Ethylene Glycol Accelerated Weathering Test – An Improved Non-Subjective Aggregate Durability Test Method

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Introduction

- Ethylene glycol has been used extensively in the past to identify rock durability issues associated with Smectite clay minerals.

- Historical test methods are predominantly based on subjective visual interpretation, describing observed degradation of individual rock pieces during the soaking process.

Purpose of the Improved Test Method

- Simplify and eliminate visual subjectivity common to historical test methods.

- Adequately quantify results to specify a contractual acceptance and rejection criteria.

- Prevent early pavement failure, specific to smectite clay minerals effecting aggregate/rock durability.

Scope of the Improved Test Method

- The new method builds on existing ethylene glycol test methods *(e.g. SANS 3001 : AG15 – 10% FACT)*, seeking to limit historical shortcomings.
- The concept is simple and use a standard aggregate crushing resistance test method.
- 2 X control samples and 2 X soaked (EG) samples tested in a SSD condition.
- The test report change in produced crushed fines (<2.36mm) between the control and soaked samples.

Main Points of Difference

- Specify fixed target load of 230kN *(constant loading rate 10±1 minutes).*

Main Points of Difference

- Test sample fraction size (13.2mm – 9.5mm).
- Reported crushed fines fraction passing 2.36mm.

Main Points of Difference

- Ethylene glycol soaking time (21 days).
- Ethylene glycol properties (ASTM 2693-07).

Main Points of Difference

- Reporting percentage crushed fines (< 2.36mm sieve)
- Test sample size (± 2.7kg x 2 controls and ± 2.7kg x 2 soaked samples)

Main Points of Difference

- 2 x saturated surface dry (SSD) testing, 21 days soaked samples
- 2 x control samples

Example of Test Data Reporting

Source	Rock Type	Crushing Resistance Tests (230 kN) Control 1	Control 2	Control Ave	Soak SSD 1	Soak SSD 2	Soak SSD Ave	Proportional Change %
	Dacite	19.1	19.2	19.2	18.5	19.1	18.8	0.0
	Andesite	9.5	9.8	9.7	14.2	14.7	14.5	49.7
	Greywacke	10.5	9.8	10.2	22.0	23.8	22.9	125.6
Ma[illegible]lies	Andesite	11.1	10.2	10.7	11.1	10.9	11.0	3.3
	Greywacke	14.2	13.6	13.9	19.7	19.1	19.4	39.6
W[illegible]ry	Andesite	17.7	18.1	17.9	18.9	18.5	18.7	4.5
W[illegible]ry	Andesite	22.4	21.3	21.9	21.5	22.5	22.0	0.7
	Andesite	22.4	22.2	22.3	23.9	23.8	23.9	7.0
I[illegible]y	Greywacke	8.7	8.7	8.7	9.7	10.1	9.9	13.8
Mi[illegible]po)	Greywacke	8.0	8.2	8.1	8.9	8.8	8.9	9.3
	Greywacke	10.3	9.8	10.1	10.9	10.7	10.8	7.5

Case Study: Early Pavement Failures

Failure mode – Excessive wheel ruts and pumping of fines

Case Study: Early Pavement Failures

LWP rut depth plots from HSD

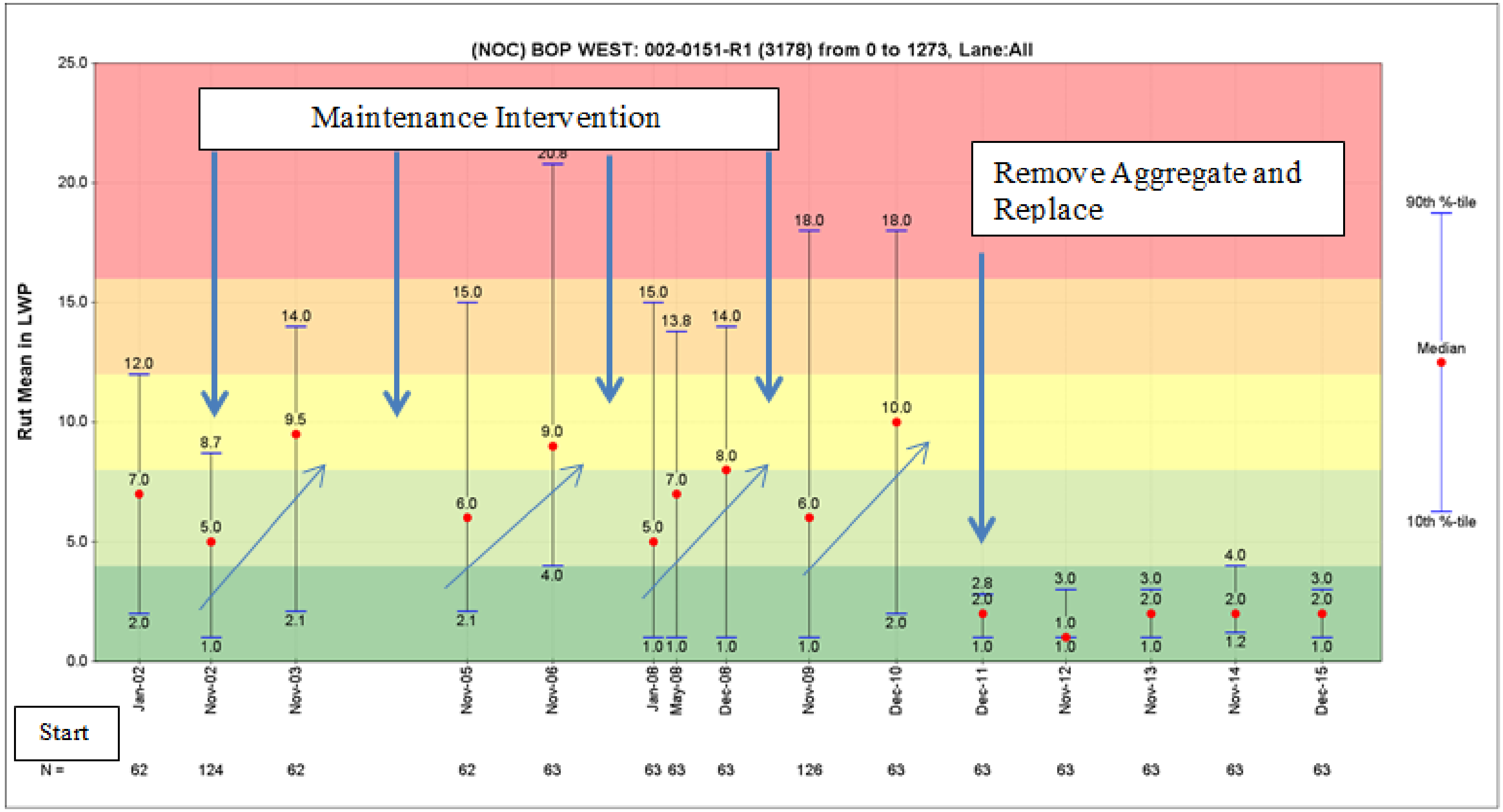

Figure 1 Typical rut depth and progression trends reported from annual high speed data surveys

Case Study: Field Investigation Findings

- Significant increase in clay fines (< 0.075mm) from 5% to 11%
- Increase in plasticity index (PI) from 5 to14.
- Reduction in sand equivalence (SE) from 40 to 25.
- The above are all indications that an increased in clay minerals were identified.

Case Study: Initial Exploratory Test Results (130kN)

Quarry Source	Rock Type	Specified Load of 130kN (Stone Fraction 9.5mm – 13.2mm)		
		% Fines Passing < 2.36mm		Percentage Change in Fines (X - Y) / (Y)
		Control	21 Day Soaked	
		Crushing dry condition (Y)	Crushing oven dry condition (X)*	
	Andesite	6.3	5.9	-6%
	Greywacke	6.1, 7.3	5.6, 7.1	-8%, -3%
	Andesite	7.3, 5.4, 4.1, 4.2	13.7, 9.3, 7.3, 6.8	88%, 76%, 78%, 62%
	Greywacke	5.5, 4.2	5.7, 4.3	4%, 2%
	Greywacke	1.6, 4.2, 4.3	1.6, 4.3, 4.7	0%, 2%, -
	Greywacke	4.3	3.6	-16%
	Greywacke	6.7, 8.4	8.7, 9.9	30%, 18%
	Greywacke	3.9, 3.5, 3.7	4.5, 4.2, 4.4	15%, 20%, 19%

Initial Test Results - Exploring an Improved Test Protocol

- Poplar Lane quarry showed ± 75% increased change in fines between control and soaked test samples.
- Test results validated and confirmed observed field performance.
- The results showed a strong link between early failures and aggregate durability.
- NZTA T20 - Ethylene Glycol Accelerated Weathering Test).

T20 Specification – Test Results

Quarry Source	Rock Type	Specified Load of 230kN (Stone Fraction 9.5mm – 13.2mm)		
		% Fines Passing < 2.36mm		
		Percentage change in averaged % fines for duplicate test samples		Presence of smectite clays through XRD analysis
		(X-Y)/Y	(Z-Y)/Y	
	Greywacke	12%	-	Minor
	Andesite	-1%	-7%	None
	Andesite	0%	9%	Trace
	Dacite	15%	-3%	None
	Andesite	5%	3%	Trace
	Greywacke	1%	6%	Trace
	Andesite	59%	89%	Abundant
	Andesite	3%	1%	Trace
	Andesite	4%	1%	None
	Greywacke	31%	31%	Abundant
	Greywacke	12%	12%	Minor
	Basalt	-2%	-6%	None
	Basalt/ Andesite	32%	55%	Abundant
	Basalt	-12%	-13%	None
	Greywacke	-16%	-17%	None
	Greywacke	6%	20%	Minor
	Greywacke/Mudstone	131%	207%	Abundant
	Limestone	13%	22%	None
	Basalt	9%	9%	None
	Andesite	11%	11%	None
	Andesite	-	50%	Abundant

X-Ray Diffraction Analysis

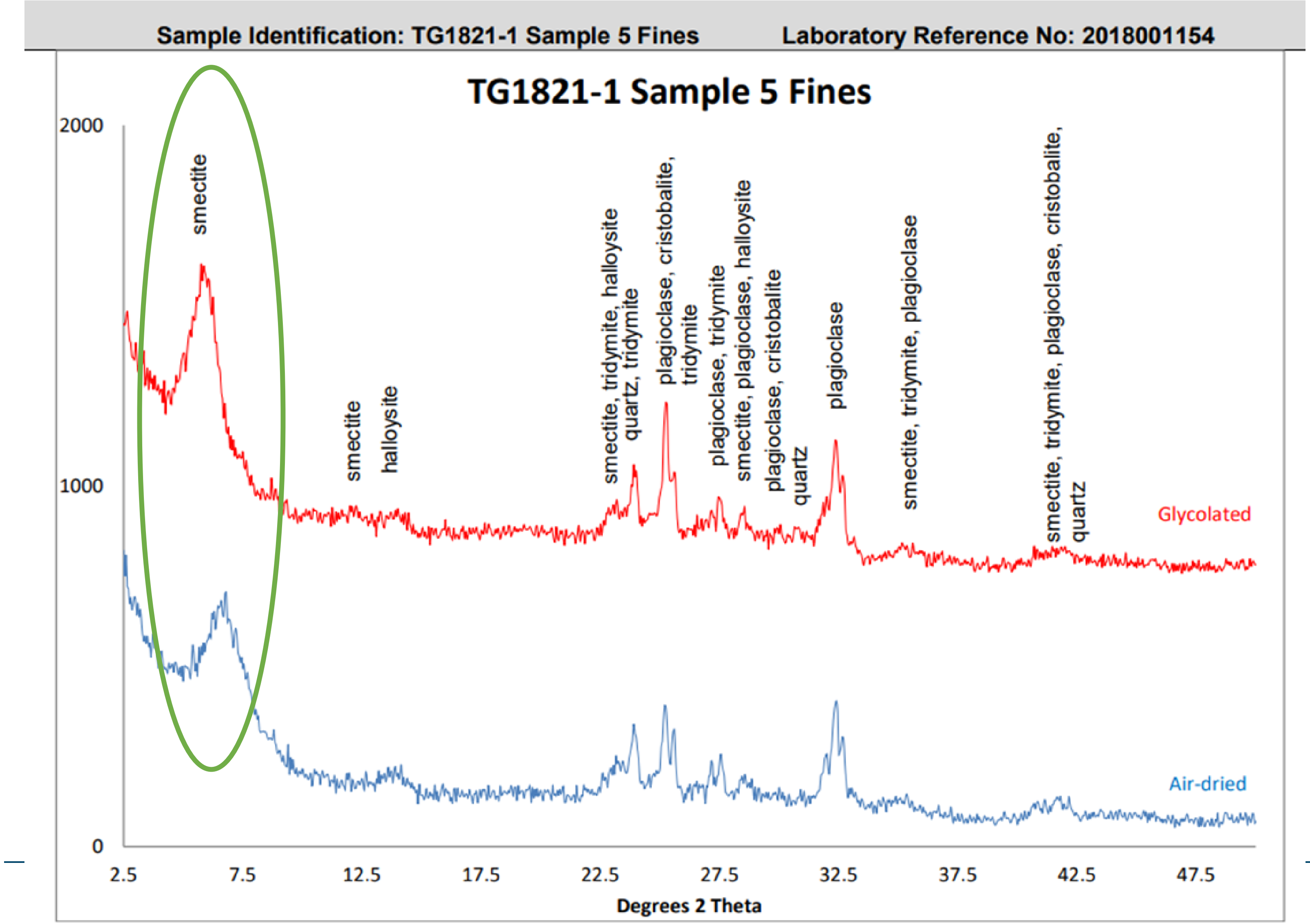

Figure 3. XRD scan showing the mineralogy of TG1821-1 Sample 5 Fines as indicated by the labelled scan peaks

Preliminary Correlation between % Fines Increase vs XRD Analysis

% Change (SSD)		XRD Smectite Clay: Abundant	Minor	Traces	None
210	200				
100	95				
95	90				
90	85				
85	80				
80	75				
75	70				
70	65				
65	60				
60	55				
55	50				
50	45				
45	40				
40	35				
35	30				
30	25				1
25	20		1		1
20	15				
15	10		1		2
10	5			2	2
5	0			2	1
0	-5				1
-5	-10				2
-10	-15				
-15	-20				1

Preliminary Correlation between % Fines Increase vs Clay Index

Clay Index / % Change (SSD)		10	9	8	7	6	5	4	3	2	1
		9	8	7	6	5	4	3	2	1	0
210	200							Matawai			
100	95										
95	90										
90	85										
85	80										
80	75										
75	70										
70	65										
65	60										
60	55										
55	50										
50	45										
45	40										
40	35										
35	30										
30	25										
25	20				1	1					
20	15							1			
15	10						1		1		1
10	5					2	1			2	2
5	0							2	1	2	
0	-5										2
-5	-10								1		
-10	-15									1	
-15	-20									1	

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Summary of Findings

- All five (5) rock sources showing > 30% increase in change in percentage fines has a known history of poor field performance, and
- abundant smectite clay minerals were identified through XRD analysis for these five (5) samples only.
- Testing soaked samples in SSD condition seems to produce a greater percentage change in fines and more accurately reflects field moisture conditions.
- The data seems to indicate a change > 30% fines increase maybe an appropriate upper limit for contractual acceptance and rejection criteria.

Summary of Findings

- Test data shows good repeatability between duplicate test samples.
- Rock quality and quarry production consistency will influence the ability of the test method to report the “same” result over a prolonged test period.

Conclusion

- Research conducted on metamorphic and volcanic crushed rock shown to be successful in quantifying aggregate degradation specific to Smectite clay minerals.
- Test data shows good repeatability between duplicate test samples (IANZ accredited).
- Rock quality and quarry production consistency will influence the ability of the test method to report the "same" result over a prolonged test period.
- An improved specification has been developed and implemented, that maybe used as a contractual acceptance and rejection criteria.

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Best Paper Winner K.B. Woods Award TRB 2017

"It was clearly the best paper reviewed by the Aggregates Committee (AFP70) last year. But I can't take any credit for its success as it had to demonstrate its own quality in competition first against top papers from the other 6 committees in the Geological and Geoenvironmental Engineering Group and then against top papers selected in a similar way from the other 7 groups in the Design & Construction Section – that's 59 committees altogether, representing something like 1500 submitted papers. So to win the award is a considerable achievement".

Prof Andrew Damsons Nottingham University UK