Consideration of Local Soil Conditions Through Modified Correlated R-value Formulation

Naresh C. Samtani, Ph.D., P.E., D.GE, F.ASCE
NCS GeoResources, LLC, Tucson AZ
www.ncsgeoresources.com
naresh@ncsgeoresources.com

Current Practice by Most Agencies within Arizona

\[
\log_{10}(W_{18}) = Z_R x S_o + 9.36 x \log_{10}(SN + 1) - 0.20 \\
+ \log_{10} \left[ \frac{\Delta \text{PSI}}{4.2 - 1.5} \right] \\
+ 0.40 + \frac{1094}{(SN + 1)^{5.19}} \\
+ 2.32 x \log_{10}(M_R) - 8.07
\]

\[
SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3
\]

\[
M_R = 1815 + 225*(R_{\text{mean}})+2.40*(R_{\text{mean}})^2
\]

\[
R_{\text{mean}} = \frac{N_t R_t \sigma_c^2 + N_c R_c \sigma_t^2}{N_t \sigma_c^2 + N_c \sigma_t^2}
\]
Tested (Measured) Resistance R-value, T or R_t
- AASHTO T190 or ASTM D2844

![Graph showing Tested (Measured) Resistance R-value, T or R_t](https://example.com/graph.png)

ADOT Correlated R-value, C or R_c

\[
\log R\text{-value at 300 psi} = 2.0 - 0.006(\text{Pass 200}) - 0.017(\text{PI})
\]

where, Pass 200 = % passing a #200 sieve (aka % Fines), PI = Plasticity Index

![Table showing ADOT Correlated R-value, C or R_c](https://example.com/table.png)
Basis of ADOT Correlated R-value Equation

- As per ADOT Preliminary Engineering and Design (PE&D) Manual

“Extensive regression and correlation analyses have been performed using the gradation and the Plasticity Index, Liquid Limit and Sand Equivalent test as indicators and predictors of R-value. Of the many candidate equations and relationships considered, a family of curves was finally chosen as the best workable relationship between gradation and Plasticity Index.”

Concept of Correlated R-value

Note

The normal probability distribution function (PDF) is schematic and shown for discussion purposes. Its position or size on the chart is not to be literally scaled.
Subgrade Acceptance – ADOT

**SUBGRADE ACCEPTANCE CHART**

*Example Project*

- **UNACCEPTABLE**
- **ACCEPTABLE**

**Percent Fines (Percent Passing No. 200 sieve)**

**Plasticity Index (PI)**

---

**X = (Pass 200) + 2.83(PI)**

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Projects in Tucson Metro Area - Correlated vs Measured R-values

- 28 projects
- 156 data points
Projects in Tucson Metro Area - Correlated vs Measured R-values

Interstate 10 (I10) Projects - Correlated vs Measured R-values
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Projects in Tucson Metro Area - Correlated vs Measured R-values

- Perfect Fit (1:1) Line
- 0.75:1 Line
- 0.5:1 Line
- 0.25:1 Line
- All Projects
- Rounded power function
- Poly. (PCDS curve)
- Power (Equiv Power function)

Equation:

\[ T = 0.29C^{1.19} \]

\[ T = 0.30C^{1.20} \]

Round coefficients to nearest 0.05

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Power Curve Adjustment of ADOT Equation versus New Equation

1. Power adjustment approach of ADOT equation as follows:
   \[ C_{\text{Pima}} = x C_{\text{ADOT}}^y \]
   where, \( x = 0.30 \) and \( y = 1.20 \)
   \( C_{\text{Pima}} = \) Pima County Correlated R-value
   \( C_{\text{ADOT}} = \) ADOT (base) Correlated R-value given as follows:
   \[ \log C_{\text{ADOT}} \text{ (value at 300 psi)} = 2.0 - 0.006(\text{Pass 200}) - 0.017(\text{PI}) \]

2. Potential new equation(s) for Pima County
   \[ \log C_{\text{Pima}} \text{ (value at 300 psi)} = 1.88 - 0.007(\text{Pass 200}) - 0.020(\text{PI}) \]
   \[ \log C_{\text{Pima}} \text{ (value at 300 psi)} = 1.8772 - 0.0072(\text{Pass 200}) - 0.0204(\text{PI}) \]

**Note:** Other Equations were also investigated, e.g., \( R = \text{func}(\#4 \text{ sieve}, \#40 \text{ sieve}, \#200 \text{ sieve}, \text{PI}, \text{LL}, \text{USCS}, \text{AASHTO Group}, \text{etc.}) \)

Advantages of Using Power Curve Adjustment Approach

1. Not generate an "urban legend" with "sacred" values
2. Can develop project-specific \( x \) and \( y \) parameters
   – Readily available power function trendline fit in Microsoft Excel®
3. Create a more transparent design approach
   – Ensure consistency of methodology application across designers and local agencies
4. Can continue to use other ADOT design steps
5. No change in slope of equation for X-value used in Materials Design Report, i.e., \( X = (\text{Pass 200}) + 2.83(\text{PI}) \)
   – Subgrade acceptance charts have the familiar look requiring no changes in the end-application by the field personnel
Subgrade Acceptance – ADOT

SUBGRADE ACCEPTANCE CHART
Example Project

<table>
<thead>
<tr>
<th>Plasticity Index (PI)</th>
<th>Percent Fines (Percent Passing No. 200 Sieve)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>10</td>
<td>100</td>
</tr>
</tbody>
</table>

- **UNACCEPTABLE**
- **ACCEPTABLE**

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SUBGRADE ACCEPTANCE CHART FOR ADOT R_c VALUES

Design R-Value = 15 to 60

Note: For any chosen Design R-value, if the tested elasticity index and percent fines of a soil plot below that R-value line, the soil is considered to be acceptable. If the elasticity index and percent fines of a soil plot above that R-value line, the soil is considered to be unacceptable and shall not be used as subgrade material. Also, the X-value shown in the legend for each R-value represents the maximum X-value for each Design R-value based on the equation, X = Percent Fines x 0.83978.

SUBGRADE ACCEPTANCE CHART FOR PIMA COUNTY R_c VALUES

Design R-Value = 15 to 60

Note: For any chosen Design R-value, if the tested elasticity index and percent fines of a soil plot below that R-value line, the soil is considered to be acceptable. If the elasticity index and percent fines of a soil plot above that R-value line, the soil is considered to be unacceptable and shall not be used as subgrade material. Also, the X-value shown in the legend for each R-value represents the maximum X-value for each Design R-value based on the equation, X = Percent Fines x 0.83978.
Sustainable – Euphemism for What?

1. Is the industry using fancy and empty words?
2. Are pavements being designed to fail?
3. Are we using design procedures (old or new) without fully understanding the issues related to input data development processes?
4. Are local agencies blindly following lead agencies?
5. Are lead agencies blindly imposing their rules on local agencies?
6. Are maintenance costs increasing?
7. Are taxpayer dollars being wasted?

New Guidelines for Pima County Projects (also used by Pima Association of Governments (PAG))

1. Calculate the ADOT correlated R-value ($C_{ADOT}$)
   \[ \log C_{ADOT} \text{ (value at 300 psi)} = 2.0 - 0.006 \text{(Pass 200)} - 0.017 \text{(PI)} \]

2. Calculate the Pima County correlated R-value ($C_{PIMA}$) as follows:
   \[ C_{PIMA} = x \ C_{ADOT}^y \]
   where \( x = 0.30 \) and \( y = 1.20 \)

3. The $R_{mean}$ is the design R-value. Since the correlated R-value has been adjusted above, the design R-value is also the construction control R-value.
New Guidelines for Pima County Projects (also used by Pima Association of Governments (PAG))

- Recognize that a site-specific correlation may provide cost saving opportunities

- Perform sufficient number of actual R-value laboratory tests (typically anticipated to be 10-20 per geologic formation) in order to develop site-specific correlated R-values ($R_C$) using the power function trendline option in Microsoft Excel®

- When site-specific correlation is used, a site-specific subgrade acceptance chart must also be created based on the $x$ and $y$ values for the power function
Consideration of Local Soil Conditions Through Modified Correlated R-value Formulation

Example 1

Tested (Measured) R-value, T vs. Correlated R-value, C

- Perfect 1:1 Line
- 0.75:1 Line
- 0.5:1 Line
- 0.25:1 Line
- Project Data Power Curve

Example 1

Tested (Measured) R-value, T vs. Pima County Correlated R-value

- Project Data

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Example 2 – Preliminary Testing

Tested (Measured) R-value, T

Correlated R-value, C

- Perfect Fit (1:1) Line
- 0.75:1 Line
- 0.5:1 Line
- 0.25:1 Line
- Project Data

Example 2 – Additional Testing

Tested (Measured) R-value, T

Correlated R-value, C

- Perfect Fit (1:1) Line
- 0.75:1 Line
- 0.5:1 Line
- 0.25:1 Line
- Project Data

Site-specific Power Curve

T = 3.74C^{0.77}

Fit R^2 = 0.54

Round coefficients to nearest 0.05

T = 3.75C^{0.75}
Some Other Causes for Potential Subgrade Issues

- Volume change behavior
  - Native (in situ) collapse-susceptible soils
  - Native (in situ) expansive soils
  - Compacted soils

- Wetting and drying induced changes in performance characteristics of native and compacted soils
n More Issues

1. Sampling and testing procedures
2. Mitigation of poor subgrade
3. Why do we get different R-values from different labs?

.........................
n-2 ....................
n-1 ....................
n Need another workshop........

Key Message

Recognize and fix the underlying issues with (mis)characterization of subgrade stiffness and construction quality control (QC)