REAAA Roadshow
The Use of Statistical Acceptance Criteria in the Roading Sector

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Quality

- Roading products must be within certain quality limits to provide a pavement that is fit for purpose.
- Need to control the quality of the product
- Determine whether the product delivered meets the specified limits
What Happens at the Moment?

Current Specification

- Limits are generally pass/fail without consideration to the variability of the tests.
- This can lead to accepting product that is below an acceptable quality.
- Also rejecting a product that is acceptable.
Use of Statistical methods implies that variability is the natural order

• In all cases where measurements are taken there is associated levels of uncertainty.

• If a measurement is taken using a metre rule there will be a certain error.
Accepting Variability

• When one looks at a shovel of aggregate every shovel load will be different.

• Variability in the manufacturing process + variability in sampling + variability of testing.

• We need to acknowledging this variability and determining what level of uncertainty is acceptable.
What we need to take into account

- Cost of compliance
- Cost of testing/measurement
- Ability of contractor’s to meet the requirement.
- Effect of non-compliance
Moving to Statistically based Specifications

• The current acceptance criteria will need to be questioned and re-evaluated.

• The rules should be explicit
  • less subjectivity in the engineer’s decision to determine whether the non compliance with the specification is “real” and whether it will affect performance on the road.
Acceptance Criteria - M/4 broken Faces requirement

• The aggregate broken face content in each of the three aggregate fractions between the 37.5mm and 4.75mm sieves shall not be less than 70% by weight and shall have two or more broken faces, when tested according to NZS 4407 : 1991, Test 3.14 Broken Face

• Important requirement protect against shear and premature rutting.

• If required 100% of aggregate to have 2 or more broken faces it would not be cost effective.
If life = quality
Scenario 1 suggests that life would decrease in a linear fashion
Scenario 2 suggests that material is acceptable at $\geq 70\%$ and unacceptable $<70\%$
Scenario 3 suggests that life will decrease gradually below $100\%$ to $70\%$ and then accelerate until $30\%$ where life would be unacceptably short.
Which Scenario Should we Choose

- If an appropriate performance curve can be constructed then we could determine what percentage of crushed is acceptable for different types of road.
- The current acceptance criteria needs be re-evaluated.
- Research information from CAPTIF trials and repeated load triaxial testing may be able to assist in developing such a performance curve.
Acceptance Criteria - Compaction of Hotmix

• The sub-lot shall be deemed acceptable in terms of density if the air voids for a surfacing mix are between 2.5 and 6.5%, or for a base or binder mix between 2.0 and 6.0%.

• If an individual core has air voids outside the above range then four additional cores shall be taken randomly within the sub-lot. If the mean value of these four cores lies between the limits given above, the relevant sub-lot shall be deemed acceptable in terms of density.
If an Individual Core has not complied

<table>
<thead>
<tr>
<th>Core No</th>
<th>Core Air Voids</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.5</td>
<td>5.5</td>
<td>6.5</td>
</tr>
<tr>
<td>2</td>
<td>3.5</td>
<td>3.5</td>
<td>6.5</td>
</tr>
<tr>
<td>3</td>
<td>7.0</td>
<td>5.5</td>
<td>6.5</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>4</td>
<td>10</td>
</tr>
</tbody>
</table>

May want to challenge but all are compliant
Distribution of Cores 2 and 3

Same mean but very different range. Indicating that just specifying the mean will not control the quality appropriately. Need to also consider SD.
The acceptance mechanism depends on the level of risk which is acceptable and this can be quantified by a value “k” called the acceptance constant.

If a particular attribute (Q) must lie between maximum and minimum values \( Q_u \) and \( Q_l \) an upper and lower characteristic value is calculated: 
\[
Q_u = \text{mean} + k \times s \\
Q_l = \text{mean} - k \times s
\]

<table>
<thead>
<tr>
<th>Sample Size</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>k</td>
<td>0.52</td>
<td>0.62</td>
<td>0.67</td>
<td>0.72</td>
<td>0.75</td>
</tr>
</tbody>
</table>
Seven random samples shall be taken from the stockpile and tested for percentage crushed. The stockpile will be accepted if:

\[ \text{Mean} - 0.75 \times \text{SD} \geq 70 \]

Where:
Mean is the average of the seven results;
SD is the standard deviation of the results and 0.75 is a “k” value related to the number of samples and the producer’s risk.
Using Statistical Acceptance Criteria in Practice

Standard Deviation for the process one = 3 process two = 5 and process three = 10

\[
\text{Mean} - 0.75 \times \text{SD} \geq 70\%
\]

<table>
<thead>
<tr>
<th>Mean</th>
<th>SD = 3</th>
<th>SD = 5</th>
<th>SD = 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>67.75</td>
<td>66.25</td>
<td>62.5</td>
</tr>
<tr>
<td>73</td>
<td>70.75</td>
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</tr>
<tr>
<td>78</td>
<td>75.75</td>
<td>74.25</td>
<td>70.5</td>
</tr>
</tbody>
</table>

Appears tougher to comply but maybe we can reduce the acceptance criteria
What Progress have we made

Members of the Statistical Acceptance Criteria Working Group

- David Hutchison  Downers
- Bryan Pidwerbesky  Fulton Hogan
- Robert Davies  Consultant Statistician
- Peter Cenek  Opus Research
- AQA  AQA
- David Alabaster  NZTA
- John Donbavand  NZTA
What to tackle first

• Originally the group was going to look at statistical acceptance criteria for constructed basecourses

• Soon became apparent that if the base course material was not complying with the acceptance limits then the basecourse is very likely to not comply regardless of the construction quality

• Focus on basecourse material
Current Requirements

The aggregate suppliers are the only part of the industry that do not have mandatory QA requirements.

We wanted to look at the current quality.
Actual Statistics From 46 Quarries

Q13 (53 obsv.)

GRADING  SHAPE  BROKEN
 CONTROL  FACES
Actual Statistics From Quarry

Q29 (62 obsv.)
Actual Statistics From Quarry

Hard Rock (10 obsv.)
Considerations

• We can see the quality is quite variable

• One of the main issues is grading of the larger fraction sizes. – Could it be segregation through poor sampling

• How important are the current ranges?
Process Quality Control for Producers

• If NZTA proceed with a QA system for quarries
• Each quarry will need a documented process to show how Source Quality, Production Quality, and Aggregate Handling are controlled
• All aggregate producers for NZTA will need a formal quality system
• A useful guide is:

Quality Assurance of Aggregates for Roads Developed by Roading NZ, Aggregate and Quarry Association and the Transport Agency.
Roading NZ Guide for Testing

• IANZ not mandatory.
• Important to get test results quickly.

Eg. Dry grading may be performed rather than washed which will be quicker,
a visual assessment by the plant operator of percentage of crushed faces.
Will need to carry out full testing by a IANZ registered laboratory for verification
Test Frequency

Testing frequency should vary:

• While checking that the process is in control testing will be more frequent

• Once process is in control the testing frequency will be reduced.
Collecting and Charting Results

Quality control charts should be used to display data.

The producer will have to determined that the process standard deviation is such that at least a certain percentage (95%?) of the production will fall within the M4 limits.
Comparing Two different Standard Deviations for Percentage passing 9.5mm Sieve

SD = 5.0

SD = 2.5

Result of 17 measurements

Outside warning limits
Standard Deviation = 2.5

9.5mm sieve – 43% to 57%  
200 measurements

2 failures over 200 measurements
Standard Deviation = 5.0

9.5mm sieve – 43% to 57% 200 Measurements

27 failures in 200 measurements
Any QA System must take into account

- Desired level of quality
- Cost of sampling and testing
- Level of risk for client and supplier
- Capability of plant, equipment and staff to achieve the level of quality
- Acceptance and quality control testing relationship
Thank You