-Grade/Below-Grade Waterproofing
    - All types of low and steep sloped roofing
  - Commissioning BECx
    - OPR/BOD/Commissioning Plan
- Mechanical/HVAC Systems
  - HVAC design
  - Plumbing systems
  - Commissioning and testing

ABBAE Core Services

- Consulting and third-party peer review services
- Engineer of record for building envelope systems
- Contract administration services
- Inspection services (usually direct with owner)
- Air and water performance testing
- Mock-up design, observation, and testing
- Building assessments and forensic investigations
- Litigation support and expert witness services
- Educational seminars with AIA credits

ABBAE HISTORY

- **ABBAE is an Architectural Engineering Firm specializing in making buildings last longer.**
- **Specializing in Roofing, Waterproofing, Curtain Walls, Stucco, Windows, Below Grade, Etc.**
- **Our 2,200+ projects: 45% have been new Construction projects, and 55% Repair and Forensic projects.**
- **We make buildings sustainable, lower maintenance and repair cost; lower energy cost and make buildings more reliable**

What is Green Roofing?

- 20 years ago, Term Green Roofs was used for Garden Roof or living roof with plants or grasses

- Today, Green roof stands for many factors like:
  - Reflectivity
  - Insulation
  - Energy saving
  - Eco Friendly material usage
  - Water management

Overview-Green Roofs Dead or Alive

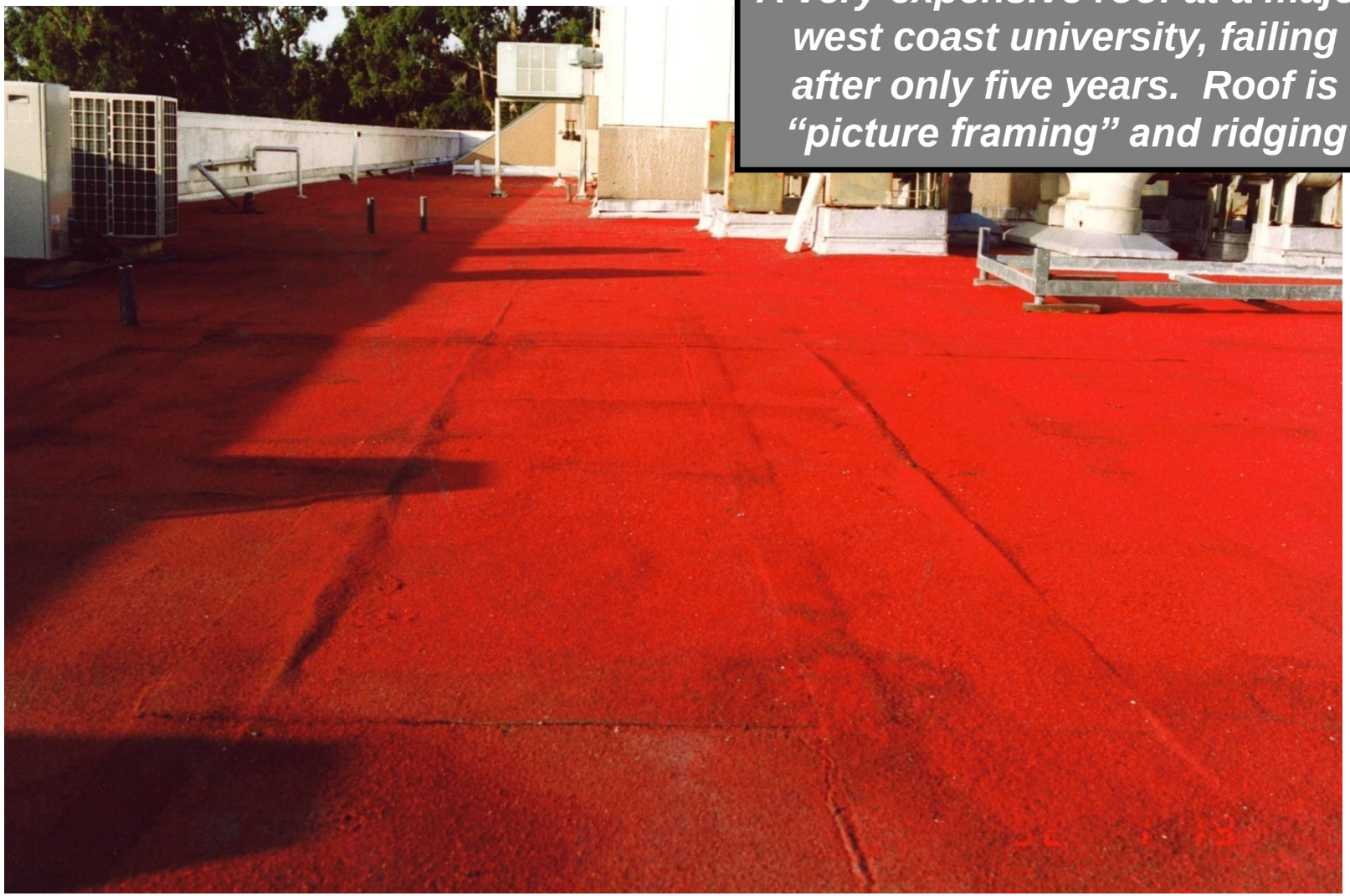
- Environmental impact of roofs
  - Waste from Re-roofing
  - Urban Heat Island Effect
  - Water Run-off
  - Building Energy Consumption
- Benefits of Various Eco-Friendly Roofs
  - Reduce CO2
  - Reduce Building Energy Consumption
- New Title 24 Impact on Roofing
  - New Guidelines for insulation and reflectivity
  - Impact on re-roofing

Waste Due to Short Roof Lifespan

- Roofs can last 30 to 50 years, but most don’t
- Average life expectancy is between 12 and 16 years.
- Re-roofing involves demolition and huge impact to our landfill
- Re-roofing materials require large CO2 for manufacturing
- Huge Cost impact to Owner
- Inconvenience to occupants

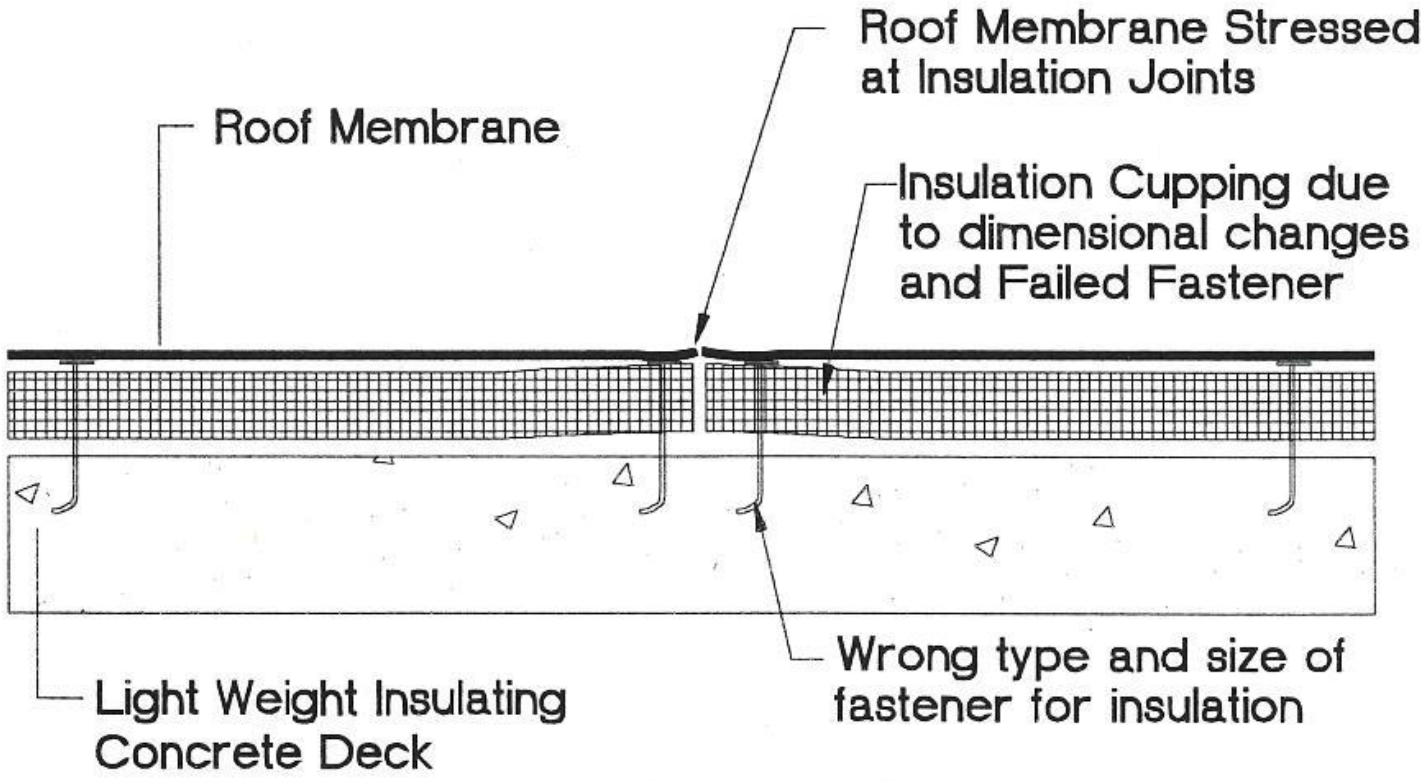
Premature Roof Failure

A very expensive roof at a major west coast university, failing after only five years. Roof is "picture framing" and ridging



DEFECT: Improper securement of roof. Inappropriate insulation fasteners, poorly installed, causing cupping of insulation material.

Improperly Attached Roof Caused Failure



PICTURE FRAMING + ROOF SPLITTING CAUSED BY POOR FASTENING OF INSULATION BOARD TO SUBSTRATE

Poor Flashing Causes Premature Failure

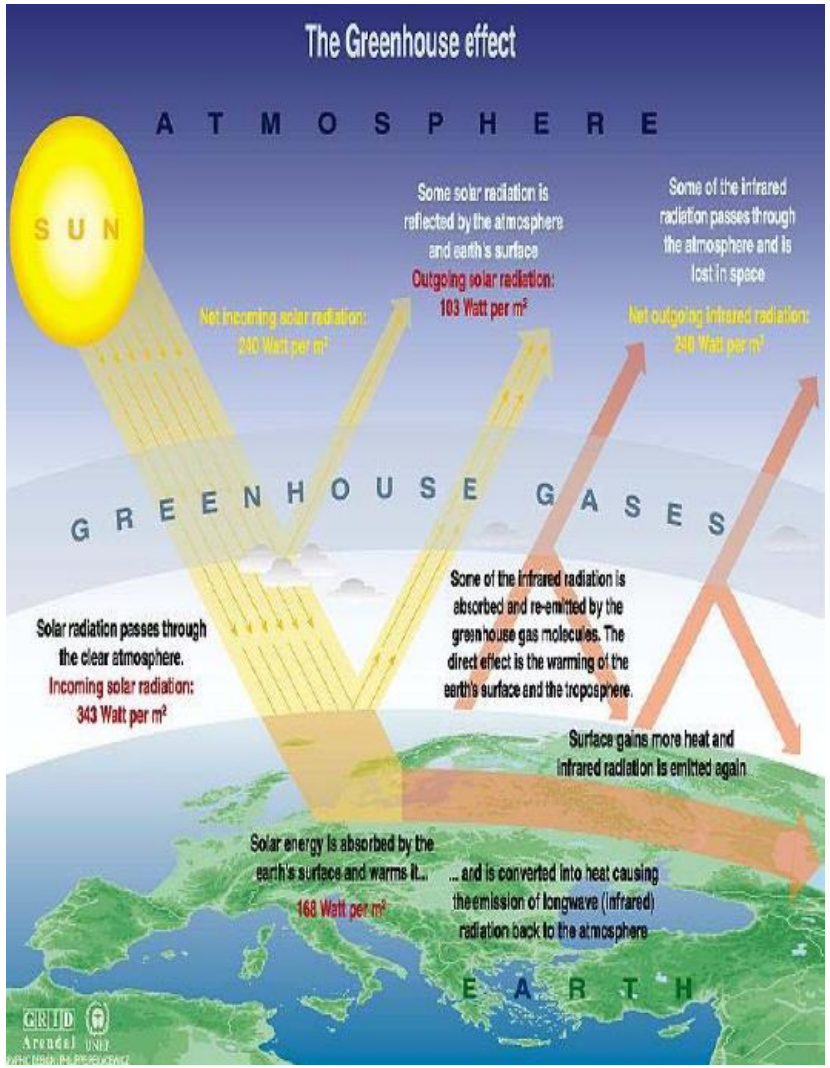
Edge flashing at 34 year old roof is splitting, due to improper workmanship (fastening). Embedded edge metal require fastening at 3”o.c. staggered, absence of which results in splitting at joints in metal

Ponding Water Leads to Deterioration

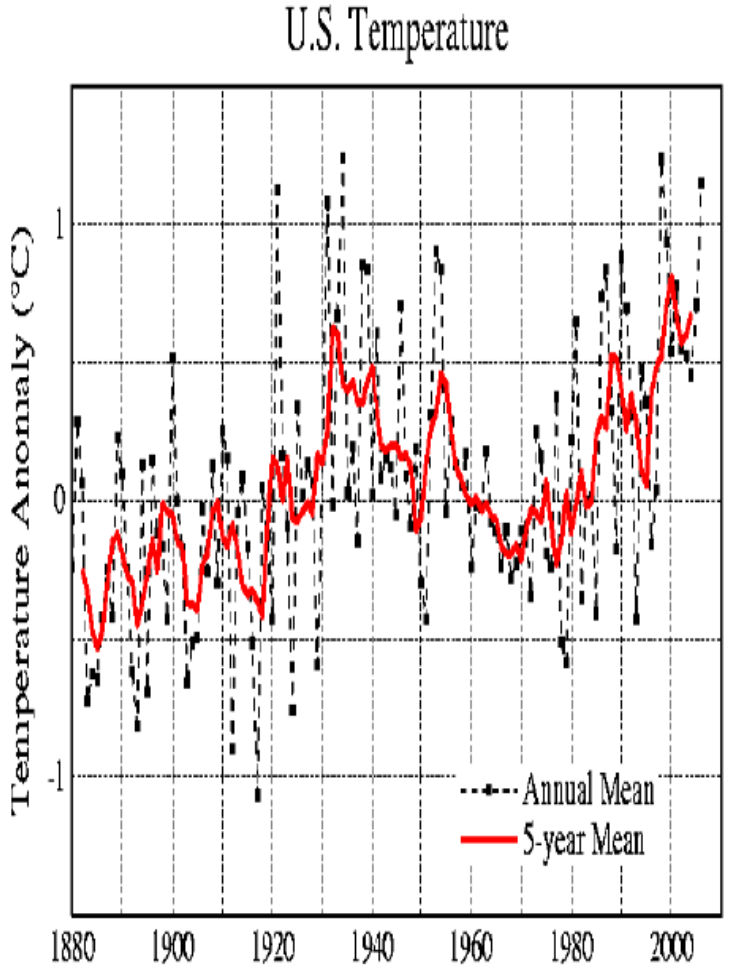
Urban Heat Island Effect

- On warm summer days, the air in urban areas can be 2°-8°F hotter than its surrounding areas. Scientists call these cities “urban heat islands.”
- Dark Roofs and Roadways contribute to the extra heat
- Rooftop temperatures Range from 140°F to 180°F
- The higher temperatures in urban areas and on Rooftop increases air conditioning usage and raises pollution levels.

Greenhouse Effect



Source: EPA Heat Island Reduction Initiative



Source: NASA Goddard Institute for Space Studies

Dark Roofs Absorb and Trap Heat

Approximately 50% of the rise in near surface air temperatures since the 1960s is attributable to land use change.

Impact of urbanization and land-use change on climate

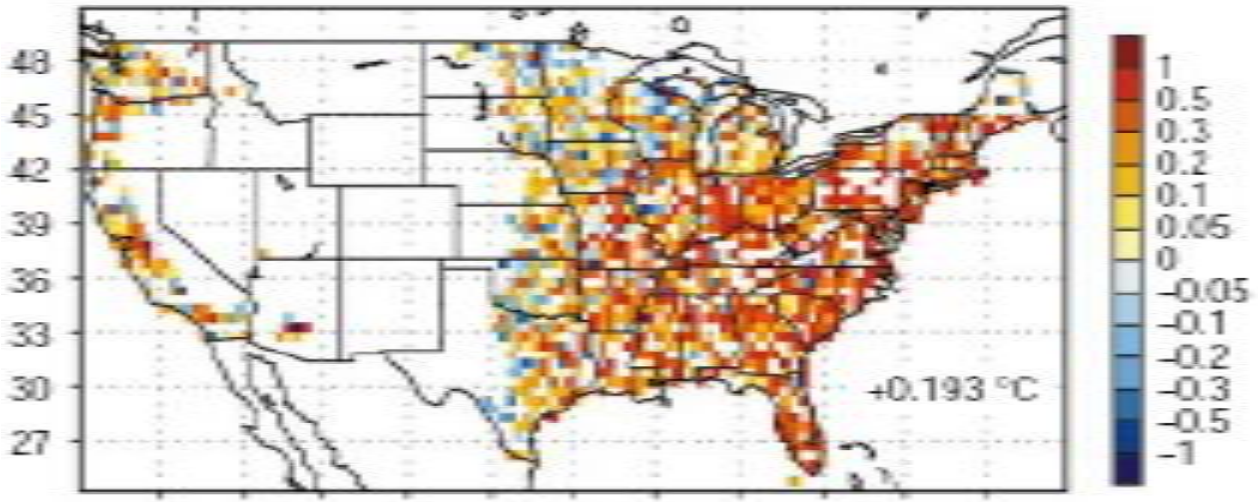
Eugenia Kalnay & Ming Cai

University of Maryland, College Park, Maryland 20770-2425, USA

The most important anthropogenic influences on climate are the emission of greenhouse gases[1] and changes in land use, such as urbanization and agriculture[2]. But it has been difficult to separate these two influences because both tend to increase the daily mean surface temperature[3,4]. The impact of urbanization has been estimated by comparing observations in cities with those in surrounding rural areas, but the results differ significantly depending on whether population data[5] or satellite measurements of night light[6–8] are used to classify urban and rural

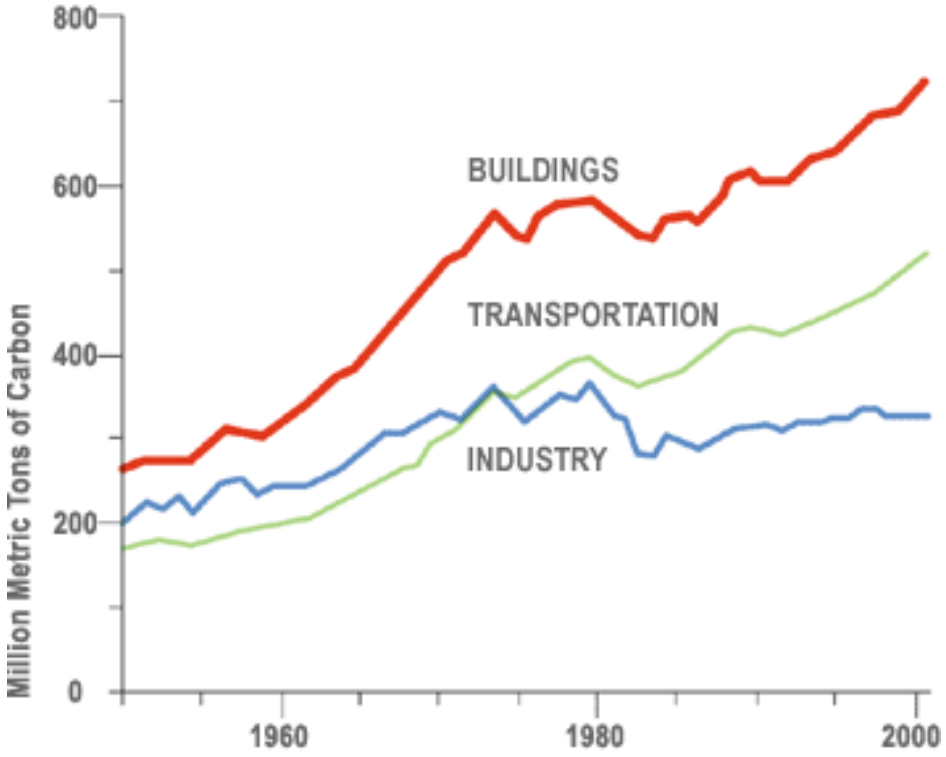
...e the difference between trends in observed ...s in the continental United States and the ...ls in a reconstruction of surface temperatures ...reanalysis of global weather over the past 50 ...sitive to surface observations, to estimate the ... changes on surface warming. Our results ...he observed decrease in diurnal temperature ...n and other land-use changes. Moreover, our ... mean surface warming per century due to

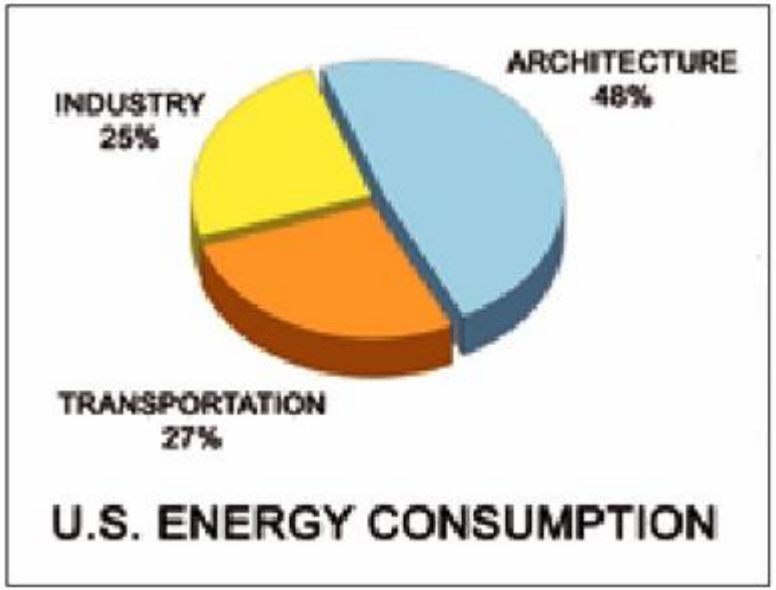
NATURE | VOL 423 | 29 MAY 2003 | www.nature.com/nature



Source: Kalnay & Cai, 2003

US Energy Consumption





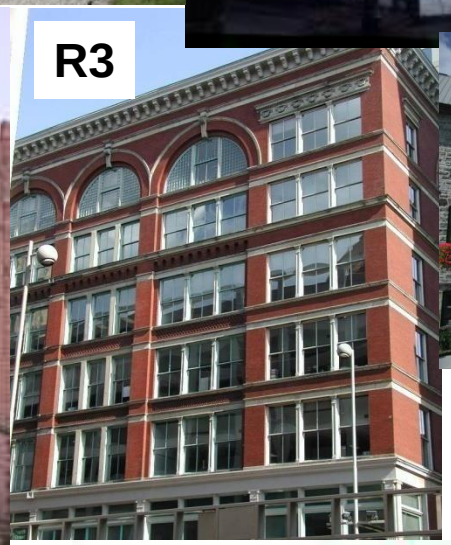
www.BuildingScience.com


R2


R6


R6


R6


R3


R4


R4
GENERAL MOTORS


R5


R1.5


R2

Cool (Highly Reflective) Roofs Save Energy

Photo courtesy of Gardner-Gibson Inc., an RCMA member.

Cool Roofs Reflect Heat

- Heat is not absorbed by the building
- Cool roofs reduce energy consumption
- Are required by law
- Lower surface temperature
- Can be retrofitted

What Is Emittance?

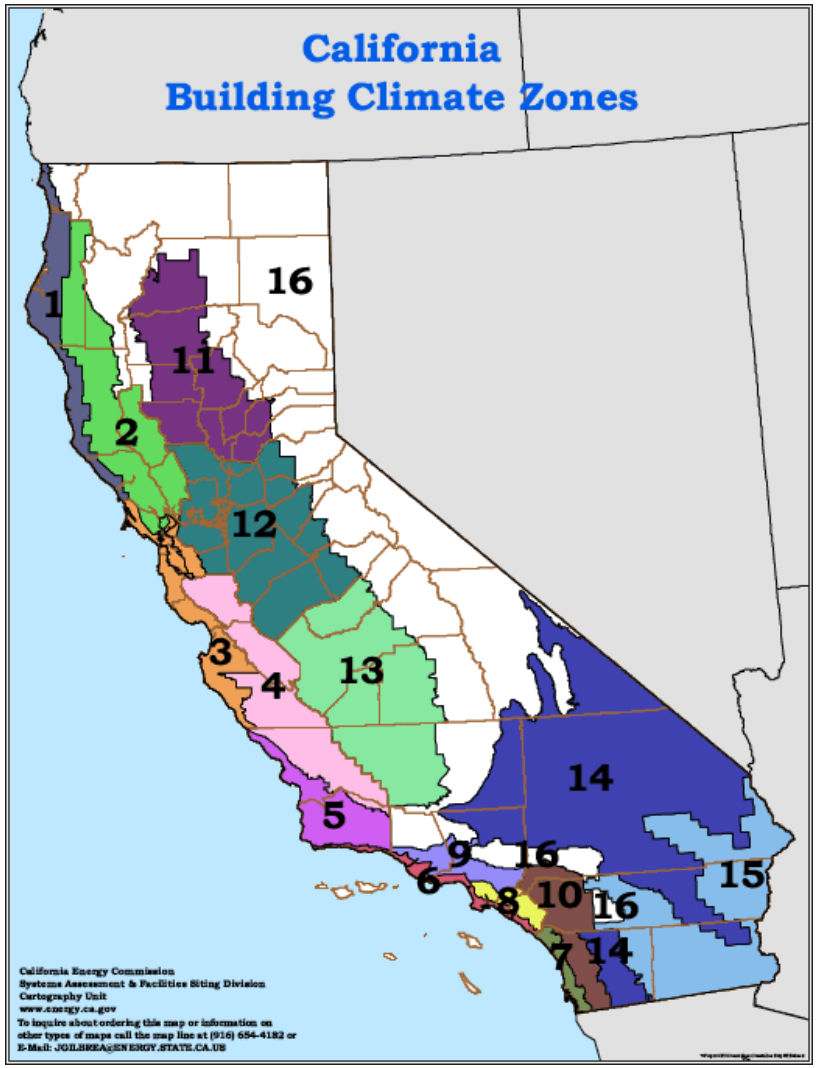
- Some of the sun's energy does not bounce off; it is absorbed.
- The absorbed energy is given off (emitted) at different rates by different materials.
- "Emittance" is the measure of how quickly or efficiently absorbed energy is given off.
- Heat emitted slowly has time to penetrate downward into the building
- Both emmitence and reflectivity are important

Title 24 Cool Roof Requirement

- 2008 – Title 24 Part 6 Roofing Products
- Low slope – initial reflectance 0.70 & initial
- emittance 0.75
- Low slope – 3 year aged reflectance 0.55,
- aged emittance 0.75, 64 aged SRI
- Non-certified material default values
- Asphalt Shingles – 0.08 reflectance / 0.75 emittance
- All other roofing Products – 0.10 reflectance / 0.75 emittance

- *Energy Star listed material is not adequate!*

Title 24 Requirements Different by Zones



Title 24 New Construction Requirement

TABLE143-A – PRESCRIPTIVE ENVELOPE CRITERIA FOR NONRESIDENTIAL BUILDINGS (INCLUDING RELOCATABLE PUBLIC SCHOOL BUILDINGS WHERE MANUFACTURER CERTIFIES USE ONLY IN SPECIFIC CLIMATE ZONE; NOT INCLUDING HIGH-RISE RESIDENTIAL BUILDINGS AND GUEST ROOMS OF HOTEL/MOTEL BUILDINGS)

			Climate Zone															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Roofs/Ceilings	Metal Building		0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
	Wood Framed and Other		0.049	0.039	0.039	0.039	0.049	0.075	0.067	0.067	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
Roofing Products	Low-sloped	Aged Reflectance	NR	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	NR
		Emittance	NR	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	NR
	Steep Sloped (less than 5 lb/ft²)	Aged Reflectance	NR	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
		Emittance	NR	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
	Steep Sloped (5 lb/ft² or more)	Aged Reflectance	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
		Emittance	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Walls	Metal Building		0.113	0.061	0.113	0.061	0.061	0.113	0.113	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.057	0.061
	Metal-framed		0.098	0.062	0.082	0.062	0.062	0.098	0.098	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
	Mass Light		0.196	0.170	0.278	0.227	0.44	0.44	0.44	0.44	0.44	0.170	0.170	0.170	0.170	0.170	0.170	0.170
	Mass Heavy		0.253	0.650	0.650	0.650	0.650	0.690	0.690	0.690	0.690	0.650	0.184	0.253	0.211	0.184	0.184	0.160
	Wood-framed and Other		0.102	0.059	0.110	0.059	0.102	0.110	0.110	0.102	0.059	0.059	0.059	0.059	0.059	0.059	0.042	0.059
Floors/Soffits	Mass		0.092	0.092	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.269	0.092	0.092	0.092	0.092	0.092	0.058
	Other		0.048	0.039	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.071	0.039	0.071	0.071	0.039	0.039	0.039
Windows	U-factor		0.47	0.47	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.47	0.47	0.47	0.47	0.47	0.47	0.47
	RSHG North	0-10% WWR	0.72	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.72
		10-20% WWR	0.49	0.51	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.51	0.51	0.51	0.51	0.51	0.51	0.49
		20-30% WWR	0.47	0.47	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.47	0.47	0.47	0.47	0.47	0.47	0.47
		30-40% WWR	0.47	0.47	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.47	0.47	0.47	0.47	0.40	0.40	0.47
	RSHG Non-North	0-10% WWR	0.49	0.47	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.47	0.47	0.47	0.47	0.46	0.46	0.49
		10-20% WWR	0.43	0.36	0.55	0.55	0.55	0.61	0.61	0.61	0.61	0.36	0.36	0.36	0.36	0.36	0.36	0.43
		20-30% WWR	0.43	0.36	0.41	0.41	0.41	0.39	0.39	0.39	0.39	0.36	0.36	0.36	0.36	0.36	0.36	0.43
		30-40% WWR	0.43	0.31	0.41	0.41	0.41	0.34	0.34	0.34	0.34	0.31	0.31	0.31	0.31	0.31	0.31	0.43
Doors, U-factor	Non-Swinging		0.50	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	0.50
	Swinging		0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Skylight	U-factor	Glass, curb	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
		Glass, no curb	0.68	0.68	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.68	0.68	0.68	0.68	0.68	0.68	0.68
		Plastic	1.04	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.04
	SHGC	Glass, 0-2%	NR	0.46	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.46	0.46	0.46	0.46	0.46	0.46	NR
		Glass, 2.1-5%	NR	0.36	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.36	0.36	0.36	0.36	0.36	0.36	NR
		Plastic, 0-2%	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
		Plastic, 2.1-5%	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57

Notes:
1. Mass, Light walls are defined as having a heat capacity greater than or equal to 7.0 Btu/h-ft2 and less than 15.0 Btu/h-ft2. Heavy mass walls are defined as having a heat capacity greater than or equal to 15.0 Btu/h-ft2.
2. No skylight SHGC requirements are defined for climate zones 1 and 16. A climate zone without a requirement is designated as "NR".

Title 24 Re-Roofing Requirement

TABLE 149-A INSULATION REQUIREMENTS FOR ROOF ALTERATIONS

	Nonresidential		High-rise Residential and Guest Rooms of Hotel/Motel Buildings	
Climate Zone	Continuous Insulation R-value	U-factor	Continuous Insulation R-value	U-factor
1	R-8	0.081	R-14	0.055
2	R-14	0.055	R-14	0.055
3	R-8	0.081	R-14	0.055
4	R-8	0.081	R-14	0.055
5	R-8	0.081	R-14	0.055
6	R-8	0.081	R-14	0.055
7	R-8	0.081	R-14	0.055
8	R-8	0.081	R-14	0.055
9	R-8	0.081	R-14	0.055
10	R-14	0.055	R-14	0.055
11	R-14	0.055	R-14	0.055
12	R-14	0.055	R-14	0.055
13	R-14	0.055	R-14	0.055
14	R-14	0.055	R-14	0.055
15	R-14	0.055	R-14	0.055
16	R-14	0.055	R-14	0.055

Energy Star Compliant Single Ply Roofing

Case Study PVC

Case Overview: *Department Store*

- Large department store in Northern California.
- Eighteen years old.
- No repairs, no leaks, no problem?
- Purpose of the investigation: Determine longevity of single ply.
- We were with a team of other skeptical consultants.

Example of roof installed in 1983, inspected in 2001.

Forensic Methodology

- Visual inspection to observe performance of system for sustainability.
- Limited destructive testing.
- Laboratory testing of samples to compare between original membrane and aged membrane.

Sustainability Checklist

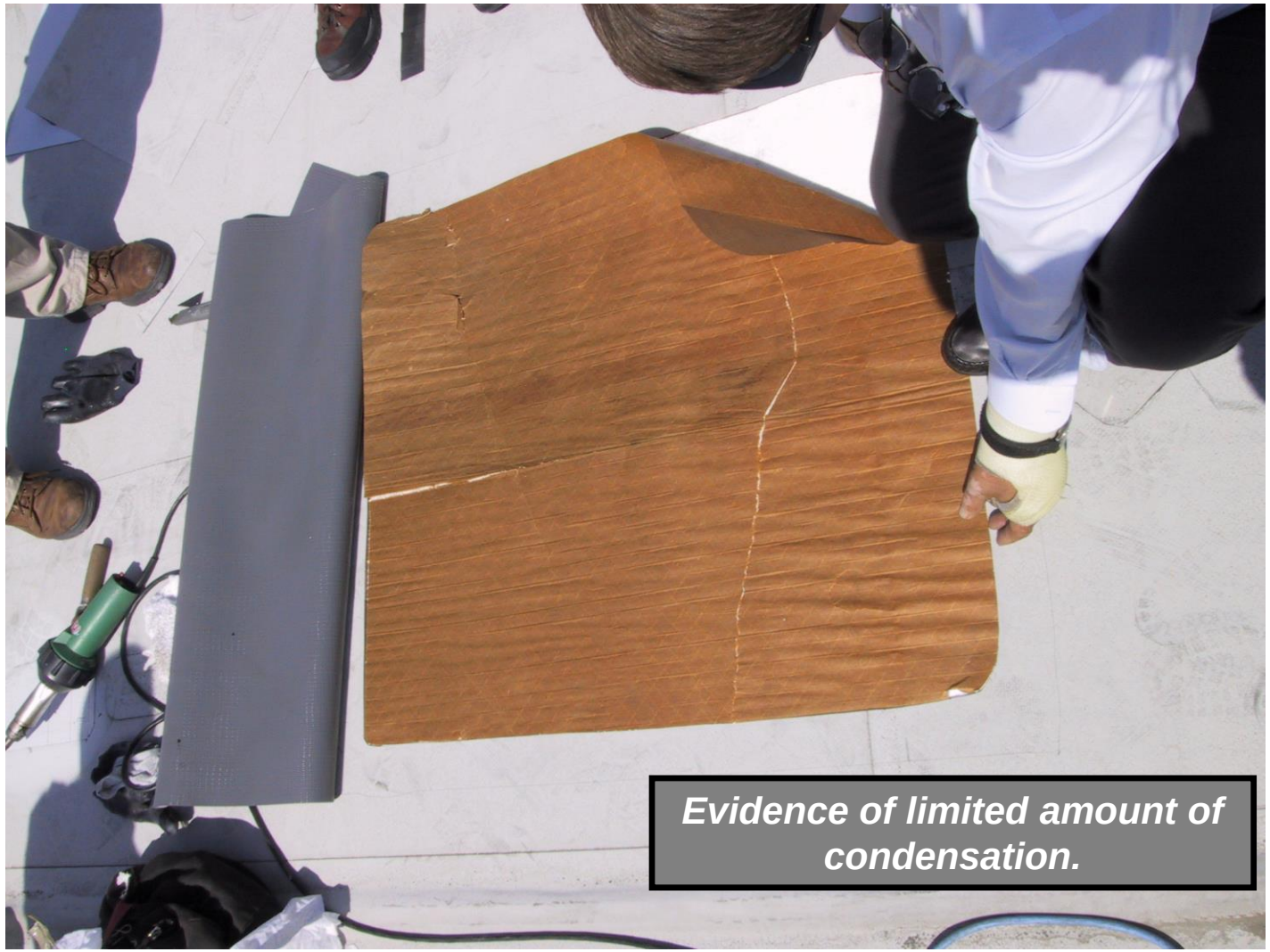
- Roof system's ability to handle foot traffic and impact damage.
- Membrane's ability to handle ponding water and condensate.
- Membrane's ability to be patched and repaired.
- Membrane's physical properties, tensile strength, thickness, bend test, etc.

Sustainability Checklist (con’t)

- Was roof system sustainable for type of use (retail store)?
- Was original design of the roof system adequate for its intended use?
- Was original application (construction) installed per manufacturer’s requirements?

Test Cut Analysis

Test cut exposing rosin paper and insulation.

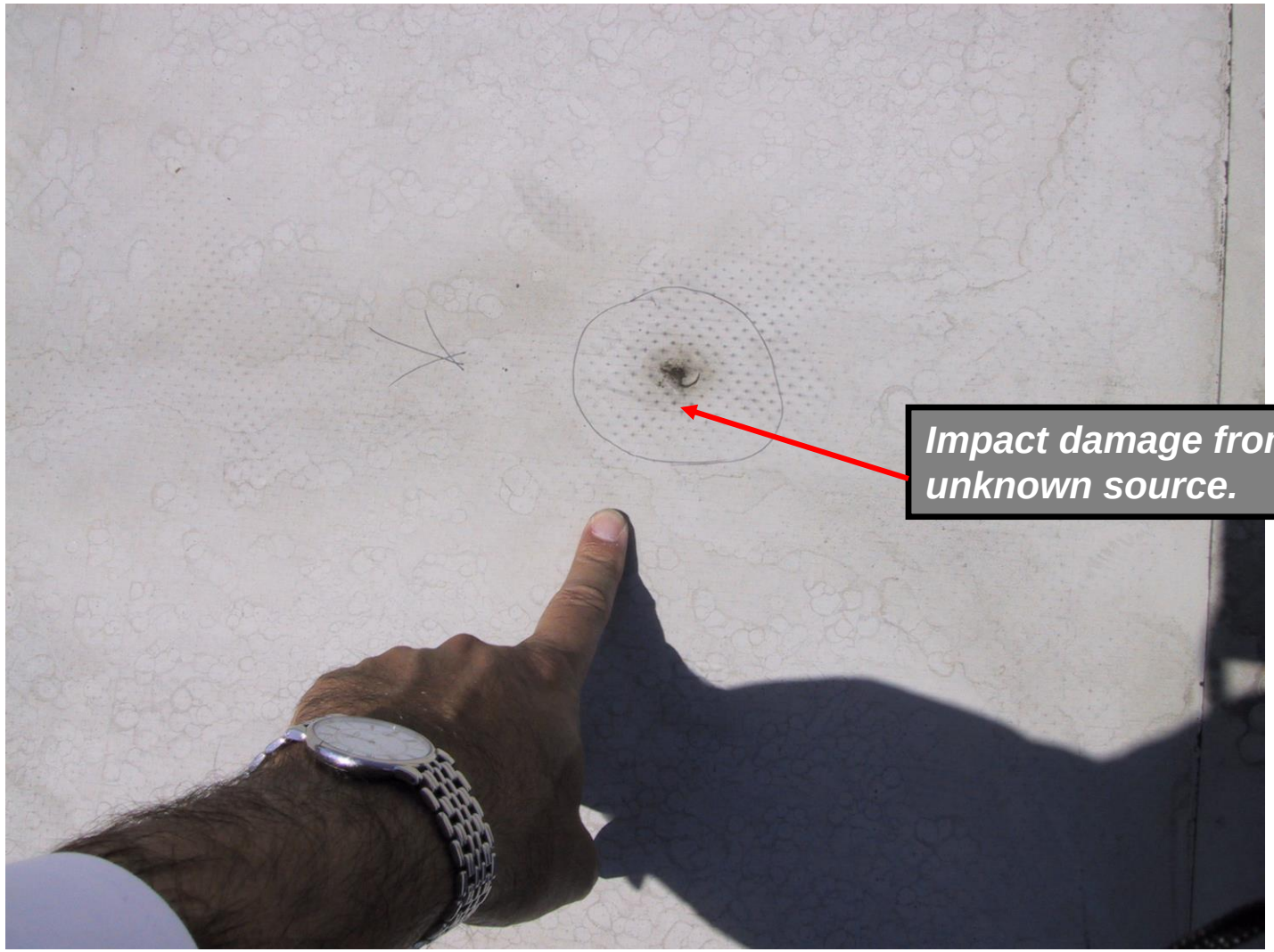


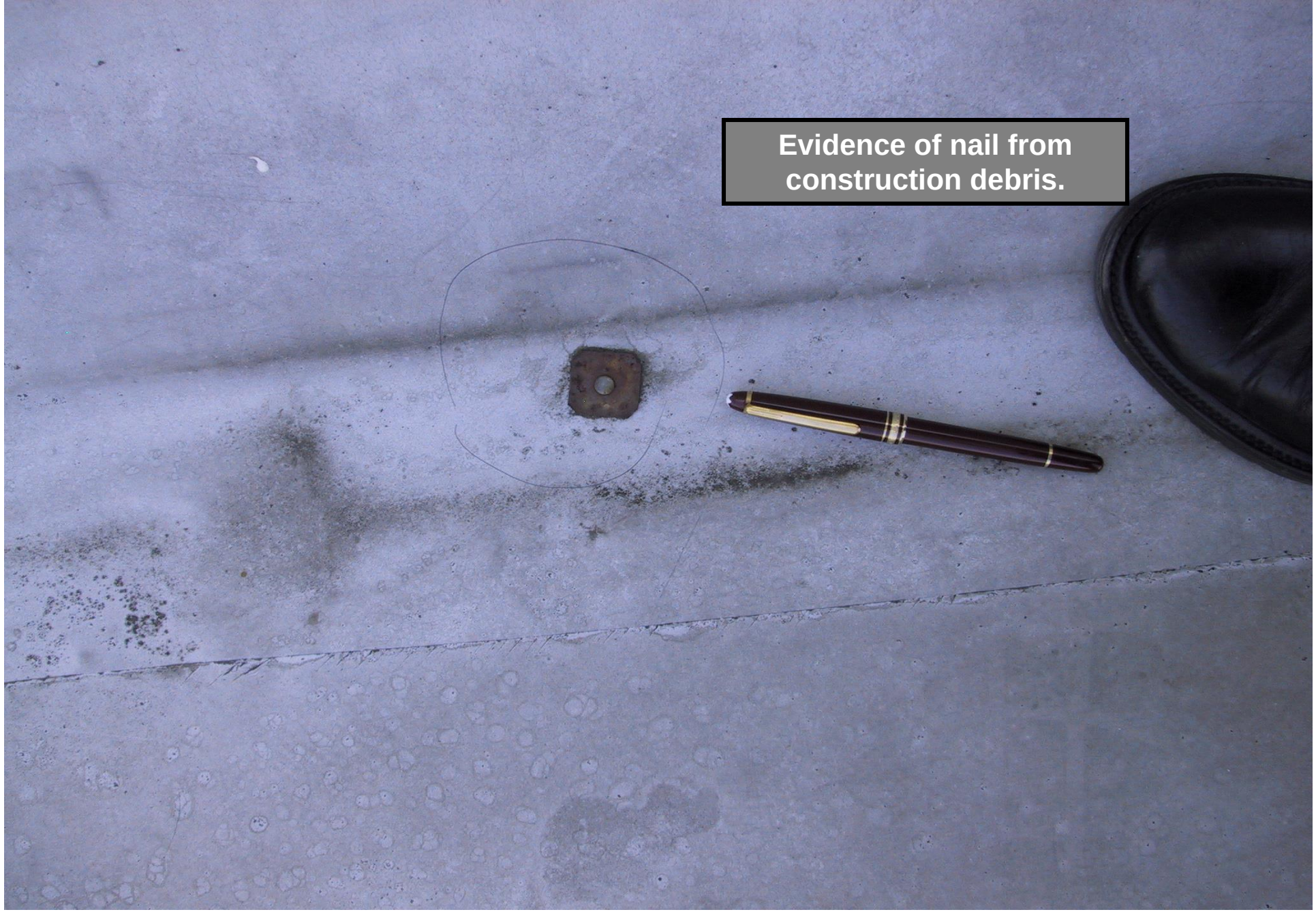
Mechanical bar fastener in excellent condition.

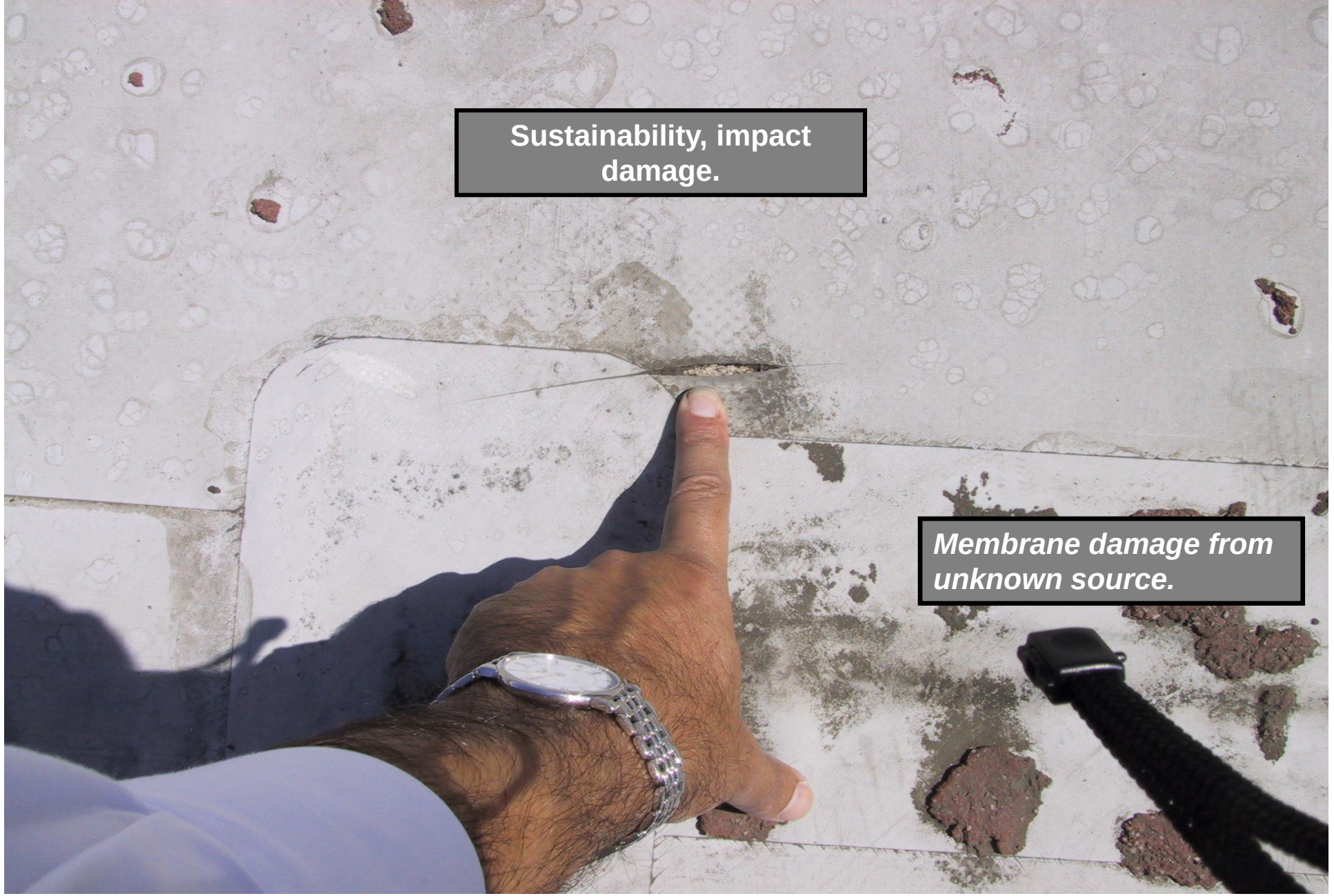

Membrane patching was no problem.

Visual Analysis

Design Issue





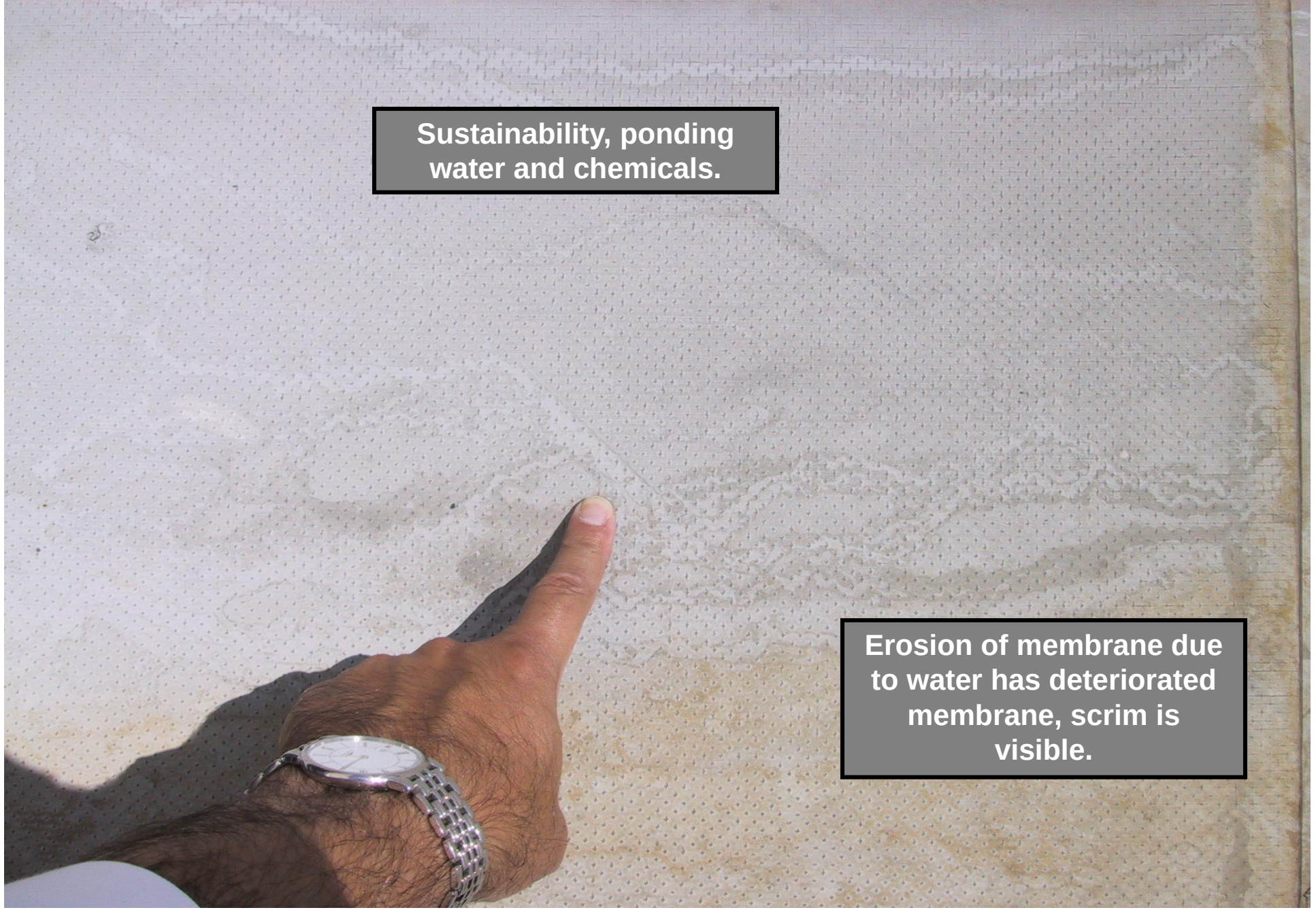


Tenant Improvement Work

New electrical pipe added, pipe jack set in mastic (not properly flashed with single ply) and wood block set in mastic (incompatible with PVC).


Visual signs of chalking and age were observed in areas of ponding water.


Cooling tower and condensate water leaking over roof.



Laboratory Test of this 18 year old single ply

- Samples tested for thickness
- Tensile strength
- Shrinkage and dimensional change
- Seam strength

- 95%+ samples met original membrane test results

Sustainability Score

- MEMBRANE MATERIAL
  - Field areas of membrane performance good/excellent 20+ years
  - Easy to patch
- TRAFFIC AND IMPACT DAMAGE
  - Susceptible from impact damage
  - Damage easy to identify and repair

Sustainability Score

- DESIGN
  - Original poor design of pipe supports caused damage
  - Poor design of roof drainage caused ponding water and damage
  - Poor design of condensation control mechanism caused damage

Sustainability Score

- MAINTENANCE
  - Lack of frequent inspection
  - Lack of proper roof protection during remodel construction
  - Lack of proper maintenance of HVAC equipment damaged the roof
  - New pipe penetrations not properly flashed (use of asphalt mastic)

Lessons Learned (Single Ply)

- Sustainability depends on many factors.
- Membrane's ability to handle normal exposure to sun, rain and elements.
- In 20+ years, expect the roof to go through many different challenges.
- When designing a roof, consider, building may undergo remodel, HVAC replacement, new electrical addition, etc.
- Impact of original design defects.
- Owner's lack of frequent inspections, timely repairs, and use of proper patching techniques.

Garden (Living) Roofs

- Green Benefits:
- Absorb sun’s energy by plants
- Urban Heat Island Mitigation
- Noise Reduction
- Soil absorb rain water and plants use the water. Reduction in storm water run-off
- Cools atmosphere by evaporation

Water Run-Off

- Naturally, a lot of the rain water is absorbed in the soil, support trees and plants
- Urbanization creates hard, non-absorbing surfaces and displace plants and trees
- Hardscaping, pavement surfaces and roofs create run-off. Water is collected and directed to storm drain system, or sewage treatment plants
- Overall reduction of energy/CO2 absorbing plants

Garden Roof Systems

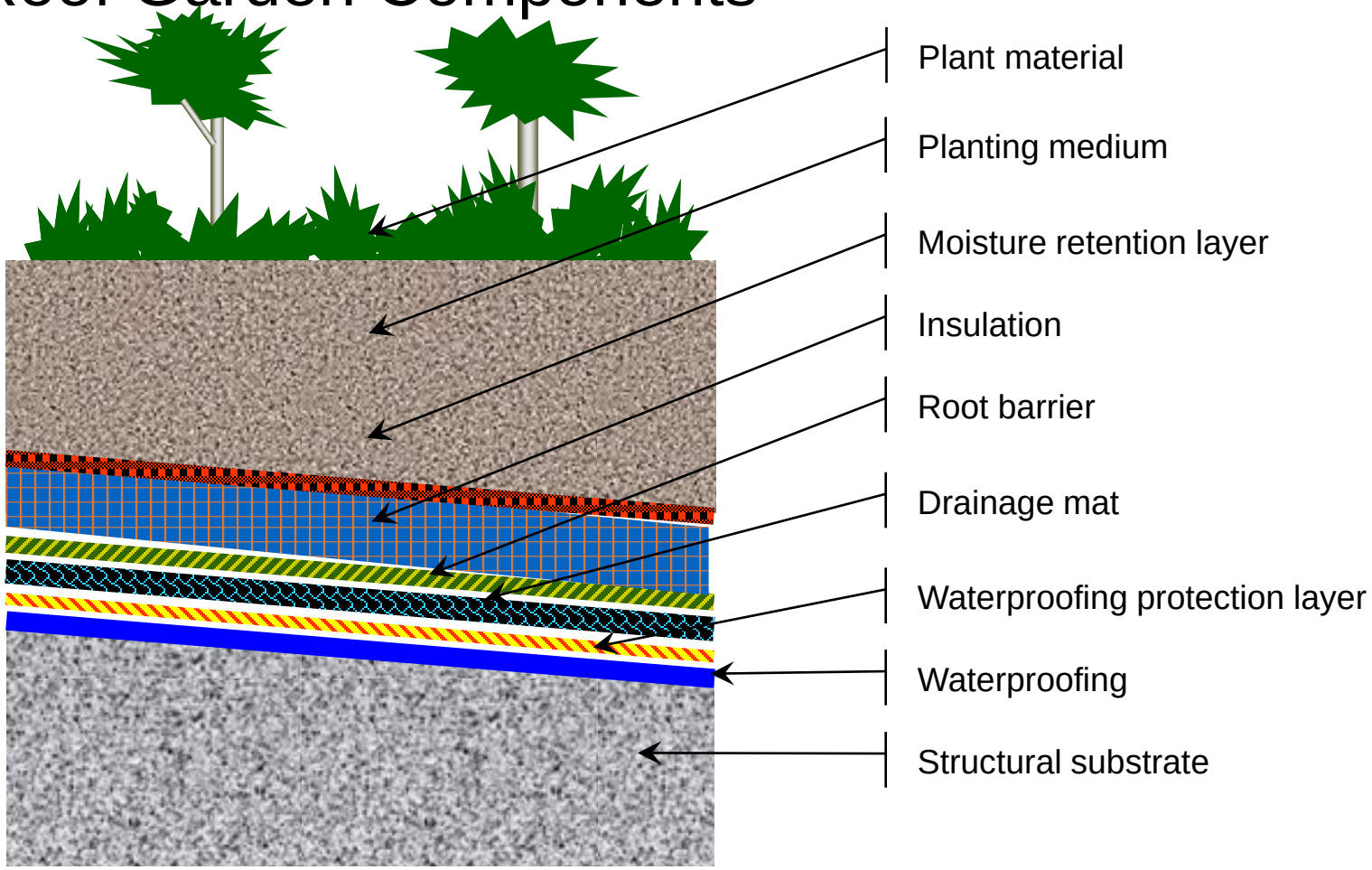
- **Extensive**
- Thin layers of growing medium (3” to 6”)
- Shallow root structures
- Minimal irrigation desired
- Low system weights (15 to 30 psf)
- Used over large areas of roofing

Garden Roof Systems

- **Intensive**
- Extensive soil layers (6” to 8’+)
- Deep root structures and tall plantings
- Irrigation typically required
- Heavy system weights (30 to >100 psf)
- Typically limited layout (but not always)

Garden Roof Systems

- Typical Roof Garden Components



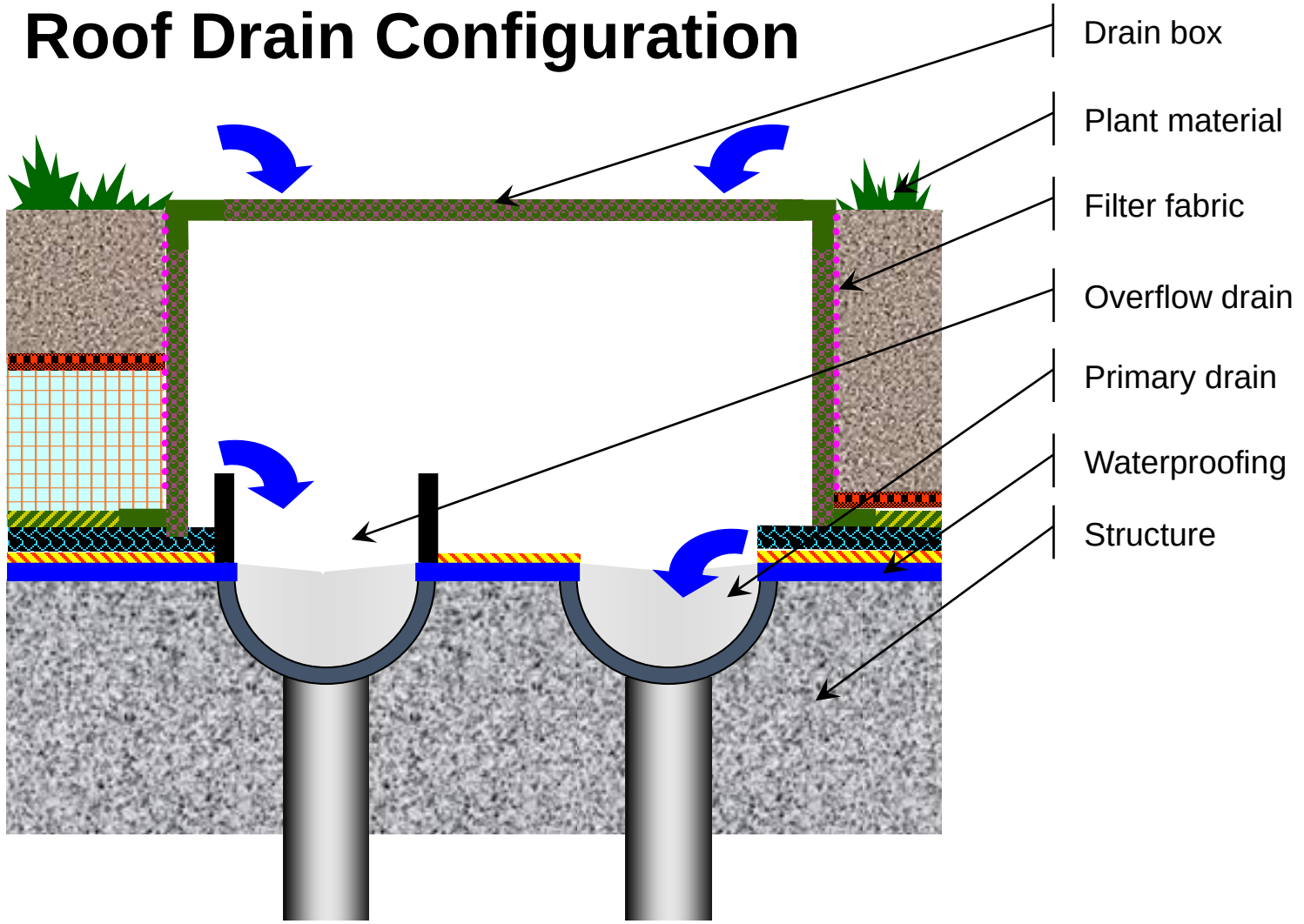
Roof Garden Components

- **Drainage**
- Slope the waterproofing substrate 2% min.
- IBC 2006 Section 1507
- All* low-slope roof membranes to:

> ***"…have a design slope of a minimum of one-fourth unit vertical in 12 units horizontal (2% slope) for drainage."***

Roof Garden Components

Roof Drain Configuration



Roof Garden Components

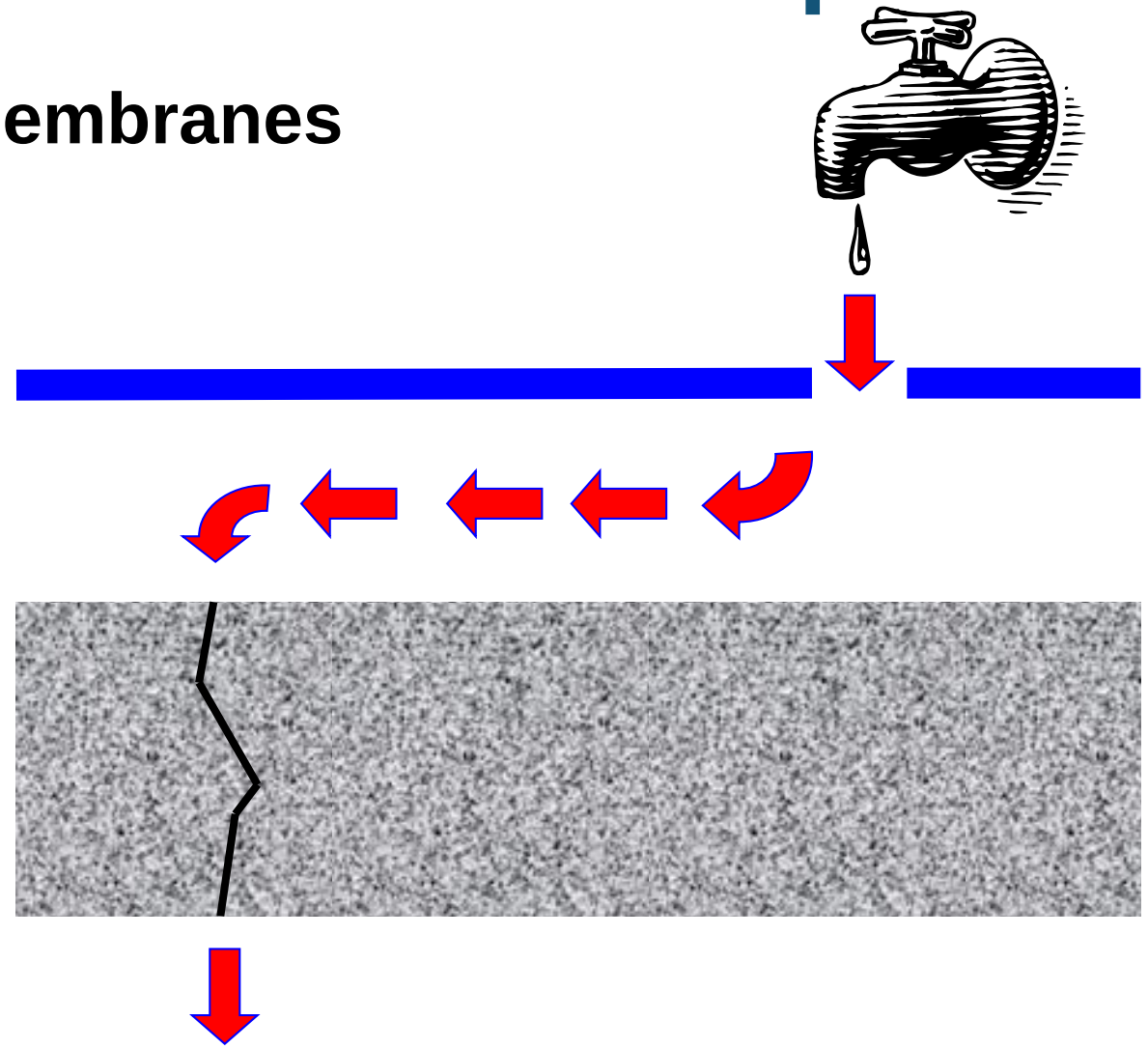
- **Waterproofing**
- System component that keeps us dry
- Lowest cost element in the garden system
- Most expensive to correct if it fails
- Select systems that have long track record
- Select stable manufacturers
- Recommend fully adhered (bonded) systems

Roof Garden Components

- **Waterproofing**
- Two Major Categories
  - Fluid Applied
    - Almost always fully bonded to substrate
  - Sheet Applied Membranes
    - May be:
      - fully bonded
      - partially bonded
      - loose laid

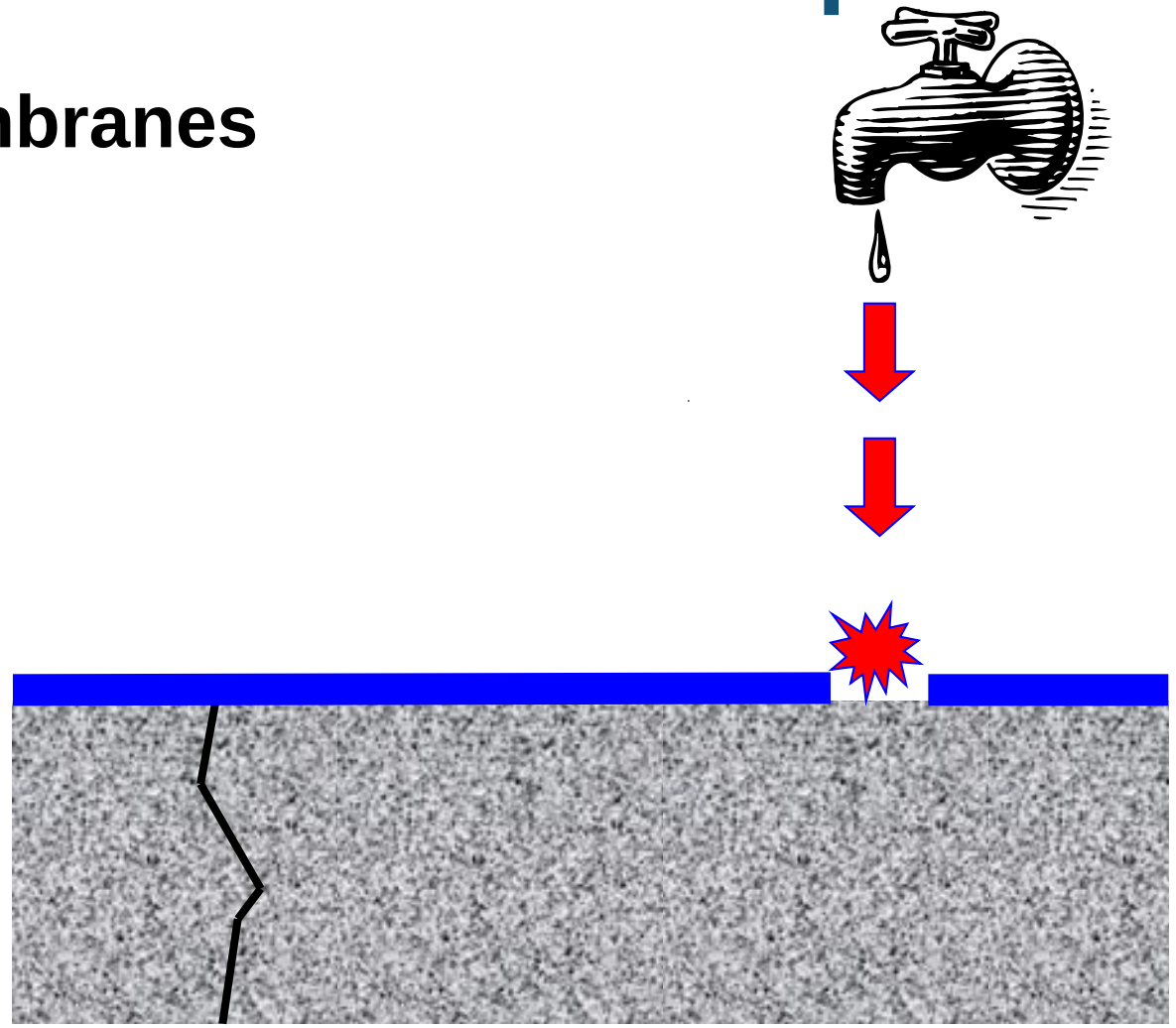
Roof Garden Components

- **Unbonded Membranes**



Roof Garden Components

- **Bonded Membranes**



Roof Garden Components

- **Waterproofing**
- Fluid Applied – Cold Process
  - Cold fluid that cures into elastomeric mass
    - Solvent cure (water, alcohol or light petroleum)
    - Catalyst cure (water)
    - Chemical reaction cure
  - Best for:
    - Remote locations where kettle is impractical
    - Small areas where large quantities are not needed

Roof Garden Components

- **Waterproofing**
- Fluid Applied – Heated
  - Hot fluid that cools into elastomeric mass
    - Most are rubberized asphalt systems
    - Very few rubberized cold tar pitch systems
    - Heated in a oil jacketed kettle at “lower” temperature
  - Best for:
    - Large areas where bulk materials are desired
    - Phased construction sites
    - Very forgiving of construction activities- easy to fix

Roof Garden Components

- **Waterproofing: Hot** *Fluid Applied Application*

Roof Garden Components

- **Waterproofing:** *Fluid Applied Application*

Roof Garden Components

- **Waterproofing**
- Sheet Applied Membranes
  - Thermoplastic sheets
    - Factory fabricated sheets 60 to 210 mils thick
    - Sheet sizes are typically 2 meters wide
    - Most common material is PVC or PVC Alloy
    - All sheets are fiberglass or polyester reinforced
    - Seams are fused by:
      - Hot air welding (thermoplastic like PVC)
      - Chemical fusing (thermoset like HDPE)

Roof Garden Components

- **Waterproofing:** *Sheet Membrane Application*

Roof Garden Components

- **Waterproofing:** *Sheet Membrane Application*

Roof Garden Components

- **Waterproofing:** *Sheet Membrane Application*

Roof Garden Components

- **Waterproofing:** *Sheet Membrane Application*

Roof Garden Components

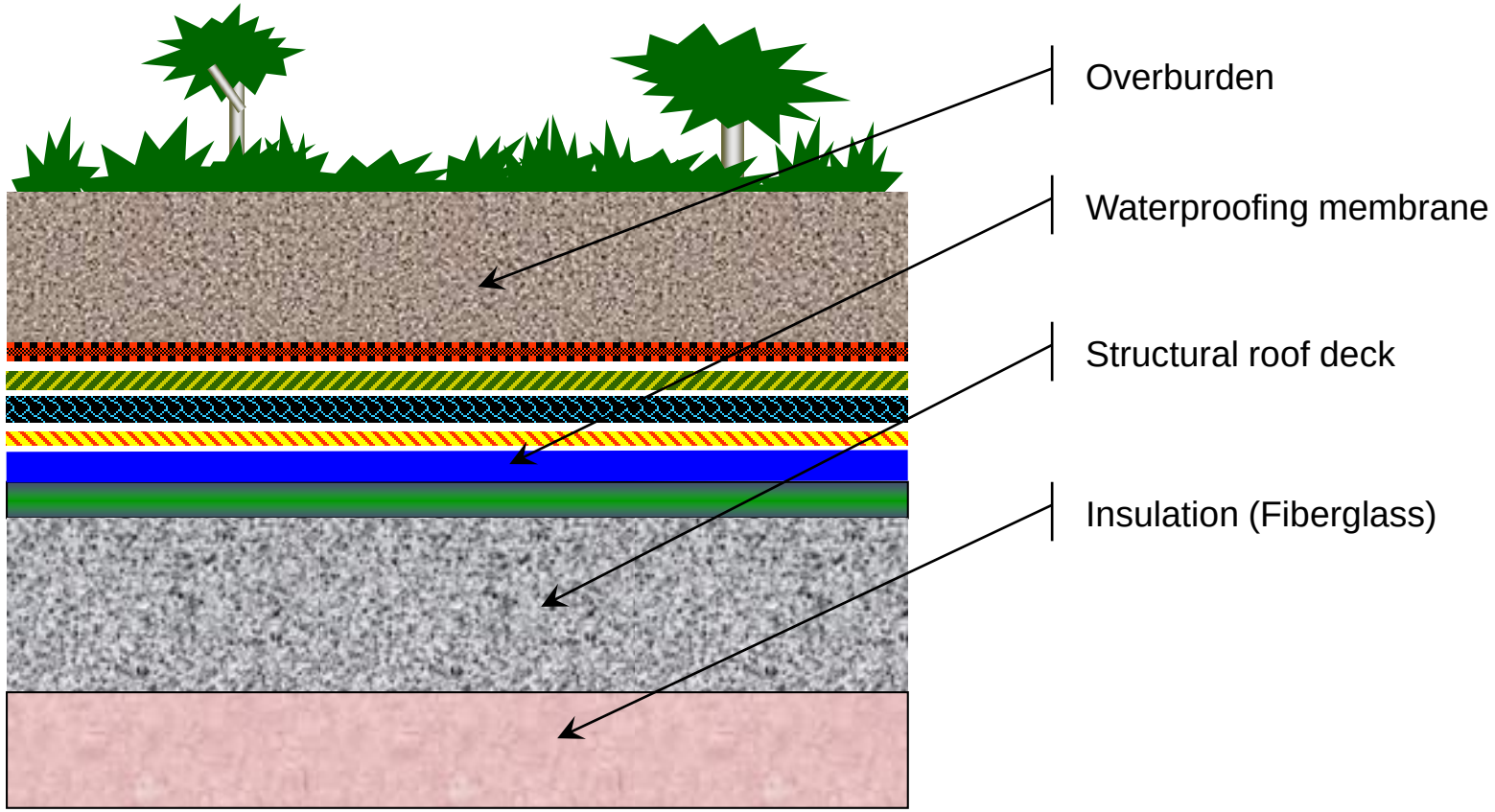
- **Waterproofing:** *Sheet Membrane Application*

Roof Garden Components

- **Insulation**
- Where to place?
  - Under roof deck (☺)
  - Above waterproofing membrane (😐)
  - Between roof deck and membrane (☹)

Roof Garden Components

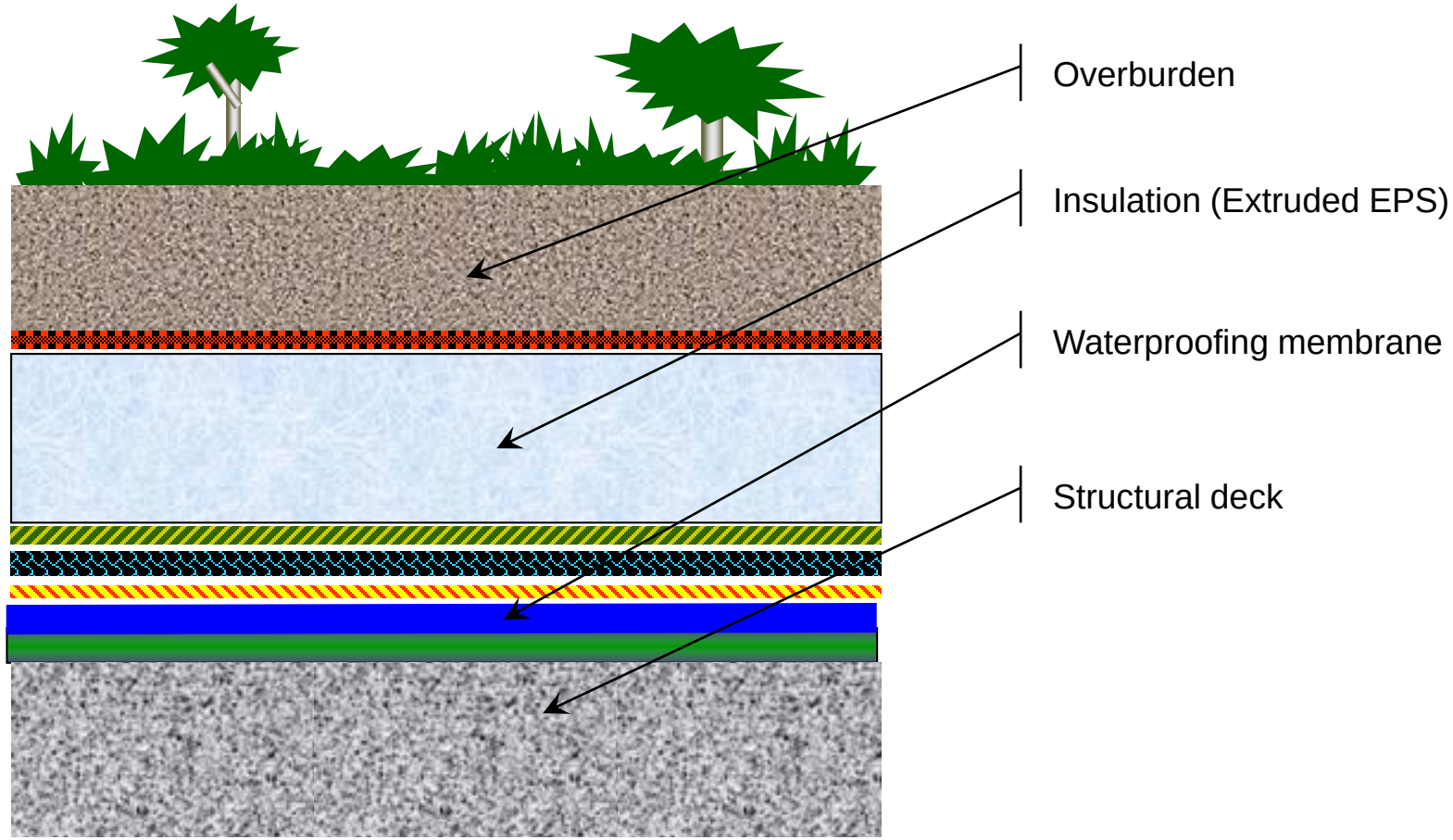
- **Insulation:** *Under Roof Deck*



Insulation is independent of waterproofing and roof garden

Roof Garden Components

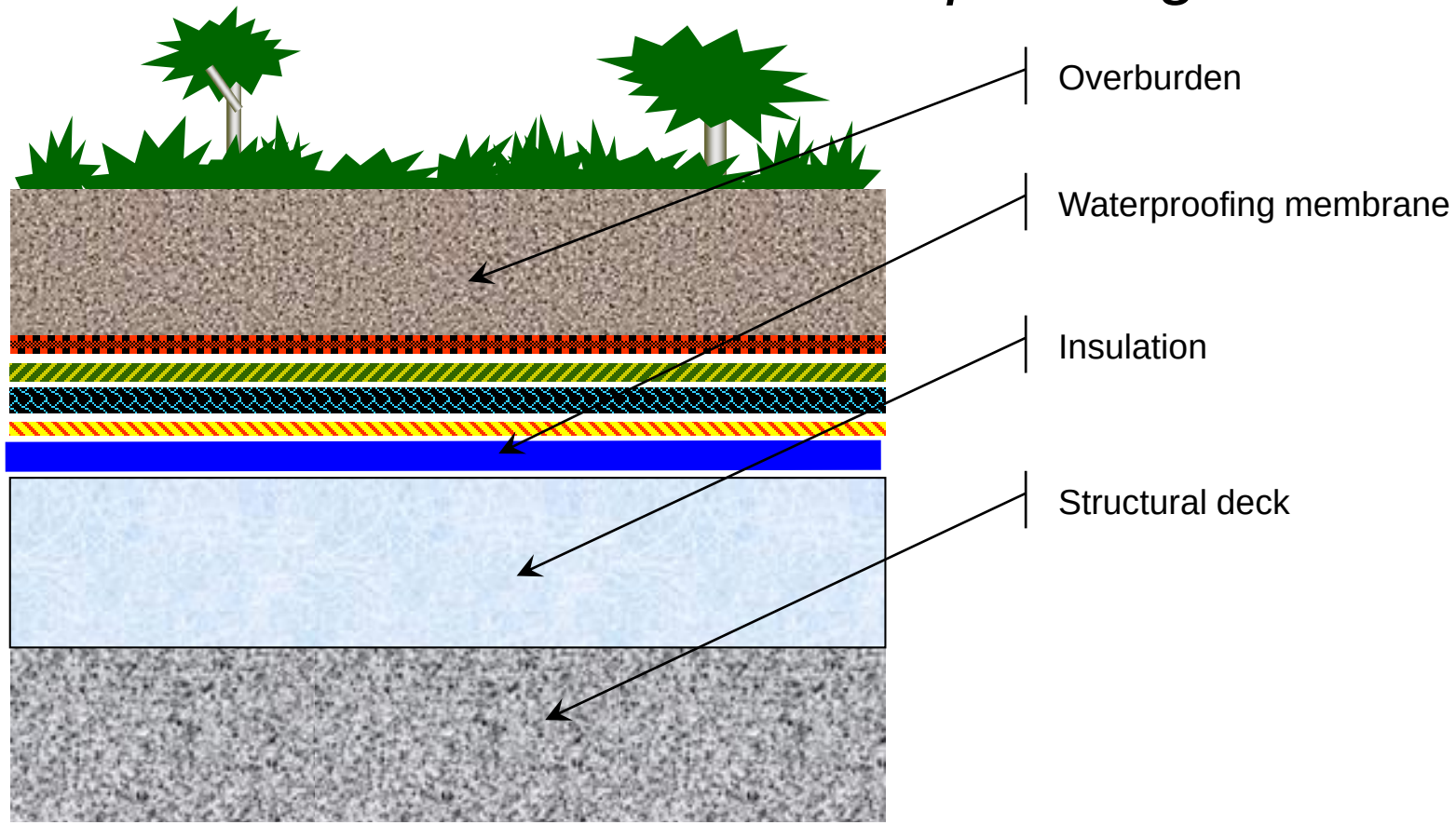
- **Insulation:** *Above Waterproofing Membrane*



Insulation must have sufficient compressive strength (60 to 100) psi and must not absorb water

Roof Garden Components

- **Insulation:** *Between Deck and Waterproofing*



Don’t do it…you will never locate a leak

Roof Garden Components

- **Insulation:** *Closed Cell Foam*

Garden (Living) Roof – One with Nature

Roof Garden Components

- **Questions?**