Evolution of Concrete Pavements: Lessons Learned for Long Life Concrete Pavements

(Special thanks to Todd Hanson, Iowa DOT)

National Concrete Pavement Technology Center
Iowa's Lunch–Hour Workshop
In cooperation with the Iowa DOT
and the Iowa Concrete Paving Association

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1904 1st Concrete Street LeMars, Iowa

1950 Photo

- First Street (Eagle Street)
- 2nd oldest concrete street in America
- Fed up with dust when dry & mud when wet
- 1904-1968
- 6ft diagonal panels scored into 4” squares to prevent horse slipping

LeMars, Iowa - Today

Sept 2016 Google Street View

1904 1st Concrete Street LeMars, Iowa

- Two lift construction
- 5” lean concrete base (sand, cement & gravel)
- 1 ½” surface had higher cement content
- Modeled similar to sidewalk construction

1909 - Eddyville Cemetery Rd

- Oldest Farm to Market Road in Iowa
- Top 10 Oldest in U.S.

- What was Unique?
  - Transverse grooves set in pavement
  - Citizens fed up with deep sand in dry weather

108 Years Old

1913 - Iowa Highway Commission Forms

Several Short Projects (1/4 to 1.3 mile) 6”-7” thick

- Cerro Gordo
- Louisa
- Benton
- Dallas
- Muscatine (1914)

Muscatine 103 Years Old - 2011 Photo

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1913 - Iowa FA-1 Cerro Gordo Co. (between Clear Lake and Mason City)

Specifications

Type A (Full depth) or Type B (two course)

1st penalty clause

- **Divide into 50 ft blocks**
- **Count bags of cement**
- **If any 3 adjacent blocks 4% less or 7 1/2 % more, remove and replace the blocks**

Texture 3-ply belt 10” wide

104 Years Old

6” thick, 16’ wide *w/* ½” square transverse bars every 15’-1”

1 mile of pavement for a cost of $11,500 ($1.23 /SY)

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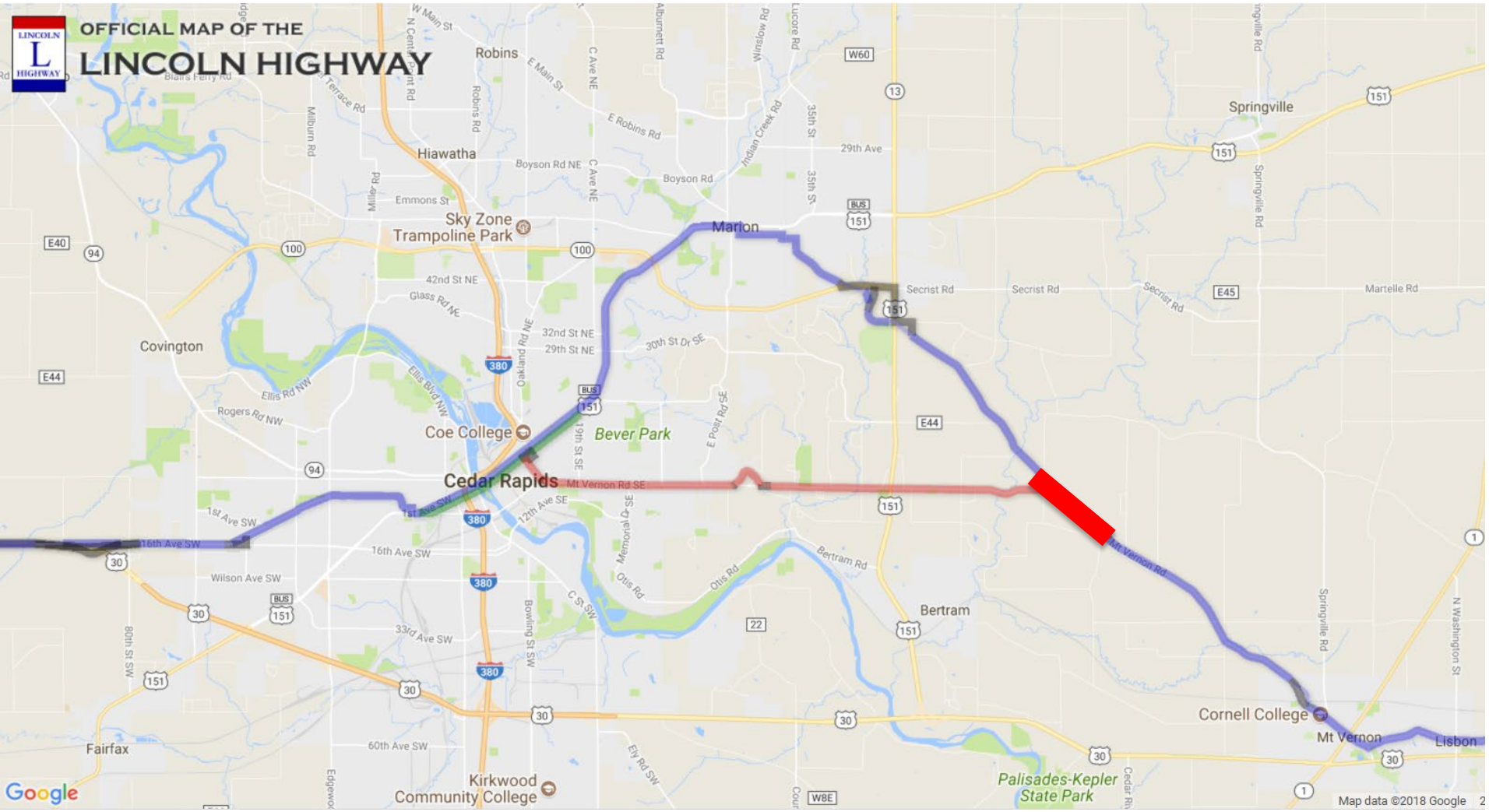
1918 – Seedling Mile

- Linn County
- Northwestern States Cement donated 3,000 barrels of cement
- Ford Paving Company bid of $3.15/yd^2
- Highway Commission talked them down to $2.84/yd^2 due to change from Type B to Type A and changing from crushed limestone to Muscatine Gravel

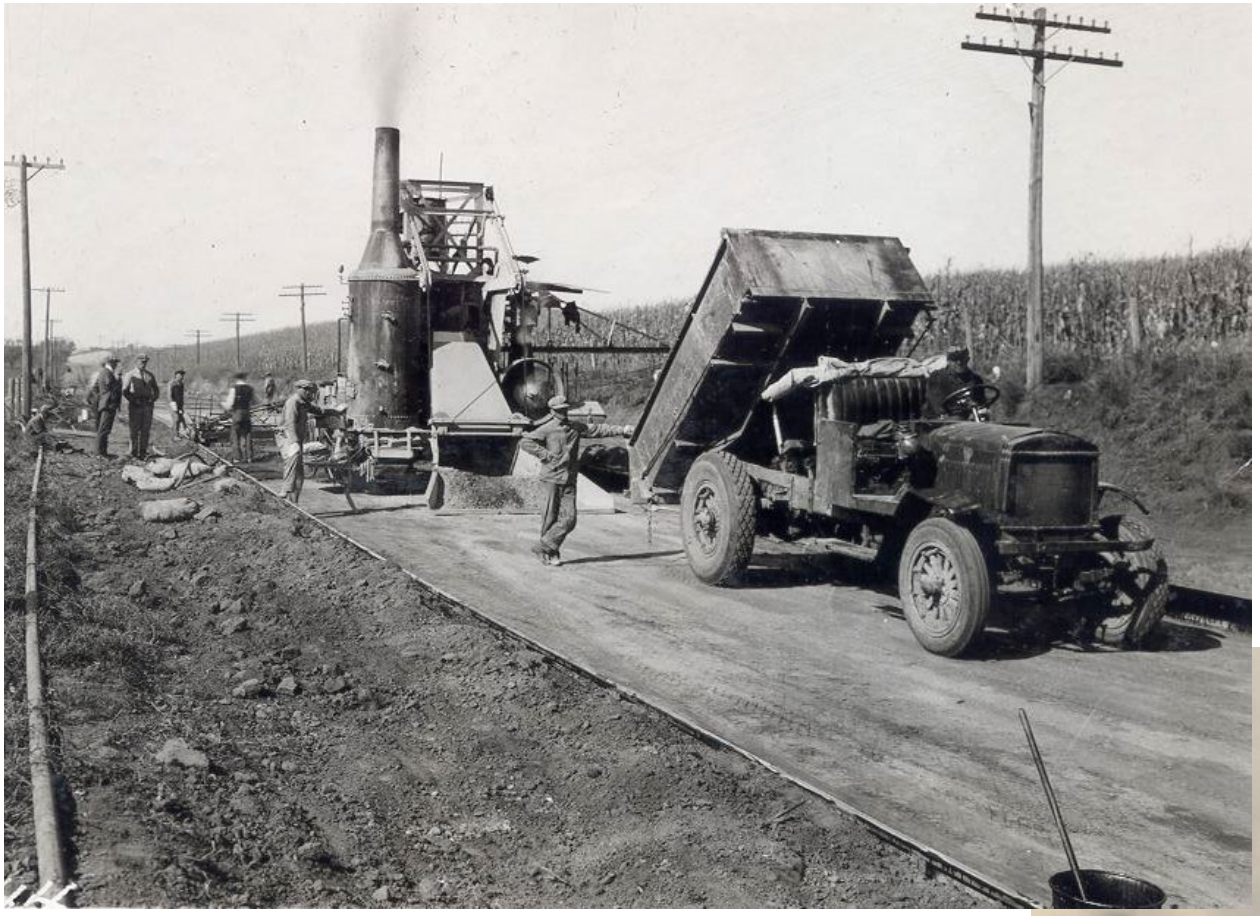
99 Years Old
Part of Lincoln Highway

1918 – Seedling Mile



Linn Co. Rd E48 (W. Mount Vernon Road)

1921 US 20 - Woodbury County



What was Unique?

- Dry materials dumped into skip hoist
- Water lines laid out along grade

96 Years Old

skip hoist

1921 US 20 - Woodbury County

- Curing Prior to 1930
- 1 day wet burlap cure for 24 hours
- Then 2” of wet sand or earth or 6” of straw
- After October 15, used calcium chloride in mix (rate of 2lb per bag of cement) and required wet burlap for 24 hours
- In 1930, sand or wet earth or straw required for 6 days, with opening to traffic in 7 days

96 Years Old

1921 US 20 - Woodbury County

- 10” PCC
- Fine & Coarse Aggregate:
  Correctionville
- Cement: Marquette-Northwestern
- No Joints (1920-1925)

96 Years Old

1930 - Mitchell County

- Curing by Ponding
- 1925 specs: 2” min. ponding depth in lieu of earth cure
- 1948 specs: ½” min. ponding depth for 48 hours

87 Years Old

1930's – 1950's

- Paving slowed during the war era
- By the 1940s there were 5,000 miles placed. Today there are approximately 10,000 miles. A majority of these miles were paved in the 1950s – 1970s.
- 1956 Interstate Highway System
- As the need for paving grew, demands on earlier opening also increased

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1958 – Interstate Paving

- 1958 to 1966 jointed mesh reinforced
- 76.5’ joint spacing
- Mesh reinforced
- Tandem pavers
  - **Bottom lift placed**
  - **Place mesh**
- Top layer placed by second paver

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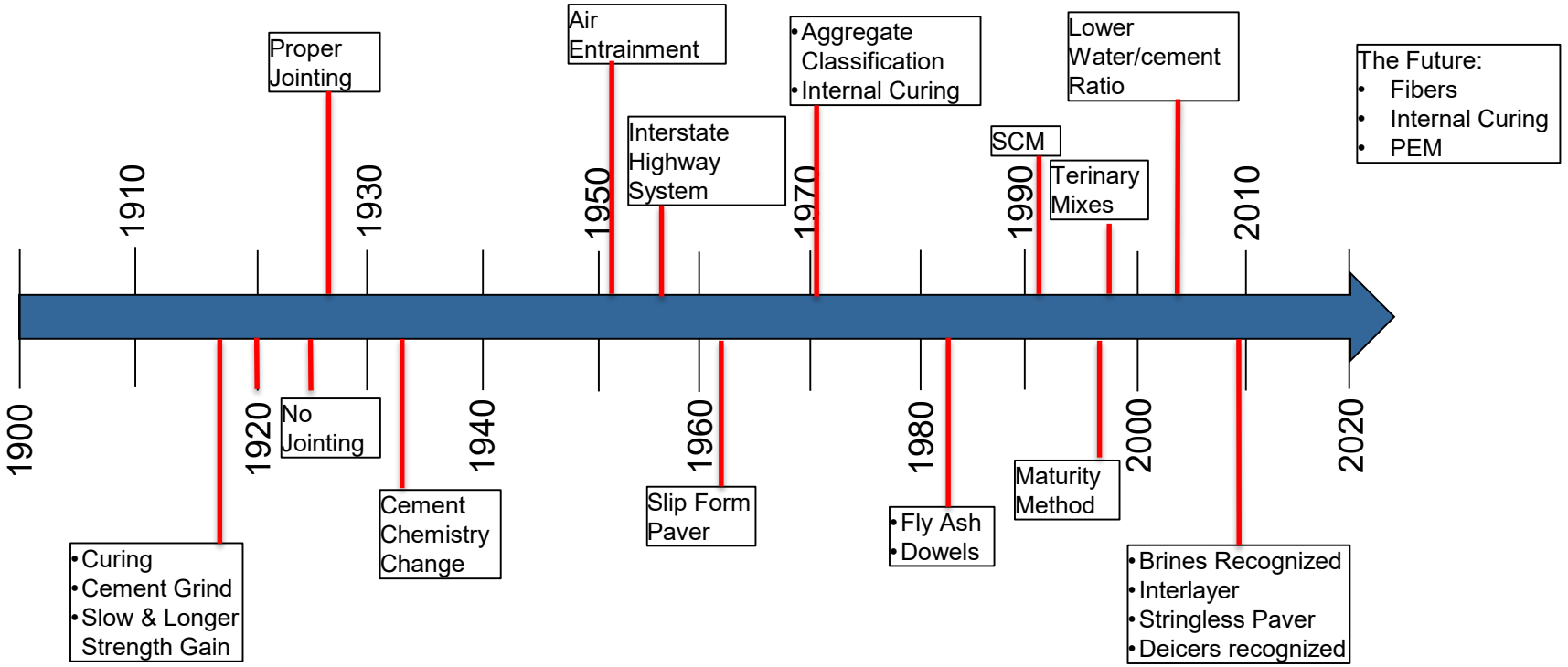
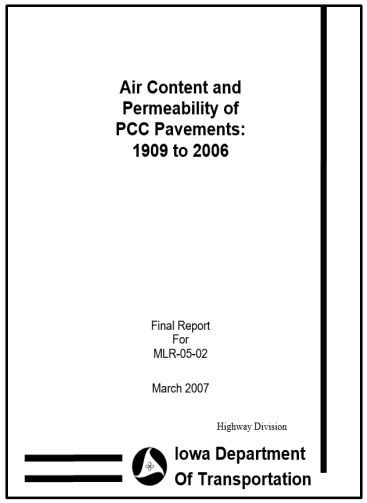
1976 - Delaware Avenue

- Polk County pavement (from 1st St. to 36th St, Ankeny)
- 7” PCC
- 7” Class A Roadstone Base
- PCI of 86 in 2014

41 Years Old

Iowa Concrete Paving Milestones





What has Changed?

- 13 Pavements
- Constructed from 1909-2006
- Studied Air Content & Permeability

Table 1 - List of Pavements Investigated

County	Year	Location	Fine Agg	Coarse Agg	Cement
Mahaska	1909	Eddyville Cemetery Rd	Eddyville	Eddyville Gravel	n/a
Woodbury	1921	Old 20 E of Sioux City	Correctionville	Correctionville Gravel	Marquette Northwestern
Wapello	1929	Old 63 S of Ottumwa	Ottumwa	Dewey Stone	Marquette Atlas
Monona	1938	IA 175 MP 8.7 to 14.4	Correctionville	Correctionville Gravel	Ash Grove
Pocahontas	1946	IA 15 MP 0 to 5.5	Sacton	Sacton Gravel	Hawkeye
Greene	1955	US 30 MP 94.5 to 99.1	Sprague	Sprague Gravel	Northwestern Penn Dixie
Marshall	1963	US 30 MP 172.2 to 179.9	Clemons	Ferguson Stone	Dewey I Lehigh I
Hamilton	1975	US 20 MP 141.5 to 149.5	Sturtz	Moberly Mine	Marquette Lehigh I
Boone	1980	IA 17 MP 21.6 to 32.7	Christensen	Sturtz Gravel	Northwestern I Penn Dixie I
Story	1992	US 30 MP 151.9 to 156.8	Christensen	Ames Mine	Ash Grove 15% C fly ash
Linn	1997	US 151 MP 33.6 to 36.6	Ivanhoe	Bowser Stone	Holcim IS(35) 10% C fly ash
Jones	2002	US 151	Anamosa	Stone City	Lafarge IS(20) 20% C fly ash
Fremont	2006	IA 2	Oreapolis #8	Weeping Water	Ash Grove IP(25) 20% C fly ash

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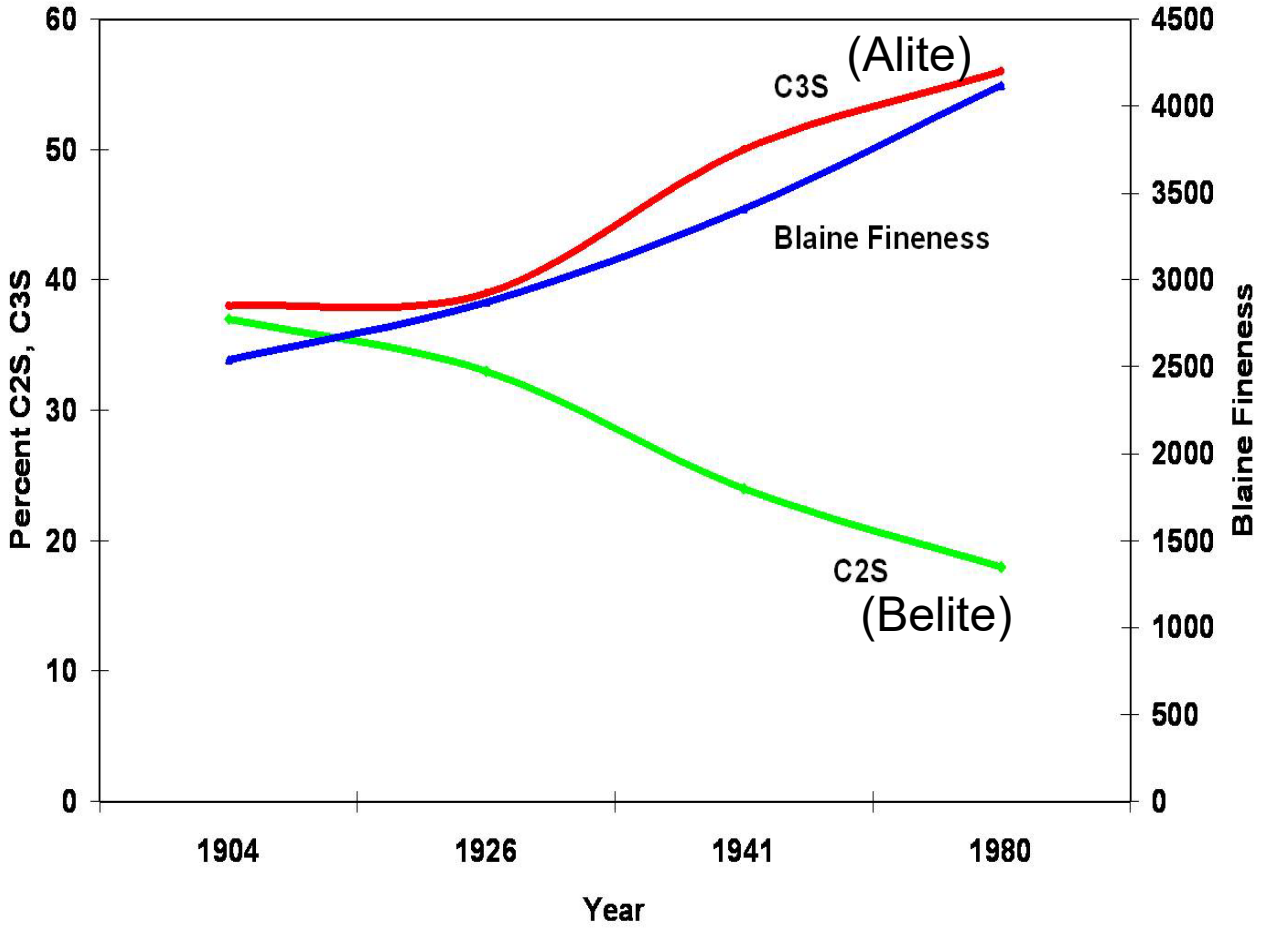
What has Changed?
Cement Chemistry



Cement chemistry has changed over the years, but we have the same or better results

Iowa DOT Report MLR-05-02, March 2007

What has Changed? - Air

Air Entrained Concrete Specifications

1952 3-5%
1956 4-6%
1960 5-7%
1995 6-8% (increase to account for loss through paver)
2000 5-7.5%

2017 6-10% (on grade prior to paver)
5.5- 7.5% (non-slip form paver)

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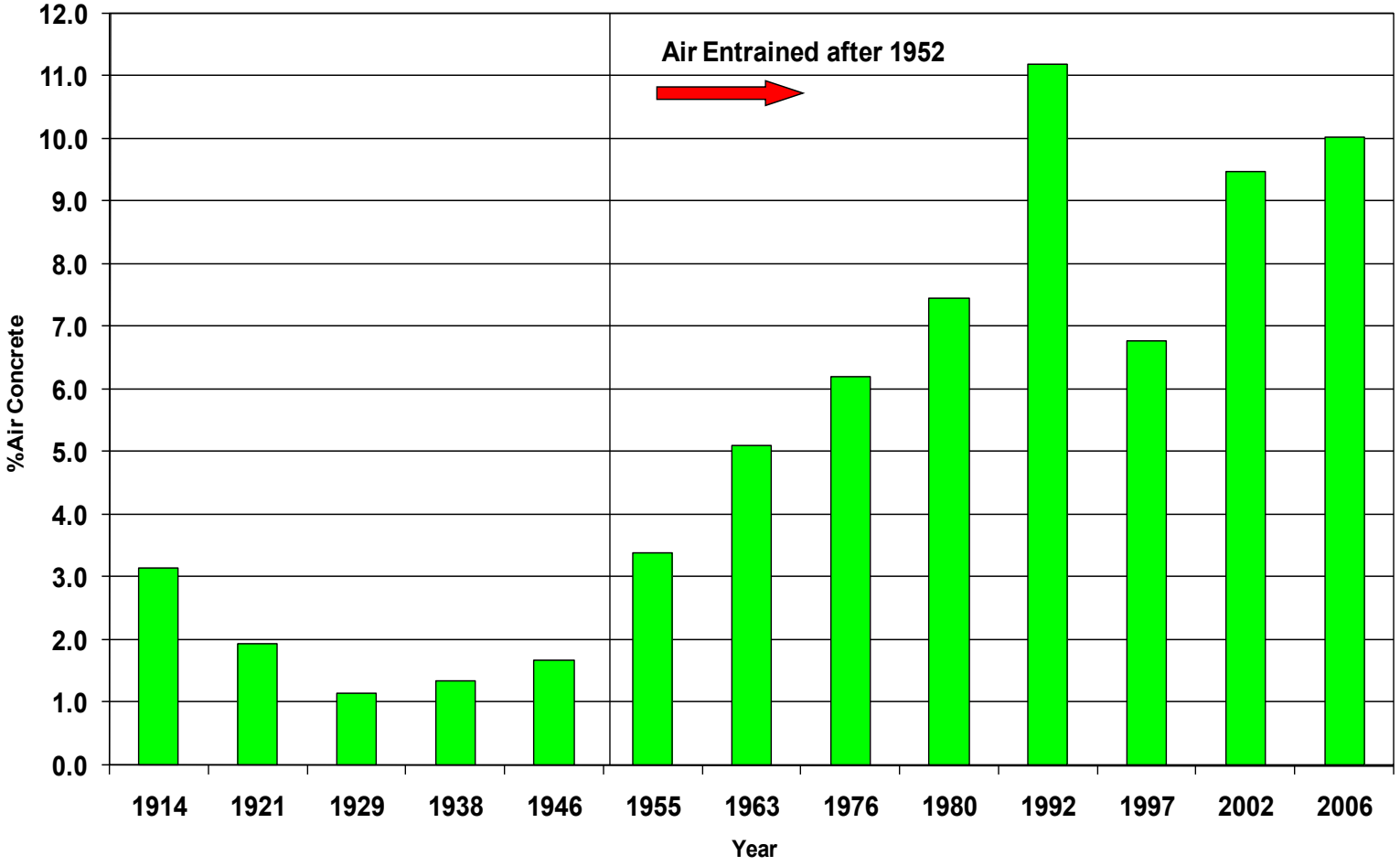
What has Changed? - Air

13 project sample size

Iowa DOT Report MLR-05-02, March 2007



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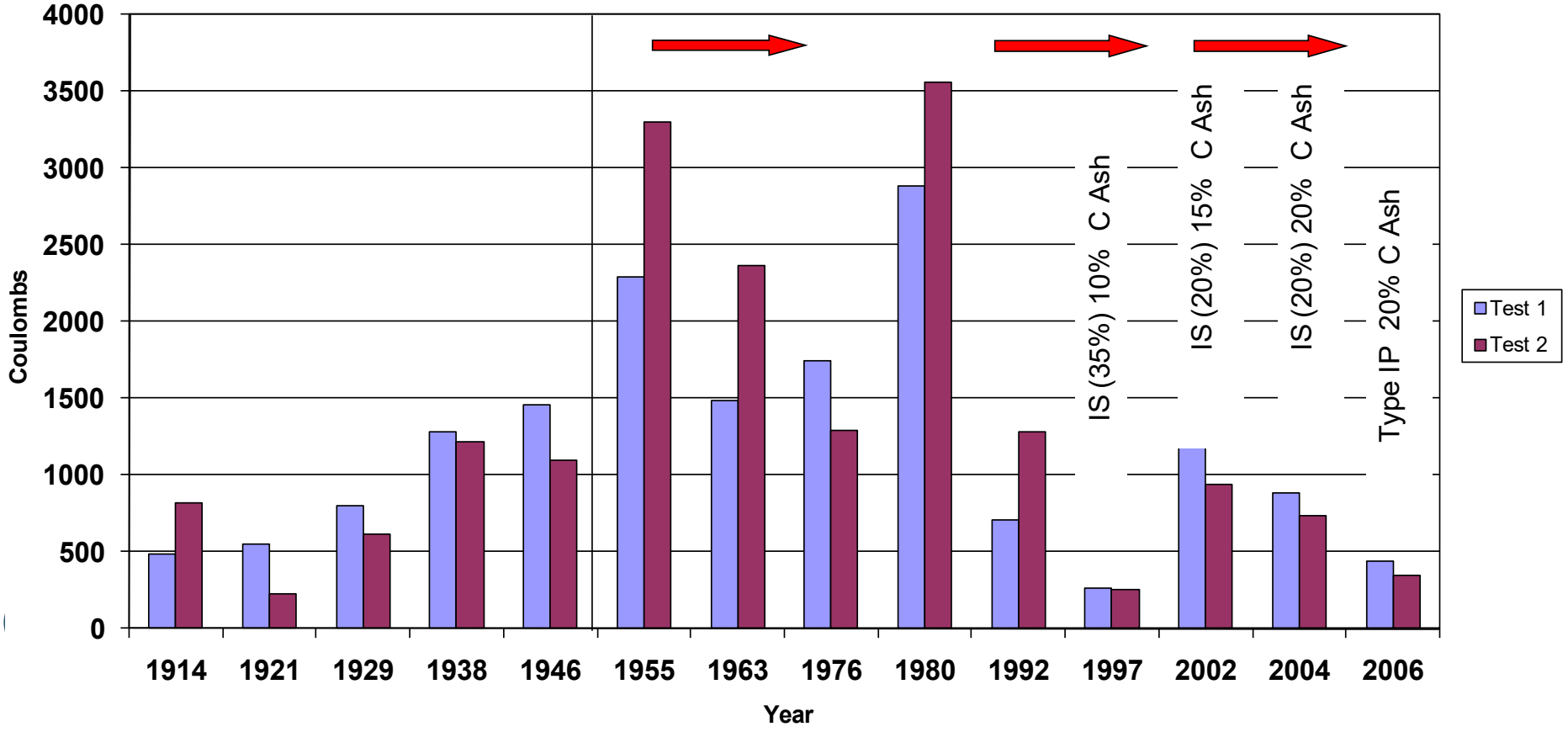
What has Changed? - Permeability

RCP - **AASHTO T 277**

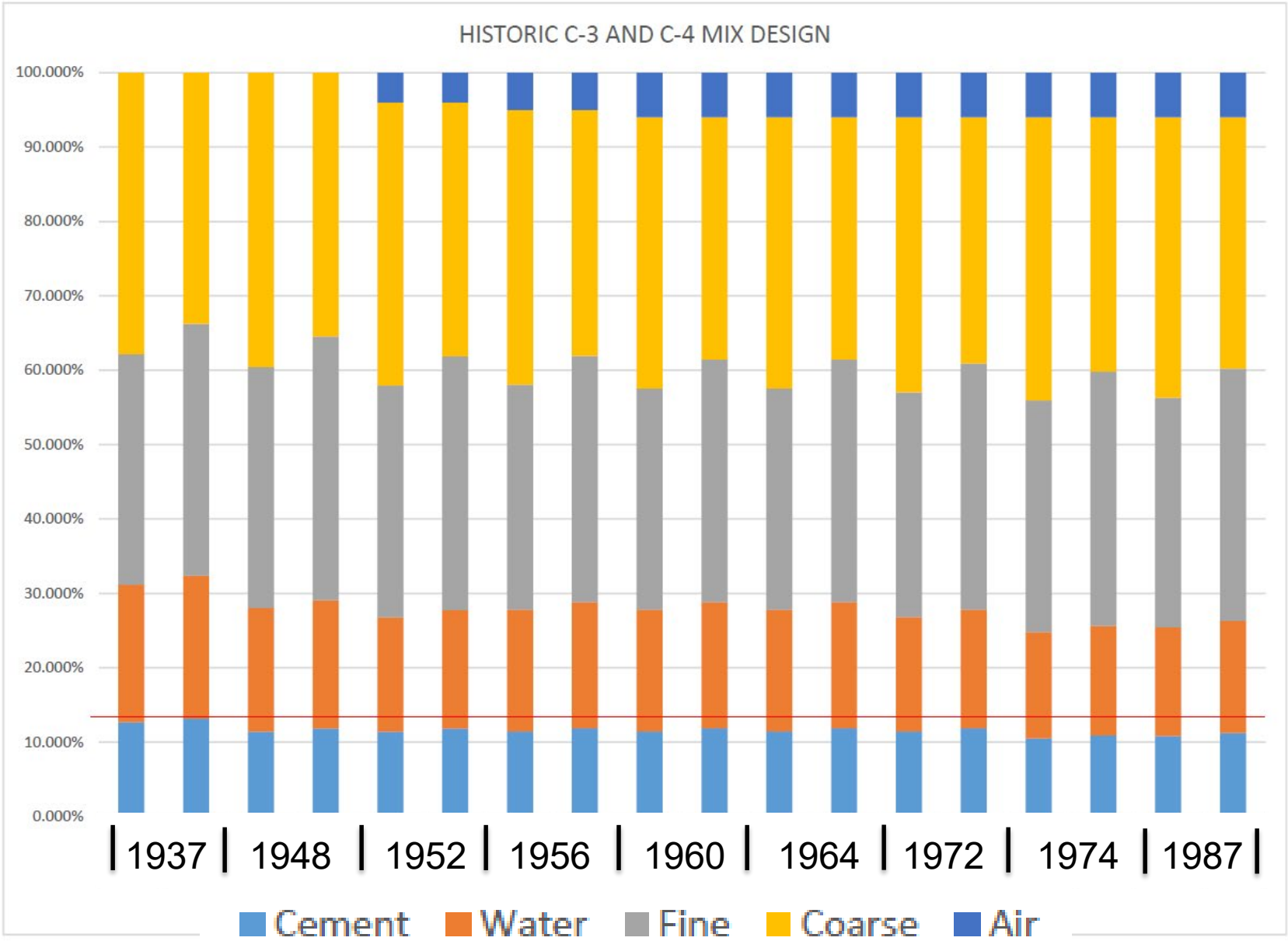
13 project sample size

Iowa DOT Report MLR-05-02, March 2007

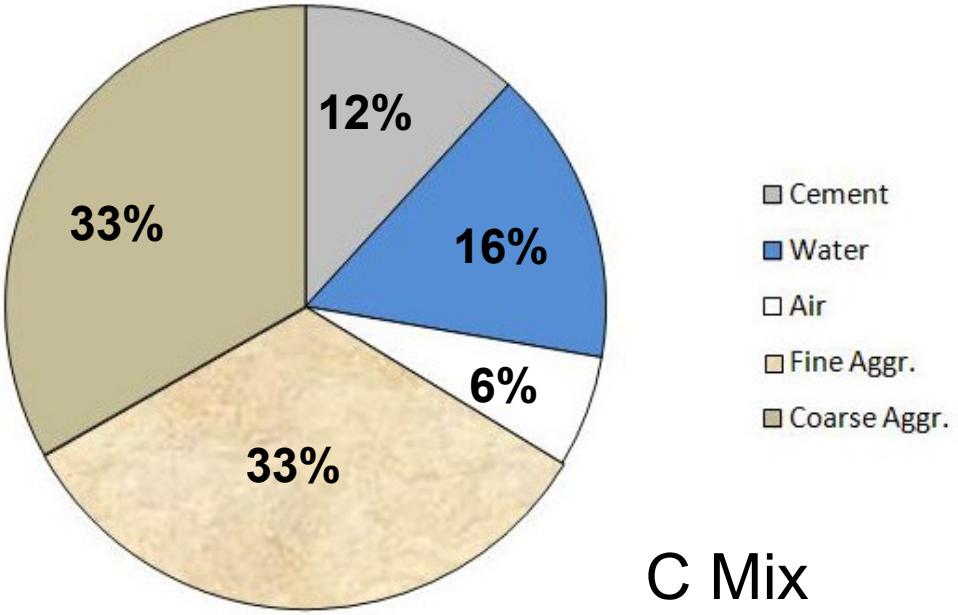


Low permeability is more important than air (based on older pavements)

What has Changed? – Not the mix



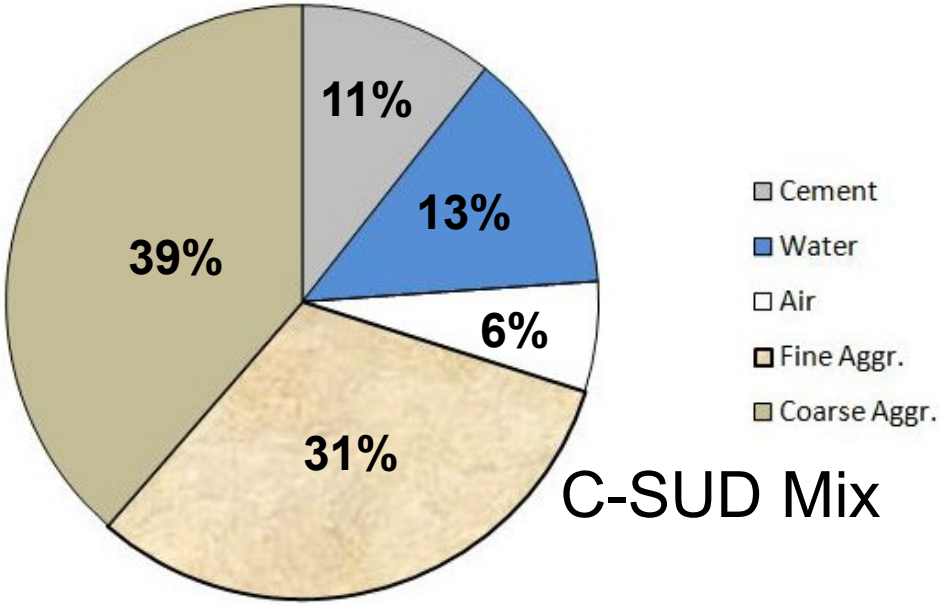
Current Class C-4 & Class C-SUD



C Mix

Class C-4 Mix

Cement	0.118
Water	0.159
Air	0.06
Fine Aggr.	0.331
Coarse Aggr.	0.332



C-SUD Mix

Class C-SUD Mix

Cement	0.106
Water	0.133
Air	0.06
Fine Aggr.	0.315
Coarse Aggr.	0.386

Results of Iowa DOT (MLR-05-02) Report

- The air content for projects placed prior to the requirement for air entrainment in 1952 is less than 3%
- Air contents increased as specification limits increased.
- The indicated permeability of older pavements is very low.
- **The permeability of pavements utilizing a Shilstone type gradation and supplementary cementitious materials, such as slag and fly ash, can reduce indicated permeability to the level of older pavements.**

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What has Changed?
Pavement Section

Uniform depth until 1926

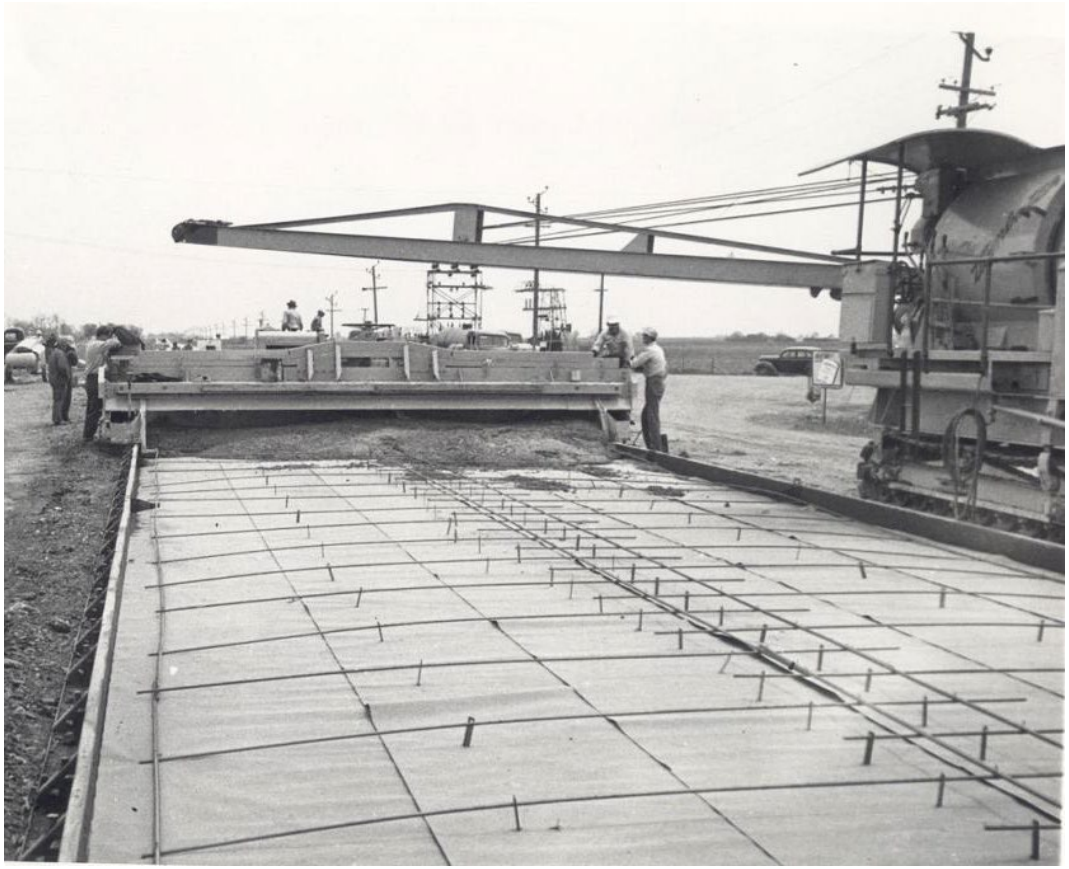
Thickened edge 1926-1957

18’ wide until mid-1930’s

20’ wide until 1948

22’ wide until 1959

Expansion joint with load transfer every 80’ to 120’



What has Changed? Deicing Practices

- Salts were common in the 1950s
- Brine became common in late 1990s

Source: Iowa DOT

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Deicers - Impact on Joints

- The formation of Calcium Silicate Hydrate (C-S-H) and Calcium Hydroxide (CH) are the two principal ingredients that mesh into a solid mass forming concrete pavement.
- Magnesium and calcium chloride will react with CH with water at between 32° F and 122° F, depending on the salt concentration.

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Deicers - Impact on Joints

- This reaction results in the formation of calcium oxychloride which results in flaking (expansion) of the hardened paste causing significant damage particularly in joints.

- Oxychloride expansion can be 3 times greater than freeze-thaw expansion.

- The use of SCM's (fly ash, slag, and silica fume) has shown to reduce the formation of calcium oxychlorides.

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What has Changed? Aggregates

- Aggregate quality very critical in performance of concrete durability
- 1930s pit run gravel was predominant
- Then, limestone and dolomite sources were mined
- Durability of these carbonate aggregates largely dependent on pore system
  - D-cracking
  - Deicer attack
- Aggregate is now tested to ensure long term performance

What has Changed? Aggregates

- 1967 study of D-cracking pavements
- Significant cracking after 5-10 years for certain aggregates (calcitic limestone, calcitic dolomite, dolomitic limestone)
- Led to Durability classification in 1971
- Pore system studied by Iowa DOT Office of Materials (shale, clay, tripolitic chert)
- D-cracking is related to pore size
- Led to Iowa Pore Index Test (in use since 1978)

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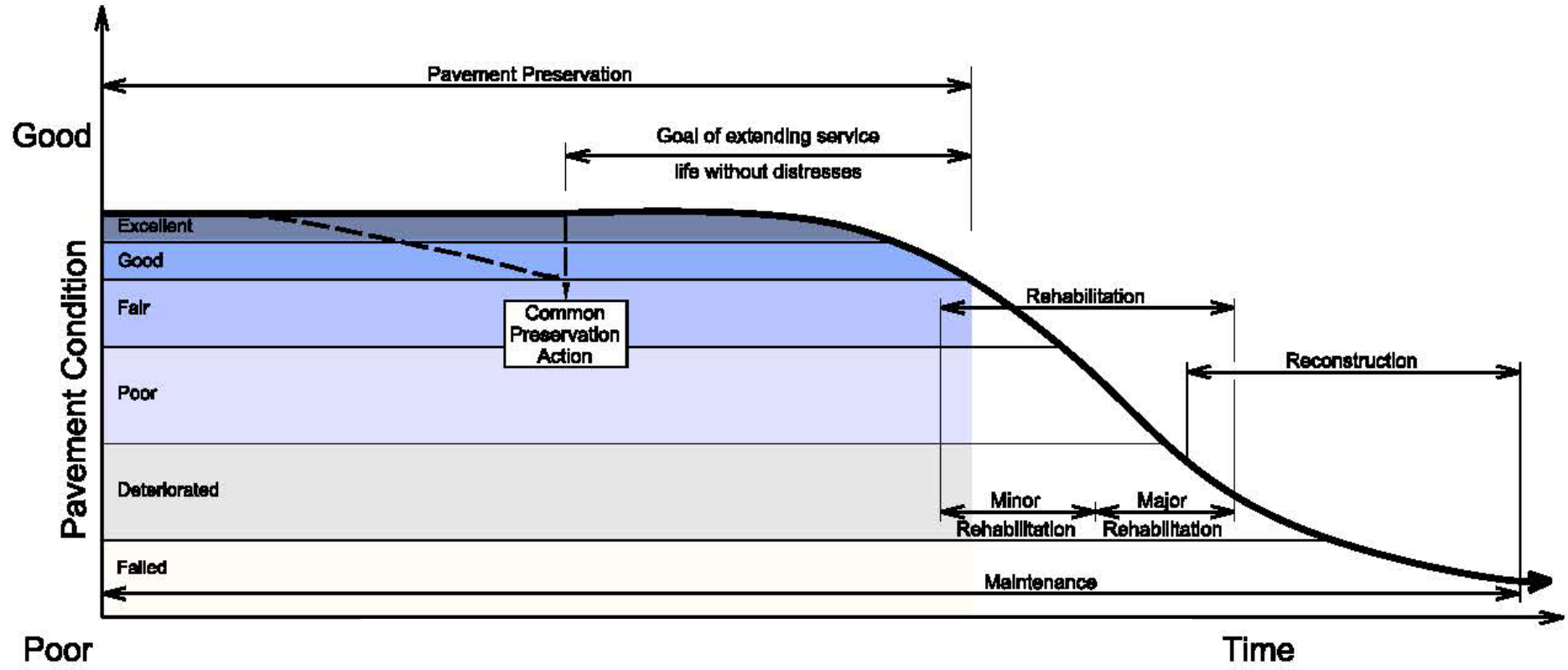
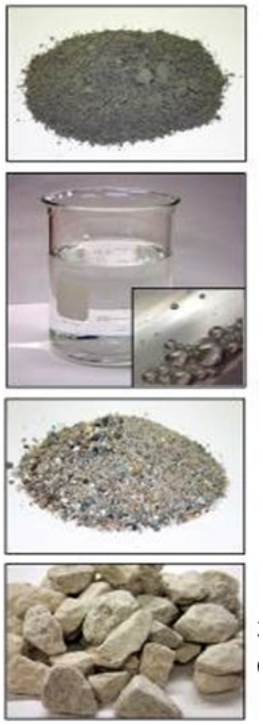
What is Essential for Long Life Concrete Pavements?

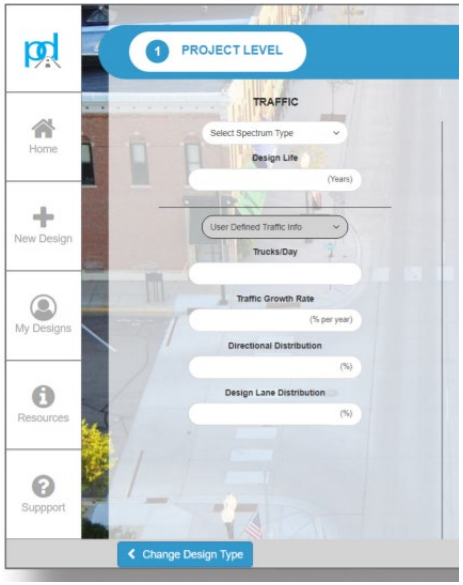


Summary
What is Essential for Long Life?
Low Permeability

Proper Materials



Proper Design



Proper Construction

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What is Essential?
Materials – Aggregate Durability

Durability Classification – IM T203

Class 2 – produce no deterioration of pavements in non-interstate roads after 15 years & only min. deterioration after 20 years (pore index >20)

Class 3 – produce no deterioration of pavements in non-interstate roads after 20 years & less than 5% deterioration of the joints after 25 years (pore index >25)

Class 3i – produce no deterioration of pavements on interstate roads after 30 years & less than 5% deterioration of the joints after 35 years (pore index >30)

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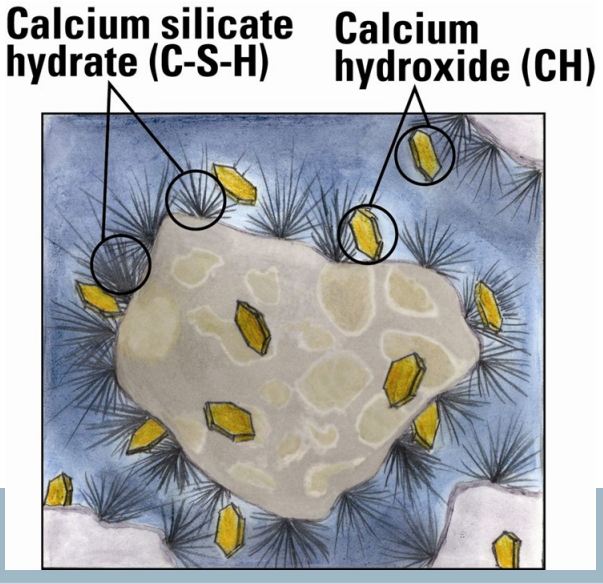
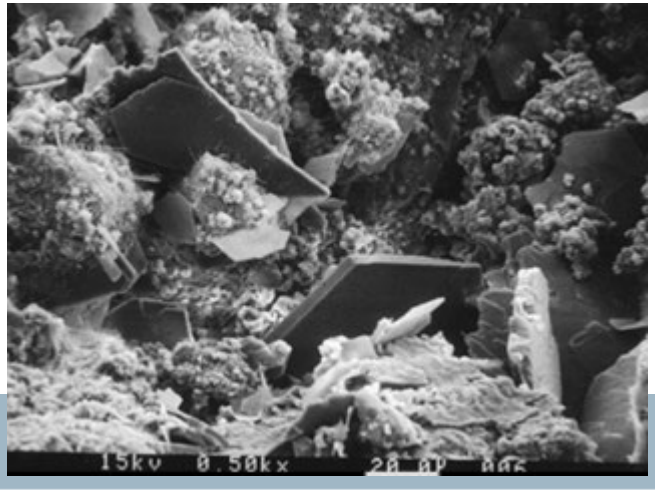
What is Essential?
Materials – Low Permeability

Use SCMs to tie up CH

Cement
+
Water **=** **C-S-H**
+

SCM + Water + CH = more C-S-H





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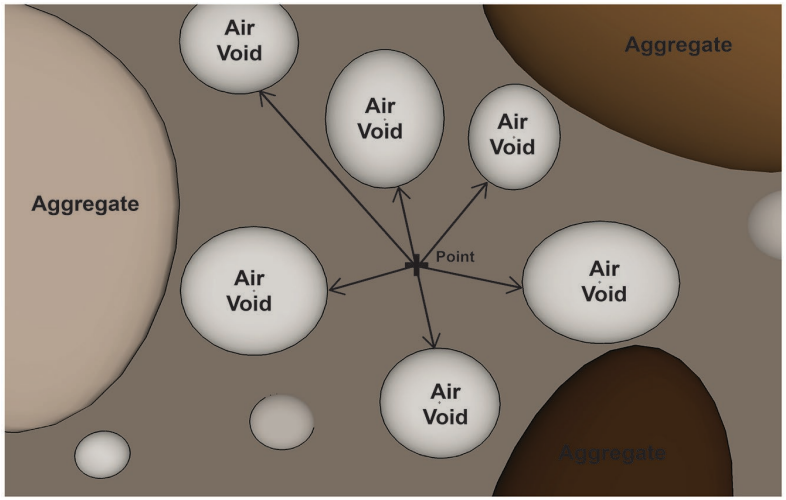
What is Essential?
Materials – Air Entrainment

Proper air void system
Spacing ≤ 0.008 in.

I.M. 318 (Air Content)
I.M. 327 (Sampling)



Super Air Meter (SAM)
(Photo by Tyler Ley)

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What is Essential?
Proper Design

- Pavement Designer is now available!
- Web-based pavement design application
- Developed by ACPA, NRMCA and PCA

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What is Essential?
Proper Design

www.pavementdesigner.org

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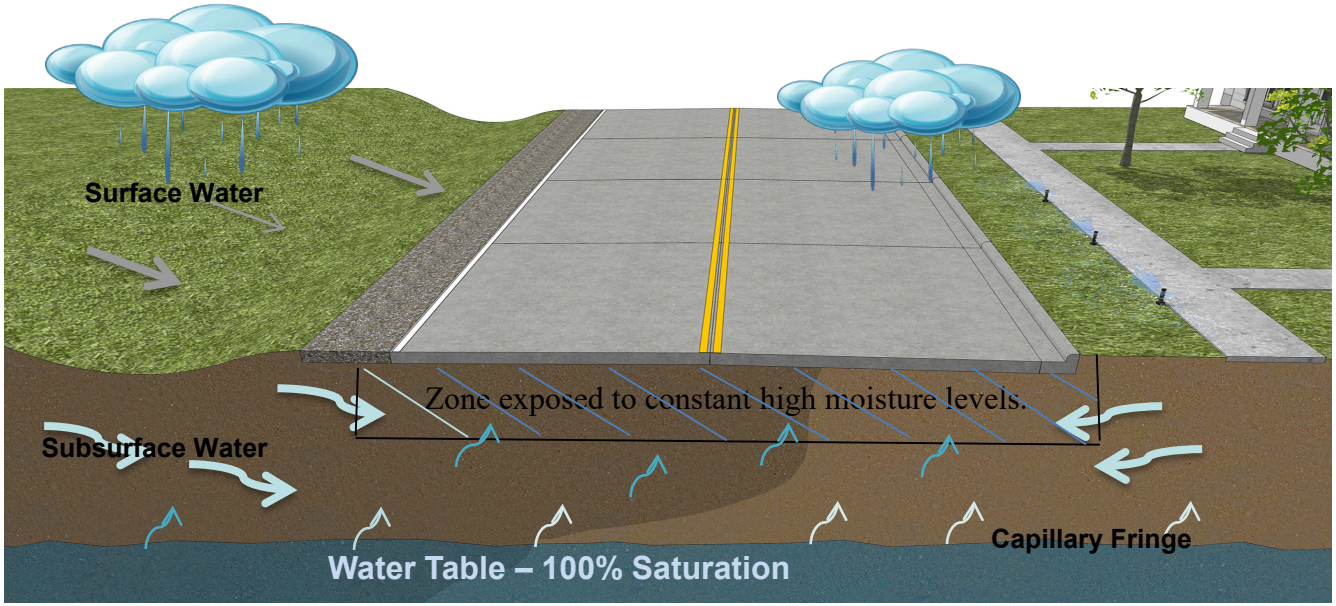
What is Essential?
Design – Drainage

Shadowing
- Potential sign of saturation

Joint deterioration – Can be caused by backer rod

What is Essential?
Design – Drainage



- Water is coming to our pavement from several sources
- We need to control this water so pavement is not saturated

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What is Essential?
Design – Drainage

- Used when soil is reasonably stable & not excessively wet.
- Provides a **working platform** during construction
- Provides **uniformity** as a support layer
- Serves as a **drainage system** to help drain surface water away from the pavement to a subdrain or ditch
- Provides a cutoff layer from subsurface moisture (and risk for pumping)

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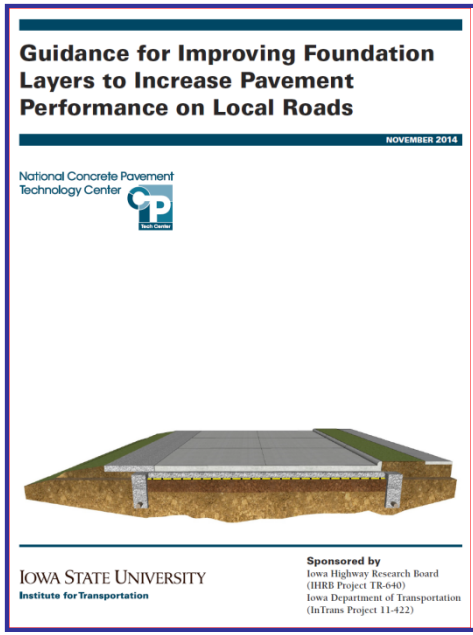
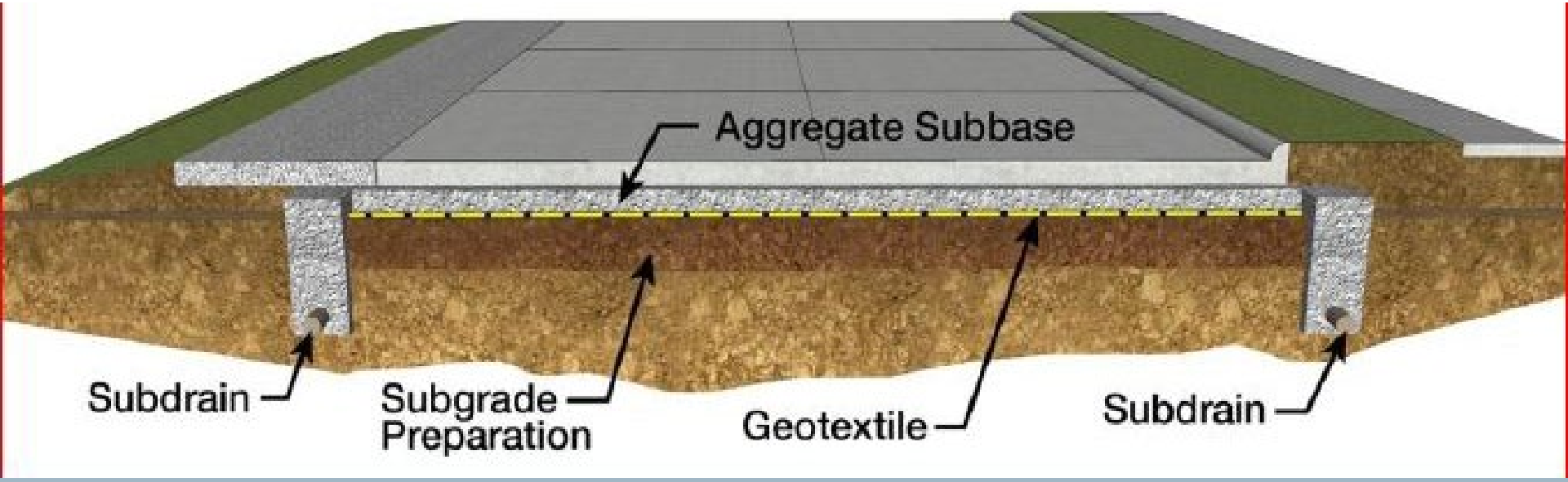
Separation Layer

Non Woven

Woven





What is Essential?
Construction – Use Proper Air

Check air after paver to determine loss

Air Content (on grade before consolidation)

- Slip form (8.0% +/- 2.0%)
- Non slip form (7% +/- 1.5%)

- Adjust the mix when:
  - Slip form Air < 7% or > 9%
  - Non slip form Air <6% or > 8%

  (on grade before consolidation)

(Ch. 9.6 Iowa DOT Field Inspection Manual)

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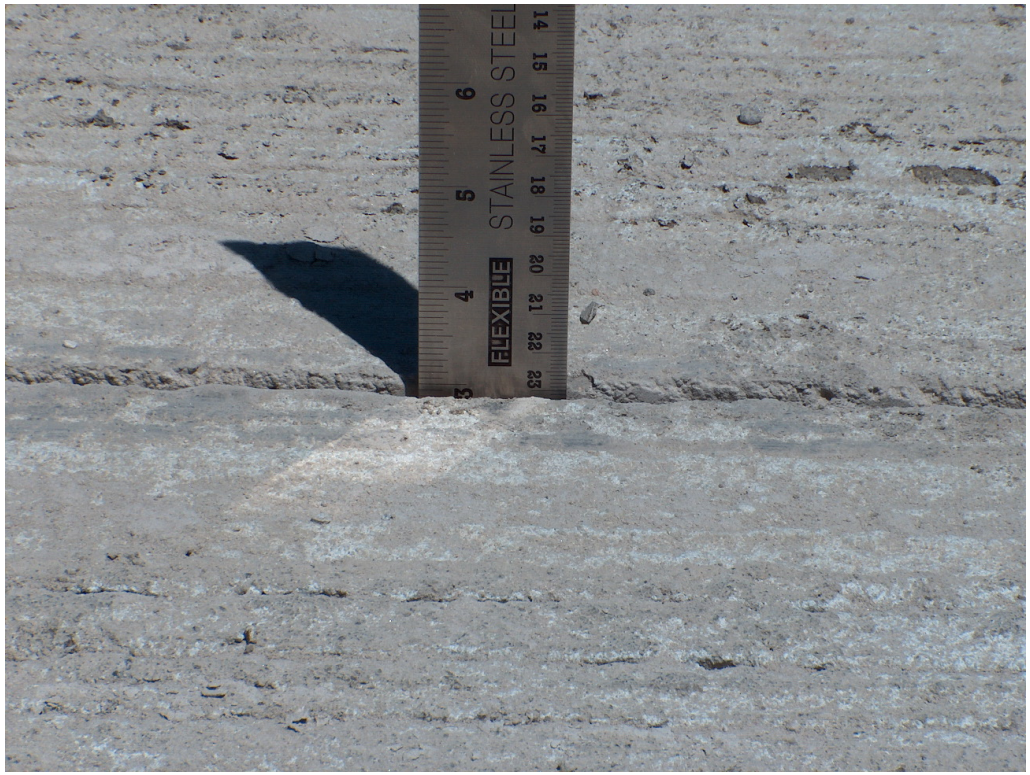
What is Essential?
Construction – Proper Cure

Curing

- Start early
- Application rate = 0.067 gal per SY
- Apply within 30 min.
- When it dries, it dies

What is Essential?
Construction – Proper Sawing



- Road Standard PV-101 (IDOT & SUDAS) defines all joints
- Check saw depth and width daily
- Inadequate depths may lead to cracking
- Check saw blade wear

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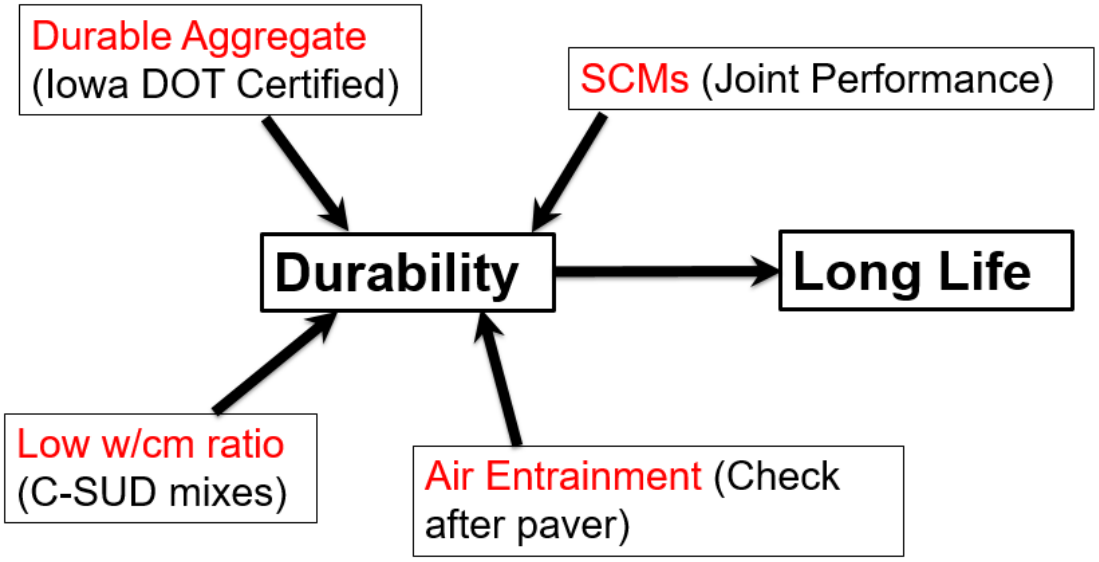
Summary
What is Essential for Long Life?

Materials
- **Low Permeability (Use SCMs)**
- **Aggregate Durability**
- **Air Entrainment**

Design
- **Thickness**
- **Drainage**

Construction
- **Proper Air**
- **Proper Curing**
- **Proper Sawing**



THANK YOU!

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