Constructability
Issues and Consequences

OHIO ASPHALT PAVING CONFERENCE
WEDNESDAY, FEBRUARY 4, 2015
aka The Post-Recession Depression of Asphalt
FROM 2008 UNTIL TODAY
Our Job is to Evaluate Risk

RUGGED REVIEW OF PRACTICES WITH NUMEROUS NATIONAL EXPERTS WAS COMPLETED IN 2014 BY THE FEDERAL HIGHWAY DISTRICTS.
Our Job is to Evaluate Risk

FOCUS ON THE:

- TYPICAL PAVEMENT CROSS SECTION,
- ASPHALT MIX DESIGN AND PRODUCTS,
- PRODUCTION, AND
- CONSTRUCTION PRACTICES CURRENTLY IN PLACE.
“Constructability defines the ease and efficiency with which structures can be built.”

- From Wikipedia, 2015
Constructability (or buildability)

The term refers to the effective and timely integration of construction knowledge into the conceptual planning, design, construction, and field operations of a project to achieve the overall project objectives in the best possible time and accuracy at the most cost-effective levels.
Copyright 1954

Recommended reading for all junior level engineers
Per capita consumption of mozzarella cheese (US) correlates with Civil engineering doctorates awarded (US)

<table>
<thead>
<tr>
<th>Year</th>
<th>Per capita consumption of mozzarella cheese (US)</th>
<th>Civil engineering doctorates awarded (US)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>9.3</td>
<td>480</td>
</tr>
<tr>
<td>2001</td>
<td>9.7</td>
<td>501</td>
</tr>
<tr>
<td>2002</td>
<td>9.7</td>
<td>540</td>
</tr>
<tr>
<td>2003</td>
<td>9.9</td>
<td>557</td>
</tr>
<tr>
<td>2004</td>
<td>10.2</td>
<td>622</td>
</tr>
<tr>
<td>2005</td>
<td>10.5</td>
<td>655</td>
</tr>
<tr>
<td>2006</td>
<td>11</td>
<td>701</td>
</tr>
<tr>
<td>2007</td>
<td>10.6</td>
<td>712</td>
</tr>
<tr>
<td>2008</td>
<td>10.6</td>
<td>708</td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Correlation: 0.958648
Constructability (or buildability)
Constructability (or buildability)
Constructability (or buildability)
Constructability (or buildability)
Divorce rate in Maine correlates with
Per capita consumption of margarine (US)

<table>
<thead>
<tr>
<th>Divorce rate in Maine</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Divorces per 1000 people (US Census)</td>
<td>5</td>
<td>4.7</td>
<td>4.6</td>
<td>4.4</td>
<td>4.3</td>
<td>4.1</td>
<td>4.2</td>
<td>4.2</td>
<td>4.2</td>
<td>4.1</td>
</tr>
<tr>
<td>Per capita consumption of margarine (US)</td>
<td>8.2</td>
<td>7</td>
<td>6.5</td>
<td>5.3</td>
<td>5.2</td>
<td>4</td>
<td>4.6</td>
<td>4.5</td>
<td>4.2</td>
<td>3.7</td>
</tr>
</tbody>
</table>

Correlation: 0.992558
The Math of Milling

The 4 Main Factors that Affect Surface Texture
1. Line Spacing
2. Forward Speed
3. Drum RPM
4. Lacing Pattern
Constructability (or buildability)
Constructability (or buildability)
Constructability (or buildability)
Line Spacing and Texture

Each cutter pattern is determined by the number of carbide teeth installed on the mandrel. More teeth produce fine patterns such as Profiling and Micro-Milling, but production rates remain low. Excavating and Traditional patterns allow for higher production rates but produce a coarser surface.

Milling Machine Cutter Drum Patterns
Indiana Glass Bead Test (ITM 812)

Total revenue generated by arcades (US) correlates with Computer science doctorates awarded (US)

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total revenue</td>
<td>1,196</td>
<td>1,176</td>
<td>1,269</td>
<td>1,240</td>
<td>1,307</td>
<td>1,435</td>
<td>1,601</td>
<td>1,654</td>
<td>1,803</td>
<td>1,734</td>
</tr>
<tr>
<td>(US) dollars in</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>millions (US Census)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer science</td>
<td>861</td>
<td>830</td>
<td>809</td>
<td>867</td>
<td>948</td>
<td>1,129</td>
<td>1,453</td>
<td>1,656</td>
<td>1,787</td>
<td>1,611</td>
</tr>
<tr>
<td>doctorates awarded</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(US) degrees awarded</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(National Science</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foundation)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Correlation: 0.985065
Constructability (or buildability)
Constructability (or buildability)
Constructability (or buildability)
Per capita consumption of chicken (US) correlates with Total US crude oil imports

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Per capita consumption of chicken (US)</strong> Pounds (USDA)</td>
<td>54.2</td>
<td>54</td>
<td>56.8</td>
<td>57.5</td>
<td>59.3</td>
<td>60.5</td>
<td>60.9</td>
<td>59.9</td>
<td>58.7</td>
<td>56</td>
</tr>
<tr>
<td><strong>Total US crude oil imports</strong> Millions of barrels (Dept. of Energy)</td>
<td>3,311</td>
<td>3,405</td>
<td>3,336</td>
<td>3,521</td>
<td>3,674</td>
<td>3,670</td>
<td>3,685</td>
<td>3,656</td>
<td>3,571</td>
<td>3,307</td>
</tr>
</tbody>
</table>

Correlation: 0.899899
Has the surface been thoroughly cleaned and properly tacked?
Constructability (or buildability)
Constructability (or buildability)
Per capita consumption of cheese (US) correlates with the number of people who died by becoming tangled in their bedsheets.

### Per capita consumption of cheese (US) (Pounds (USDA))

<table>
<thead>
<tr>
<th>Year</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pounds</td>
<td>29.8</td>
<td>30.1</td>
<td>30.5</td>
<td>30.6</td>
<td>31.3</td>
<td>31.7</td>
<td>32.6</td>
<td>33.1</td>
<td>32.7</td>
<td>32.8</td>
</tr>
</tbody>
</table>

### Number of people who died by becoming tangled in their bedsheets (Deaths (US) (CDC))

<table>
<thead>
<tr>
<th>Year</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deaths</td>
<td>327</td>
<td>456</td>
<td>509</td>
<td>497</td>
<td>596</td>
<td>573</td>
<td>661</td>
<td>741</td>
<td>809</td>
<td>717</td>
</tr>
</tbody>
</table>

Correlation: 0.947091
Constructability (or buildability)
Constructability (or buildability)
Principles of Constructability Mapped on to the Procurement Process

- Integration
- Construction knowledge
- Team skills
- Corporate objectives
- Available resources
- External factors
- Programme
- Construction methodology
- Accessibility
- Specifications
- Construction innovation
- Feedback
Standard Specifications, current EVER CHANGING edition
Standard Specifications

- Minimum VMA,
- Optimum Air Voids,
- Reasonable Gradation Bands,
- Achievable Compaction Levels, and
- Defendable Recycling Levels.
Hot Mix Asphalt (HMA)
Mix Design Submittal
Is the plant producing the mix per the design?

Design with minus #200 to:

- Account for breakdown,
- Predict field VMA, and
- Ensure JMF target asphalt content is produced.
Asphalt Mix Design:

- Requires accurate, reliable, and consistent aggregate bulk (dry) specific gravities that must be run on processed products.
- Watch the $G_{se}$ from design through production paving. ($G_{se}$ change = $G_{sb}$ change)
Volumetric’s 400
Importance of VMA

- Improve Mechanical Stability
- Improve Resistance to Permanent Deformation
- Reduce Moisture/Air Penetration
- Improve Fatigue Resistance
- Reduce Low-Temperature Cracking Potential
Why do we care about compaction?

- Density,
- Smoothness,
- Strength.

- Permeability,
- Public,
- Power.

Fatigue and low temperature cracking.
Reclaimed Asphalt Pavement
Constructability (or buildability)
VMA, dust to binder ratio, & AC

At the end it will be:

\[ V_{be} = VMA - V_a \]

\( V_{be} = \text{Effective Volume of Asphalt} \)
\( VMA = \text{Voids in the Mineral Aggregate} \)
\( V_a = \text{Air Voids} \)
Asphalt Production & Construction:

‘Use all equipment in accordance with the manufacturers recommendation.’
Dust balls
Fat Spots in Pavement
Fat Spots in Pavement
Fat Spots in Pavement

Issue

- Top half AC = 6.1%
- Bottom half AC = 4.8%

Solution: Eliminate steam build up in the MTV
Constructability (or buildability)

A project management technique to review construction processes from start to finish during pre-construction phase. It is to identify obstacles before a project is actually built to reduce or prevent errors, delays, and cost overruns.
Constructability (or buildability)

A project management technique to review construction processes from start to finish during the pre-construction phase. It is to identify obstacles before a project is actually built to reduce or prevent errors, delays, and cost overruns.

The more constructible a structure is, the more economical it will be.

prevent errors, delays, and cost overruns.
Quit living on the fringe

- Improve production volumetric measurements. *(If you can design it, then you can produce it)*
- Enhance gradation to be a smooth ‘S’ shaped curve. *(Reduce testing variability)*
- Understand that minimums are just that, they are not average minimums. *(Improve the life of asphalt)*
QC – Mean & Spread Relationship

“Typical” $Sn$

90 PWL
90 PWL

75 PWL

“Smaller” $Sn$