Sustainable Airfield Concrete Pavements

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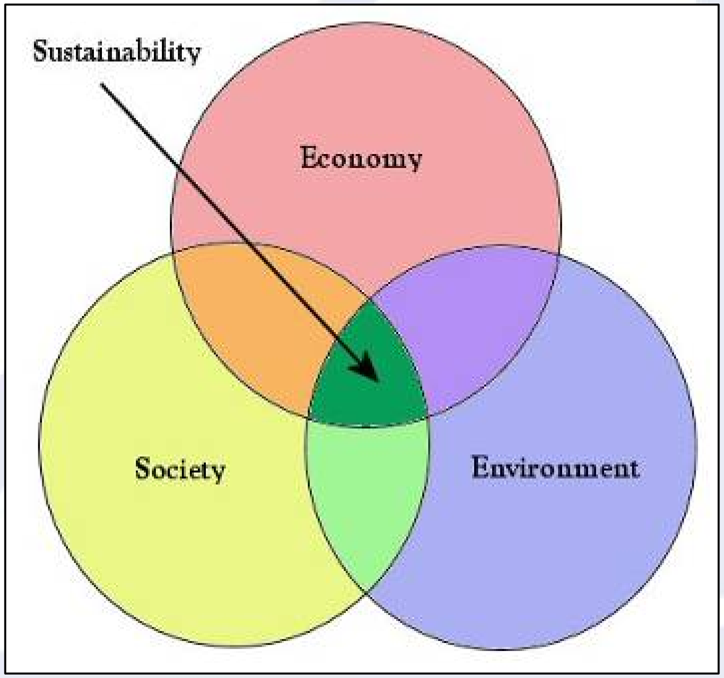
Concrete Pavements and Sustainability

SUSTAINABILITY?

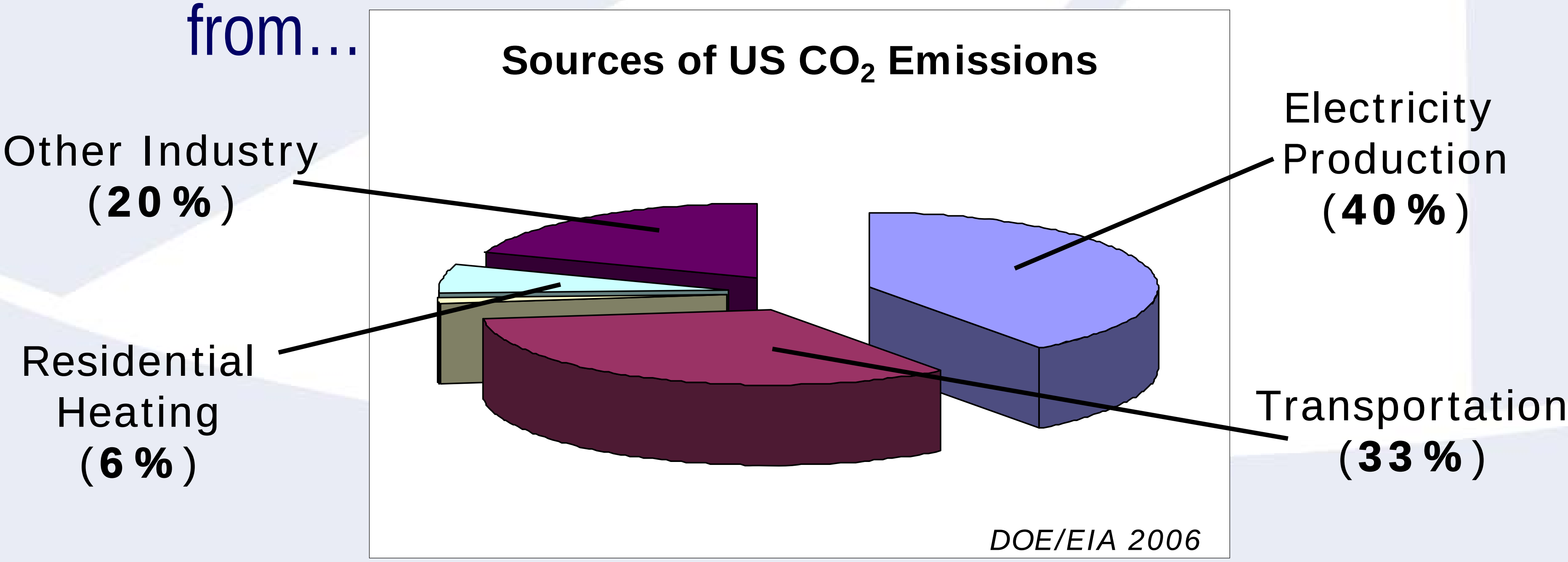
What is Sustainability?

- *“Meet[ing] the needs of the present without compromising the ability of future generations to meet their own needs”* *[UN General Assembly 1987]*
- Triple bottom line:
  - Environmental
  - Social
  - Economic



What about Cement?

- Although cement is a relatively energy and CO_2 intensive material to manufacture…* cement manufacturing accounts for only 1.5% of US man-made CO_2 – the balance comes from…

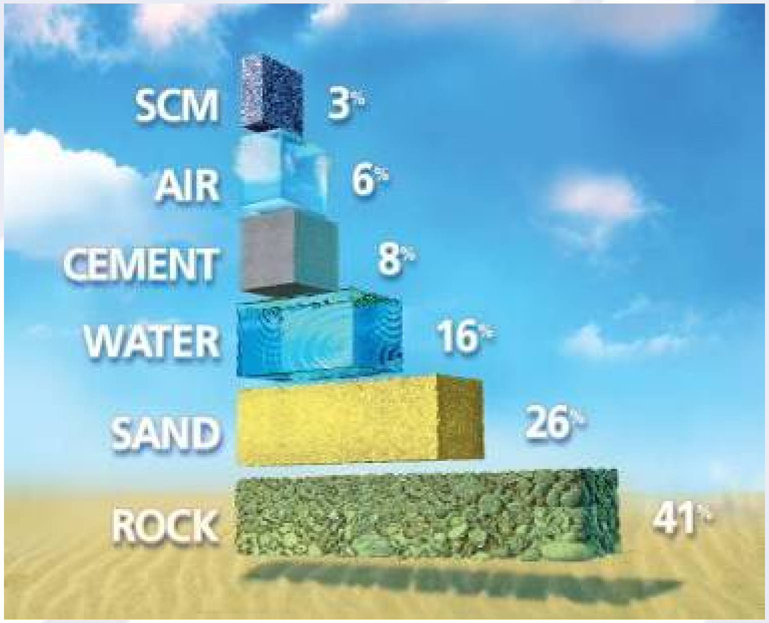


What about Cement?

- Includes CO_2 emissions of cement manufacture for all concrete and masonry uses (not just pavement)…
- Concrete most widely used material on earth, apart from water *(www.wbcsd.org)*
- Cement industry has lowered the amount of energy required to make a ton of cement by 33% since 1972
- CMS program pledge another 10% by 2020

What about Concrete?

- 92% of paving concrete is comprised of materials that have a low CO_2 footprint…
- All these materials are available/manufactured here in the US, often locally



- Overall sustainability benefits associated with use of concrete for pavements dramatically outweigh the impact of the cement manufacturing process…

Concrete Pavements and Sustainability

LONGEVITY

Concrete Pavements!

- **Longevity** - hallmark of concrete pavements
- I-10 east of Los Angeles: Originally constructed in 1946 as part of US Route 66
  - Ground in 1965 (1st continuous grinding project in north America) to correct joint spalling and faulting
  - Reground for 3rd lease on life in 1984
  - In 1997 the 51 yr old PCCP was ground again
  - Today the concrete is carrying 240,000 vpd…

A true testament to concrete pavement sustainability!

Longevity means…

Less-frequent reconstruction

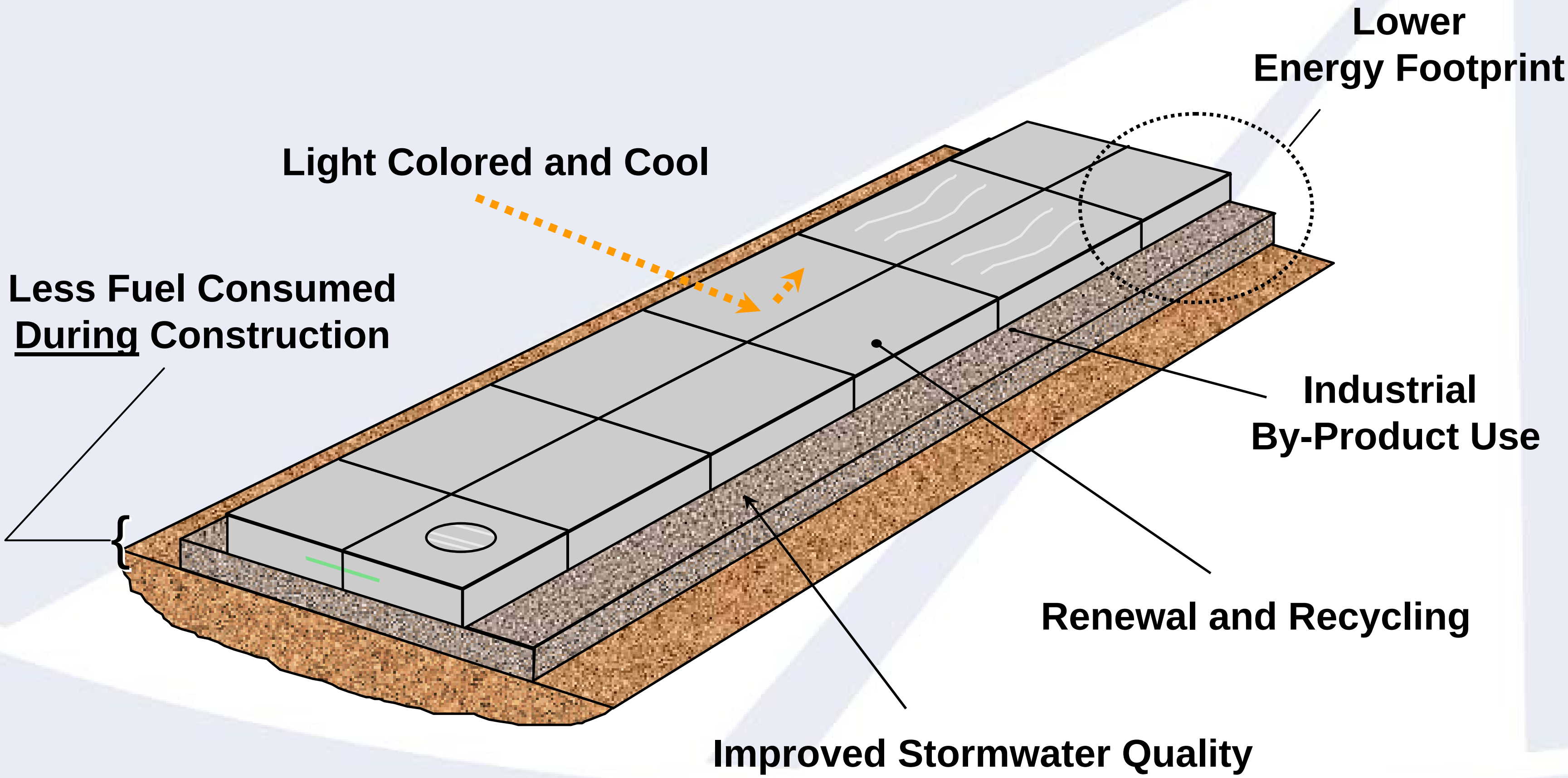
- Lower consumption of raw materials
  - Cement, aggregates, steel
- Lower energy consumption
  - Raw material processing
  - Rehab and reconstruction

Concrete Pavements and Sustainability

OTHER BENEFITS

Sustainable Benefits *Beyond* Longevity

Can be achieved through design and mixture optimization!



Concrete Pavements and Sustainability

Lower Fuel Consumption During Construction

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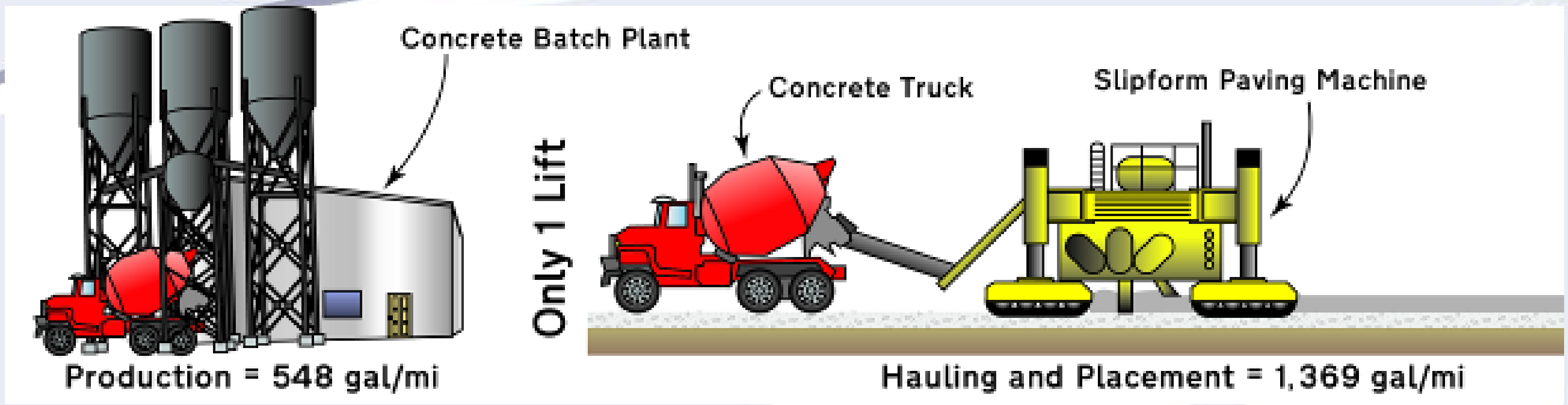
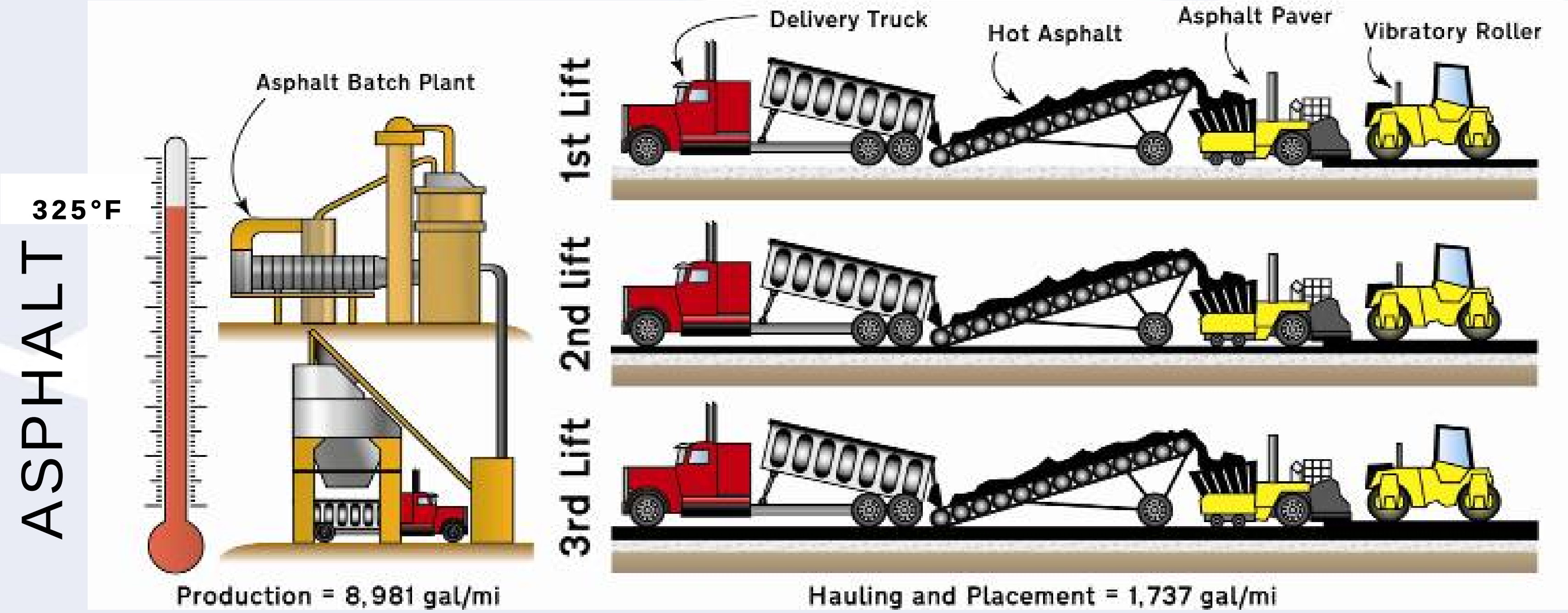
CONCRETE



ASPHALT



Concrete Pavements and Sustainability

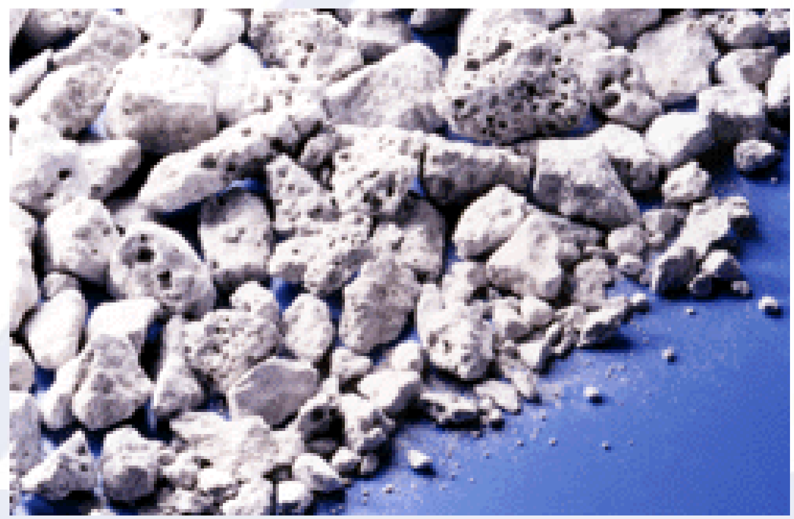
Use of Industrial By-Products

Use of Industrial By-Products

- Concrete is a huge consumer of industrial by-products
  - Up to 25% Fly Ash (from burning coal)
  - Up to 50% slag cement (from iron smelting of ore)
  - Others, ternary mixtures, and blended cements
- Opportunities for **mixture optimization** that:
  - Lowers cement intensity
  - Reduces disposal
  - Improves performance and longevity
  - Reduces cost!

Use of Industrial By-Products

- Over 15,000,000 tons fly ash used in concrete in US annually
  (*ACCA 2006*)
  and growing…
- Slag cement…
- Slag aggregates (from steel making) are also used in concrete…



Concrete Pavements and Sustainability

Renew-ability, Recycling and Reuse

Renew-ability, Recycling and Reuse

- Renewal through grinding
  - Caltrans study suggests an additional 17 years service life gained *(ARA 2005)*
  - Design for multiple grind activities…
  - Minimal use of energy and natural resources

Renew-ability, Recycling and Reuse

- What is the most recycled material in United States?
- CONCRETE, according to Construction Materials Recycling Association *(2008)*

Renew-ability, Recycling and Reuse

- Concrete is 100% recyclable
- Recycled concrete aggregate (RCA) can be used in:
  - new concrete
  - subbases
  - granular fill

- Opportunities for on-site operations that reduce time and energy use…

Final Report Project 03-5 July, 2006 recycled concrete.pdf (SECURED) - Adobe Reader

File Edit View Window Help

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An *IPRF* Research Report
Innovative Pavement Research Foundation
Airport Concrete Pavement Technology Program

Report IPRF-01-G-002-03-5

Evaluation, Design and Construction Techniques for Airfield Concrete Pavement Used as Recycled Material for Base

Programs Management Office
5420 Old Orchard Road
Skokie, IL 60077

July, 2006

Concrete Pavements and Sustainability

Light Colored and Cool

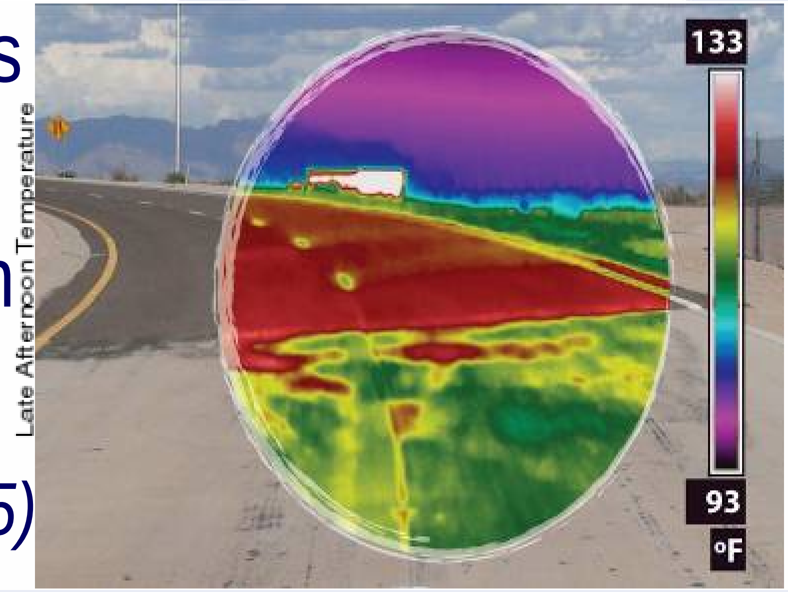
Light Colored and Cool

Enhanced Visibility:

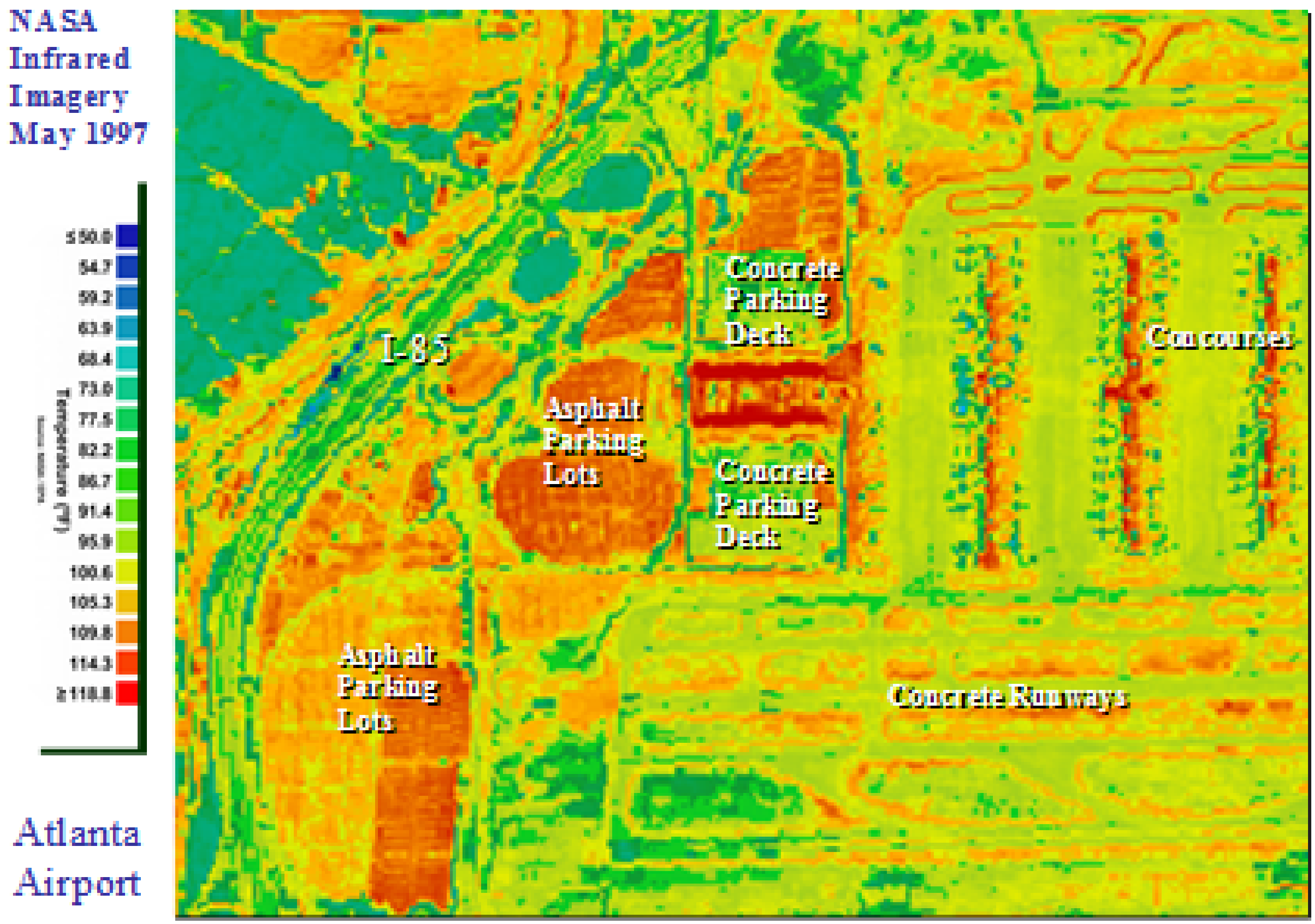
Light Colored and **Cool**

Urban Heat Island Mitigation:

- Urban areas up to 9°F warmer due to UHI → greater energy use and resulting pollution
- PCCP is an effective mitigation strategy
  - lower city temperatures
  - lower cooling costs
  - reduce smog formation
- Pot. energy savings $5B in US alone *(LBL'05)*



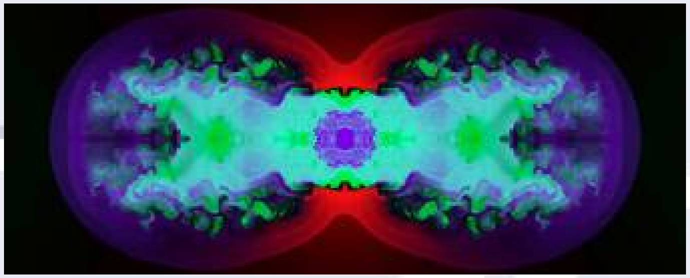
NASA Infrared Imagery Atlanta Airport May 1997



Concrete Pavements and Sustainability

Lower Energy Footprint

Lower Energy Footprint

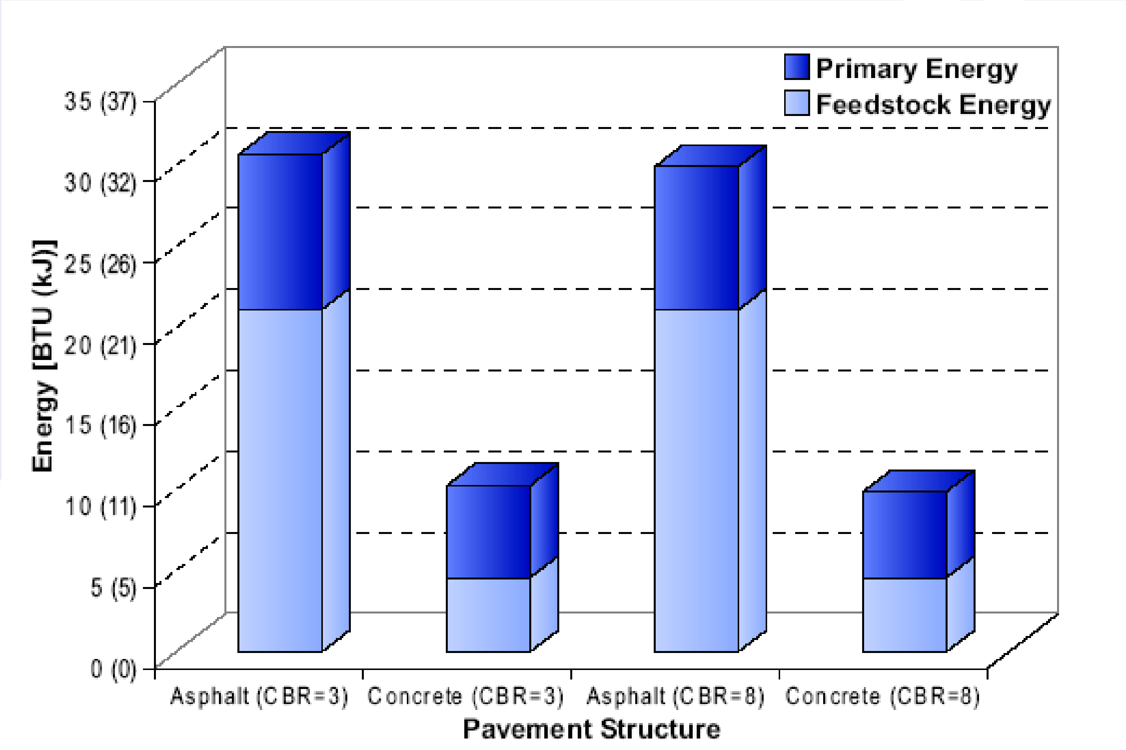


- Embodied primary energy is a measure of all energy use associated with the production, delivery and maintenance of a facility over a specific period
- Includes both <u>feedstock</u> and <u>primary</u> energies
- ASMI analyzed total embodied primary energy for various equivalent concrete & asphalt pavement structures for several different road types in various geographic regions over a period of 50 years

(Athena '06)

Lower Energy Footprint

- Considers:
  - Extracting
  - Processing
  - Production
  - Construction
  - Maintenance
  - Rehabiltation



- Concrete lower for all classes analyzed!

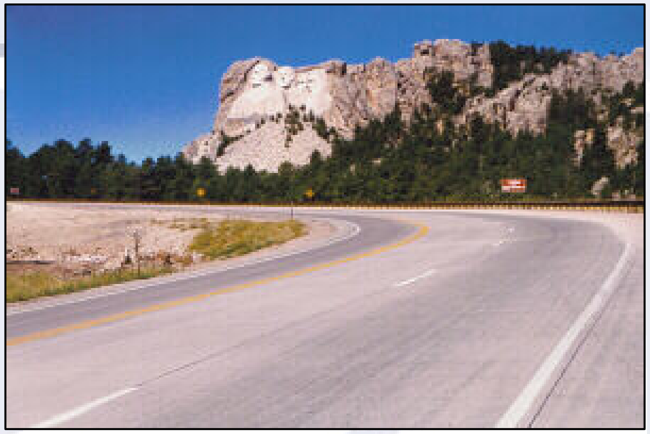
  23% **lower** for urban freeways

  71% lower if feedstock energy is considered!

Concrete Pavements and Sustainability

CONCLUSIONS

Summary



Concrete pavement –

a truly sustainable choice!

- Lower overall energy footprint!
  - Long lasting and renewable
  - Less fuel and CO_2 to construct
  - Less resource intensive

Summary

- Use of industrial by-products,
- Renewal, recycle, recapture
- Urban heat island mitigation, better visibility

All of this can be achieved through design and mixture optimization!

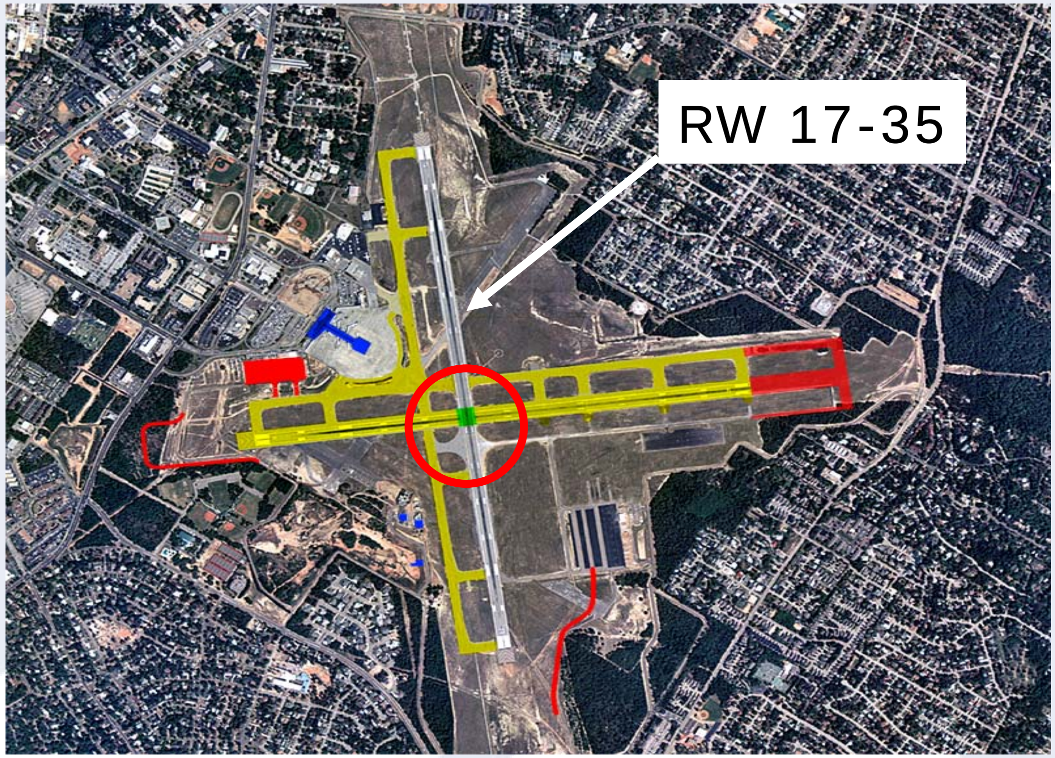
Cost Comparison …

- General thought is asphalt pavement is less expensive
- Life-cycle cost of PCC can be less expensive
- **PCC can be first cost competitive**
- First cost is not always what it seems
- Pensacola, Florida case study …

PNS Background

- Fastest growing Airport between Jacksonville and New Orleans
- Planned $27 million RW rehab
- RW – 7000’ X 150”

Background



- May 2005 let rehab project
- 12” P-401
  5” P-154
  12” Compacted Subgrade
- Mandatory Pre-bid

- 3 Contractors
- 1 dropped out
- 2 joined forces
- Submitted single bid – $9 million over budget

Rejected the Single Bid

Engineer Revised Plans

- Added Concrete Option
- Design Criteria
  - Boeing 757 – 5781 annual operations
  - Used FAA AC 150/5320-6D
    - Equivalent Aircraft as design aircraft
  - Used LEDFAA to Compare
    - Fleet mix – sums cumulative damage from each aircraft

Pavement Typical Sections

Asphalt Section

4” P-401 Surface

8” P-401 Base

5” P-154 Subbase

12” Compacted Subgrade

So Why The Difference?

Concrete Section

17” P-501

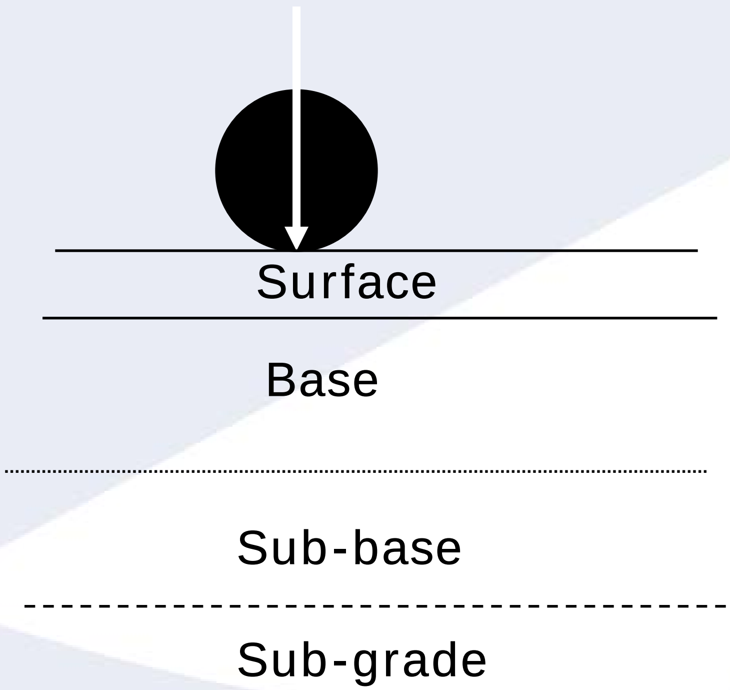
6” Cemented Treated Base

12” Compacted Subgrade

The Pavement Systems

Layered Elastic Concept

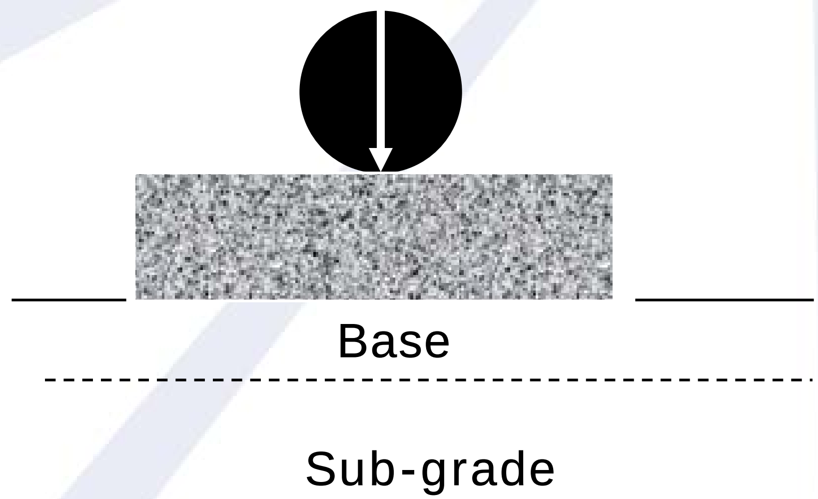
Flexible Pavement



E decreases with depth
Infinite lateral direction

Linear stress/stain Theory

Rigid Pavement



Composite Sub-base behavior
(dense liquid)

What are the issues?

- Concrete design is much more conservative – by design
- Fatigue design > 40 years for PCC
- Asphalt typically requires rehab in 15-20 years
- Concrete Contractor can not be competitive “head to head”
- Life-Cycle Cost would “level the playing field”

Life Cycle Cost Analysis (LCCA)

- How do we compare unequal designs with unequal lives?
- No Real Guidance under FAA
- AIP Handbook, Chapter 9, Paragraph 910, Life Cycle Costs in Competitive Sealed Bids
- FAA AC 150/5320-6D, Appendix 1, Economic Analysis, Example Problem

LCCA Development

- Format Developed Based on FAA Model
- Received Input from ACPA, AI and FAA
- General Parameters were:
  - Design Life - 20 Years (FAA Requirement)
  - Concrete Expected Life - 40 Years
  - Asphalt Expected Life - 30 Years
  - Discount Rate (Inflation Factor) - 5%
  - Maintenance Requirement for each alternative

Maintenance Requirements

- Concrete Runway Maintenance Activities
  - Year 0 - Insertion of TOTAL BID PRICE of Concrete Bid
  - Year 15 - Joint Seal Replacement (Maintenance)
  - Year 19 - Crack Sealing (Maintenance)
  - Year 20 - Estimated 5% Slab Replacement (Maintenance)
- Asphalt Runway Maintenance & Rehabilitation Activities
  - Year 0 - Insertion of TOTAL BID PRICE of Asphalt Bid
  - Year 6 - Pavement Preservation System (Maintenance)
  - Year 13 - Pavement Preservation System (Maintenance)
  - Year 15 – 3” Mill and Overlay (Rehabilitation)

Development of Salvage Value

- Concrete Runway LCCA
  - Took Full Bid Price at Year 0 and Used Straight Line Depreciation over 20 Year Design Period
  - Total Cost / 40 Years x 20 Years (Remaining Life) x Present Worth Factor at Year 20 = Salvage Value
- Asphalt Runway LCCA
  - Took Full Bid Price at Year 0 and Used Straight Line Depreciation over 20 Year Design Period PLUS Mill & Overlay at Year 15 over 5 Year Remaining Design Period
  - Total Cost / 30 Years x 10 Years (Remaining Life) x Present Worth Factor at Year 20 PLUS Mill & Overlay Cost / 15 Years x 10 Years (Remaining Life) x Present Worth Factor at Year 20 = Salvage Value
- Submitted Electronic Spreadsheets to All Bidders, Plan Holders & Plan Rooms

Bids Received

Life-Cycle Cost Analysis - Pensacola Airport Runway 17/35		
As-Read Bid Results	PCCP	Asphalt
Bidder 1	$23,591,682.40	$22,019,551.24
Bidder 2	$26,245,083.56	$21,767,513.21
Bidder 3	$30,053,562.17	No Bid
Bidder 4	$32,328,955.70	No Bid

Present Worth Model

$$PW = C + \sum_{i=1}^{m} M_i \left(\frac{1}{1+r} \right)^{n_i} - S \left(\frac{1}{1+r} \right)^{z}$$

- PW = Present Worth
- C = Initial Construction Cost
- m = number of maintenance or rehab activities
- M_i = Cost of the i^{th} activity
- r = discount rate
- n_i = number of years from the present of the i^{th} activity
- S = salvage value at the end of the analysis period
- Z = length of the analysis period

Excel Spreadsheet – PCC Option

Runway 17-35 Reconstruction
Pensacola Regional Airport
Life Cycle Cost Analysis Evaluation - Phoenix Construction Services, Inc.
(Low Bid) Concrete Runway

DESIGN LIFE (N):	20
EXPECTED LIFE:	40
INFLATION FACTOR (%):	5

BASE BID - SCHEDULE "A" CONCRETE RUNWAY

YEAR (N)	ACTIVITY	ITEM DESCRIPTION	UNIT	COST PER SYD	QUANTITY	TOTAL COST	PRESENT WORTH FACTOR (5%)	PRESENT WORTH
0	INITIAL CONSTRUCTION	17" PCC/6"CTB	SYD	$ 181.04	130,309	$23,591,682.40	1.0000	$23,591,682.40
1							0.9524	$ -
2							0.9070	$ -
3							0.8638	$ -
4							0.8227	$ -
5							0.7835	$ -
6							0.7462	$ -
7							0.7107	$ -
8							0.6768	$ -
9							0.6446	$ -
10							0.6139	$ -
11							0.5847	$ -
12							0.5568	$ -
13							0.5303	$ -
14							0.5051	$ -
15	MAINTENANCE	JOINT SEAL REPLACEMENT	LF	$ 1.70	113,233	$192,496	0.4810	$ 92,593.92
16							0.4581	$ -
17							0.4363	$ -
18							0.4155	$ -
19	MAINTENANCE	CRACK SEAL	SYD	$ 1.30	130,309	$169,402	0.3957	$ 67,038.01
20	MAINTENANCE	5% SLAB REPLACEMENT	SYD	$ 100.00	6,515	$651,545	0.3769	$ 245,560.46
SUBTOTAL								$ 23,996,874.78
LESS: SALVAGE VALUE								($4,445,728.49)
PRESENT WORTH				$ 150.04				$ 19,551,146.29

Note: Salvage value is based on straight-line depreciation of the expected life of the last rehabilitation item.

Excel Spreadsheet – AC Option

Runway 17-35 Reconstruction								
Pensacola Regional Airport								
Life Cycle Cost Analysis Evaluation - APAC - Southeast, Inc.								
Low Bid Asphaltic Concrete Runway								
DESIGN LIFE (N):				20				
EXPECTED LIFE:				30				
INFLATION FACTOR: (%)				5				
SCHEDULE "B" ASPHALTIC CONCRETE RUNWAY								
YEAR (N)	ACTIVITY	ITEM DESCRIPTION	UNIT	COST	QUANTITY	TOTAL COST	PERSENT WORTH FACTOR	PRESENT WORTH
0	INITIAL CONSTRUCTION	12" ASPHALT/5" SUBBASE	SYD	$ 167.05	130,309	$21,767,513.21	1.0000	$21,767,513.21
1							0.9524	$ -
2							0.9070	$ -
3							0.8638	$ -
4							0.8227	$ -
5							0.7835	$ -
6	MAINTENANCE	PAVEMENT PRESERVATION SYSTEM	SYD	$ 2.00	130,309	$260,618	0.7462	$ 194,477.16
7							0.7107	$ -
8							0.6768	$ -
9							0.6446	$ -
10							0.6139	$ -
11							0.5847	$ -
12							0.5568	$ -
13	MAINTENANCE	PAVEMENT PRESERVATION SYSTEM	SYD	$ 2.00	130,309	$260,618	0.5303	$ 138,211.29
14							0.5051	$ -
15	REHABILITATION	MILL AND OVERLAY	SYD	$ 15.12	130,309	$1,970,272	0.4810	$ 947,734.56
16							0.4581	$ -
17							0.4363	$ -
18							0.4155	$ -
19							0.3957	$ -
20							0.3769	$ -
SUBTOTAL								$ 23,047,936.22
LESS: SALAVAGE VALUE								($3,229,698.82)
PRESENT WORTH				$ 152.09				$ 19,818,237.41

Notes: Salvage value is based on straight-line depreciation of the expected life of the last rehabilitation item (same as concrete).

Bid Comparison After LCCA

- Asphalt - $19,818,237
- Concrete - $19,551,146 √ Concrete is low bid
- Difference - $267,091

Summary

- Process Isn't for Every Project
- USE Full Bid Price in Year 0
- Make Sure All Maintenance Activities & Rehabilitation Costs are Current, Based on Recent Bids
- Establish reasonable salvage value for each alternative
- Level "playing field" brings competition and value
- FAA Recognized the need for guidance
- Airport Asphalt Pavement Technology Program Report provides guidance

In Conclusion…

- US concrete paving industry strongly supports sustainable development
- Sustainability not often considered when making pavement choices… they should.
- **Environmental** and **social** sustainability can <u>and does</u> go hand-in-hand with **economic** efficiency.
- Level playing field is important to introduce competition for sustainable pavements
- This is a real opportunity for all of society!

THANK YOU!

Please contact Gary L. Mitchell with questions or comments:

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