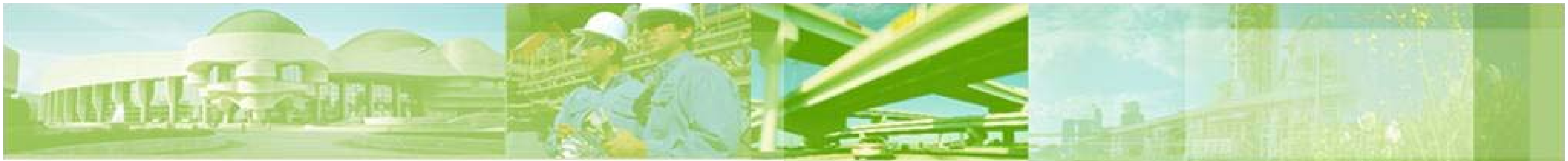


Building a Sustainable Tomorrow

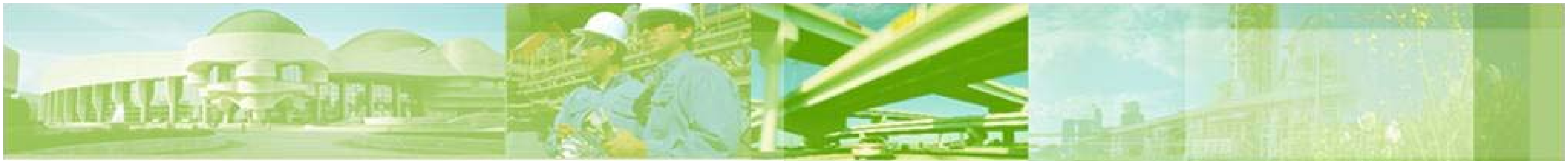
Life Cycle Cost Analysis / Assessment of Airfield Pavements

Presented at
SWIFT Conference
September 13, 2010
By
Tim Smith
Cement Association of Canada


There's plenty of room for all God's creatures.
Right next to the mashed potatoes.
SASKATOON
STEAKS • FISH • WILD GAME

Overview

- Background discussion on Life Cycle Cost Analysis (LCCA)
- LCCA example – Pensacola airport
- AirCost LCCA Tool
- Overview of concrete pavements sustainable benefits
- Life Cycle Assessment (LCA) definition
- LCA components

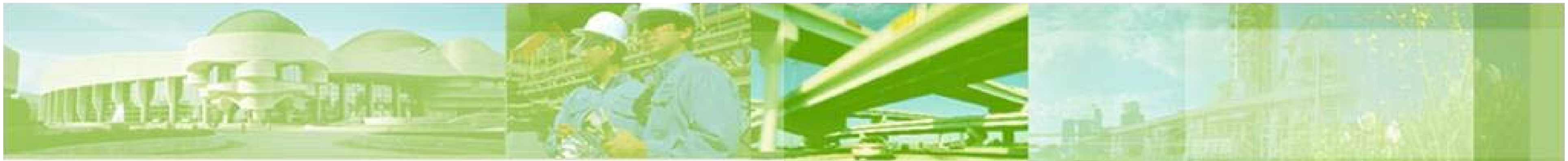


Life Cycle Cost Analysis (LCCA)

- Economic procedure used to compare competing design alternatives
- Considers all significant cost and benefits
- Expressed in equivalent dollars
- Not an engineering tool that determines how long an alternative will last or how well it will perform

Chief Considerations for LCCA Pavement Selection

- Use of comparable design sections
- Airport Authority / Agency costs
- Selection of accurate rehabilitation activities
- Bringing cost back to Present Worth values
- Discount rate (time value of money)
- Length of analysis period
- Salvage value



Agency Costs

- Initial bid price or estimate
- Maintenance costs (recent bid tabs)
- Rehabilitation costs
- Important to have good maintenance management system to provide the most accurate data to give reliable LCCA results
- If no good data is available look for airports with similar traffic levels and climatic / soil conditions

Present Worth Model

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

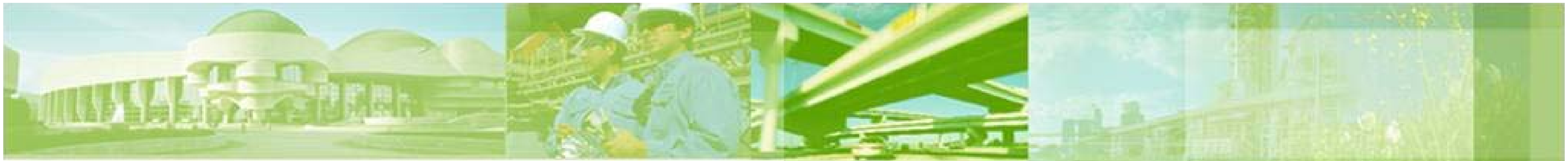
- PW = Present Worth
- C = Initial Construction Cost
- m = number of maintenance or rehab activities
- M_i = Cost of the i^{th} activity
- r = discount rate
- n_i = number of years from the present of the i^{th} activity
- S = salvage value at the end of the analysis period
- Z = length of the analysis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

Discount Rate

- Accounts for the time value of money
- DR = (INT – IFL) / (1 + IFL)
  - DR = discount rate
  - INT = Nominal interest rate
  - IFL = inflation rate
  - Historically the difference between interest rates and inflation rate is 3.0%

Salvage Value

- Reflects any remaining worth of a pavement at the end of the analysis period
- Two components:
  - Remaining service life – value of the pavement as it is continued to be used beyond the analysis period. Structural and functional aspects are evaluated to determine the serviceability and usefulness of the pavement surface
  - Residual value – actual worth of the existing pavement at the end of the service life in terms of the revenue that may be generated form the sale or recycling of the existing pavement
- Recommended that salvage values be considered in in airport LCCA, especially when shorter analysis periods (20 to 30 years) are used



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FAA AC 150/5320-6E Appendix 1. Economic Analysis

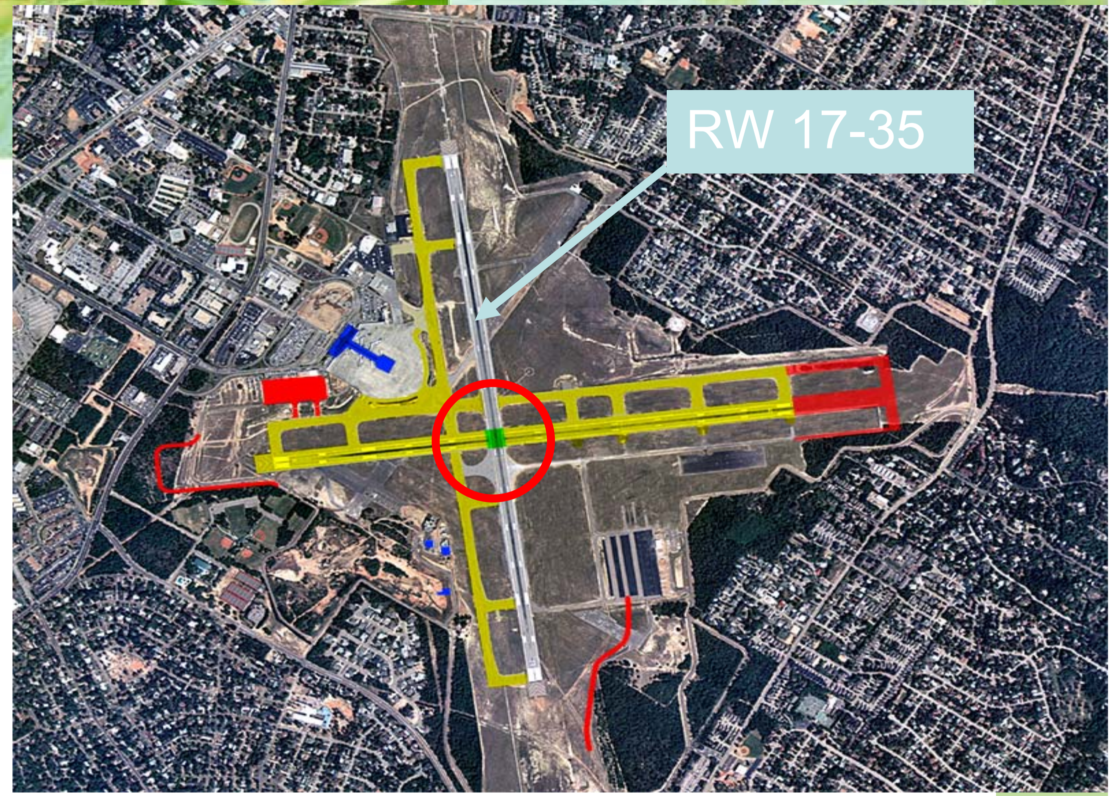
- Design procedure document appendix
  - Analysis method
  - If resulting Present Worth costs between two alternatives is within 10 percent or less it is assumed the PW is same for the alternatives
  - Step by step procedure
  - Example problem comparing seven asphalt alternatives
    - Costs of rehabilitation activities
    - Present worth LCC
    - Summary of alternatives
    - Comparative ranking of alternatives

Pensacola - PNS Background

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

- Thank Gary Mitchell of ACPA for LCCA example

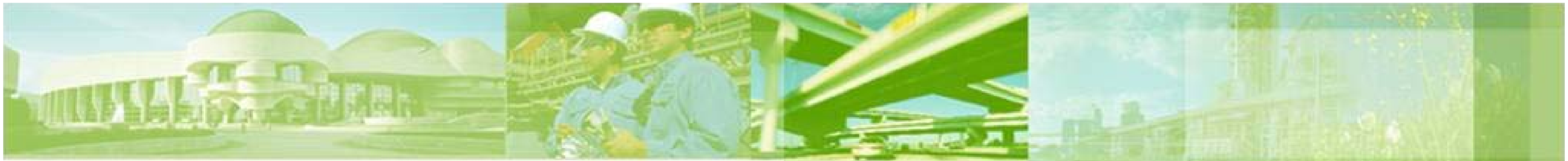
Background



- 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 – $4 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
    - gives conservative concrete pavement design

Pavement Typical Sections

Asphalt Section

4” P-401 Surface

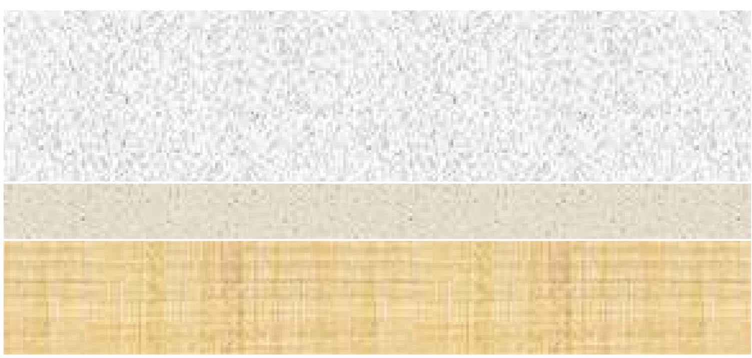
8” P-401 Base

5” P-154 Subbase

12” Compacted Subgrade

So Why The Difference?

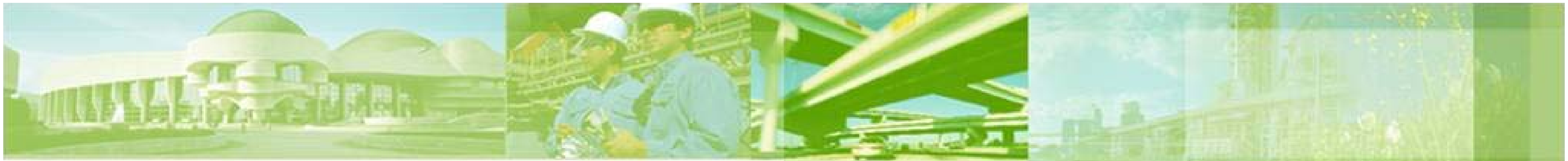
Concrete Section



17” P-501

6” Cemented Treated Base

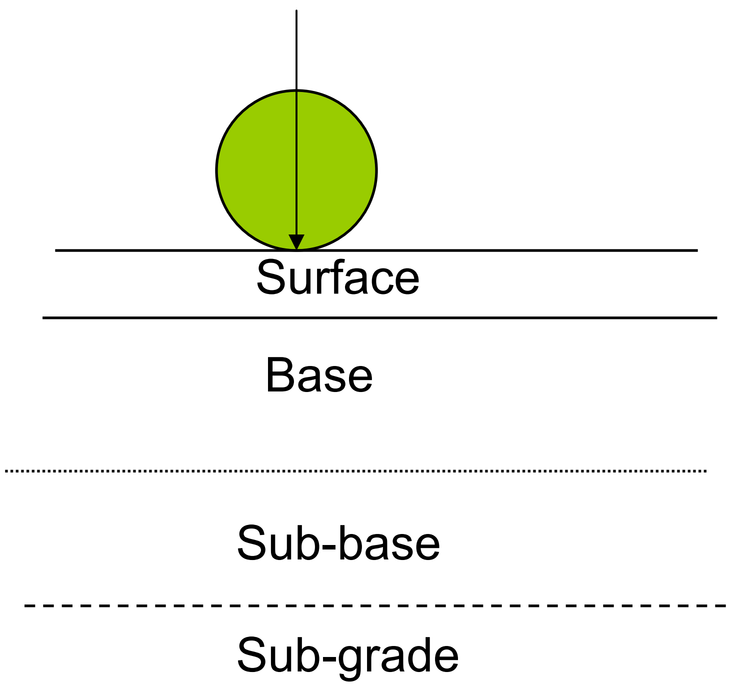
12” Compacted Subgrade



The Pavement Systems

Layered Elastic Concept

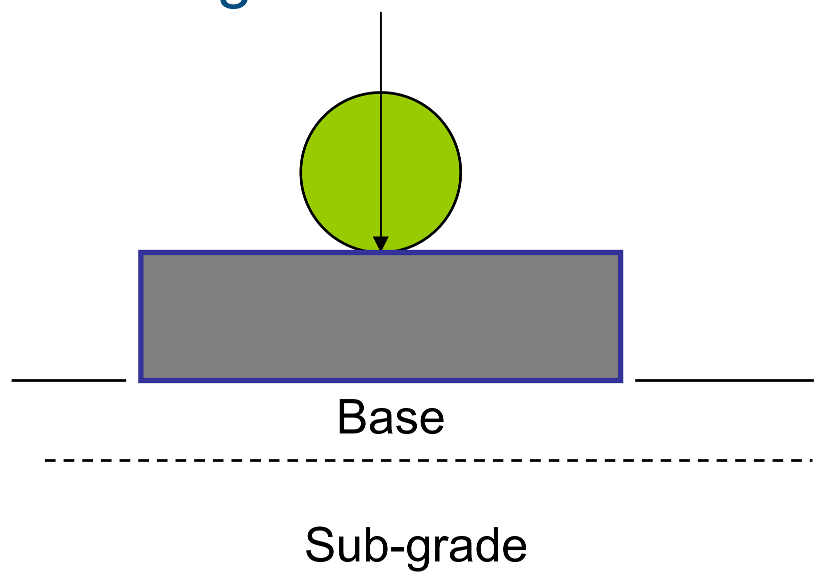
Flexible Pavement



E decreases with depth
Infinite lateral direction

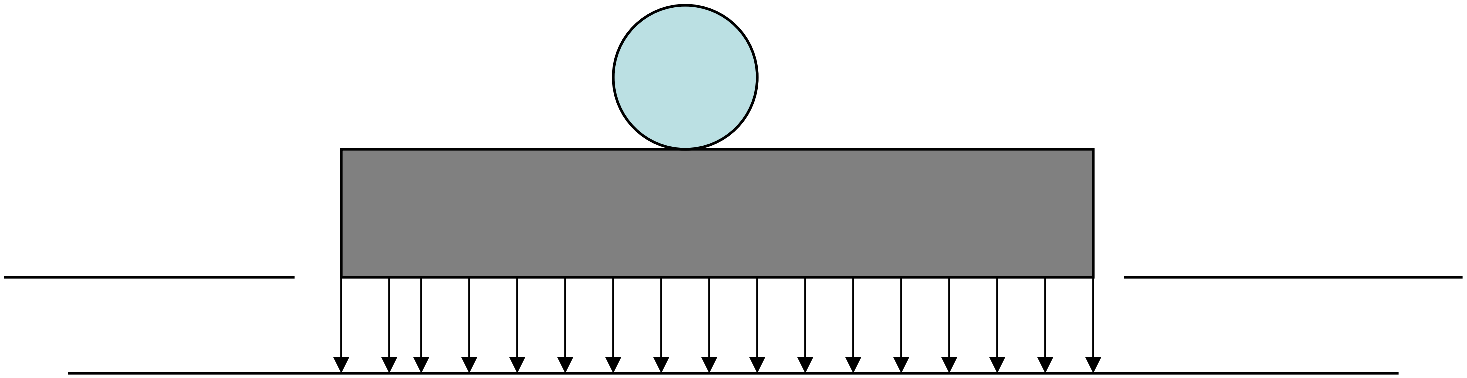
Stress / Strain Theory

Rigid Pavement



Composite Sub-base behavior
(dense liquid)

Load Transfer in Rigid

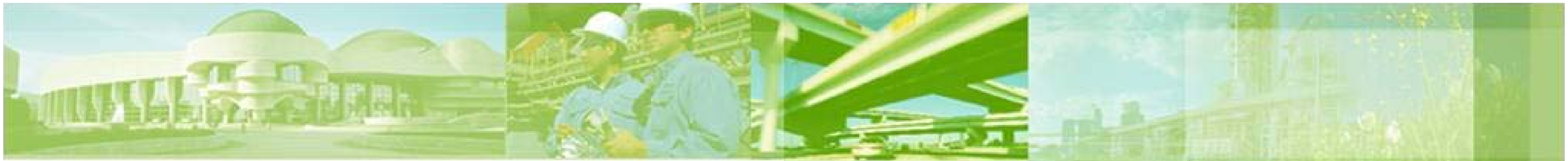


Base for consistency

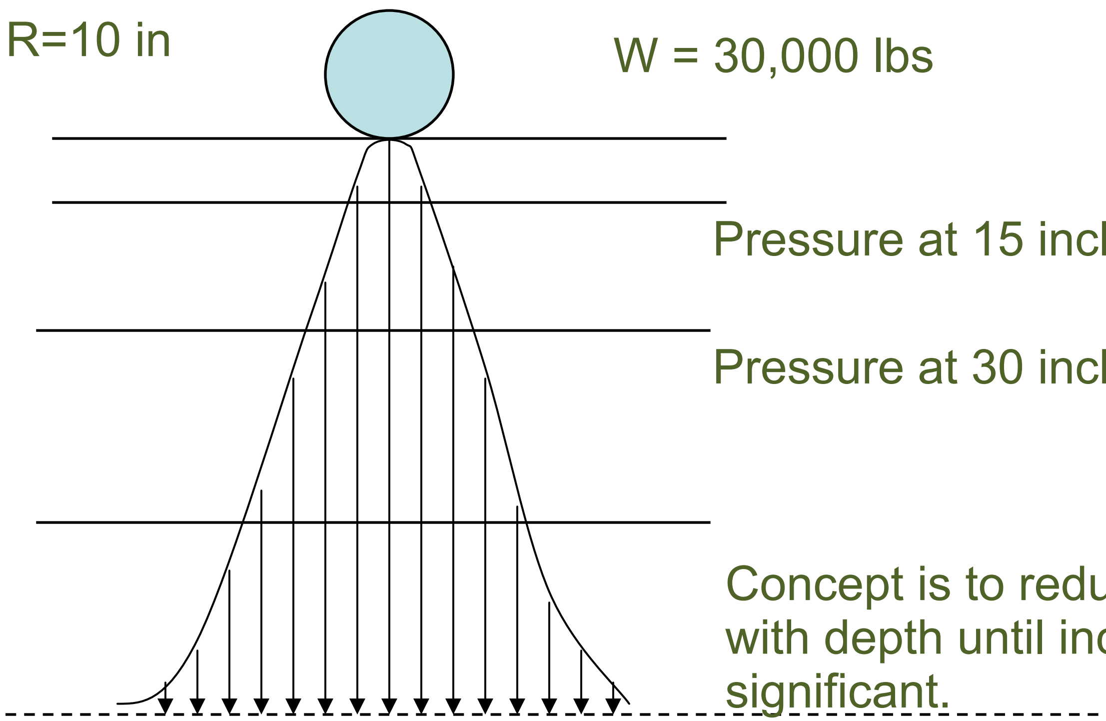
$E_{Concrete} >> E_{Base}$

For 20x20 panel: Pressure = 0.5 psi at base of panel

Design failure criteria is first crack in the slab



Load Transfer in Flexible



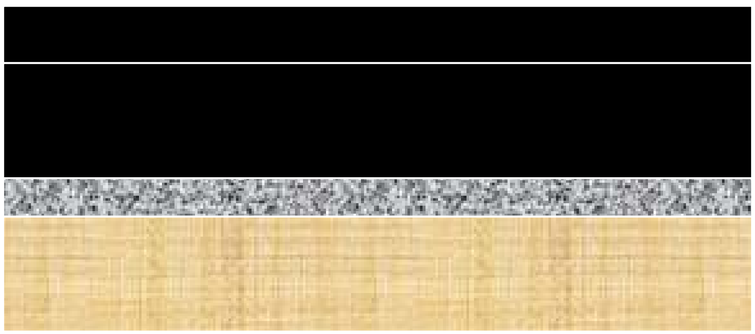
Concept is to reduce pressure with depth until increase is not significant.

Design failure criteria is vertical strain in the subgrade

How can we level the playing field?

Pavement Typical Sections

Asphalt Section



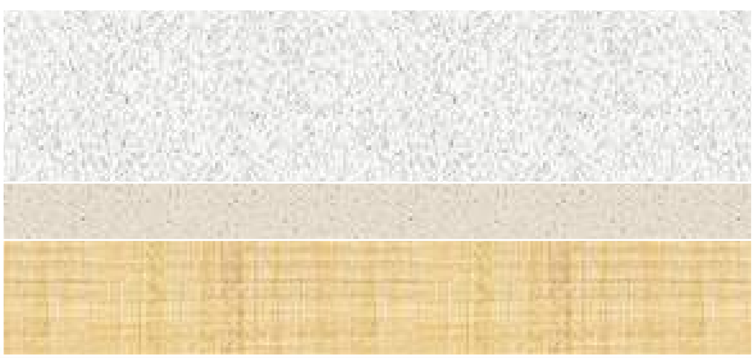
4” P-401 Surface

8” P-401 Base

5” P-154 Subbase

12” Compacted Subgrade

Concrete Section



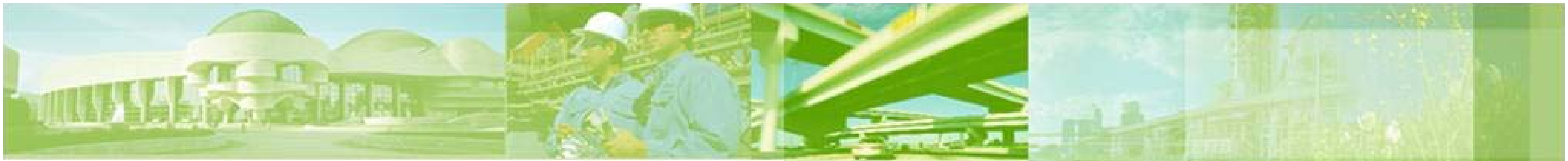
17” P-501

6” Cemented Treated Base

12” Compacted Subgrade

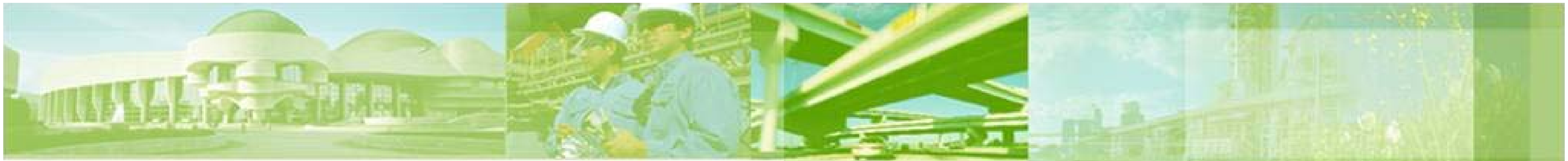
What are the issues?

- 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”



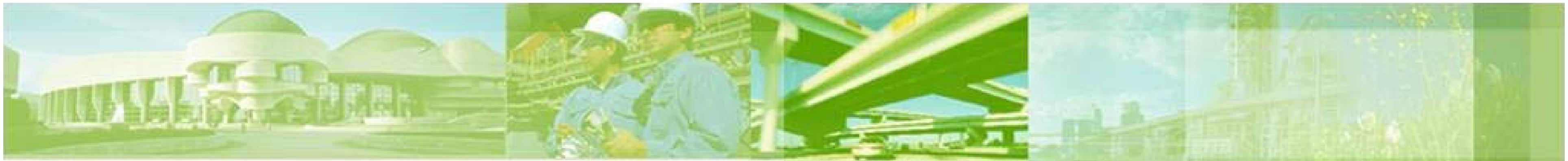
Life Cycle Cost Analysis (LCCA)

- How do we compare unequal designs with unequal lives?
- Using LCCA process to evaluate the bids
- FAA Airport Improvement Program (AIP) Handbook, Chapter 9, Paragraph 910, Life Cycle Costs in Competitive Sealed Bids can be used but does not explain how
- FAA AC 150/5320-6D, Appendix 1, Economic Analysis is part of the design procedure to see if should considered alternate bids - Example Problem



LCCA Development Bid Process

- Format Developed Based on FAA Model in FAA AC 150/5320-6D, Appendix 1, Economic Analysis
- Received Input from ACPA, AI and FAA
- General Parameters were:
  - Design Life - 20 Years (FAA Requirement based on grant period)
  - Concrete Expected Life - 40 Years
  - Asphalt Expected Life - 30 Years with mill and overlay at 15 years
  - Discount Rate (Inflation Factor) - 5%
  - Maintenance Requirement for each alternative



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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)
- Information based on Florida APMS

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

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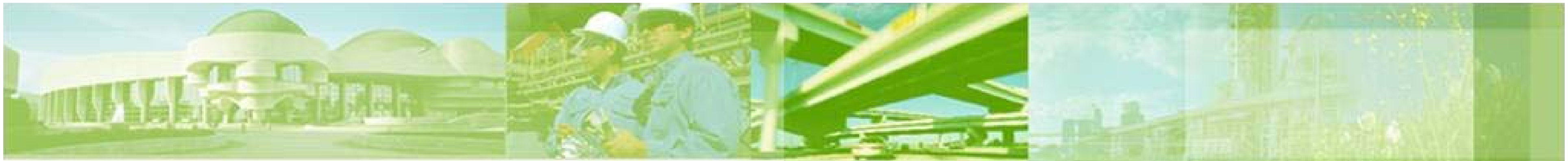
Bids Received

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



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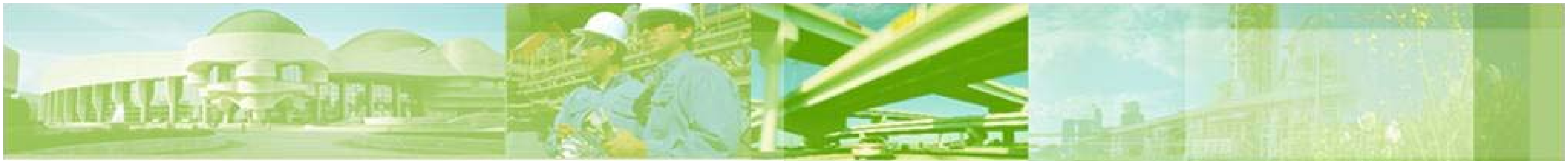
Excel Spreadsheet – PCC Option

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.



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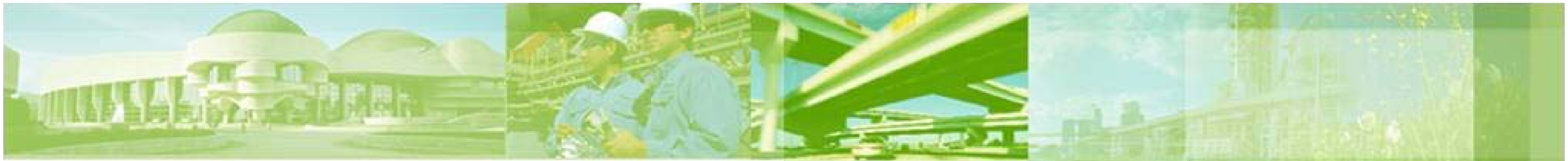
Excel Spreadsheet – AC Option

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

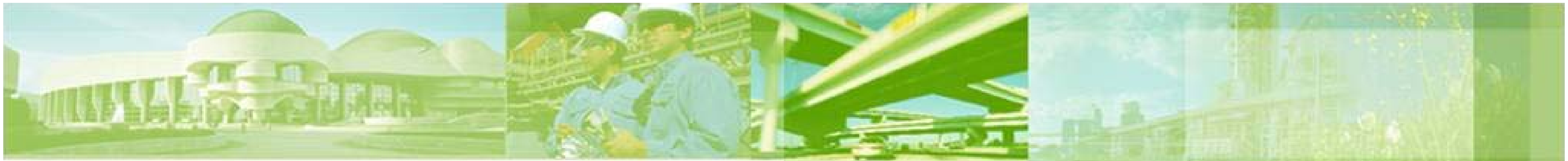
- Asphalt - $19,818,237

- Concrete - $19,551,146 √ Concrete is low bid

- Difference - $267,091

LCCA Summary

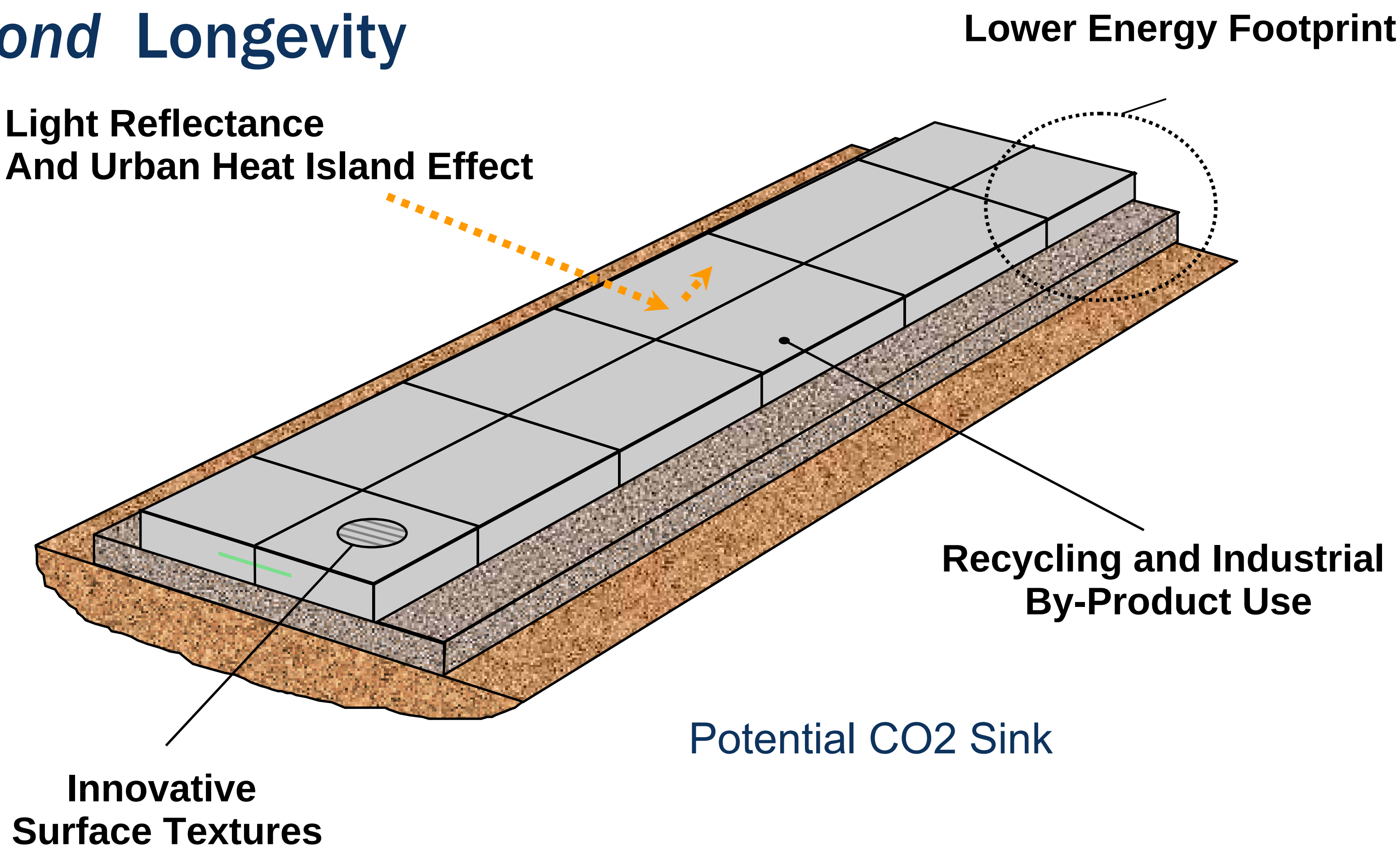
- Make Sure All Maintenance Activities & Rehabilitation Costs are Current, Based on Recent Bids
- Establish reasonable salvage value for each alternative
- Level "playing field" brings competition and value
- **FAA Recognized the need for guidance**

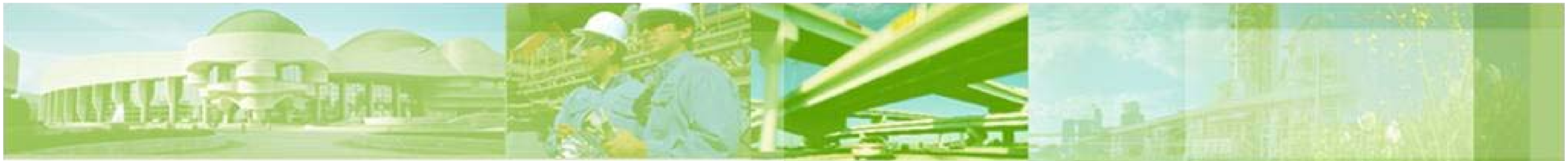


AirCost LCCA Tool

- Developed by ARA under contract with the Airfield Asphalt Pavement Technology program (AAPTP)
- Not officially released yet
- May become FAA standard
- Components:
  - Pay items and cost library which can be added to
  - Project details
  - Airport details
  - LCCA parameters
  - Summary of Alternative

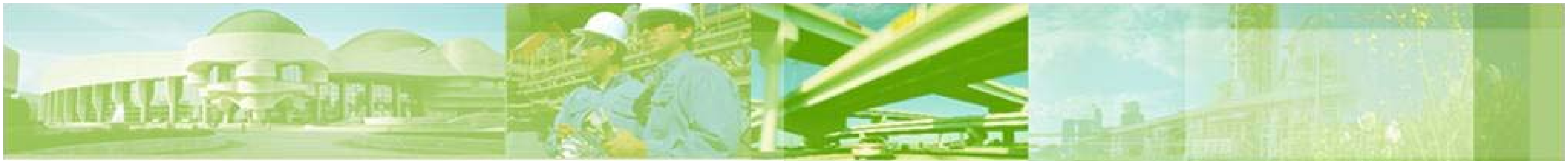
Concrete Pavement Green Benefits *Beyond* Longevity





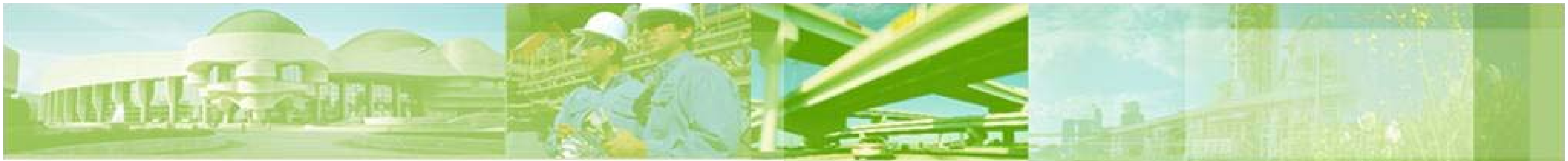
Concrete Pavements – Economic Benefits

- Durability and longevity of concrete (i.e., concrete's 35+ year design life)
- Lower life cycle cost due to reduced maintenance activities and costs
- Cement is made locally, bitumen is imported



Concrete Pavement – Environmental Benefits

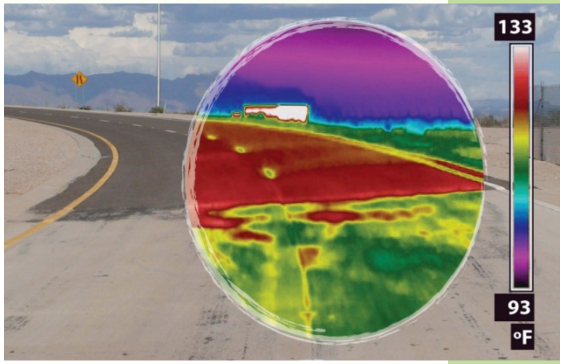
- Uses less energy to build & maintain
- Once set, concrete is inert
- Makes use of industrial by-products
- Reduces urban heat island effect
- Potential CO_2 sink



Use of Industrial by-products

- Types of Supplementary Cementing Materials:
  - Fly ash
  - Blast furnace slag
  - Silica fume
- **Benefits**
  - Decreases material going to landfill sites
  - Improves concrete pavement strength and durability (must use appropriate levels of SCMs)
  - May improve concrete pavement workability
  - Decreases amount of CO_2 associated with PCCP
  - Study completed on Use of SCMs in PCCP

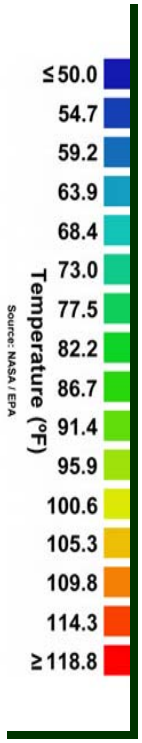
Urban Heat Island Reduction

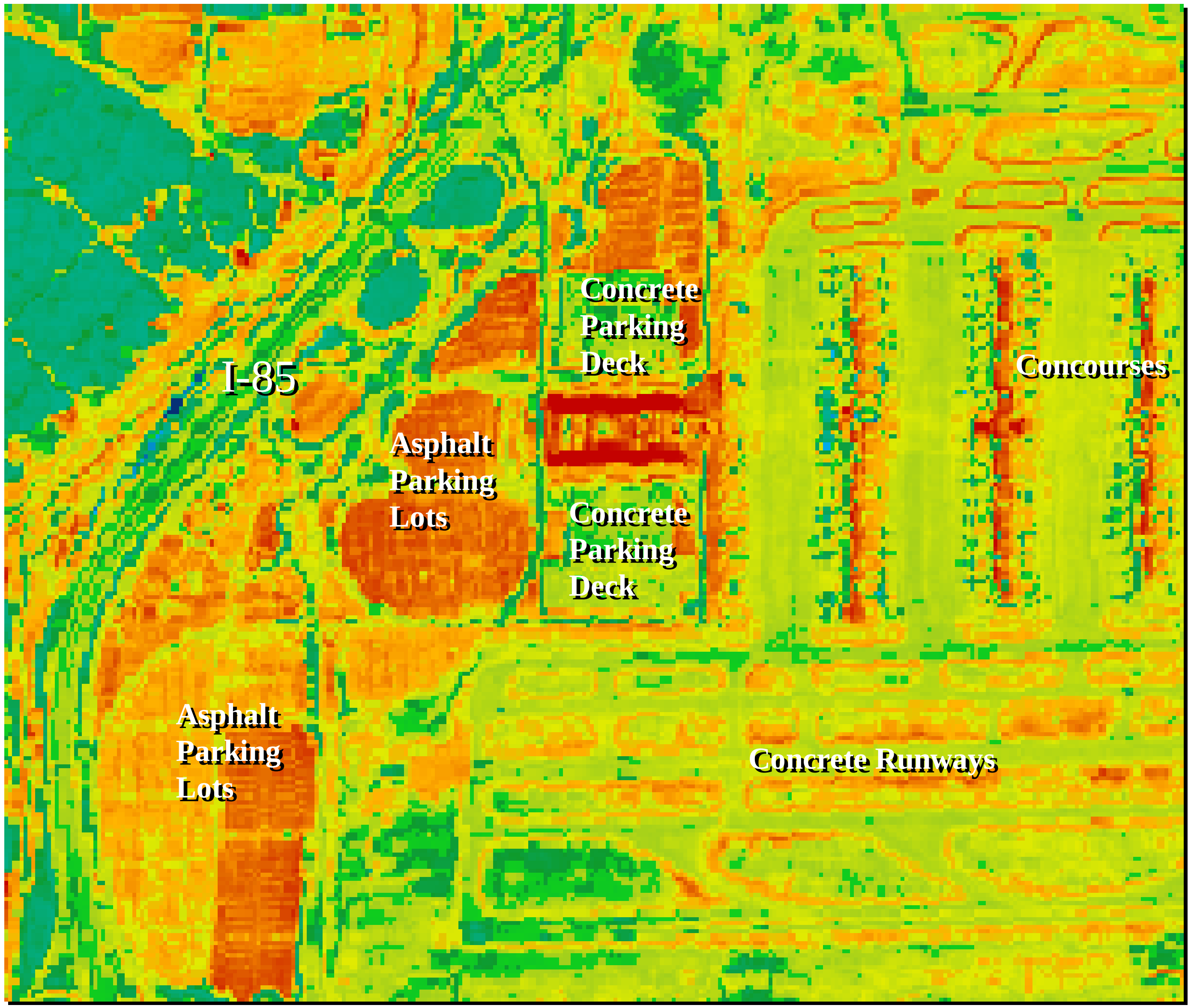


Pavement Type	Albedo (solar reflectance)
Asphalt	0.05-0.10 (new) 0.10-0.15 (weathered)
Gray Portland Cement Concrete	0.35-0.40 (new) 0.20-0.30 (weathered)
White Portland Cement Concrete	0.70-0.80 (new) 0.40-0.60 (weathered)

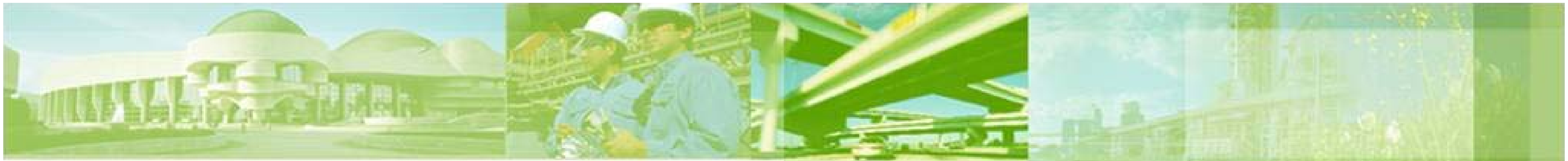
NASA Infrared Imagery Atlanta Airport May 1997

NASA Infrared Imagery May 1997





Atlanta Airport



Life Cycle Assessment

- Wikipedia definition:

  "A **life cycle assessment** (**LCA**, also known as **life cycle analysis**, **ecobalance**, and **cradle-to-grave analysis**) is the investigation and evaluation of the environmental impacts of a given product or service caused or necessitated by its existence."

- Focus comments on energy use and CO_2 footprints

Reduced Energy Consumption

- Athena Sustainable Materials Institute Update Study
  - A Life Cycle Perspective on Concrete and Asphalt Roadways: Embodied Primary Energy and Global Warming Potential:
    - ACP uses more embodied primary energy than PCCP over a 50 year Life Cycle Assessment
      - Increased energy use ranges from 2.3 to 5.3 times more
      - Increased energy use ranges from 31 to 81 % more if exclude feedstock energy

Reduced Energy Consumption

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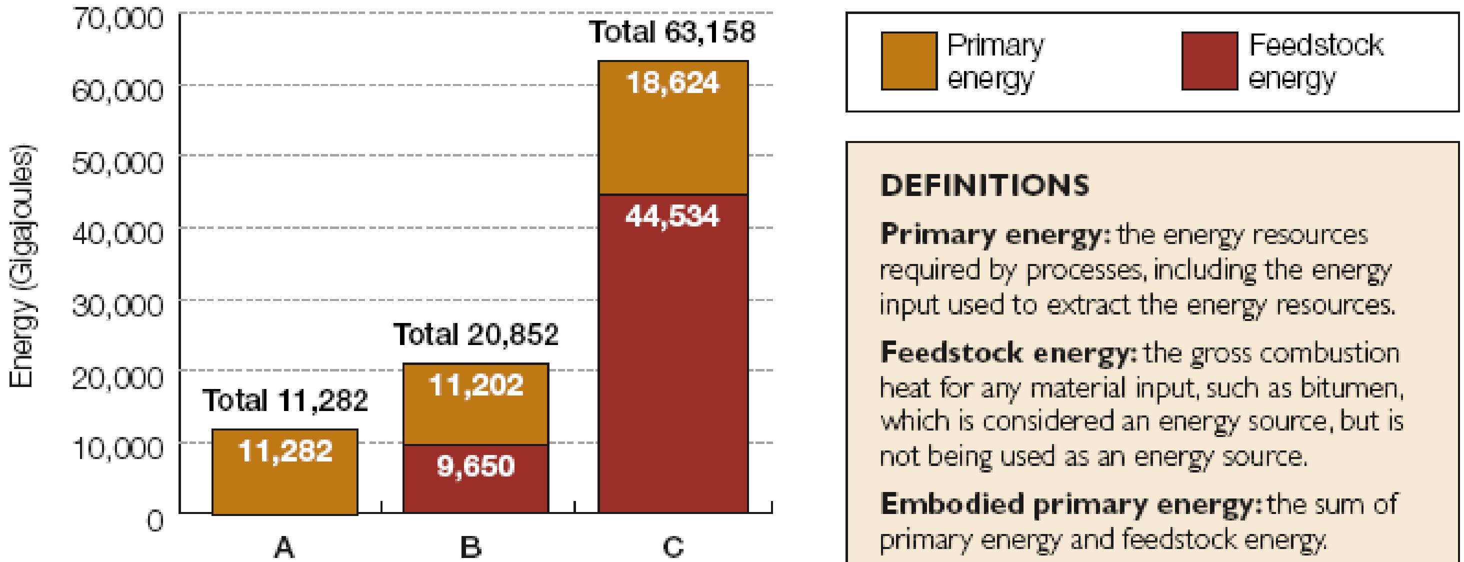
Additional Embodied Primary Energy Used by
Asphalt Pavement Design Alternatives

Highway Classification	Additional Embodied Primary Energy Used by Asphalt Pavement Design Alternatives	
	Including feedstock energy	Excluding feedstock energy
Canadian Arterial Highway		
- CBR 3	3.9 times more	67 % more
- CBR 8	4.1 times more	68 % more
Canadian High Volume Hwy		
- CBR 3	3.0 times more	66 % more
- CBR 8	3.0 times more	67 % more
Quebec Urban Freeway	5.3 times more	81% more
Ontario Highway 401 Urban Freeway	2.3 times more	31 % more

Reduced Energy Consumption



DEFINITIONS

Primary energy: the energy resources required by processes, including the energy input used to extract the energy resources.

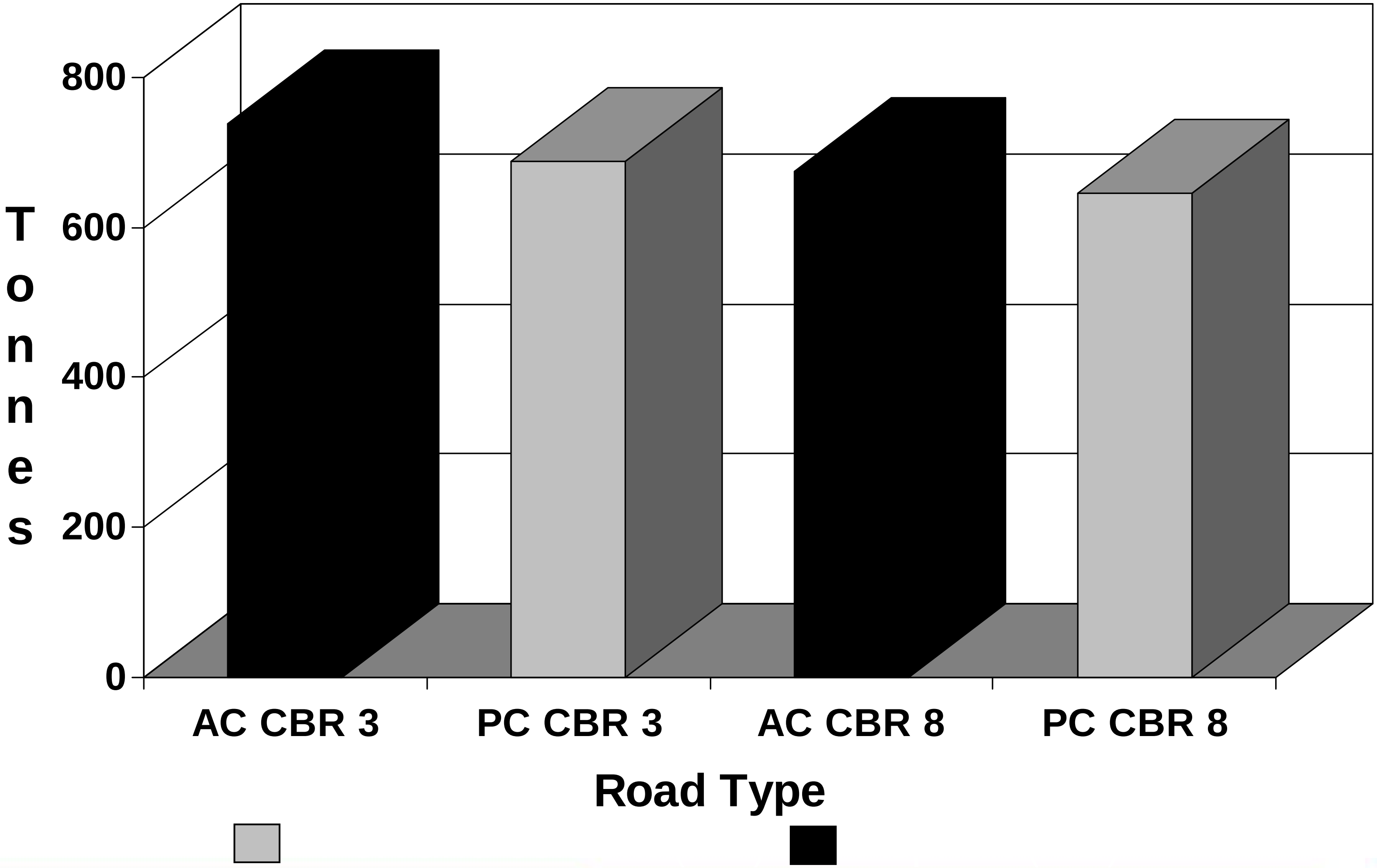
Feedstock energy: the gross combustion heat for any material input, such as bitumen, which is considered an energy source, but is not being used as an energy source.

Embodied primary energy: the sum of primary energy and feedstock energy.

Pavement structure
A) Concrete pavement (concrete shoulders, no asphalt overlay)
B) Concrete pavement (asphalt shoulders and asphalt overlay)
C) Asphalt pavement

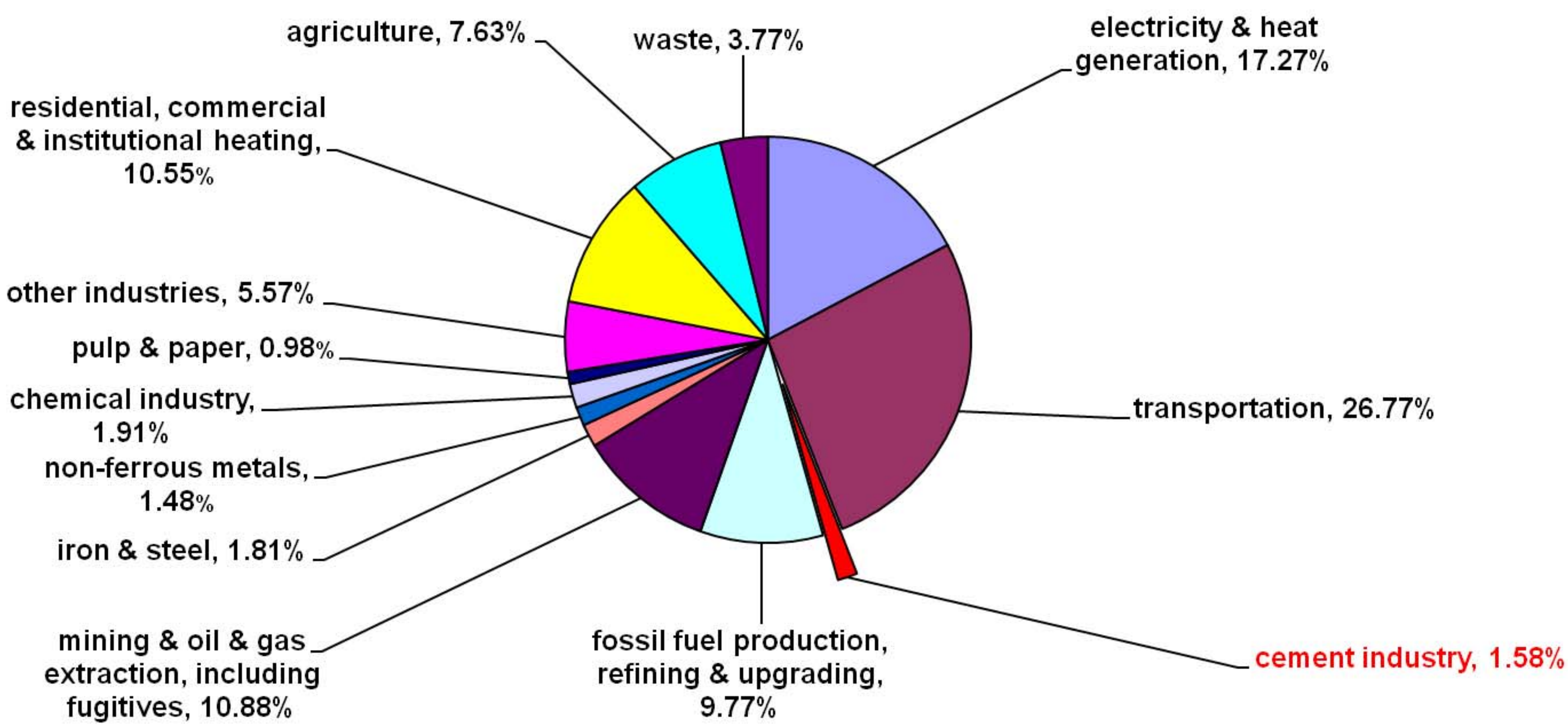
Referring to a 4-lane one kilometre highway.

Global Warming Potential (tonnes of CO2 equivalent, 0% RAP)



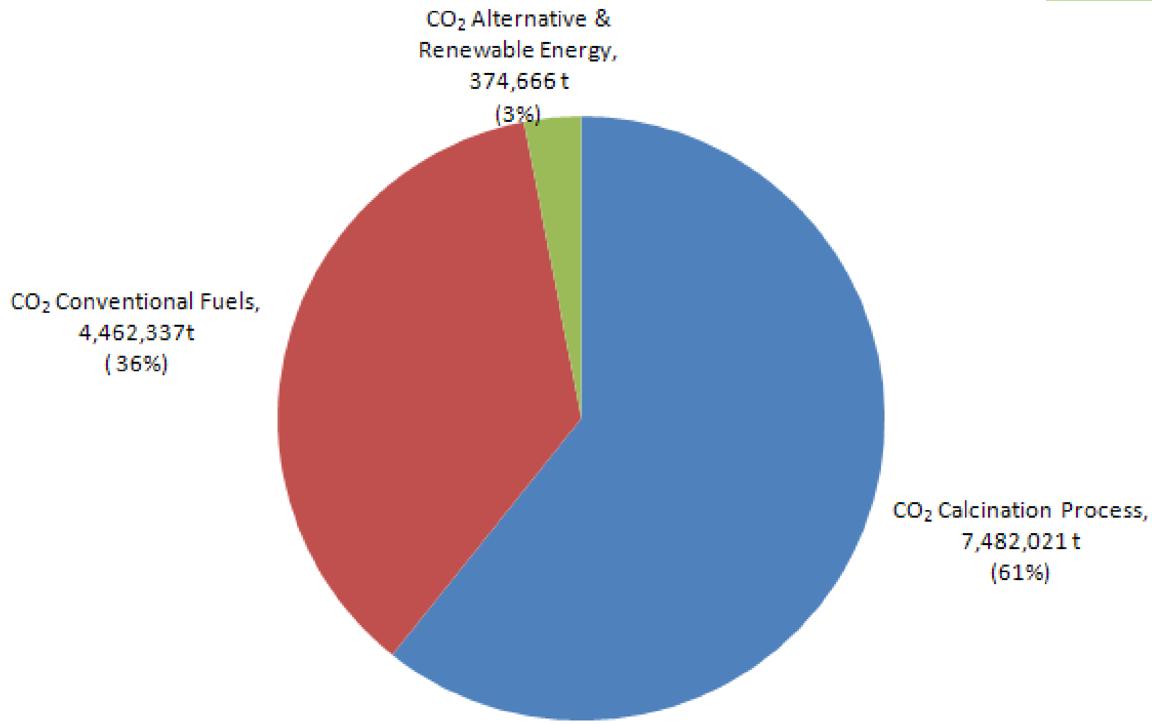
Sources of Canadian GHG Emissions, 2005

National Inventory Report, 1990-2005, Env. Canada, April 2007



Cement Sector GHG Emissions

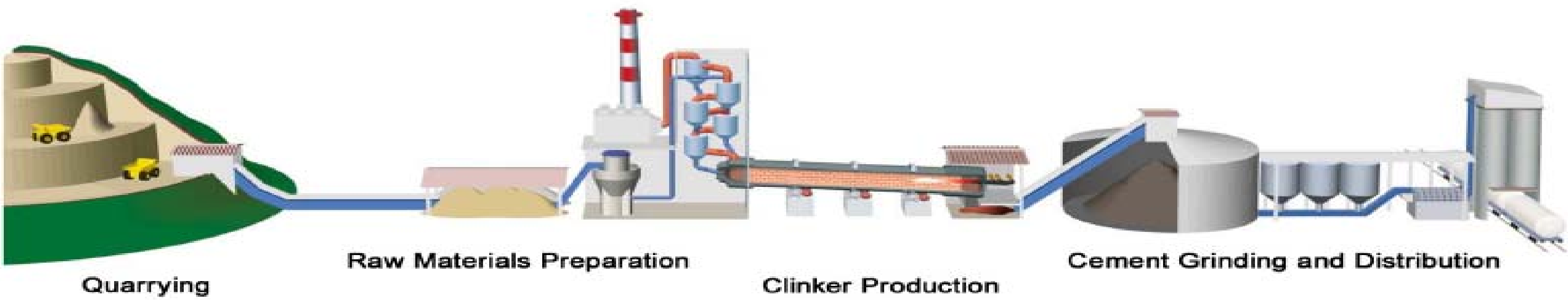
- The Cement industry accounted for 12.4 MT of greenhouse gas emissions in 2007:
  - Approx. 1.5% of total national GHG emissions
  - Approx. 3% of total industrial emissions
  - 61% irreducible, process emissions from raw materials (CaCO3 + heat = CaO + CO2)
  - 39% from combustion of kiln fuels



Cement Manufacturing Process

How Cement is Made

In Canada, cement is manufactured by 8 cement companies that operate 16 plants in 5 provinces. The production of cement is a four-step process, as illustrated below.



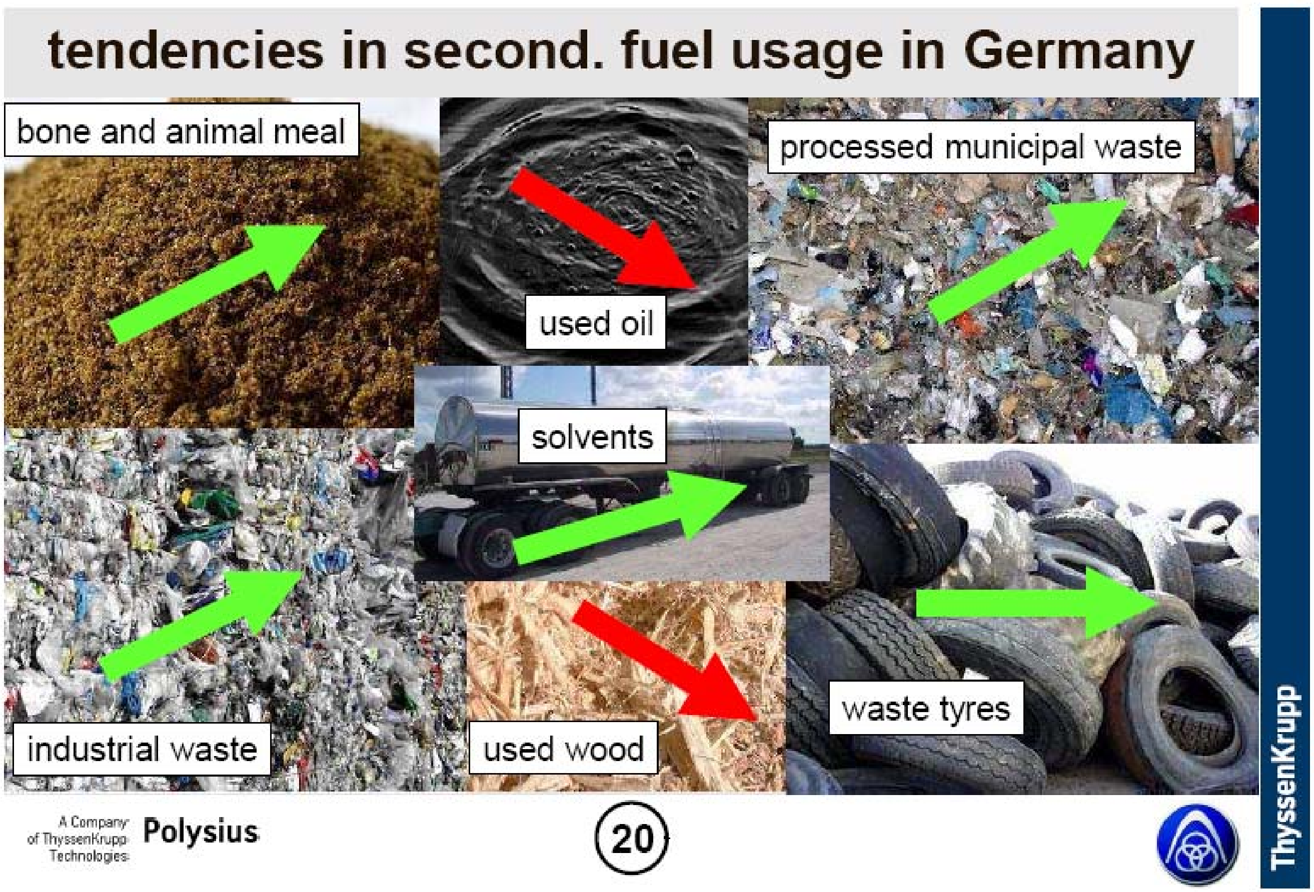
Step 1
Limestone and small amounts of sand and clay, are extracted, usually from a quarry located near the cement manufacturing plant.

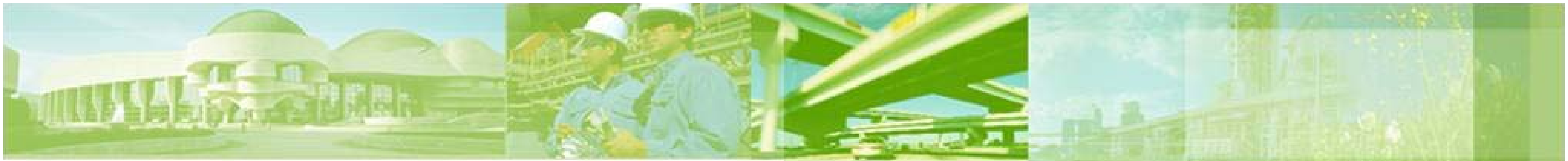
Step 2
The materials are carefully analyzed, blended and then ground for further processing.

Step 3
The materials are heated in a kiln, which reaches temperatures of 1,470 degrees Centigrade. The heat causes the materials to transform into a new marble-sized material called clinker.

Step 4
Red-hot clinker is cooled and ground with a small amount of gypsum. The end-result is a fine grey-coloured powder called Portland cement.

Renewable and Alternative Fuels



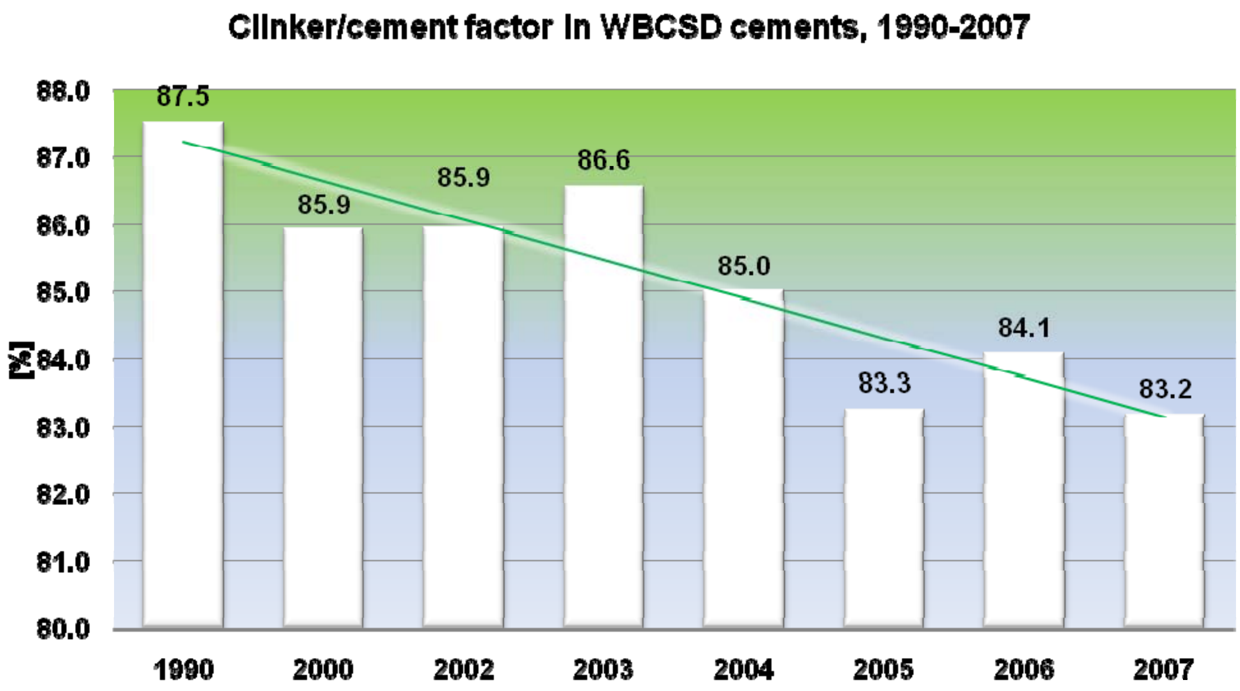


Supplementary Cementing Materials - SCM's – fly ash, slag and silica fume

- SCMs improves the properties of hardened concrete.
- Improve the performance of the concrete and reduce the clinker demand of the mixture.
- Mitigates the effect of alkali silica reactivity (ASR) in concrete.
- The use of SCMs in concrete mix designs is recognised by the LEED building rating system as an effective measure in mitigating CO_2 emissions and is awarded points towards LEED certification.

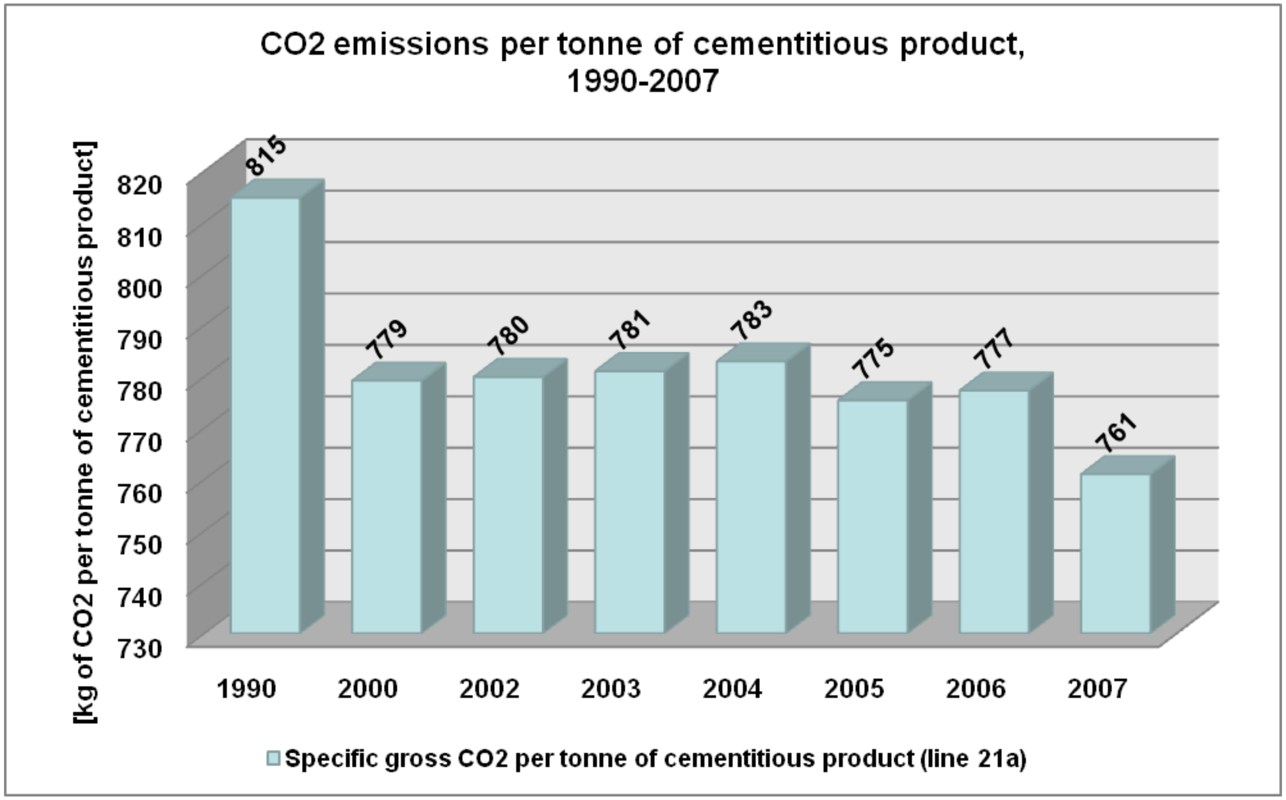
Importance of SCMs Grows

- The important clinker / cement factor continues to improve via:
  - 53% increase in the use of additions to blended cements, since 1990
  - 120% increase in direct sales of cement substitutes, since 1990



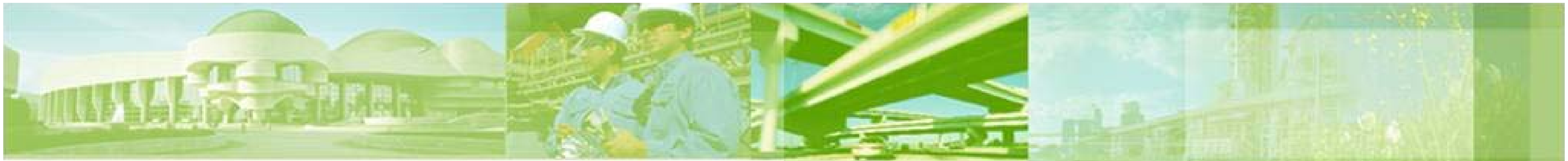
Cement GHG Intensity has Improved..

- A 6.6% improvement in GHG intensity per tonne of cementitious product , since 1990:



New Portland Limestone Cement (PLC) to Reduce Energy and CO_2 Footprint

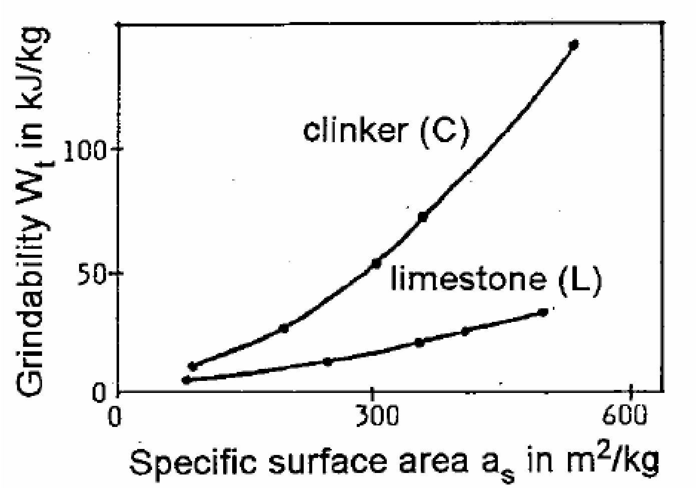
- First appeared in Germany in 1965
- 1979 First Appeared in French Standards
- 1983 5% Limestone permitted in CSA A5
- Used in Europe for 25 Years at over 20%
- Adopted in CSA A3000-08 at levels up to 15%
- Must be adopted in Building Codes before it can be used

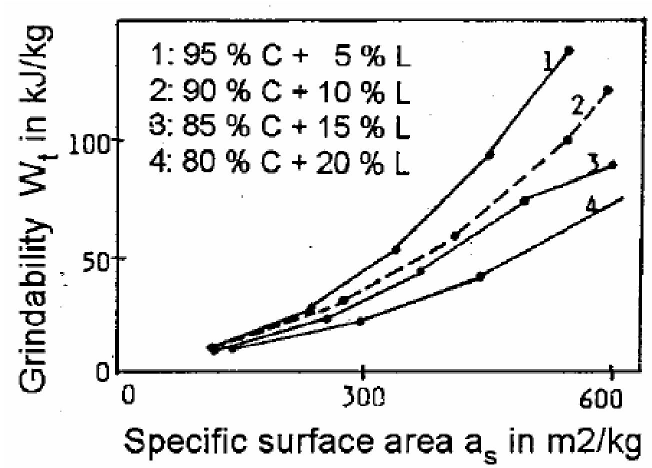


New Portland Limestone Cement (PLC)

- Portland-limestone Cement (PLC) can be produced by intergrinding or blending limestone with Portland cement.
- Key advantages with respect to GHG emissions and climate change.
  - Less energy is expended in grinding limestone than clinker.
  - Less clinker demand
  - Lower CO_2 emissions
  - Equivalent performance to traditional cements

Portland Limestone Cement (PLC) Energy Savings





Crystal Ball – Future
Material, Energy and CO_2 Savings

- Two lift concrete pavement
- NOx eating cement
- Ternary / quartnary blended cements

Do Not Expose yourself look at all your options!

Thank you !!

Questions ?