HI-LAB Pavement Testing at CAPTIF

Data Report

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Executive Summary

This project at the Canterbury Accelerated Pavement Testing Indoor Facility (CAPTIF) was initiated from the NZTA's Review 3: Investment Decision of the Gateway Review Report for Waikato Expressway – Huntly Bypass (Francis et al 2015) for Treasury. Recommendation 2 of the review was "*If not already done, NZTA should consider the urgent installation of suitably instrumented test sections at Taupiri and the CAPTIF facility to further improve confidence in the long-term performance of heavy duty Hi-Lab pavements.".* The priority assigned to the task by the report was *"Do Now."*

A test pavement at CAPTIF was constructed with four different Hi-Lab pavement sections, supported by a very weak clay subgrade, to study:

- The performance of a full-strength design with two Hi-Lab layers similar in thickness to the Huntly Bypass design (Test Section B)
- The influence of pavement depth on the performance of Hi-Lab by testing thinner sections (Test Sections B, C and D).
- The influence of maximum aggregate size on the performance of Hi-Lab by testing maximum aggregate sizes of 37.5mm and 63mm (Sections A and C)

This report presents the data from the accelerated pavement testing. The results suggest that the Huntly Hi-Lab design, constructed to the same 2xHi-Lab layer thicknesses in Test Section B, was well designed and unlikely to fail in fatigue if constructed properly in the field. It should be noted that all Hi-Lab trial sections at CAPTIF were constructed on a very weak clay subgrade (CBR≈4%), which is well below the design specifications for the Huntly and other Hi-Lab projects. Also, the loads applied during the testing at CAPTIF were 50% greater than design and the standard legal loading.

The thinner test sections suggest that fatigue is a mode of failure that needs to be designed against.

The comparison of maximum size aggregates in Sections A and C suggests that Hi-Lab 65 would be a superior material for fatigue.

Further analysis of the results forms part of an Auckland University PhD thesis by PGL van Blerk on Hi-Lab materials design and construction.

Abstract

A test pavement at CAPTIF was constructed with four different Hi-Lab pavement sections, supported by a very weak clay subgrade (CBR≈4%), to study:

- The performance of a full-strength design with two Hi-Lab layers similar in thickness to the Huntly Bypass design (Test Section B)
- The influence of pavement depth on the performance of Hi-Lab by testing thinner sections (Test Sections B, C and D).
- The influence of maximum aggregate size on the performance of Hi-Lab by testing maximum aggregate sizes of 37.5mm and 63mm (Sections A and C)

The pavement was loaded with a 60kN half single axle dual tyre (40kN is a standard half axle load). The loading was applied in a range of environmental conditions, starting with 2 million laps (4 million load passes) of dry loading on a thin dense graded asphalt surface. At industry request, the test sections were resurfaced with open graded porous asphalt and 100,000 laps of damp loading was applied, followed by 100,000 laps of wet loading and finally 150,000 laps of wet loading when saw cuts had been made in Section B with 2xHi-Lab layers (Hi-Lab40 base and Hi-Lab65 subbase layers) like the Huntly Bypass Section to simulate a surfacing failure.

Data was collected on surface deflection via Falling Weight Deflectometer and Benkelman Beam readings, rutting via transverse profile beams readings, strains in three dimensions via insitu inductive coil measurements and in-situ moisture conditions via time domain reflectometry gauges. Surface cracking was monitored and recorded with photographs.

This report presents the data from the accelerated pavement testing. The results suggest that the 2xHiLab layers like the Huntly Hi-Lab design in Test Section B was well designed and unlikely to fail in fatigue if constructed properly in the field. Hence, the pavement can be defined as perpetual in theory.

The thinner test sections suggest that fatigue is a mode of failure that needs to be designed against.

The comparison of maximum size aggregates in sections A and C suggests that the larger maximum aggregate size of Hi-Lab 65 would be superior for fatigue.

1 Introduction

1.1 Background

This project at the Canterbury Accelerated Pavement Testing Indoor Facility (CAPTIF) was initiated from the NZTA's Review 3: Investment Decision of the Gateway Review Report for Waikato Expressway – Huntly Bypass (Francis et al 2015) for Treasury. Recommendation 2 of the review was "*If not already done, NZTA should consider the urgent installation of suitably instrumented test sections at Taupiri and the CAPTIF facility to further improve confidence in the long-term performance of heavy duty Hi-Lab pavements.".* The priority assigned to the task by the report was *"Do Now."*

This report presents the data from the accelerated pavement testing.

1.2 Objectives

The test pavement was constructed with four different pavement sections, supported by a very weak clay subgrade, to study:

- The performance of a full-strength design with two Hi-Lab layers of similar thicknesses to the Huntly Bypass design (Test Section B)
- The influence of pavement depth on the performance of Hi-Lab by testing thinner sections (Test Sections B, C and D).
- The influence of maximum aggregate size on the performance of Hi-Lab by testing 37.5mm and 63mm maximum size aggregates (Sections A and C)

The test sections were labelled A to D, and the design parameters in each section are given in Table 1.1. Figure 1 and Figure 2 present the plan and cross-section views at CAPTIF, respectively.

Table 1.1 ***Test Section Details***

Section	Subgrade	Basecourse	Surface
A	100mm sand on clay	180mm Hi-Lab 65	25mm AC
B	100mm sand on clay	230mm Hi-Lab 65 with 200mm Hi-Lab 40 on top	25mm AC
C	100mm sand on clay	180mm Hi-Lab 40	25mm AC
D	100mm sand on clay	130mm Hi-Lab 40	25mm AC

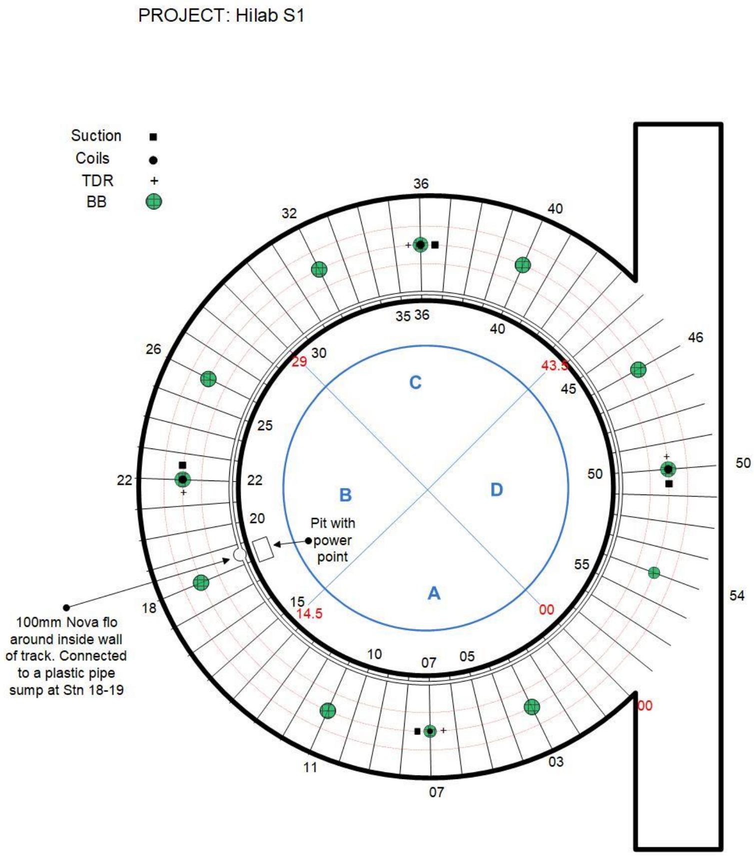

Figure 1 Test Track Layout

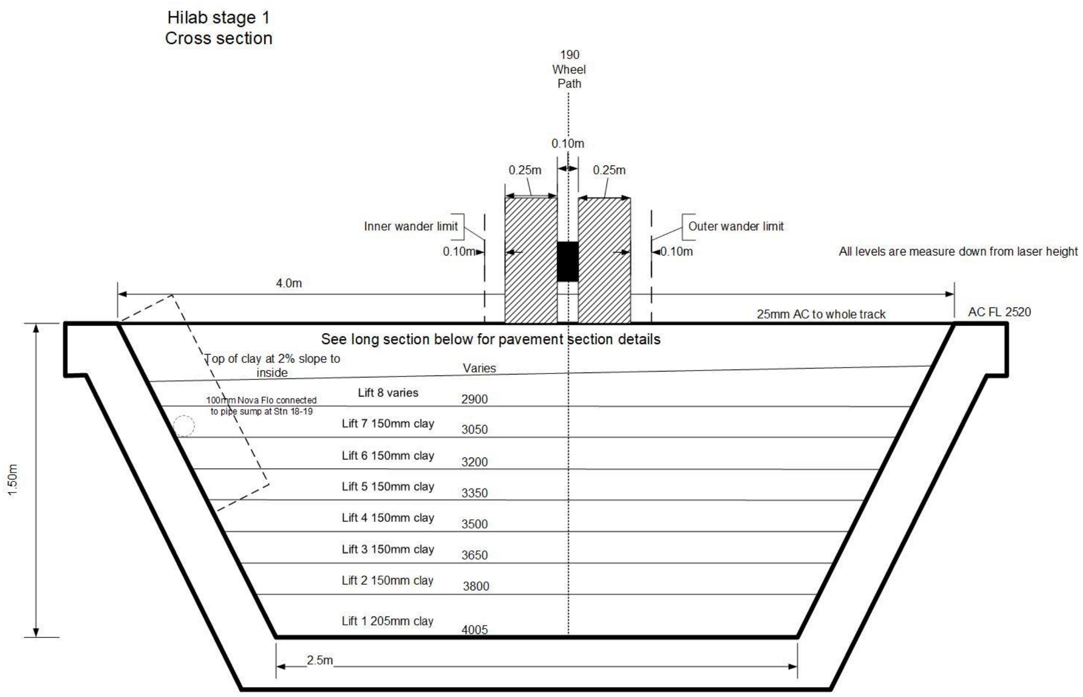

Figure 2 Test Track Cross-section

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1.3 Description of the Methodology

The research methodology involved a series of accelerated pavement test sections tested concurrently. Two key parameters in the Hi-Lab design were to be investigated: The influence of depth and the influence of the maximum aggregate size on performance.

In addition to standard tests, additional more advanced laboratory tests that characterised the properties of the treated materials were carried out. For the Hi-Lab materials, unconfined compressive strength (UCS), indirect tensile strength (ITS) and flexural beam modulus and tensile strength were also measured. The purpose of these advanced laboratory tests was to link the material properties found in the laboratory with a pavement design methodology that predicts field performance as found at CAPTIF and actual state highways built with Hi-Lab. The strain gauge system used at CAPTIF was also used to monitor Hi-Lab layers constructed in the field on various projects and the results are to be reported as part of an associated PhD study at Auckland University.

1.4 Canterbury Accelerated Pavement Testing Indoor Facility (CAPTIF)

The accelerated pavement testing was carried out at CAPTIF, in Christchurch, New Zealand. Testing took place over a period of 14 months from May 2016 to July 2017. CAPTIF consists of a circular track, 58m long (on the centreline) contained within a 1.5m deep x 4m wide concrete tank so that the moisture content of the pavement materials can be controlled, and the boundary conditions are known. A centre platform carries the machinery and electronics needed to drive the system. Mounted on this platform is a sliding frame that can move horizontally by 1m. This radial movement enables the wheel paths to be varied laterally and can be used to have the two 'vehicles' operating in independent wheel paths. An elevation view is shown in Figure 3.

At the ends of this frame, two radial arms connect to the vehicle units shown in Figure 4. These arms are hinged in the vertical plane so that the vehicles can be removed from the track during pavement construction, profile measurement, etc, and in the horizontal plane to allow for vehicle bounce. The test track is operated at a loading speed of approximately 50km/h and each load unit includes a total 200mm wheel wander (100mm each side).

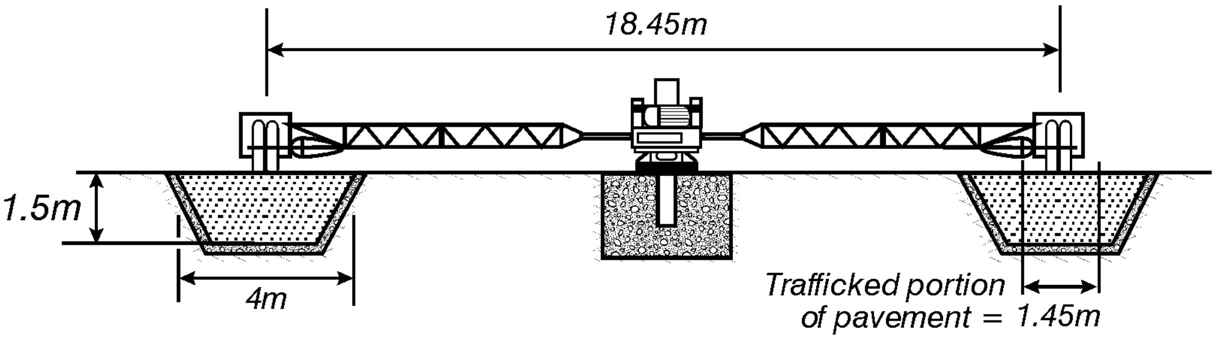

Figure 3 Elevation view of CAPTIF

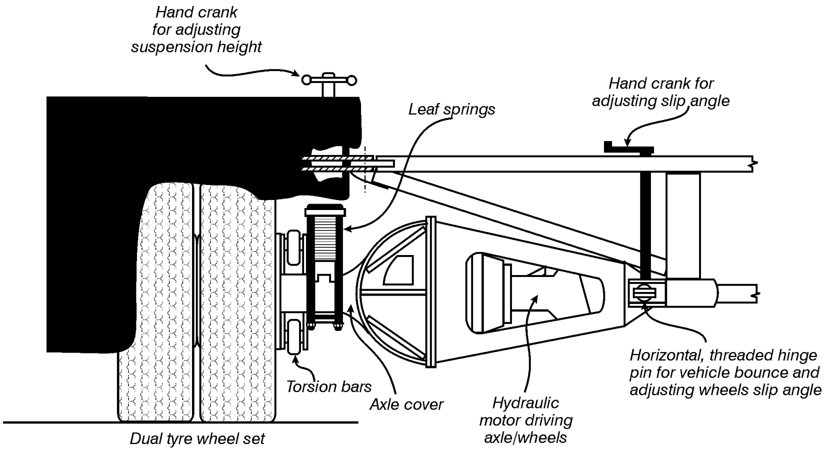

Figure 4 The CAPTIF vehicle unit

CAPTIF is unique among accelerated pavement test facilities in that it was specifically designed to generate realistic dynamic wheel forces. A more detailed description of CAPTIF is provided by Alabaster (2021).

2 Pavement design

No specific pavement design was completed for the project. The intention was to build a test section to replicate the two Hi-Lab layers proposed for the Huntly Bypass and provide additional test sections that would inform the experimental objectives. It should be noted the Hi-Lab test sections at CAPTIF were constructed on a very weak subgrade support, well below specified criteria for the Huntly and other projects. The intention was to accelerate fatigue failure within the Hi-Lab layers. The Hi-Lab pavements in the field are better supported and their Hi-Lab layers will function with much lower stresses/strains.

3 CAPTIF pavement construction

3.1 Subgrade Clay

The Tod Clay subgrade at CAPTIF was removed and re-laid for this project in lifts of 150mm and compacted using CAPTIF's pivot steer trench roller. Quality control was maintained with layer-by-layer density and moisture-content testing (Figure 5 and Figure 6).

In-situ CBR testing was conducted with a mechanical Scala penetrometer (Figure 7). The mechanical cone penetrometer used a load sensor to apply a hydraulic penetration force. The load sensor takes a reading at every 10mm penetration, the measured force is calibrated to a dynamic cone penetrometer and reported as number of blows/100mm penetration. The in-situ CBR was estimated from the RG Brickell relationship provided in the Road Research Unit TR1 technical recommendation (Brickell 1985). Once the construction of the subgrade was finished, FWD deflections of the subgrade surface were measured (Figure 8). The results show that the average CBR strength across the sections was uniform. However, further detailed investigation is needed of the deflection data as section A (used for the Hi-Lab 65 test) may have a different stress dependency.

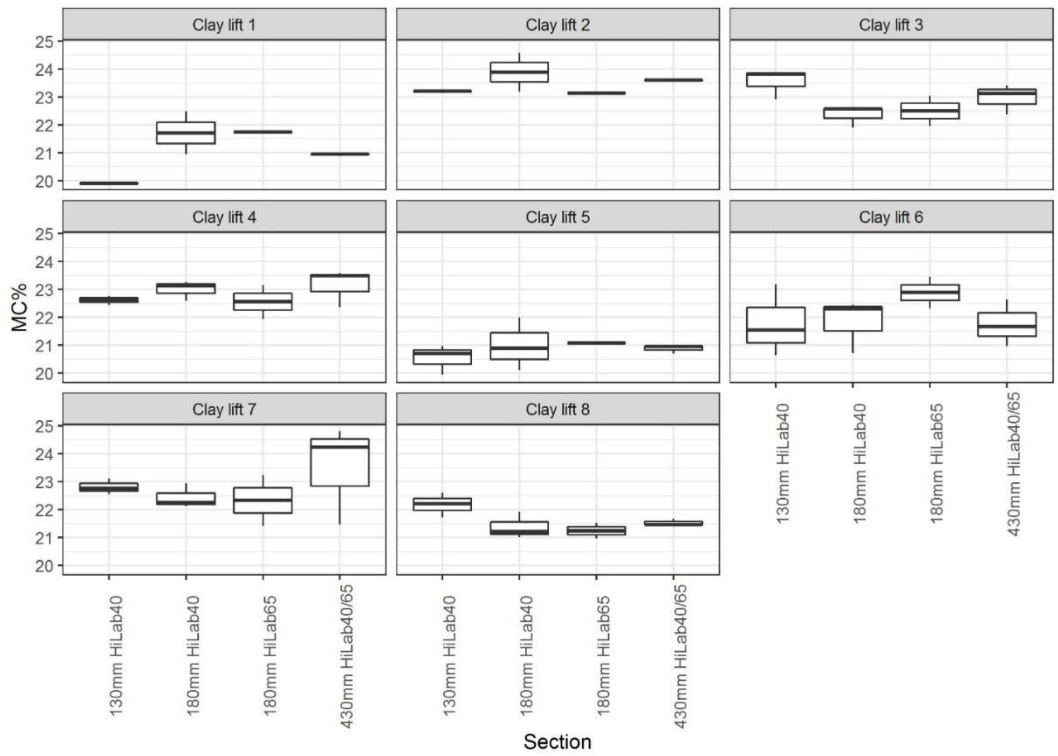

Figure 5 Subgrade Gravimetric Moisture Contents (%) by Lift Constructed and Test Section

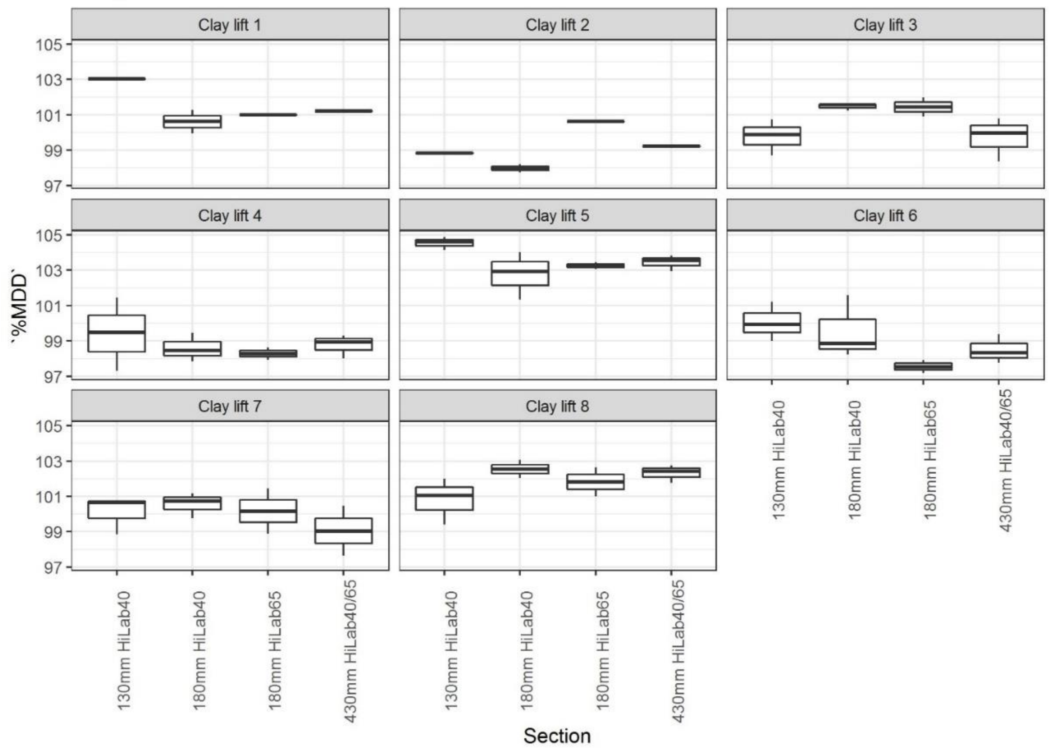

Figure 6 Subgrade Dry Density as a Percentage of the Maximum Dry Density (MDD) by Lift Constructed and Test Section

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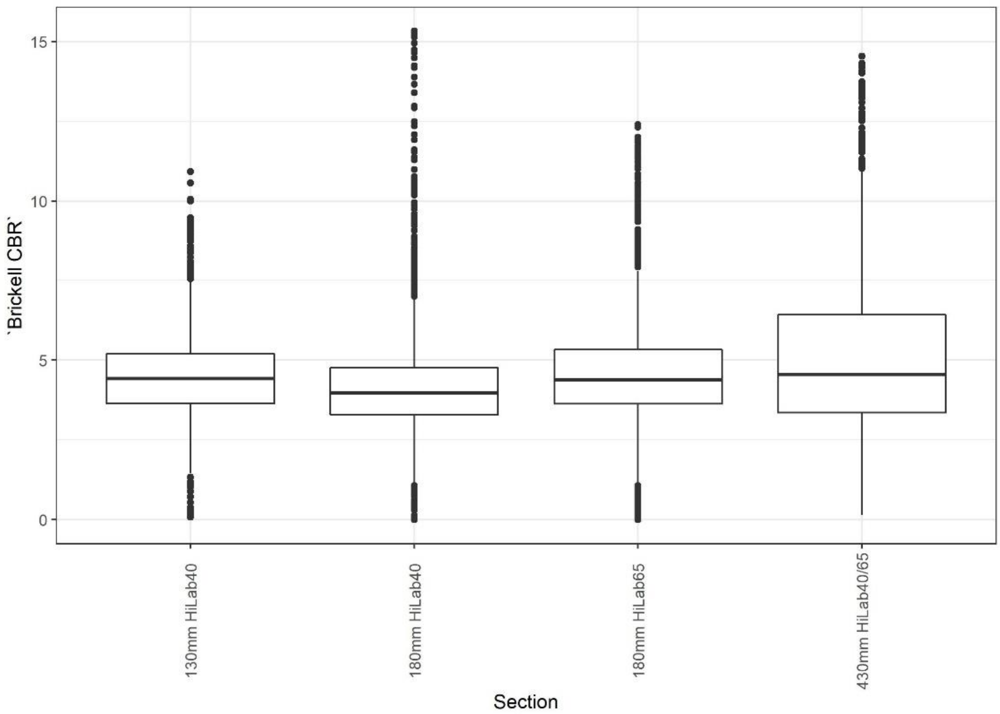


Figure 7 Inferred Subgrade CBR using the Brickell Relationship by Test Section

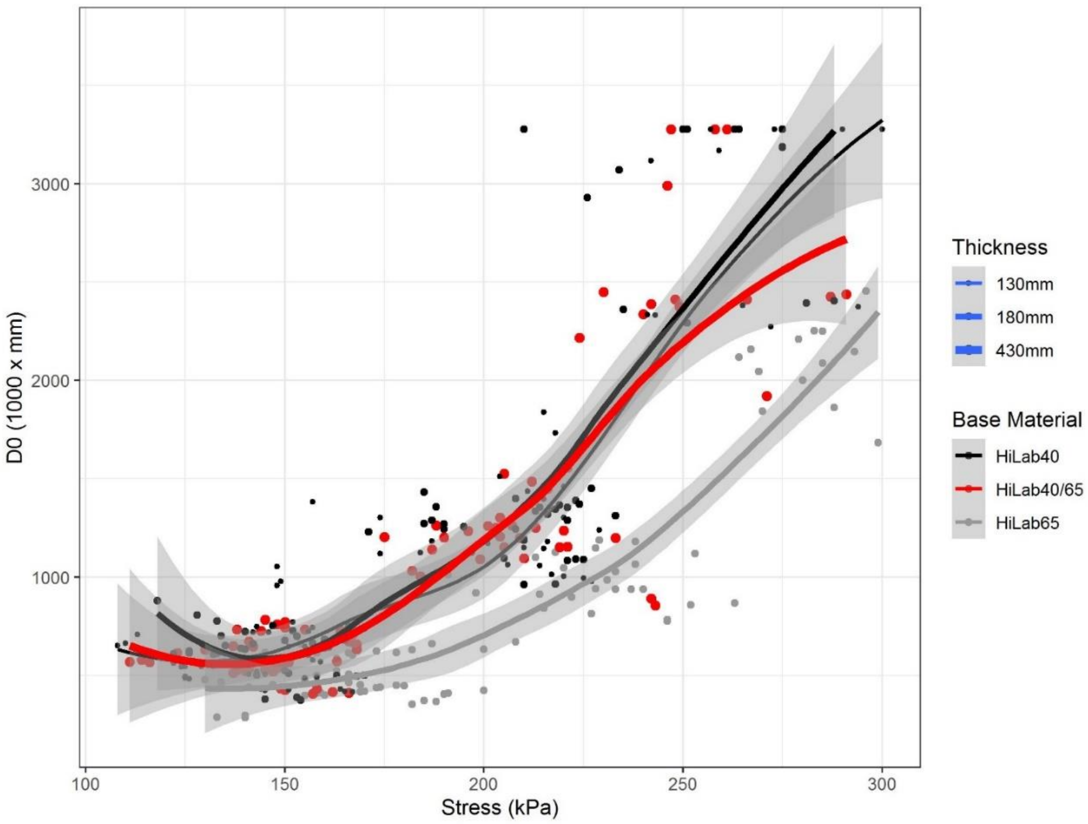


Figure 8 Subgrade Deflection Testing D0 results for Varying Loading Stresses by Test Section

3.2 Sand (100mm) Layer Construction

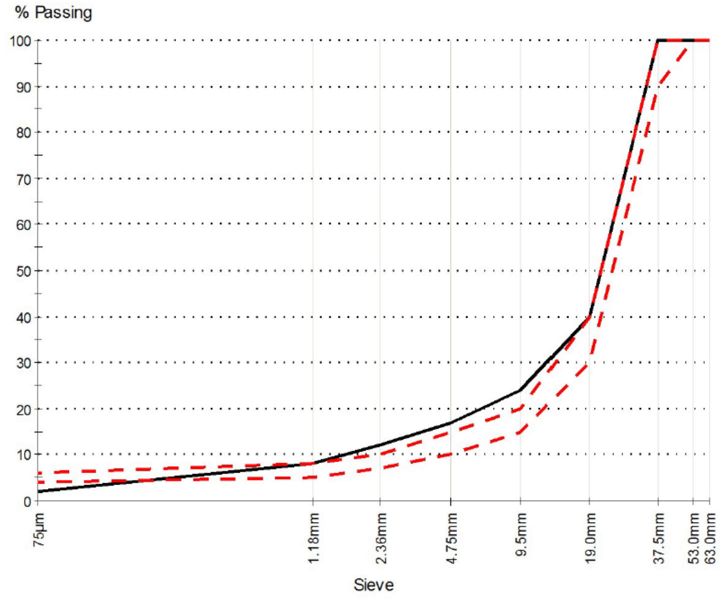
A black plastic waterproof membrane was place over the clay to assist in maintaining the clay's moisture content. Subsoil drains were placed around the inner edge of the track and connect to sumps that could be drained as required. A 100mm layer of sand (an AP5 blend typically used for making concrete) from Christchurch Ready Mix was then placed as a subgrade improvement layer over the clay. When tested to NZS 4402:1986 Test 4.1.1 the maximum dry density (MDD) of the sand was 1.90 t/m³ and the optimum moisture content (OMC) was 10%. Testing to NZS 4407 at the University of Canterbury resulted in an Unsoaked CBR of 35 when well compacted to 99% of MDD at OMC. This fell to an unsoaked CBR of 13 at 96% of MDD.

3.3 Hi-Lab construction.

The aggregate for the Hi-Lab layers was sourced from J Swap Taotaoroa Quarry in the Waikato. Hi-Lab 40 and Hi-Lab 65 aggregate was trucked to Fulton Hogan Canterbury where 3% cement by mass and water for compaction were added to the aggregate via a pugmill (Figure 9).

Figure 9 Hi-Lab Pug Mill

Figure 10 and Figure 11 present the particle size distributions of the Hi-Lab 40 and Hi-Lab 65, respectively.



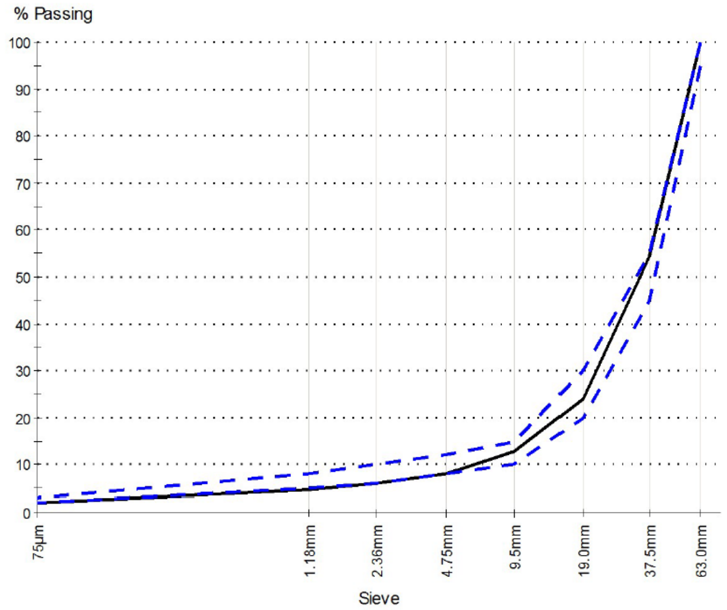
Method: NZS 4407:2015 Test 3.8.2

Drying by: Oven

Tested By: Max Burford

Sieve Size	% Passing	Limits
63.0mm	100	100 – 100
53.0mm	100	100 – 100
37.5mm	100	100 – 90
19.0mm	40	40 – 30
9.5mm	24	20 – 15
4.75mm	17	15 – 10
2.36mm	12	10 – 7
1.18mm	8	8 – 5
75µm	2	6 – 4

Figure 10 Hi-Lab 40 Gradation off the belt at the Pug Mill



Method: NZS 4407:1991 Test 3.8.2

Drying by: Oven

Sieve Size	% Passing	Limits
63.0mm	100	95 – 100
37.5mm	54	45 – 55
19.0mm	24	20 – 30
9.5mm	13	10 – 15
4.75mm	8	8 – 12
2.36mm	6	6 – 10
1.18mm	5	5 – 8
75µm	2	2 – 3

Figure 11 Hi-Lab 65 Gradation sampled from the Pug Mill

An initial trial of mixing, placing (Figure 12) and compaction (Figure 13 and Figure 14) of both the Hi-Lab 65 and the Hi-Lab 40 was undertaken in the CAPTIF yard to assess the construction process and equipment. A particular focus was to determine whether machine paving Hi-Lab was practical and whether smaller compaction plant (that would be easier to operate in CAPTIF) would work. Both options were possible. However, later work determined that the paving machine was not able to turn on the CAPTIF radius while paving Hi-Lab.

Figure 12 Hi-Lab 40 Paved in CAPTIF Yard

Figure 13 Hi-Lab 40 Primary Rolling with Padfoot

Figure 14 Hi-Lab 40 Secondary Rolling with Pap 7 to choke the surface

The final construction approach at CAPTIF was to mix the cement and water into the Hi-Lab using a pug mill. The material was transported to CAPTIF, placed in a stockpile and a loader was used to “turn” the materials within the stockpile over to improve mixing and to immediately run the material into the shed for placement. Primary compaction was complete with the 3.3 ton pad foot roller and trimming was completed with a mid-mounted blade on a tractor (Figure 15). Further compaction was completed with a 4 ton dual smooth drum roller.

Figure 16 shows the completed surface prior to sealing.

Figure 15 Hi-Lab 40 Laid in Track

Figure 16 Hi-Lab 40 finished surface prior to sealing

The final Hi-Lab surfaces were then tack coated with 180/200 bitumen with 2% kerosene at a nominal rate of 0.2 l/m2 and a nominal 25mm DG10 asphalt running surface applied.

The layer thicknesses measured in the wheel path are presented in Figure 17.

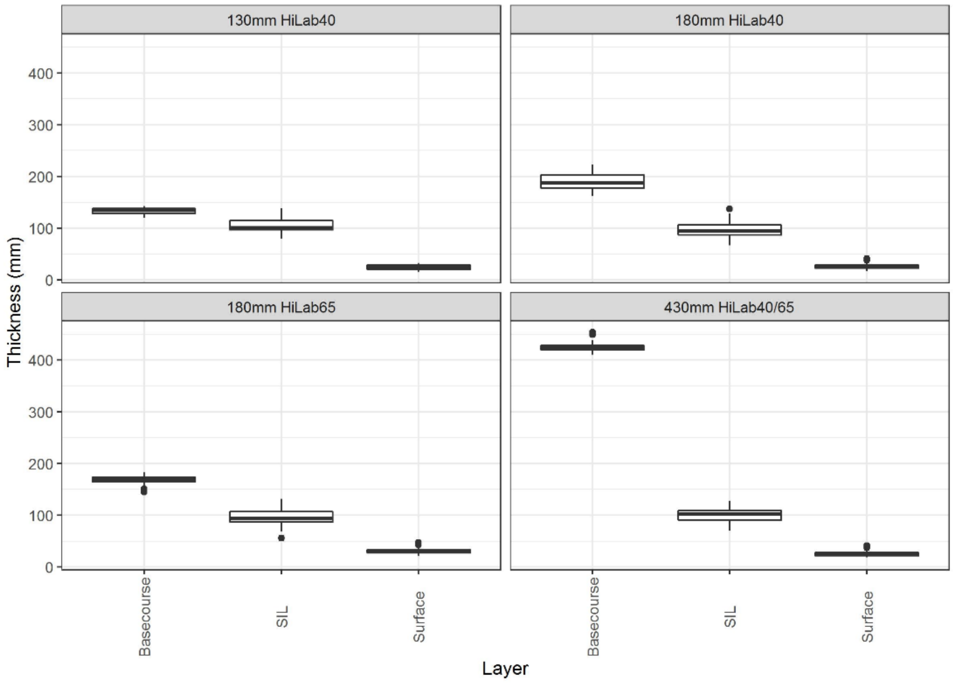


Figure 17 Layer Thicknesses in the wheel path

4 Dry Loading

4.1 Loading sequence and speed

The CAPTIF loading vehicles are half of a single-axle dual-tyre with a tyre separation of 350mm. The tyres were inflated to 700kPa and the vehicles were loaded to 60kN for each vehicle, one and a half times the standard load used for design. At the 12th power used for fatigue calculations on cement bound pavement layers (Austroads 2019) each vehicle pass is equivalent to 130 standard vehicle passes. Both vehicles operated on the same wheel path with 200mm wander. A single lap of the track in the figures below has two vehicle passes.

4.2 Data collection

The CAPTIF test sections were loaded for short periods and then extensive sets of readings were undertaken.

The sections below contain summaries of:

- Falling Weight Deflectometer (FWD) readings
- Benkelman Beam results
- Vertical, Horizontal and Longitudinal Strain readings
- Rutting results
- Moisture monitoring
- Crack monitoring

4.3 FWD results

Figure 18 presents a box plot of the Stress results of the FWD testing during loading. Observations from Figure 18 are:

- The early FWD testing consistently struggled to meet the target 650 kPa testing stress.

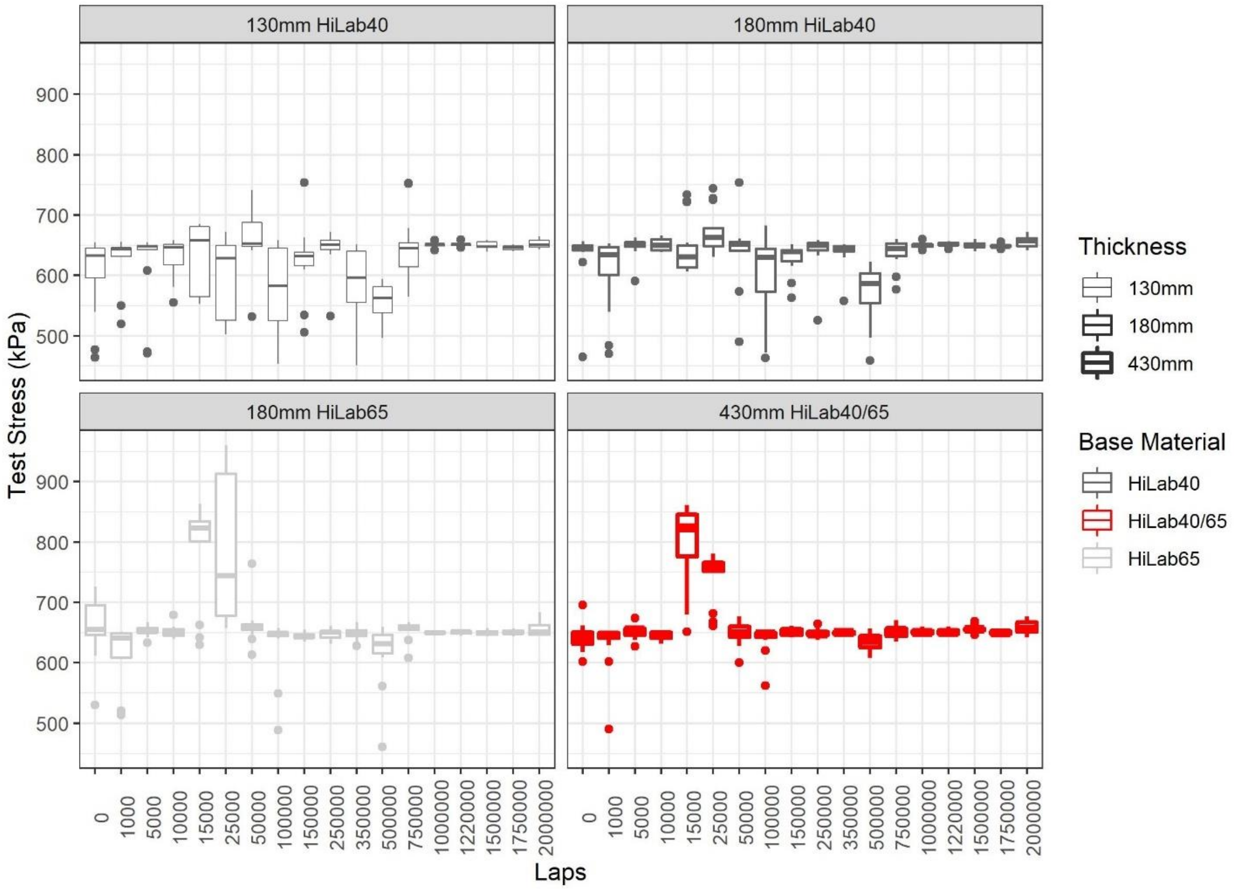


Figure 18 FWD Stress readings during loading, faceted by test section.

Figure 19 presents a box plot of the central deflection (D0) results of the FWD testing during loading. Observations from Figure 19 are:

- The weakest section (top left) is the thin 130 mm Hi-Lab section. The FWD D0 readings rise quickly as loading progresses then plateau, as the cement bonds are broken, to a value of 400 microns.
- The 180 mm of Hi-Lab 40 deteriorates more slowly than the 130 mm Hi-Lab and reaches a similar plateau D0 value of 400 microns.
- The 180 mm of Hi-Lab 65 also deteriorates more slowly and reaches a similar but slightly lower plateau D0 value of 300 microns.
- The 430mm of Hi-Lab 40/65 deteriorates the slowest and it does not appear to plateau, however the average D0 value only reaches 100 microns, which is a very small value.

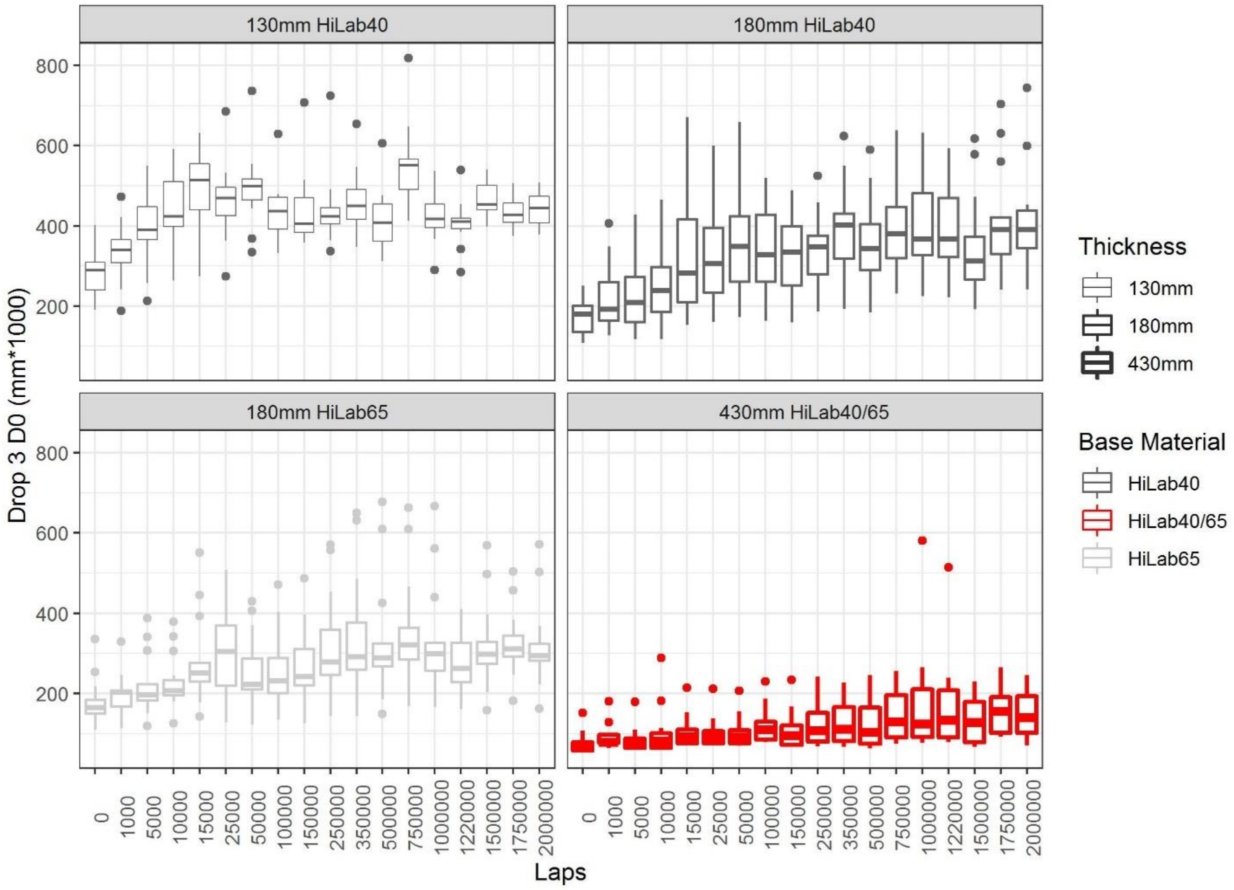


Figure 19 FWD D0 readings during loading, faceted by test section.

4.4 Benkelman Beam results (60kN)

Figure 20 presents a box plot of the central deflection (D0) results of the Benkelman Beam (BB) testing at 60kN during loading. Three readings were taken at each station and averaged before the box plot was generated for each test section. Observations from Figure 20 are:

- The weakest section (top left) is the thin 130 mm Hi-Lab section. The BB D0 readings rise quickly as loading progresses then plateaus, as the cement bonds are broken, to a value of 600 microns.
- The 180 mm of Hi-Lab 40 deteriorates more slowly than the 130 mm Hi-Lab and reaches a similar plateau D0 value of 600 microns.
- The 180 mm of Hi-Lab 65 also deteriorates more slowly and reaches a similar but slightly lower plateau D0 value of 450 microns.
- The 430mm of Hi-Lab 40/65 deteriorates the slowest and it does not appear to plateau, however the average D0 value only reaches 150 microns, which is a very small value.

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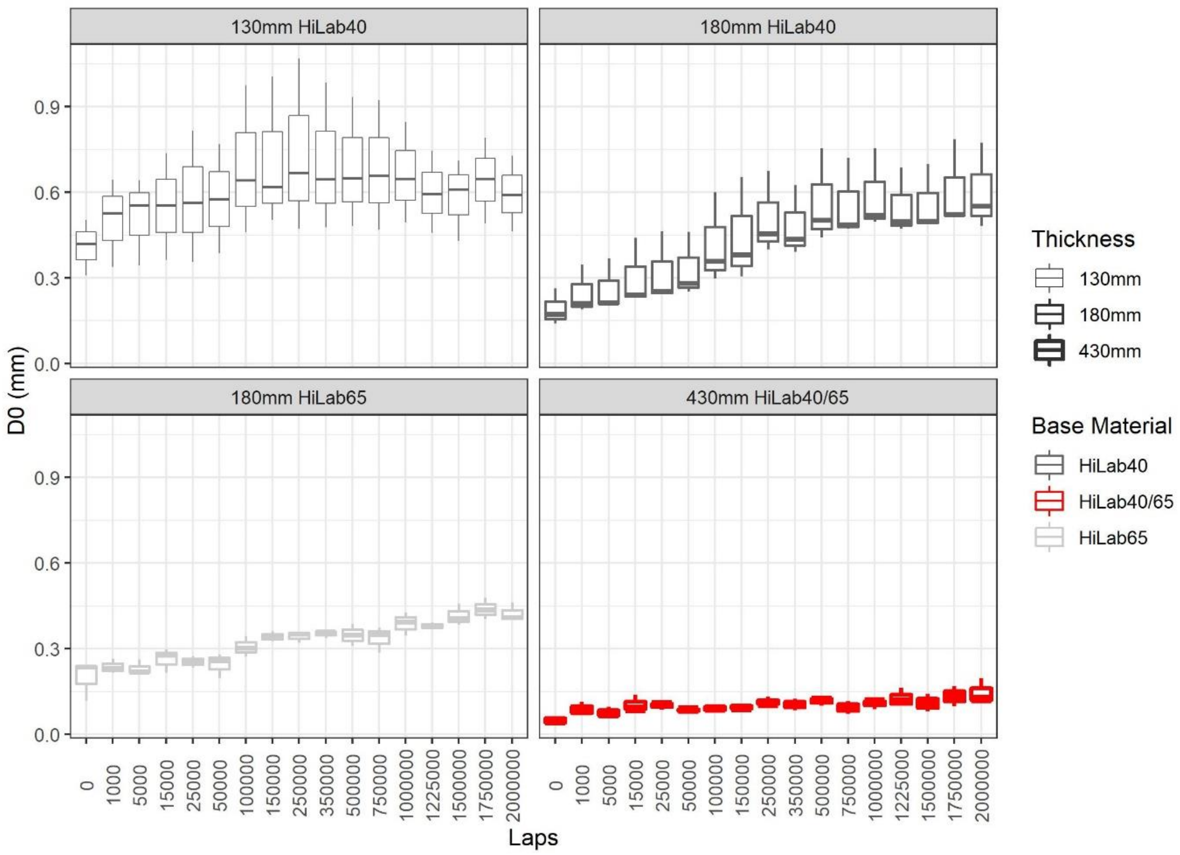

Figure 20 Benkelman Beam D0 readings during loading, faceted by test section.

4.5 Strain Data

Figure 21 presents the strain coil arrangement and numbering in the test sections. The same numbering system is used in each test section, thus coil pairs with the same number are in the same location relative to the subgrade/sand interface.

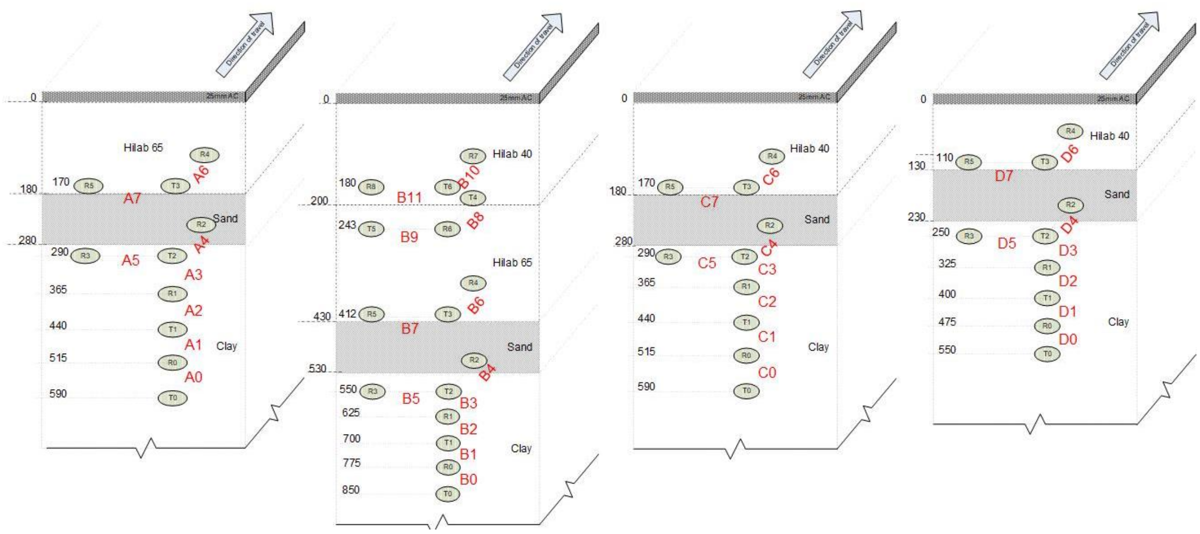

Figure 21 Strain Coil Arrangement.

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Figure 22 presents the results of the vertical strain coil testing during loading. These coil pairs are in the subgrade. Pair 0 is the deepest pair and pair 3 is placed just under the sand. Observations from Figure 22 are:

- The vertical strain testing supports the observations of the FWD testing.
- The weakest section,130 mm of Hi-Lab40, is exhibiting the highest vertical strains in all coil pairs but plateaus to values similar to those of the 180 mm Hi-Lab65 sections. The remarkably high strains seen in coil pair 3 could be the result of initial localized cracking near this pair that eventually breaks down to an area wide cracking pattern.
- The 180 mm Hi-Lab 40 section deteriorates more slowly than the 130 mm Hi-Lab 40 section and reaches a similar plateau at the end of testing in all coil pairs
- The 180 mm Hi-Lab 65 section also deteriorates more slowly than the 130 mm Hi-Lab and reaches a similar plateau at the end of testing in all coil pairs.
- The coil pairs in the 430mm Hi-Lab 40/65 section barely show any sign of movement and little (if any) deterioration in the subgrade layers

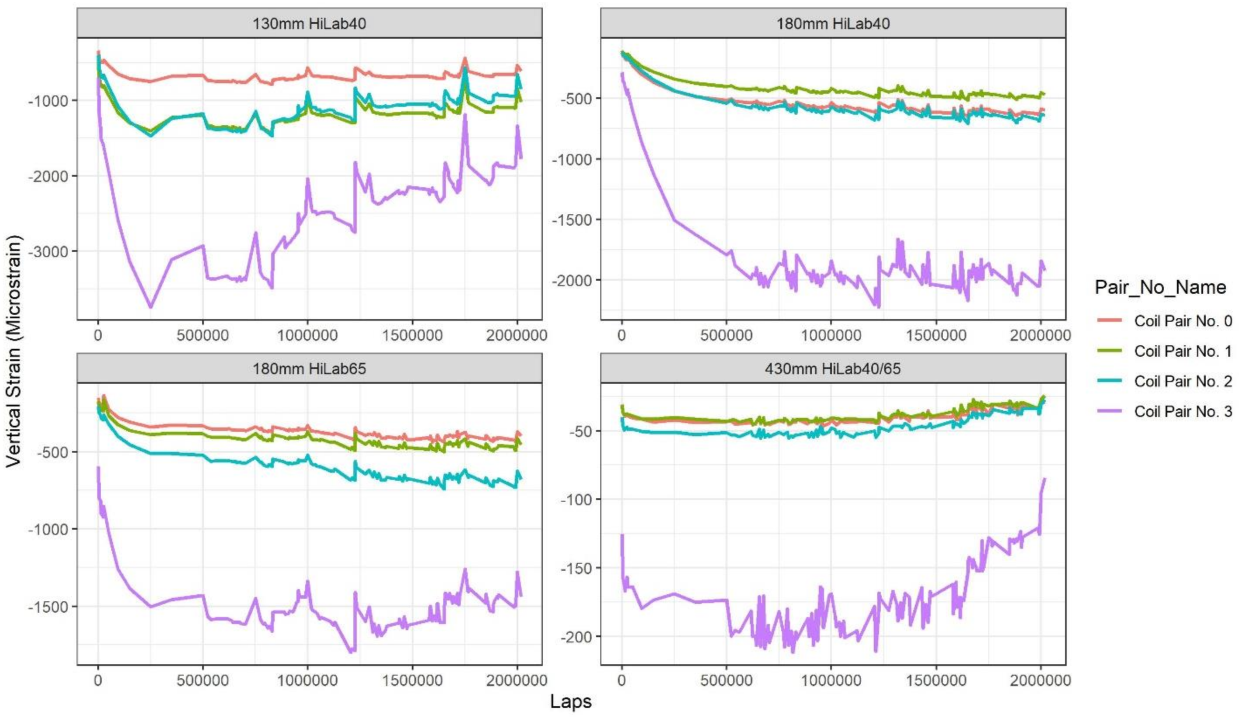

Figure 22 Vertical Strain readings during loading, faceted by Pair Name.

Figure 23 presents the results of the longitudinal strain coil testing during loading. In all test sections Coil pair 4 is in the subgrade and coil pair 6 is in the base of the Hi-Lab layers. Coil pair 8 and 10 only occur in the Hi-Lab 40/65 test section, they are in the top of Hi-Lab 65 and bottom of the Hi-Lab 40, respectively. Observations from Figure 23 are:

- The weakest section,130 mm of Hi-Lab, is exhibiting the highest longitudinal strains in all coil pairs. The remarkably high strains seen in coil pairs 4 and 6 could be the result of initial

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localized cracking near this pair that eventually breaks down to an area wide cracking pattern.

- The 180 mm Hi-Lab 40 section deteriorates more slowly than the 130 mm Hi-Lab. The initial changes in strain are seen in the subgrade and followed by the base of the Hi-Lab layer.
- The 180 mm Hi-Lab 65 section also deteriorates more slowly than the 130 mm Hi-Lab and behaves in a comparable manner to the 180mm Hi-Lab 40 section.
- The coil pairs in the 430mm Hi-Lab 40/65 section barely show any sign of movement and little (if any) deterioration in the subgrade layers or Hi-Lab layers

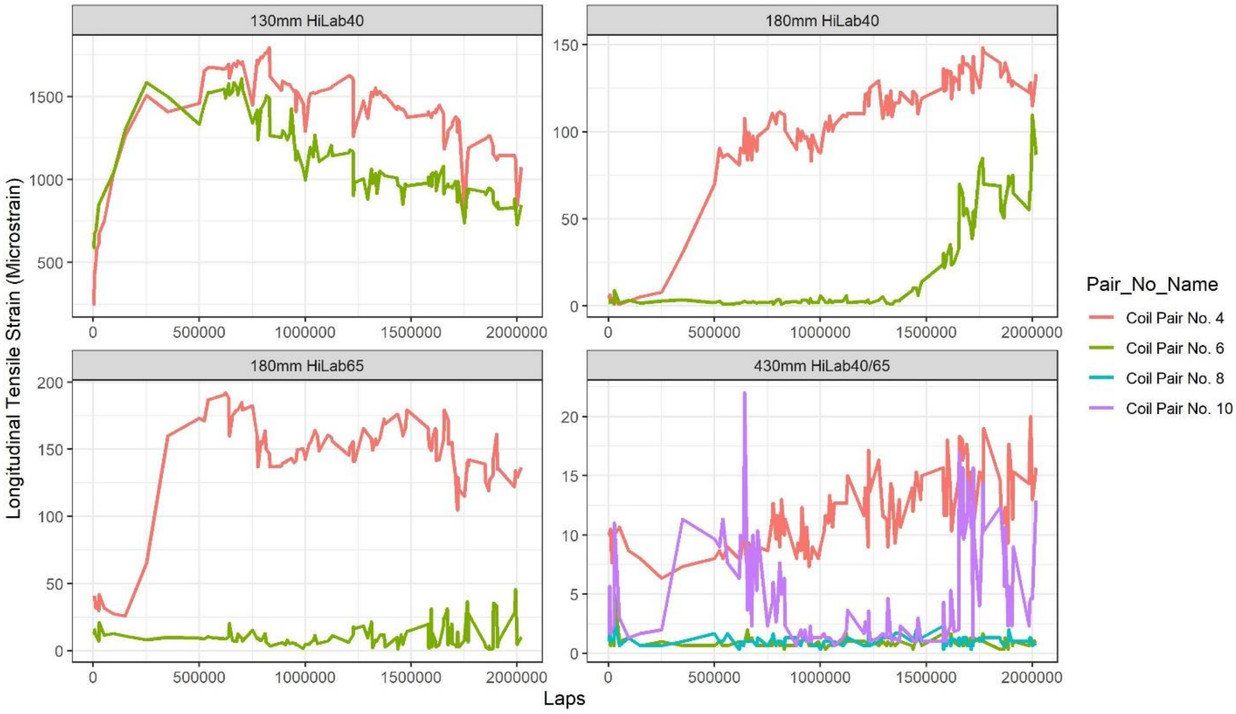

Figure 23 Longitudinal Strain readings during loading, faceted by Pair Name.

Figure 24 presents the results of the transverse strain coil testing during loading. In all test sections coil pair 5 is in the subgrade and coil pair 7 is in the base of the Hi-Lab layers. Coil pairs 9 and 11 only occur in the Hi-Lab 40/65 test section. They are in the top of Hi-Lab 65 and bottom of the Hi-Lab 40 respectively. Observations from Figure 24 are:

- The weakest section,130 mm of Hi-Lab 40, is exhibiting the highest transverse strains in all coil pairs. The remarkably high strains seen in coil pair 7 could be the result of initial localized cracking near this pair that eventually breaks down to an area wide cracking pattern. The results of pair 7 have been clipped at 1000 microstrain to aid viewing of pair 5.
- The 180 mm Hi-Lab 40 section deteriorates more slowly than the 130 mm of Hi-Lab. Changes in strain are seen in the subgrade but these are not followed by the base of the Hi-Lab layer.
- The 180 mm Hi-Lab 65 section also deteriorates more slowly than the 130 mm Hi-Lab and behaves in a comparable manner to the 180mm Hi-Lab 40.

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- The coil pairs in the 430mm of Hi-Lab 40/65 section barely show any sign of movement and little (if any) deterioration in the subgrade layers or Hi-Lab layers

Figure 24 Transverse Strain readings during loading, faceted by Pair Name.

4.6 Rutting performance

Both vertical surface deformations (VSDs) and rut depths were measured with a profilometer and calculated from the data. VSD is defined as the maximum change in height between a transverse profile taken before loading and the current transverse profile. The rut depth is calculated from a theoretical straight line between the high points either side of the wheel path to lowest point of transverse profile in the wheel path. Thus, the VSD value only presents the downward vertical movement of the pavement in the wheel path, while rutting is a combination of downward movement in the middle of the wheel path and upward movement on the edges.

The VSD measurements for each pavement section are presented in Figure 25 below. Observations from Figure 25 are:

- The weakest section,130 mm of Hi-Lab 40, exhibits the highest rutting observed in the experiment. Repairs were made at 1,000,000 and 1,500,000 loading laps.
- The 180 mm Hi-Lab 40 section deteriorates more slowly than the 130 mm Hi-Lab.
- The 180 mm Hi-Lab 65 section deteriorates more slowly than the 180 mm Hi-Lab 40 and appears to be less variable. Repairs were made at 1,500,000 loading laps
- The 430mm of Hi-Lab 40/65 performs remarkably well and is the least variable.

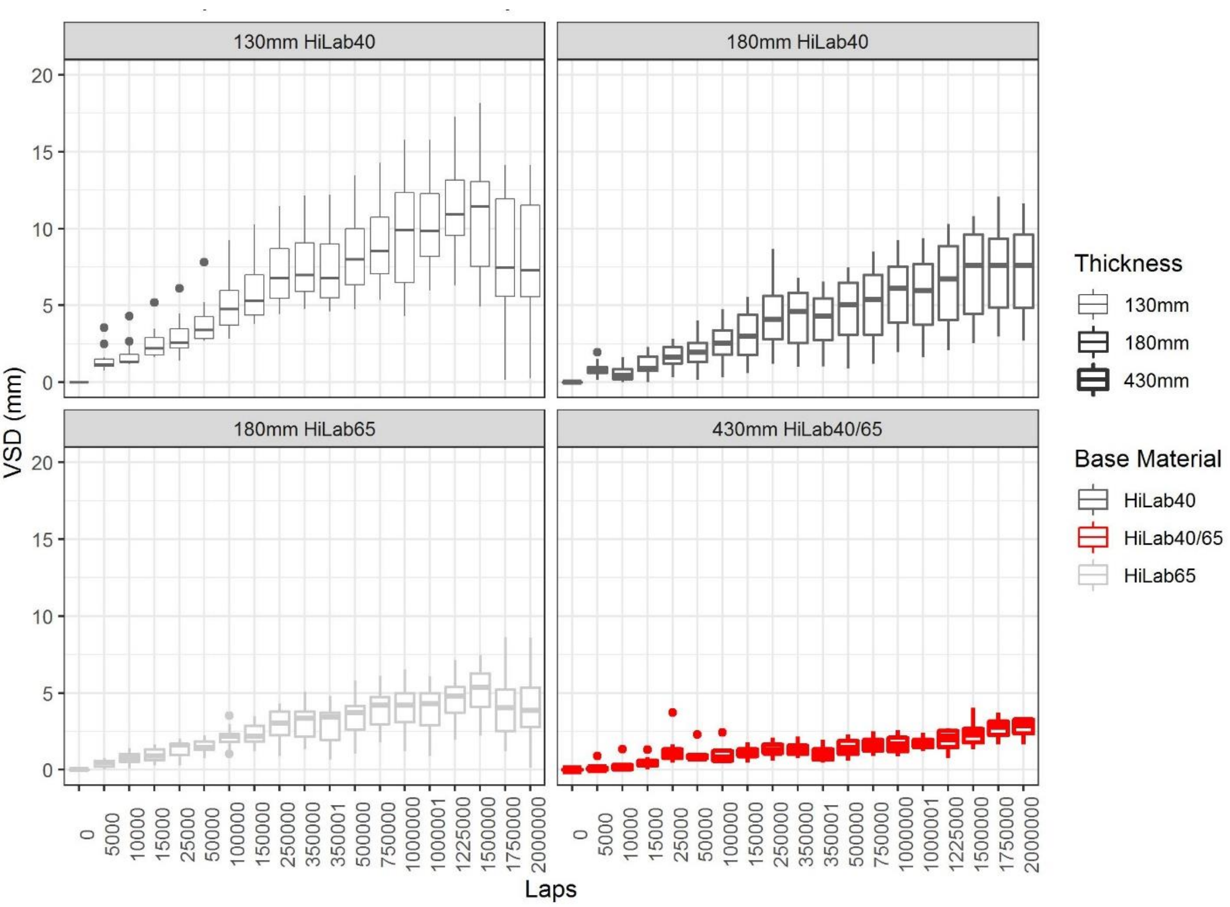


Figure 25 VSD readings during loading, faceted by test section.

The rut measurements for each pavement section are presented in Figure 26 below. Observations from Figure 26 are:

- The trends are similar to those seen in the VSD data
- As expected, the rutting data is more variable than the VSD data, with more points identified as outliers.

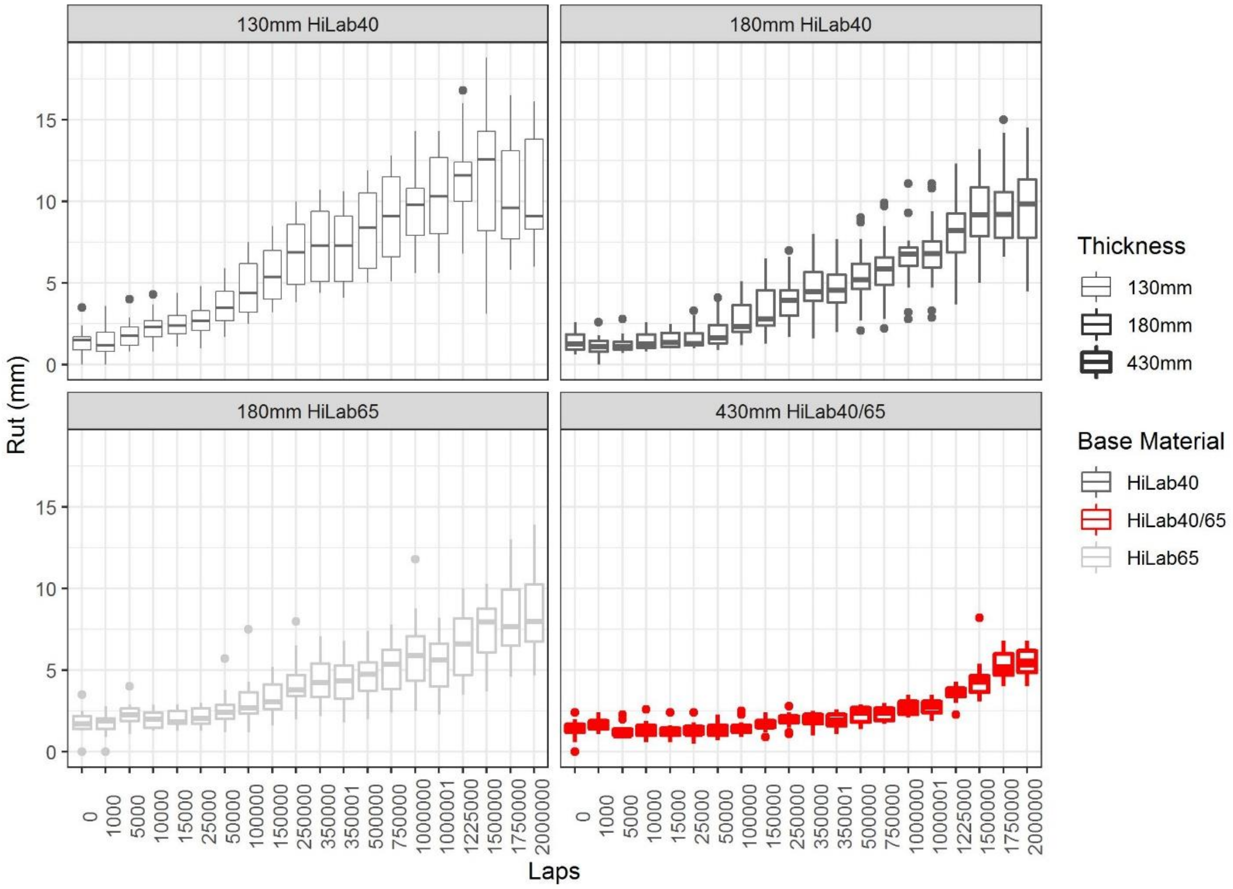


Figure 26 VSD readings during loading, faceted by test section.

Repairs were made in the surfacing of the 130mm Hi-Lab 40 section during loading at 1,500,000 laps. Figure 27 shows a straight edge placed on the Hi-Lab surface beyond the saw cut face. The rutting can be seen in the asphalt edge but not under the straight edge on the Hi-Lab.

Figure 27 Repairs during loading

The asphalt had been profiled prior to removal and the underlying 130mm Hi-Lab 40 was also profiled during the repair. The transverse profiles are presented in Figure 28. From the profiles it appears that the bulk of the rutting has occurred in the asphalt layer. The profile plot below of the Hi-Lab 40 layer (red line) shows no deformation (rutting) with the as-built cross-fall of approximately 2% sloping toward the centre of the test track. Hence, the Hi-Lab 40 layer does not mirror the asphalt surface rut profile, with little indication of rutting within the Hi-Lab 40 layer.

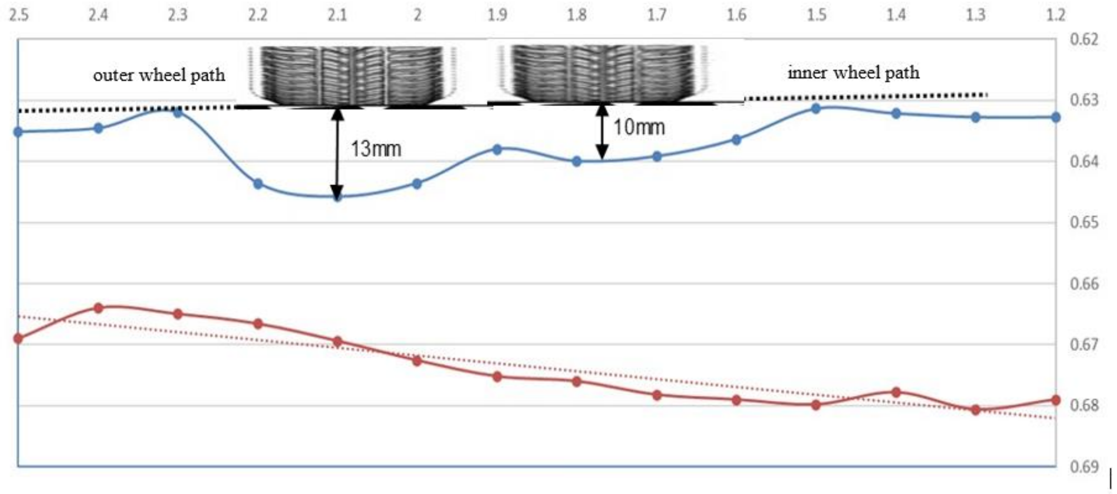


Figure 28 Repair layer profiles (AC in Blue, Hi-Lab in Red)

4.7 Moisture Monitoring

Time Domain Reflectometry (TDR) sensors were placed in the Sand and Clay layers to observe moisture conditions in the pavement during loading. The results are presented in Figure 29 below. Observations from Figure 29 are:

- The moisture conditions in the Sand and Clay layers remained constant over the dry loading.

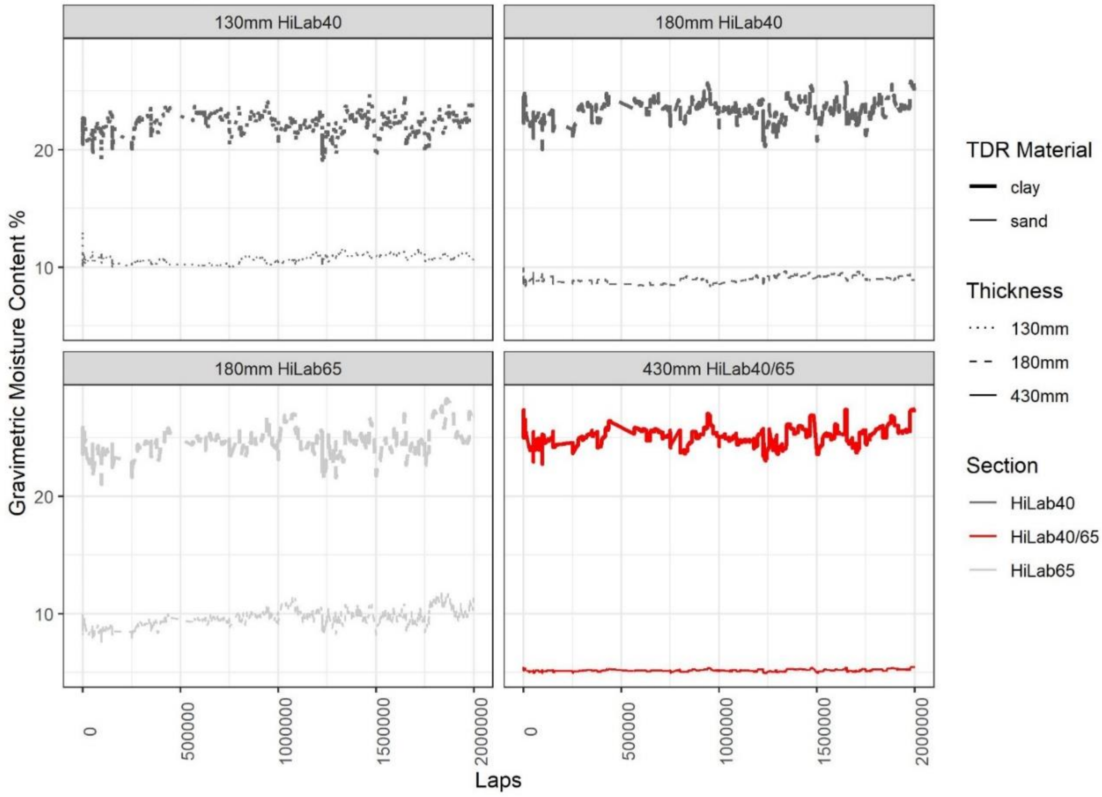


Figure 29 TDR readings during loading, faceted by test section.

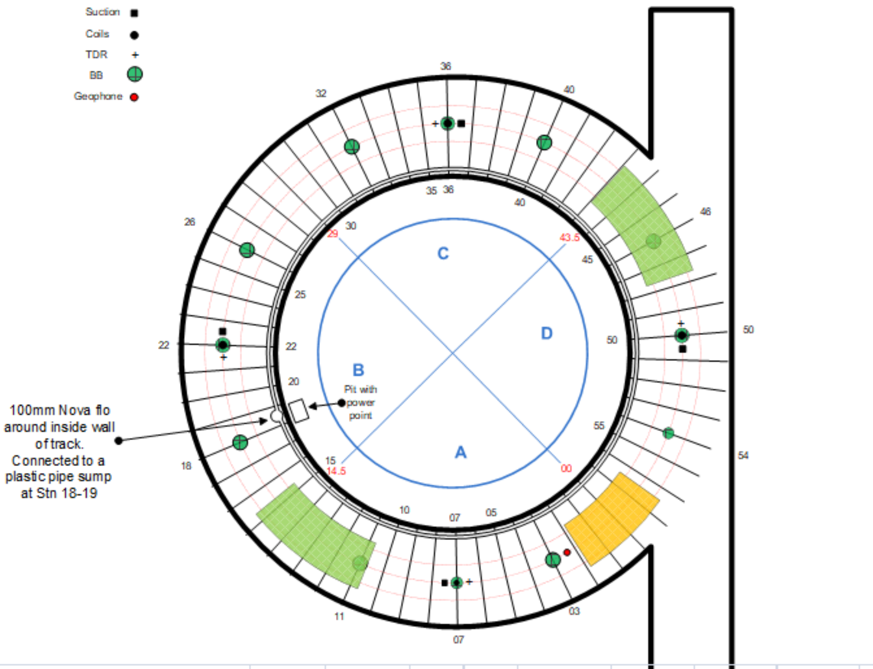
4.8 Cracking performance

Cracking was monitored during the project at major intervals when transverse profiles were undertaken. On crack initiation photographs were taken to record crack progression (Figure 30 and Appendix A Crack photos) and records kept of when the cracking required repair (Figure 31).

a

Figure 30 Cracking monitored with Photos

[UNCLASSIFIED]



AC patch repair schedule								
Date repaired	Laps completed	Stn start	Stn finish	O/set	O/set	Depth mm	area	tns
16-Sep-16	1,000,000	56.40	1.95	1.20	2.60	40	5.0	0.5
06-Dec-16	1,500,000	10.75	15.20	1.20	2.60	45	6.2	0.7
06-Dec-16	1,500,000	43.00	47.50	1.20	2.60	45	6.3	0.7

Figure 31 Cracking related surfacing failures

5 Damp and Wet Loading

At the end of the dry loading, at the request of industry, the pavement was resurfaced with Open-Graded Porous Asphalt (OGPA) and a series of damp and wet tests undertaken.

5.1 Resurfacing

The existing dense asphalt surface was milled out in a 2m wide strip. The Hi-Lab surface is intact with little evidence of rutting (Figure 32).

Figure 32 Milled out Dense Graded Asphalt

The milled surface was primed with emulsion containing 180/200 (30%), white spirits (25%) and water (45%) along with emulsifying chemicals (Figure 33). The target application rate was 0.5 l/m^2. Then it was sealed with a 180/200 binder with 4 parts kerosene and 1 part of adhesion with no AGO (Diesel fuel). The first coat was applied at 1.1 l/m^2 (hot) and a Grade 3 chip was applied. A 2nd coat was applied at 1.00 l/m^2 (hot) and a grade 5 chip was applied. After rolling and five days later a 3rd coat was applied at 1.35 l/m^2 (hot) and a final grade 5 chip was applied. The final coat contained 3 parts kerosene (Figure 34).

Figure 33 Priming of milled surface

Figure 34 Membrane Chipsealing

[UNCLASSIFIED]

5.2 Damp Running

Figure 35 illustrates the damp running condition. Figure 36 shows fines pumping to the surface and was observed in sections A, C and D during the 100,000 laps of damp loading. This supports the observation that the stiffness loss in these sections had compromised the previous dense graded asphalt surface and the newly applied OGPA surface. Section B, the Huntly design, showed no signs of distress and wetter conditions were introduced.

Figure 35 Damp Running conditions

Figure 36 Fines observed pumping to surface in sections A, C and D

5.3 Wet Running

Figure 37 illustrates the wet running condition with water pooled on the surface of the OGPA. It was impossible for the OGPA to drain as it had been laid in the strip milled in the original dense asphalt. Figure 38 illustrates the Huntly Hi-Lab design (Section B) undamaged after 100,000 laps of wet running.

Figure 37 Wet Running Conditions

Figure 38 After Wet Running

[UNCLASSIFIED]

The introduction of wet conditions to the Hi-Lab sections was to test further deformation from the observable surface cracking in some of the test sections.

5.4 Wet VSD Results

The VSD results in Figure 39 show that all the sections performed well in the damp and wet loading conditions with the OGPA surfacing.

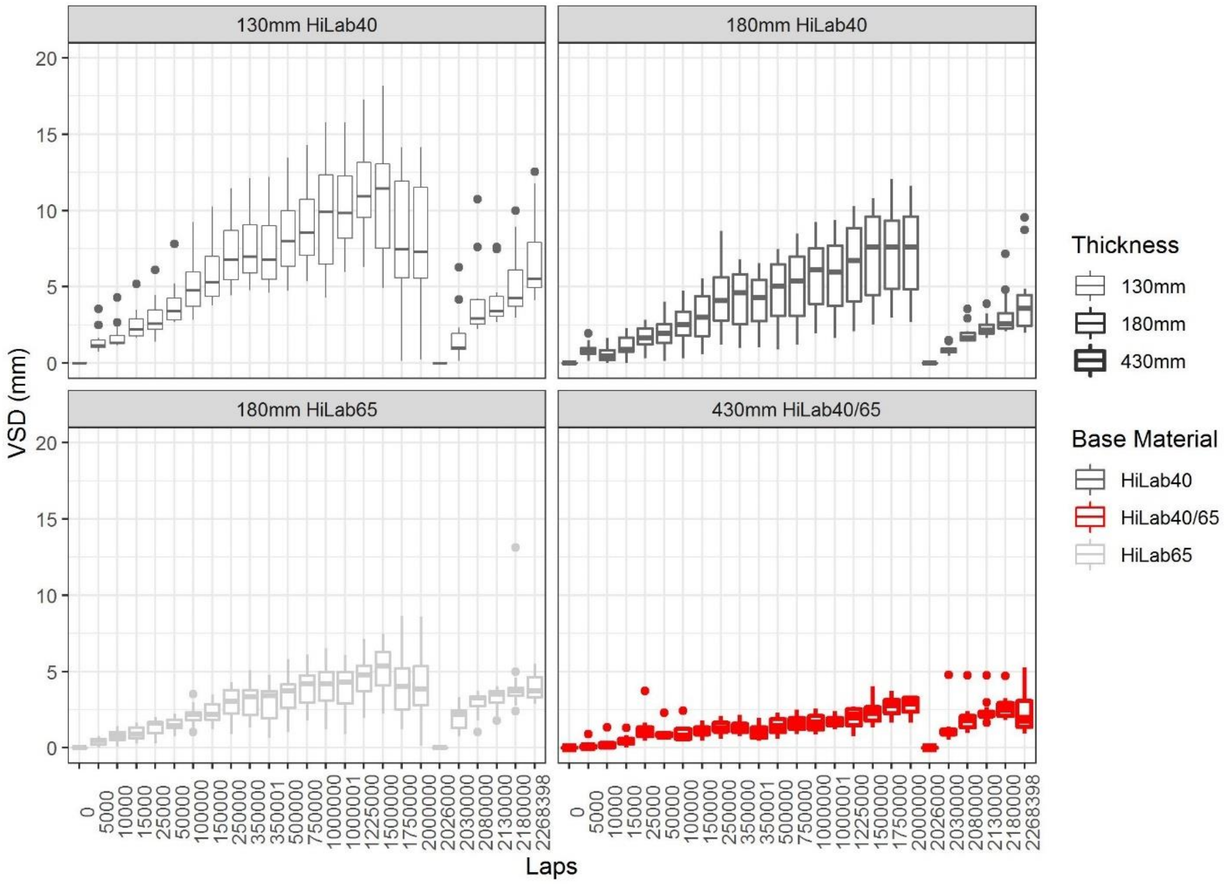


Figure 39 Damp and Wet Running VSD results

5.5 Saw Cut Wet Running

Figure 40 illustrates the final test of Section B with 2xHi-Lab layers like the Huntly Hi-Lab design. The surface and upper Hi-Lab layer were saw cut to allow water into the pavement. The objective was to observe the Hi-Lab behaviour in the event of a surfacing failure. A small pothole appeared after 150,000 laps of wet loading.

Figure 40 100,000 Laps of Wet Running after saw-cutting surface

5.6 Final TDR Results

The TDR results in Figure 41 show that the thinner sections, which had shown signs of cracking earlier, all allowed water into the Sand Subgrade Improvement Layer only when wet running began. The Huntly Hi-Lab section maintained its moisture content under damp and wet running conditions and even saw cutting the surface and upper Hi-Lab layer did not allow water to penetrate to the Sand layer. This shows the Hi-Lab layers for Section B being impermeable.

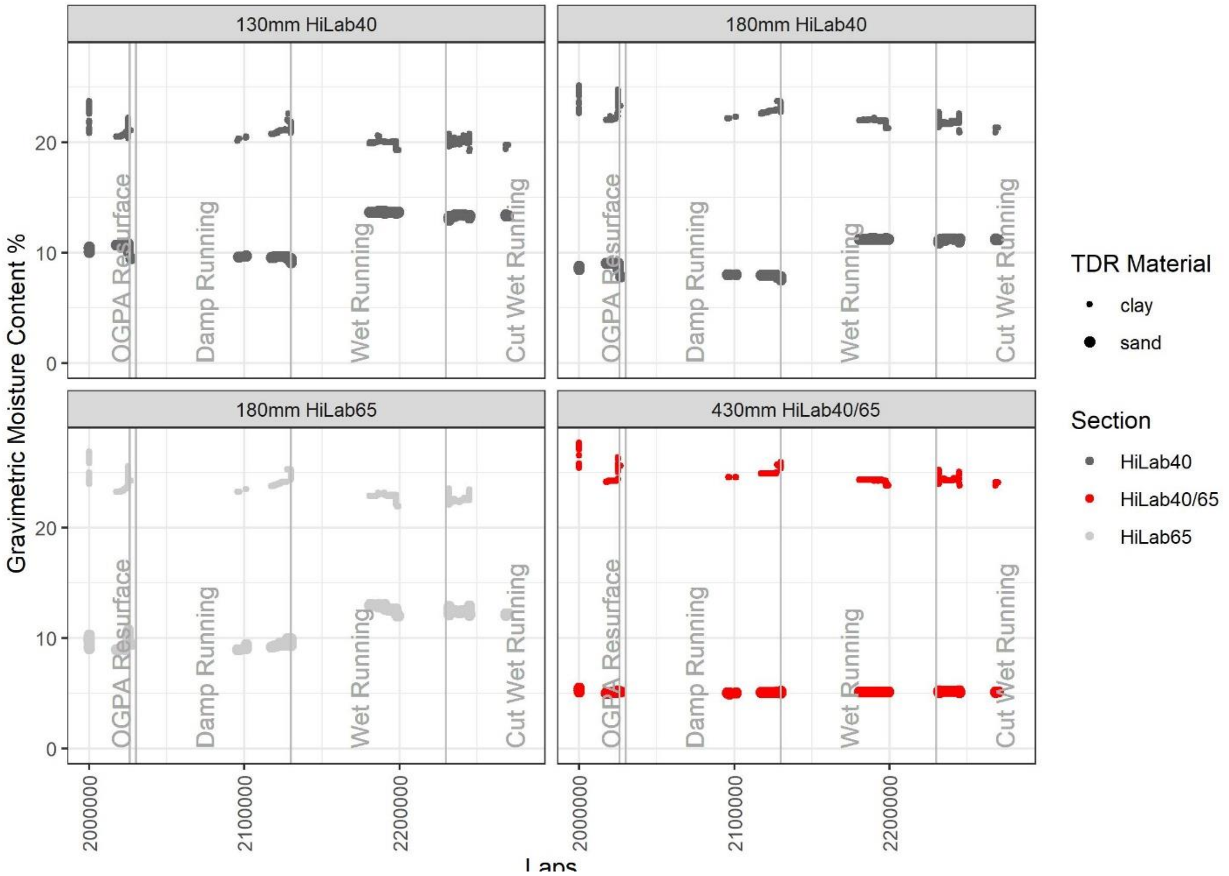


Figure 41 Damp and Wet Running TDR results

6 Post-mortem

Core and Beam samples were extracted from the wheel paths and trafficked zones of the pavement. Samples were sent to Road Science for unsoaked ITS tests to DCLTM1:2013 and Flexural Tensile Strength Tests to NZS 3112: Part 2:1986. Both used loading rates of 1mm/minute. The test results are in Appendix C.

7 Conclusions and recommendations

This project at the Canterbury Accelerated Pavement Testing Indoor Facility (CAPTIF) was initiated from the NZTA's Review 3: Investment Decision of the Gateway Review Report for Waikato Expressway – Huntly Bypass (Francis et al 2015) for Treasury. Recommendation 2 of the review was "*If not already done, NZTA should consider the urgent installation of suitably instrumented test sections at Taupiri and the CAPTIF facility to further improve confidence in the long-term performance of heavy duty Hi-Lab pavements.".* The priority assigned to the task by the report was *"Do Now."*

A test pavement at CAPTIF was constructed with four different Hi-Lab pavement sections, supported by a very weak clay subgrade, to study:

- The performance of a full-strength design with two Hi-Lab layers similar in thickness to the Huntly Bypass design (Test Section B)
- The influence of pavement depth on the performance of Hi-Lab by testing thinner sections (Test Sections B, C and D).
- The influence of maximum aggregate size on the performance of Hi-Lab by testing maximum aggregate sizes of 37.5mm and 63mm (Sections A and C)

This report presents the data from the accelerated pavement testing. The results suggest that the Huntly Hi-Lab design, constructed to the same Hi-Lab layer thicknesses as Test Section B, was well designed and unlikely to fail in fatigue if constructed properly in the field. Hence, the pavement can be defined as perpetual in theory. It should be noted that all Hi-Lab trial sections at CAPTIF were constructed on a very weak clay subgrade (CBR≈4%), which is well below the design specifications for the Huntly and other Hi-Lab projects. Also, the loads applied during the testing at CAPTIF were 50% greater than design and standard legal loading.

The thinner test sections suggest that fatigue is a mode of failure that needs to be designed against.

The comparison of maximum size aggregates in sections A and C suggests that Hi-Lab 65 would be a superior material for fatigue.

Further analysis of the results forms part of an Auckland University PhD thesis by PGL van Blerk on Hi-Lab materials design and construction.

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Standards New Zealand (1986) Methods of testing soils for civil engineering purposes. NZS 4402:1986. Wellington: Standards New Zealand.

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Appendix A Crack photos

[UNCLASSIFIED]

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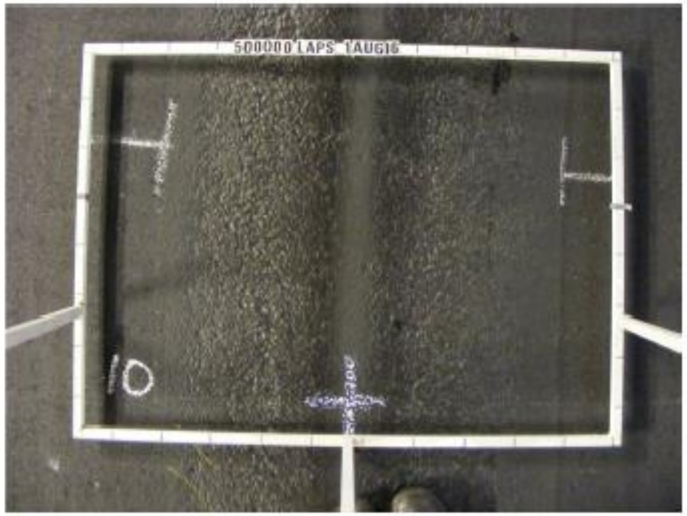

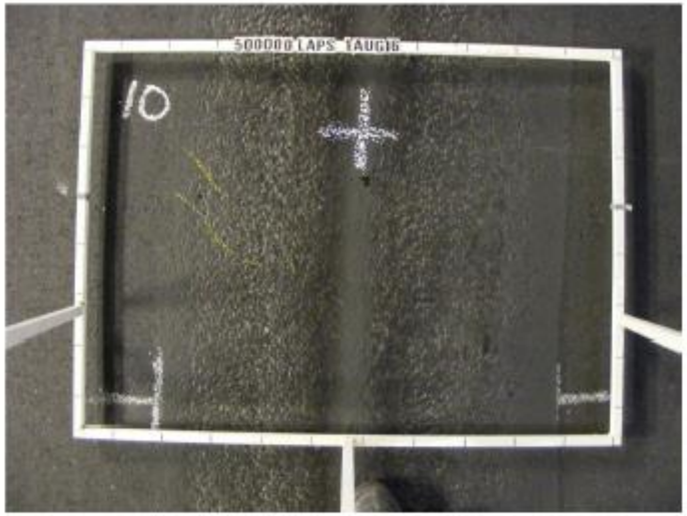

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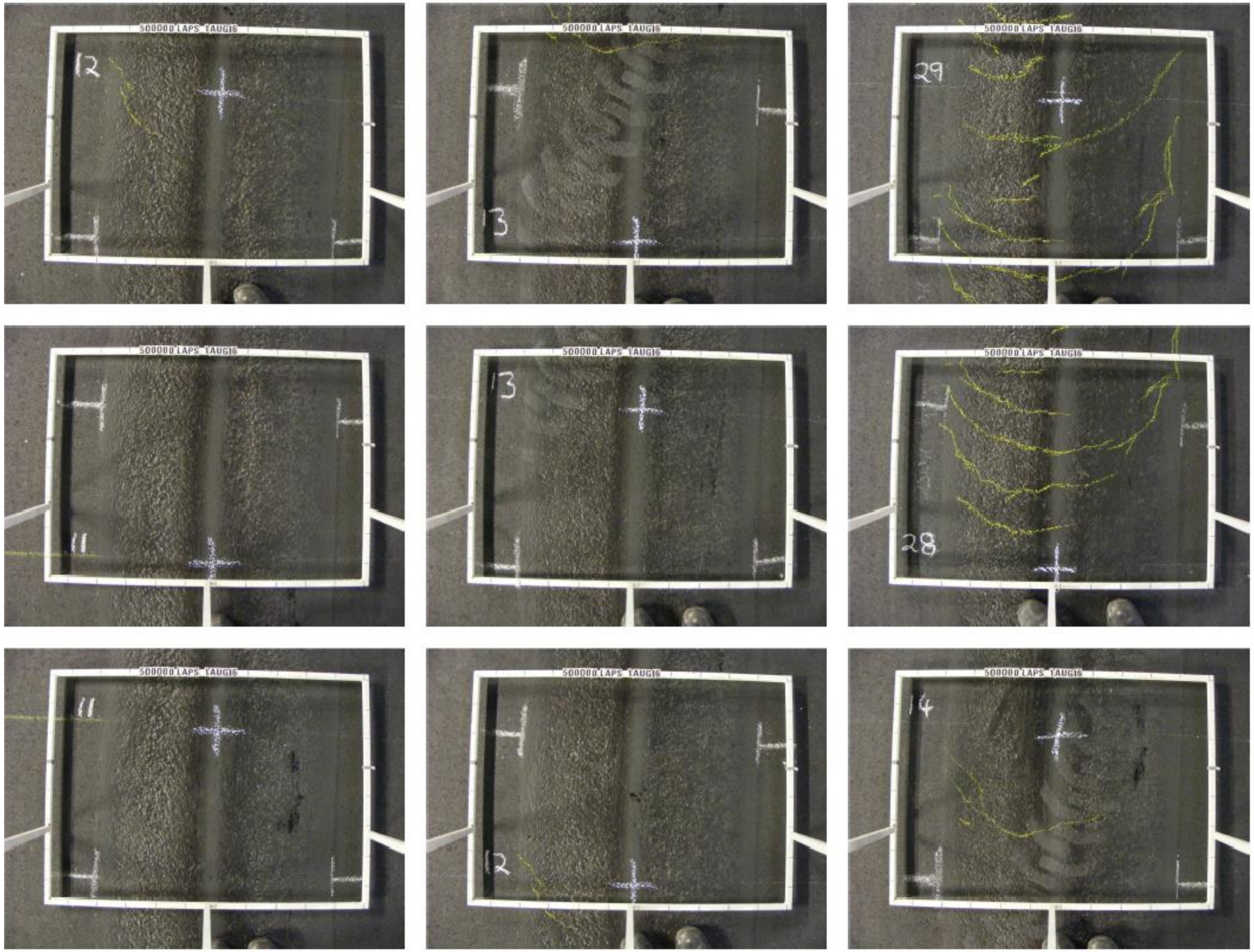

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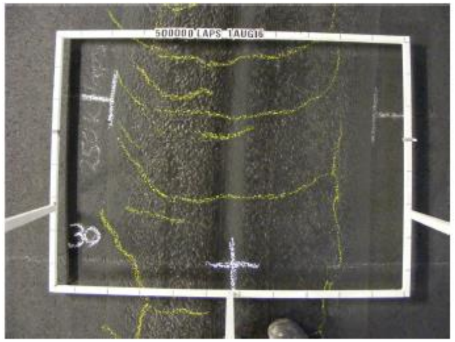
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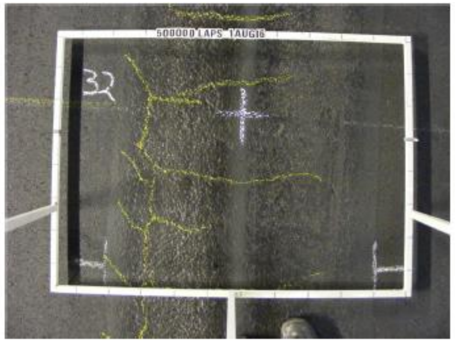
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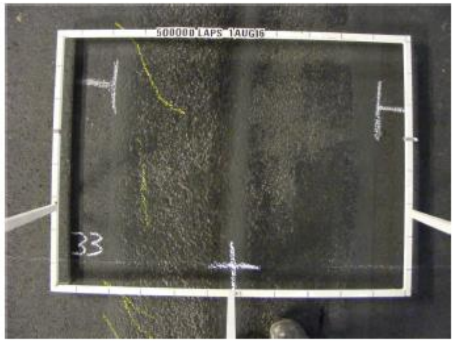
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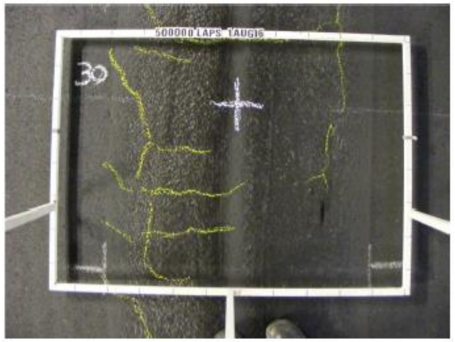
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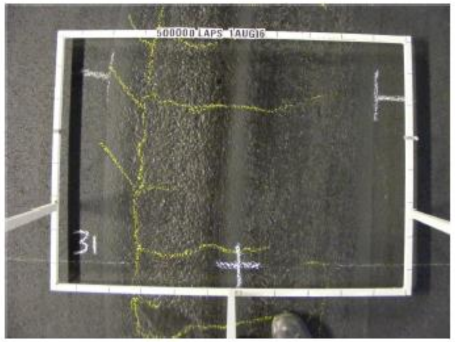
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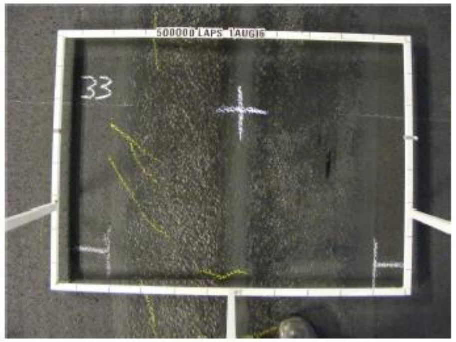
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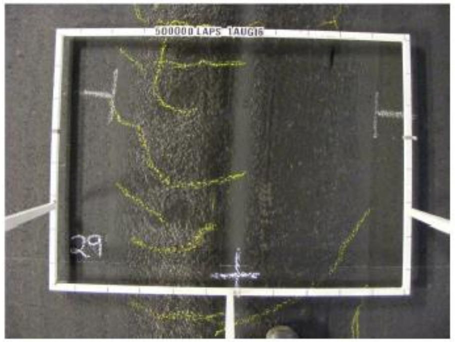
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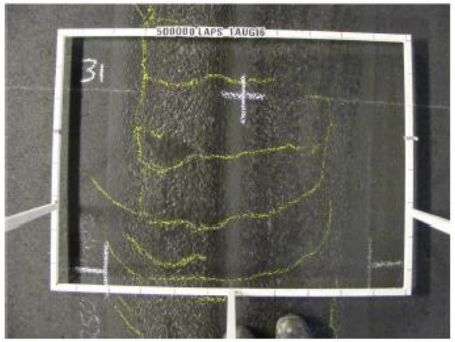
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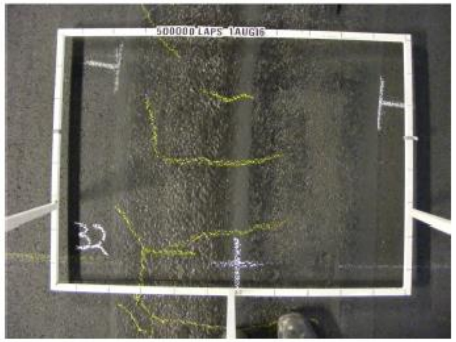
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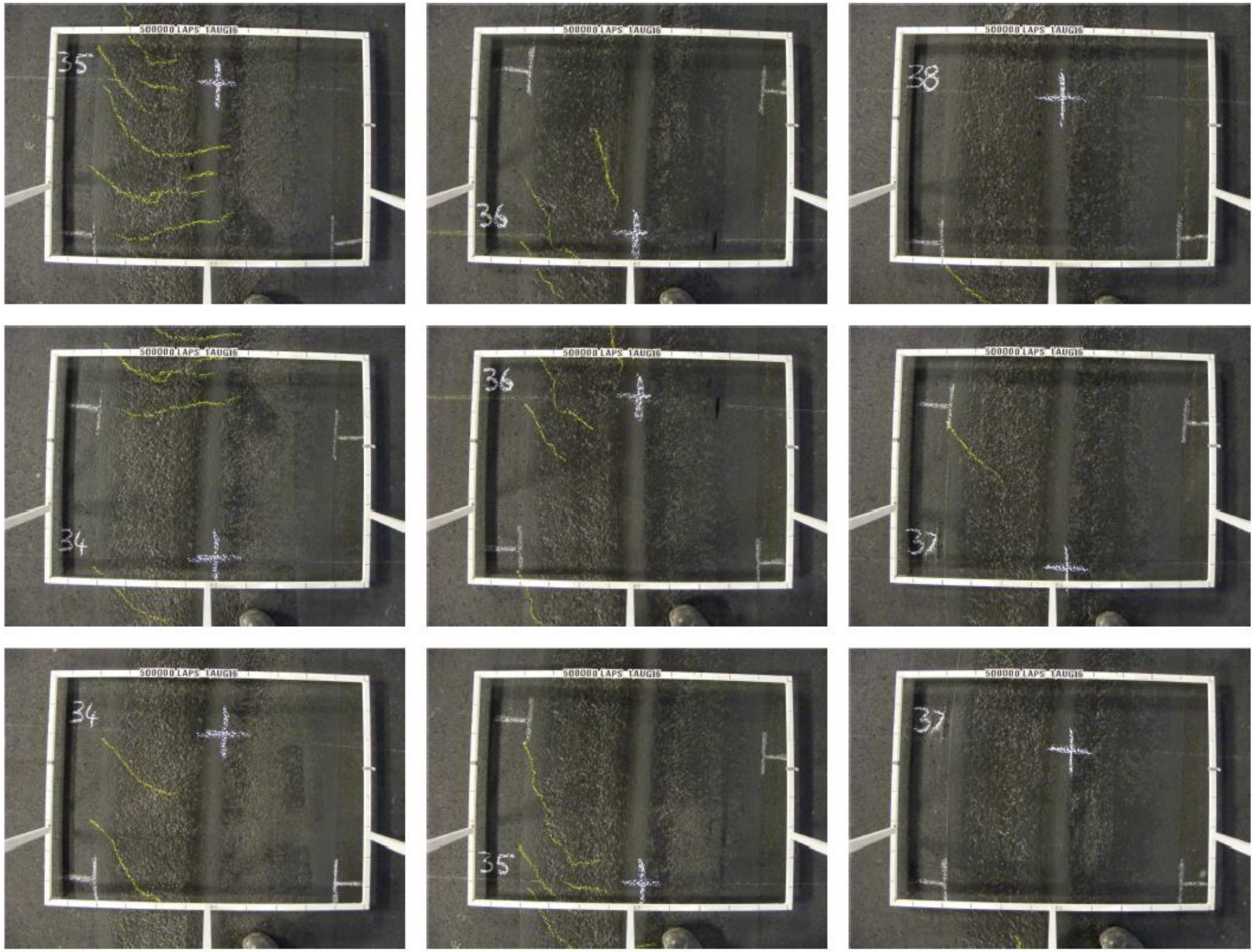

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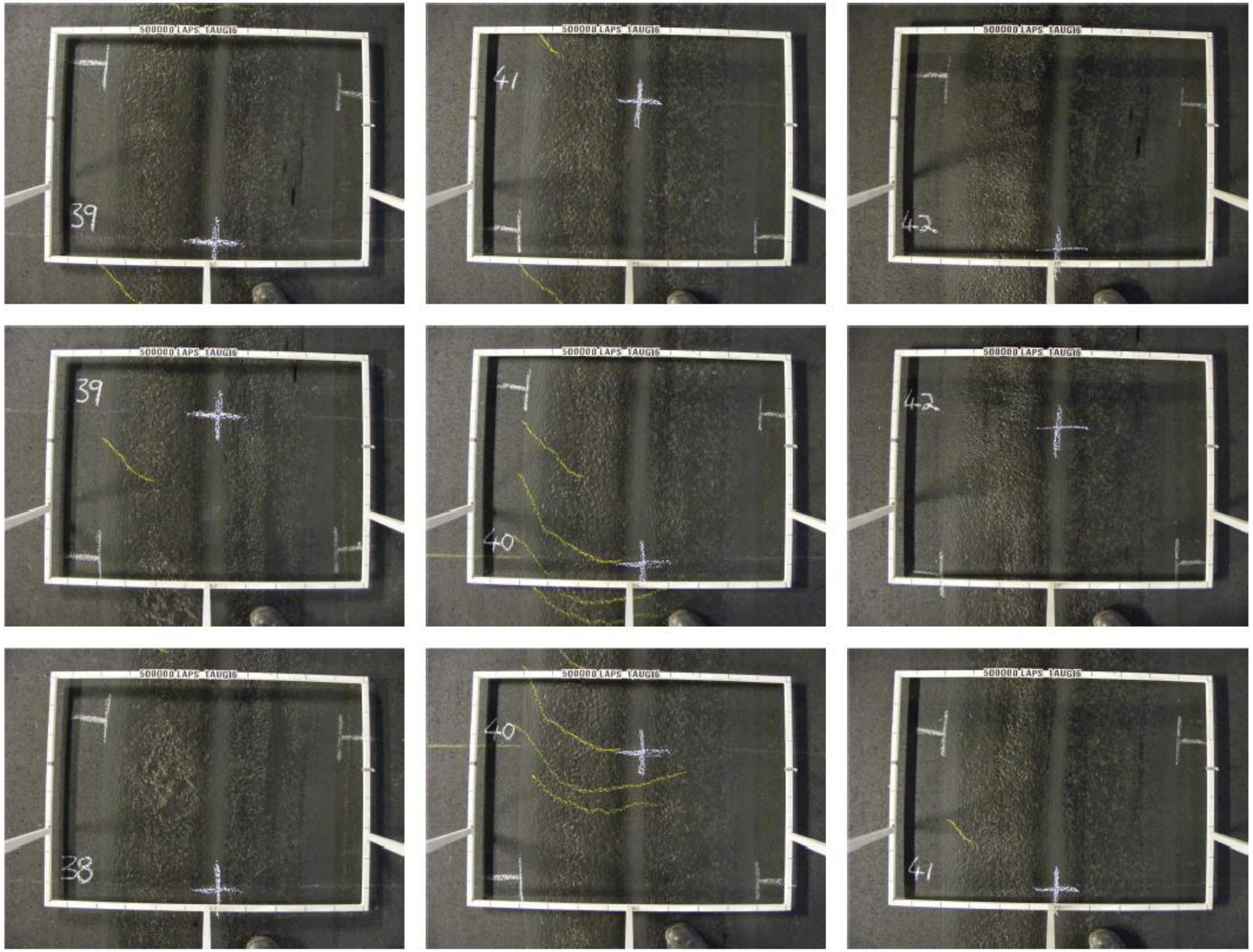

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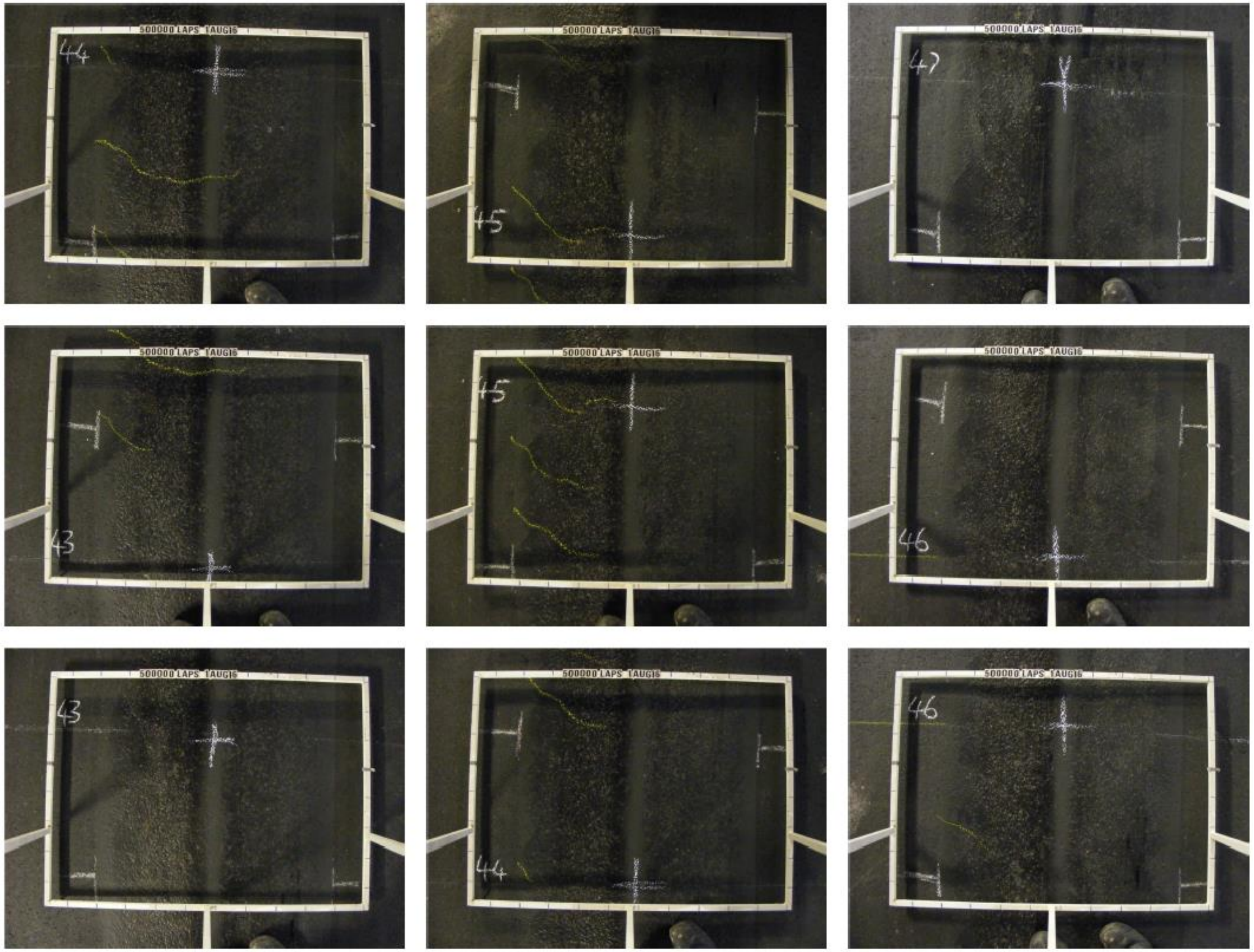

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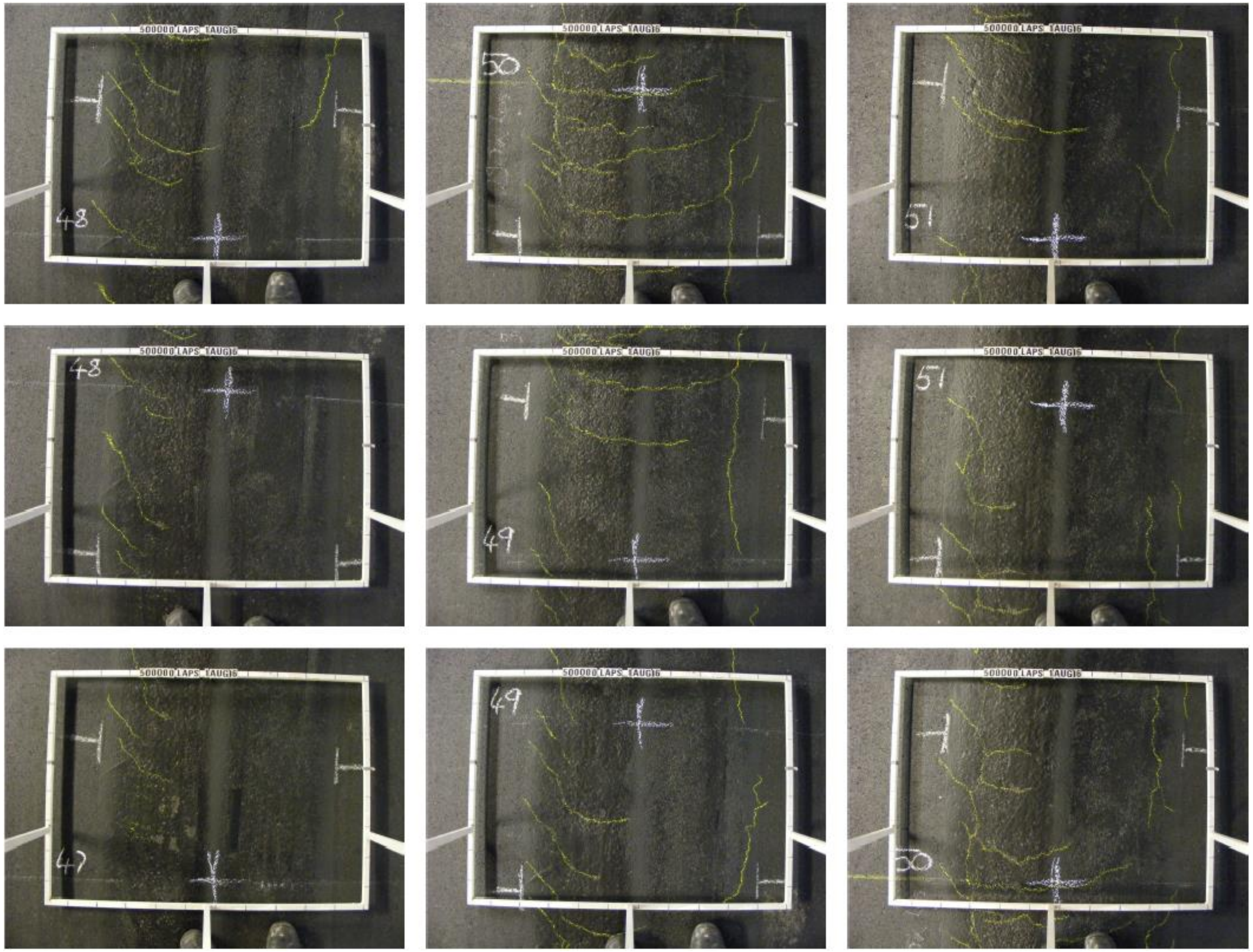

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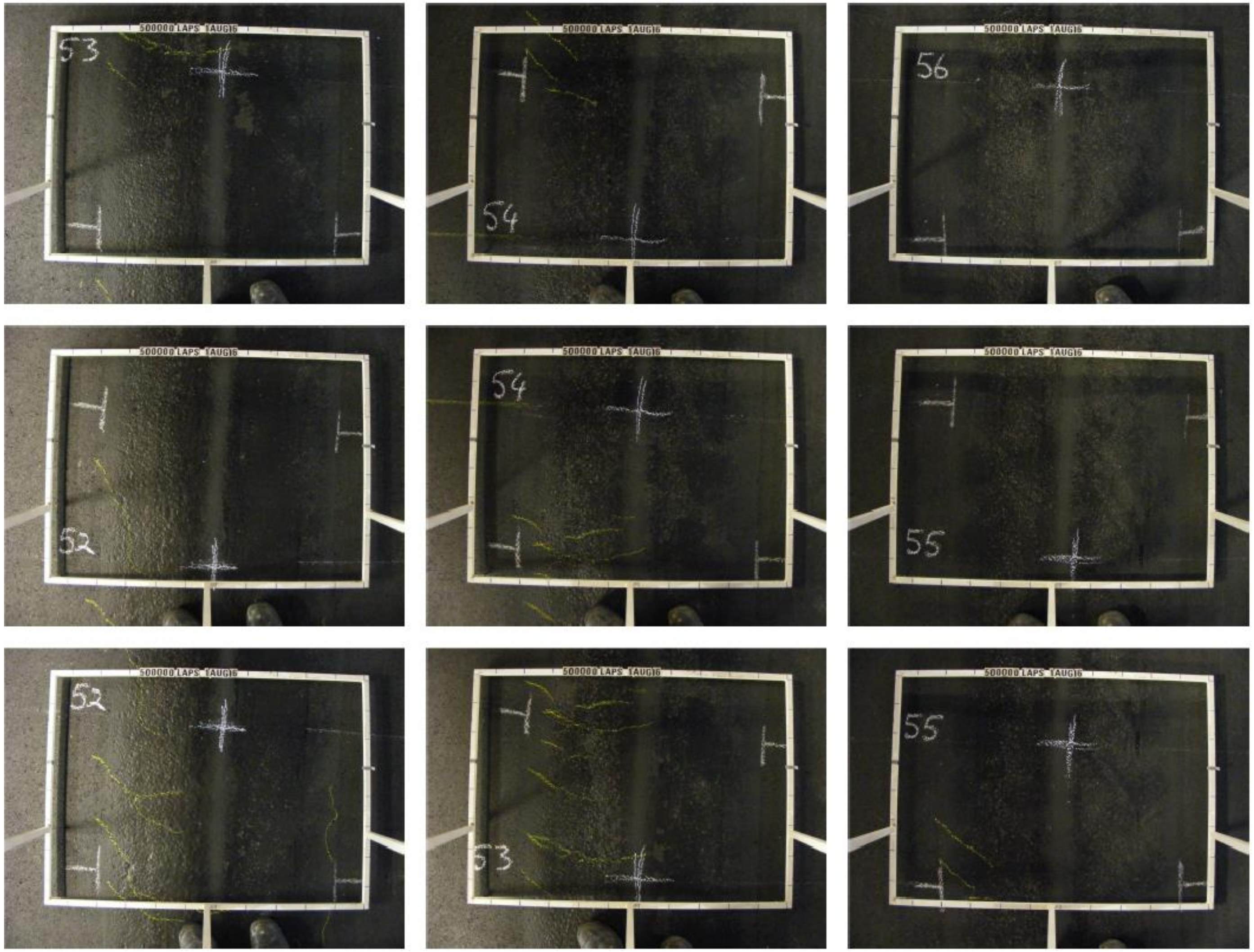

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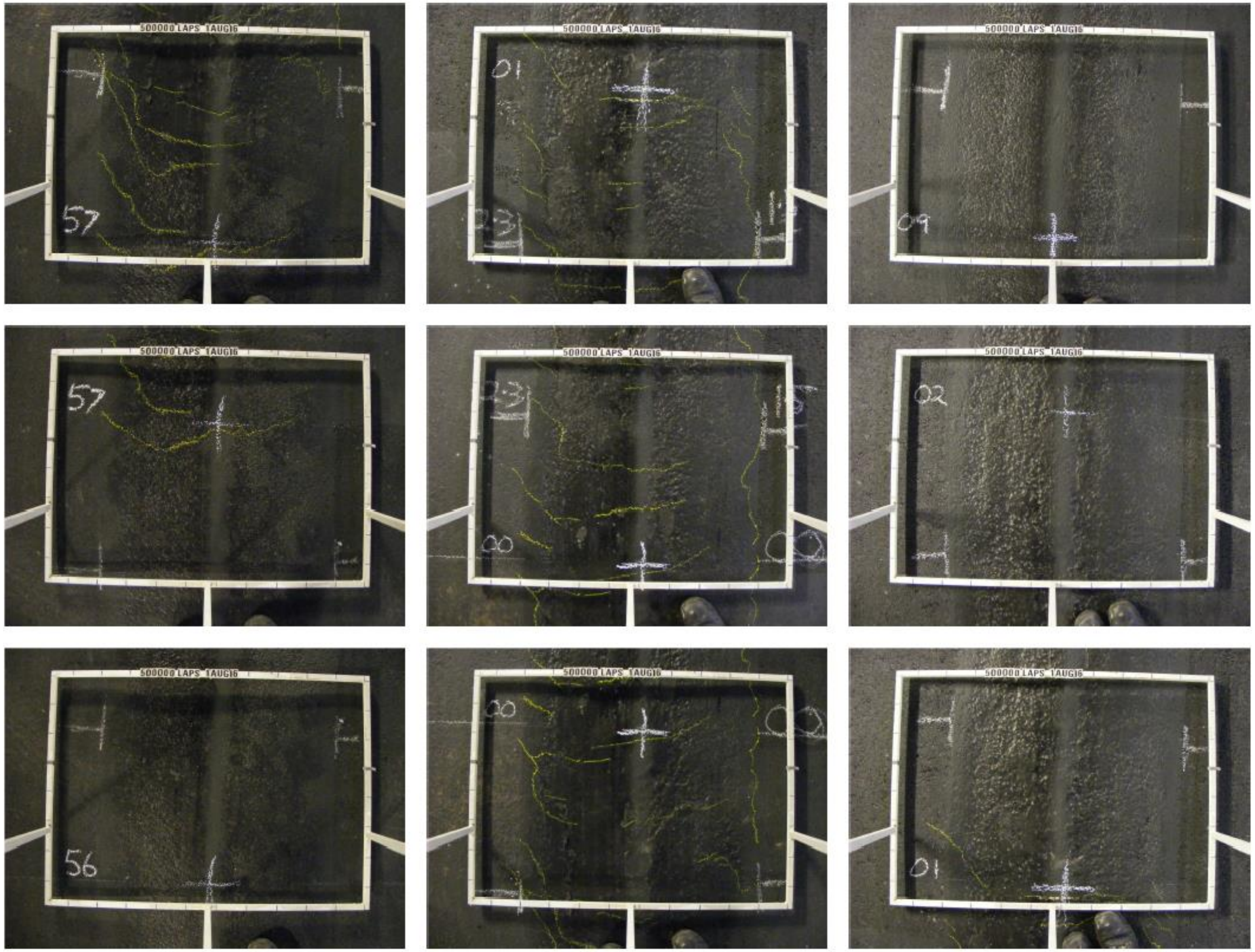

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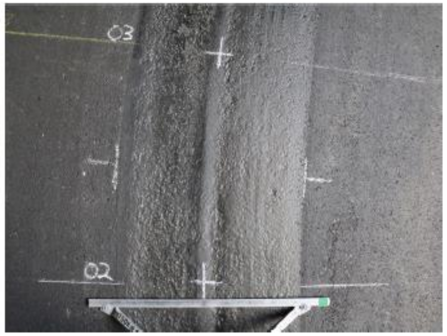

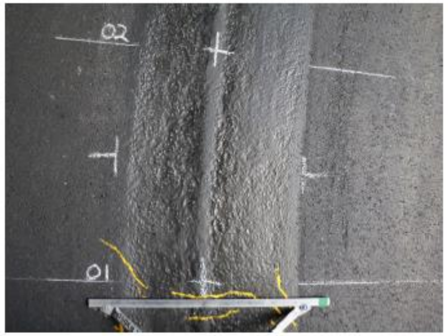

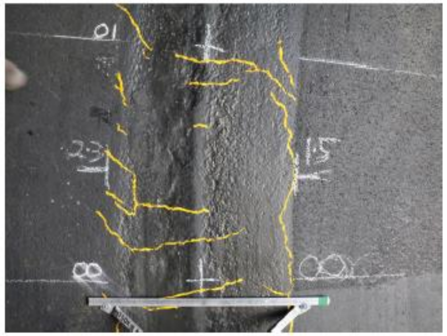

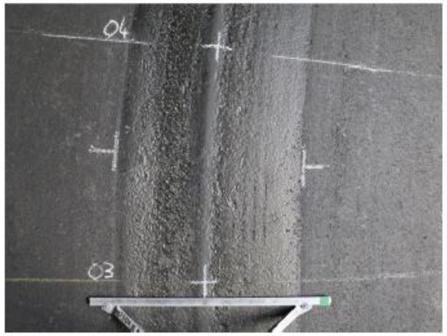

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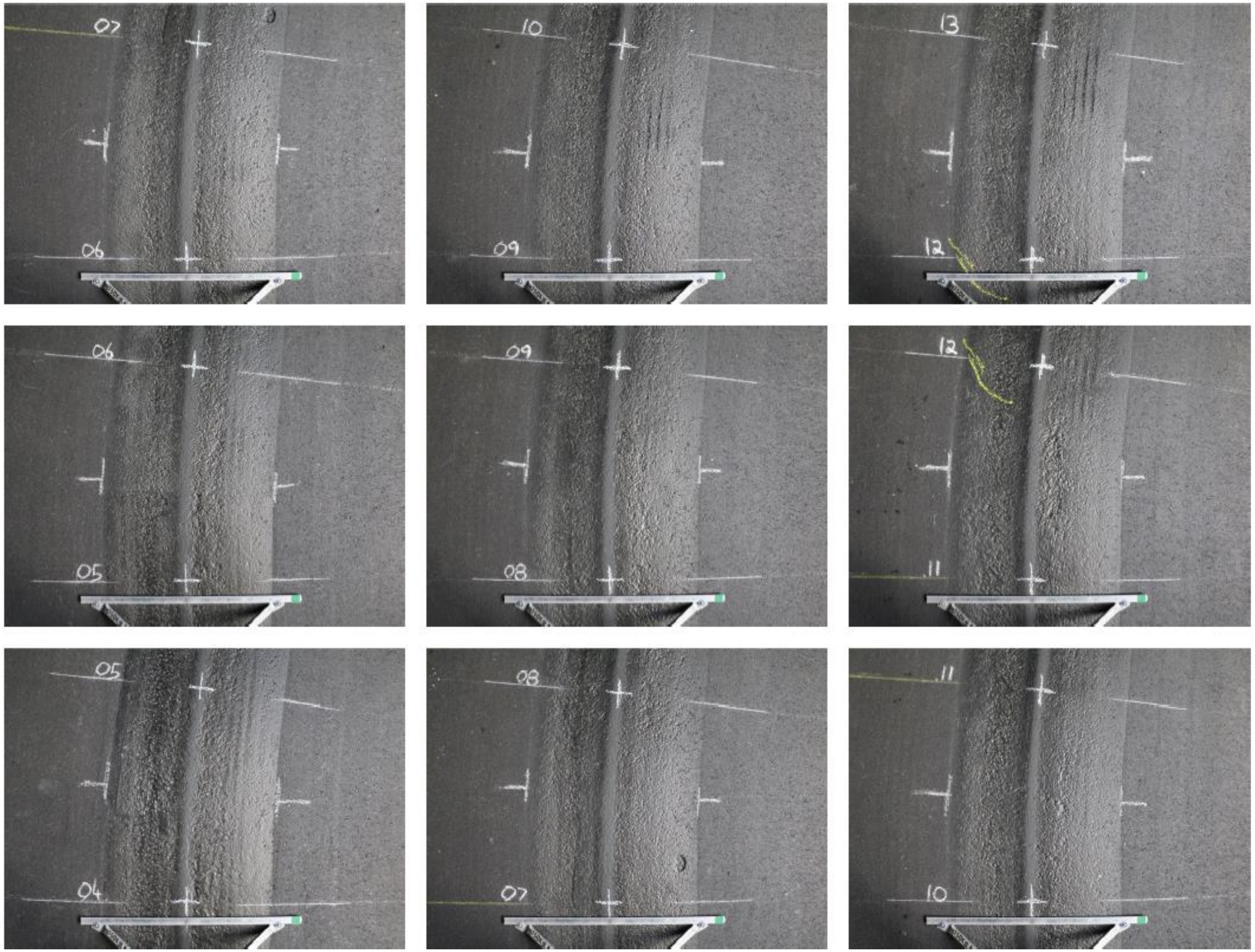

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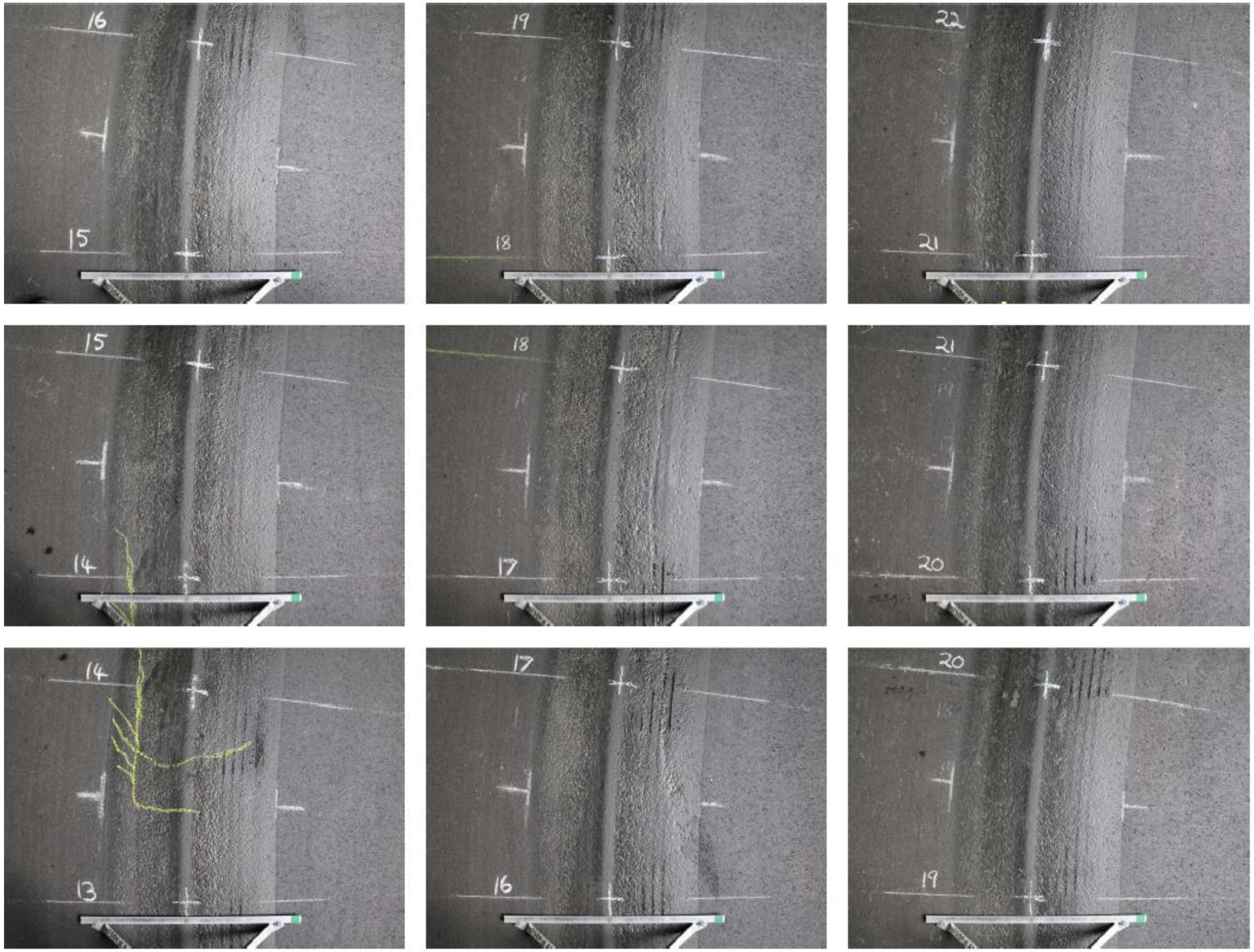

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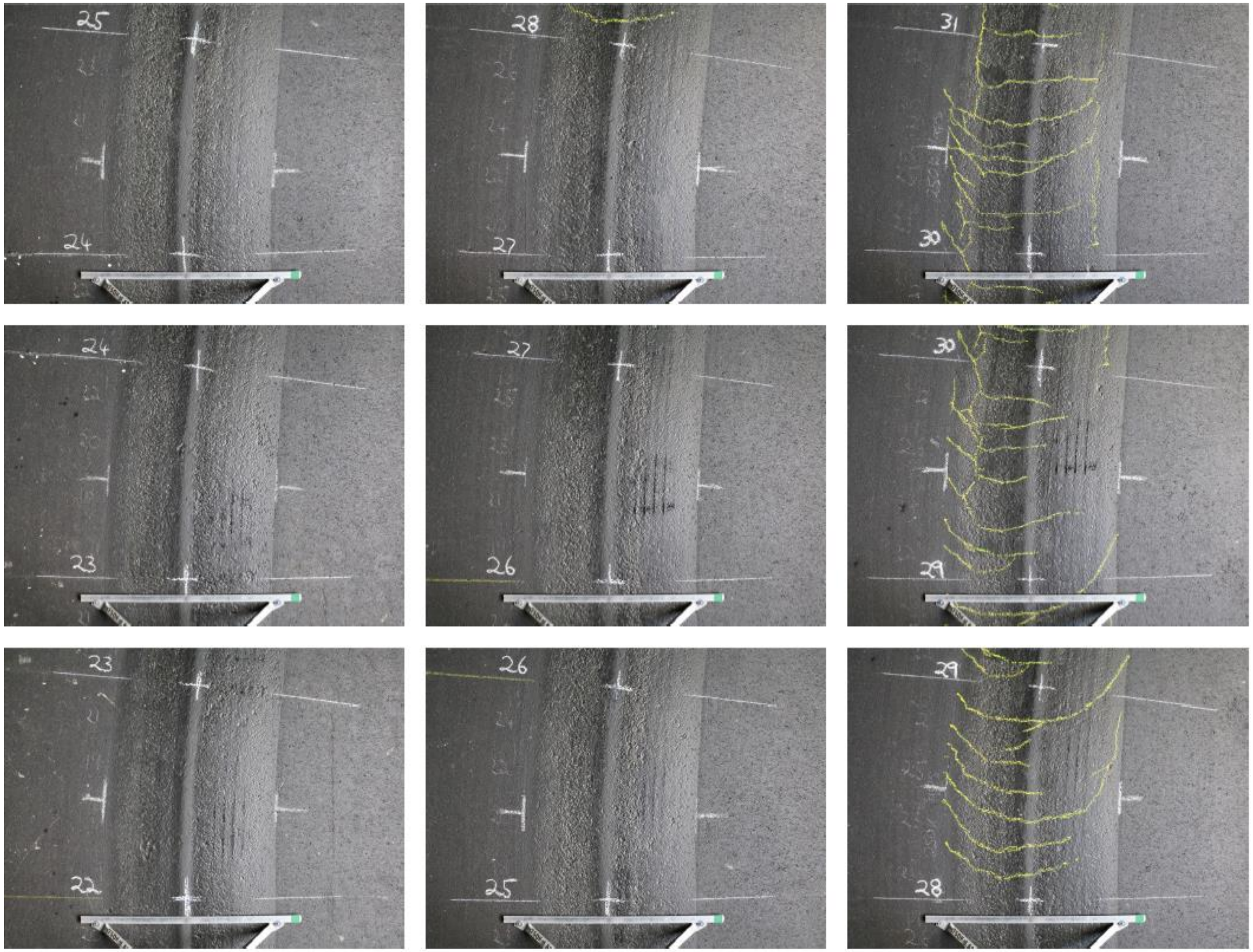

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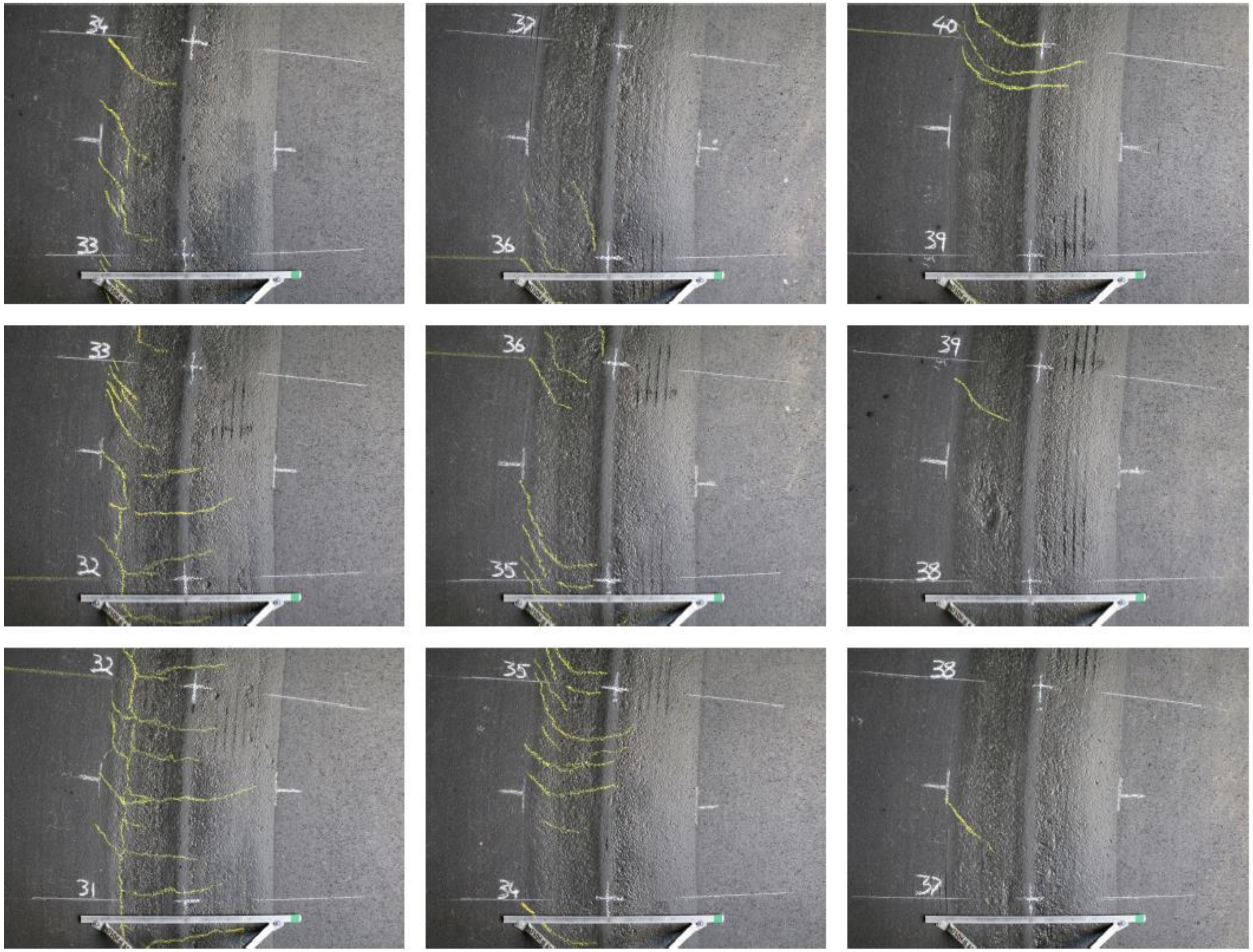

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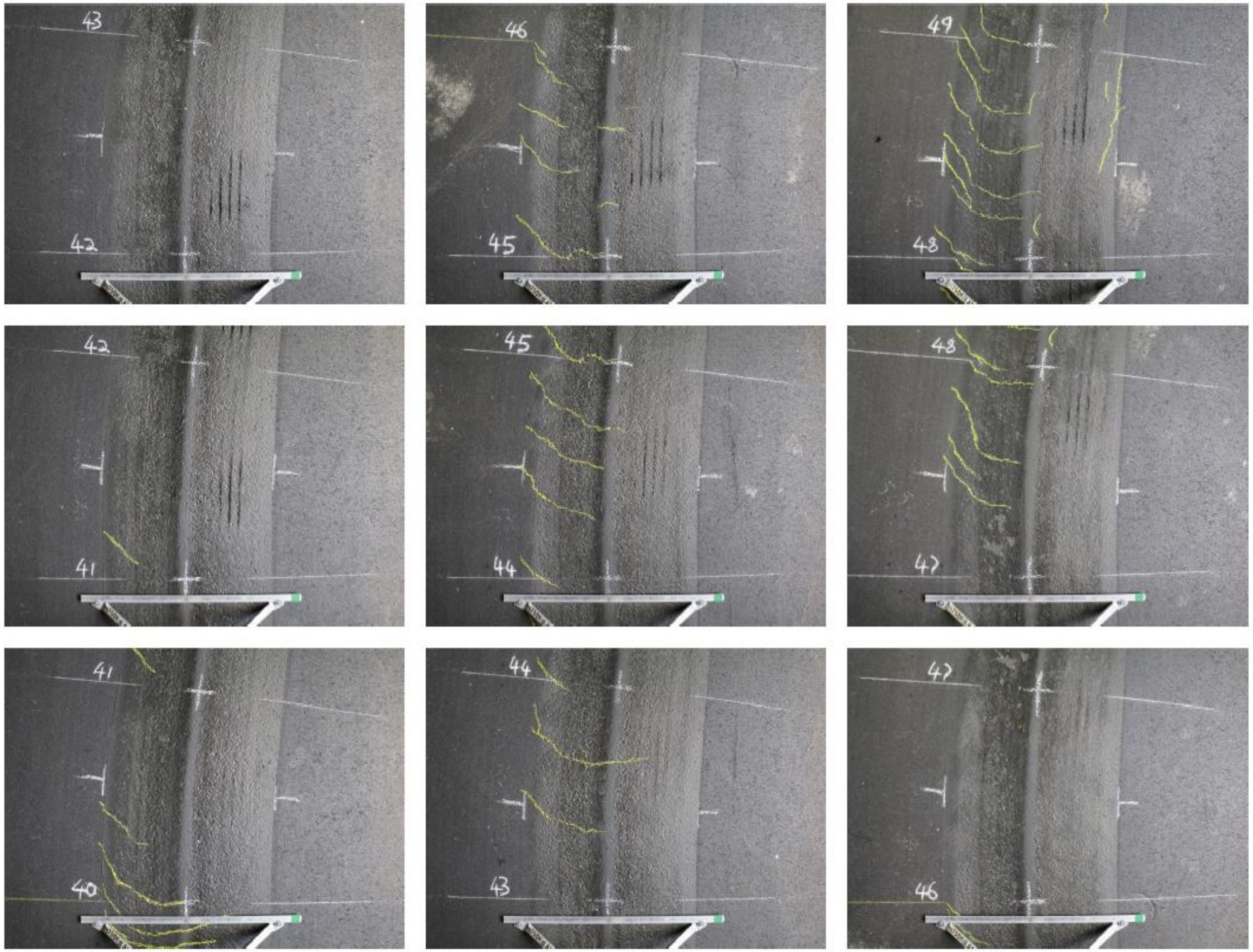

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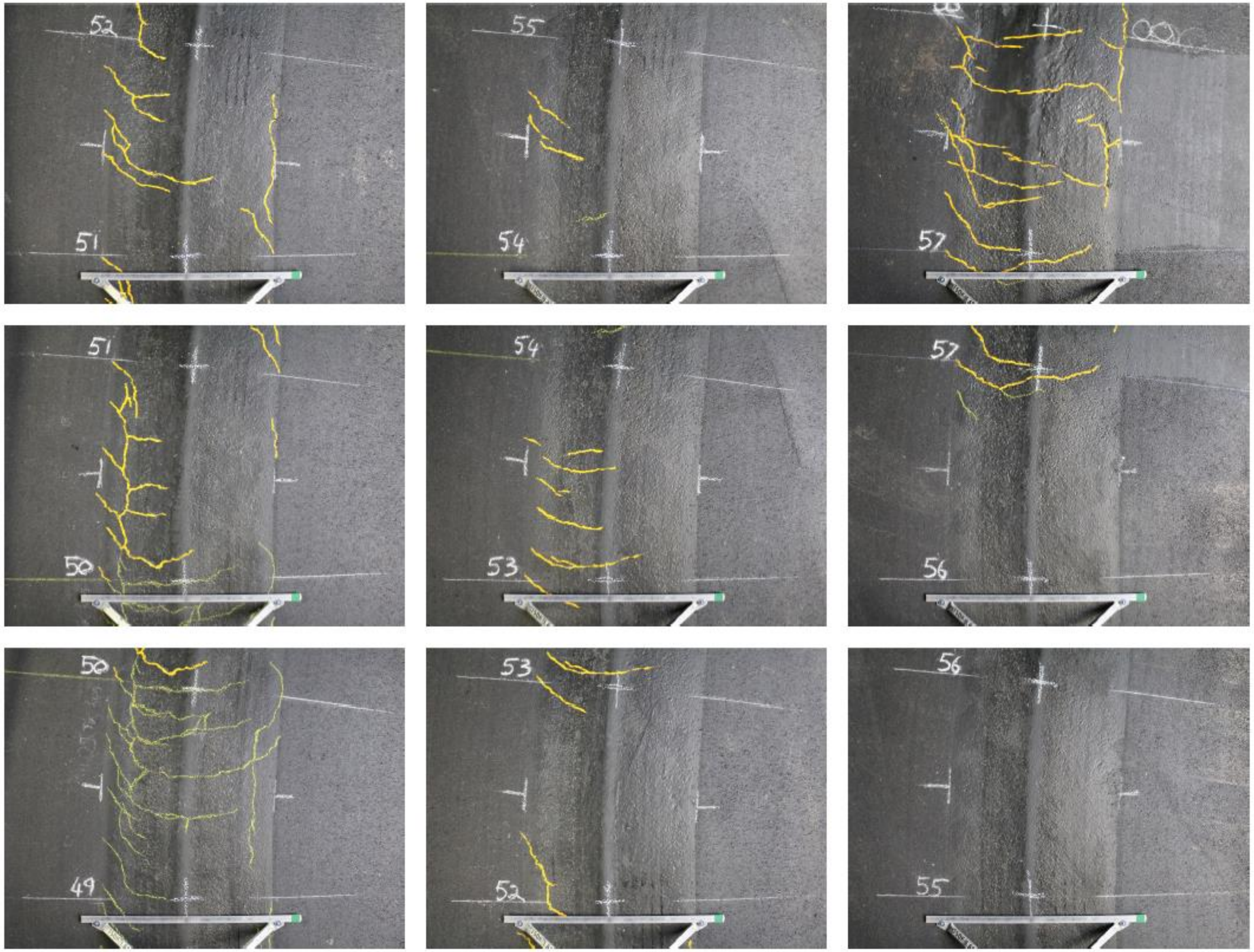

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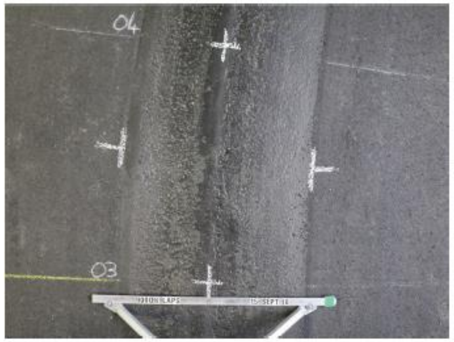

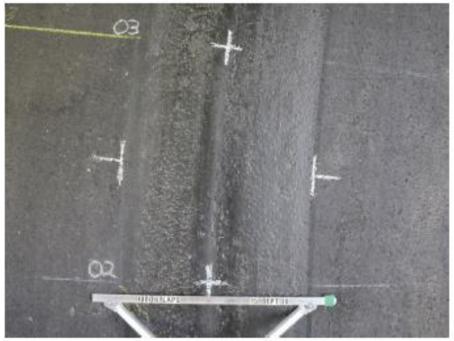

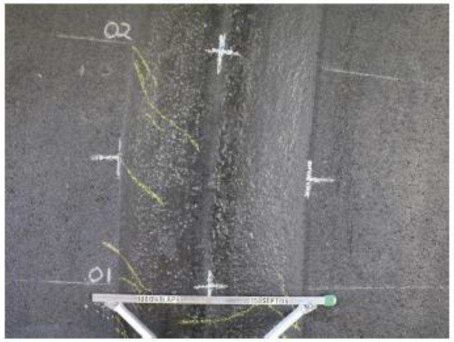

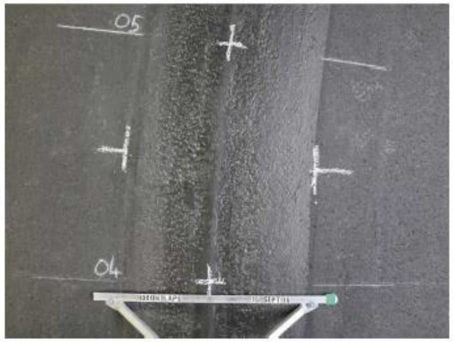

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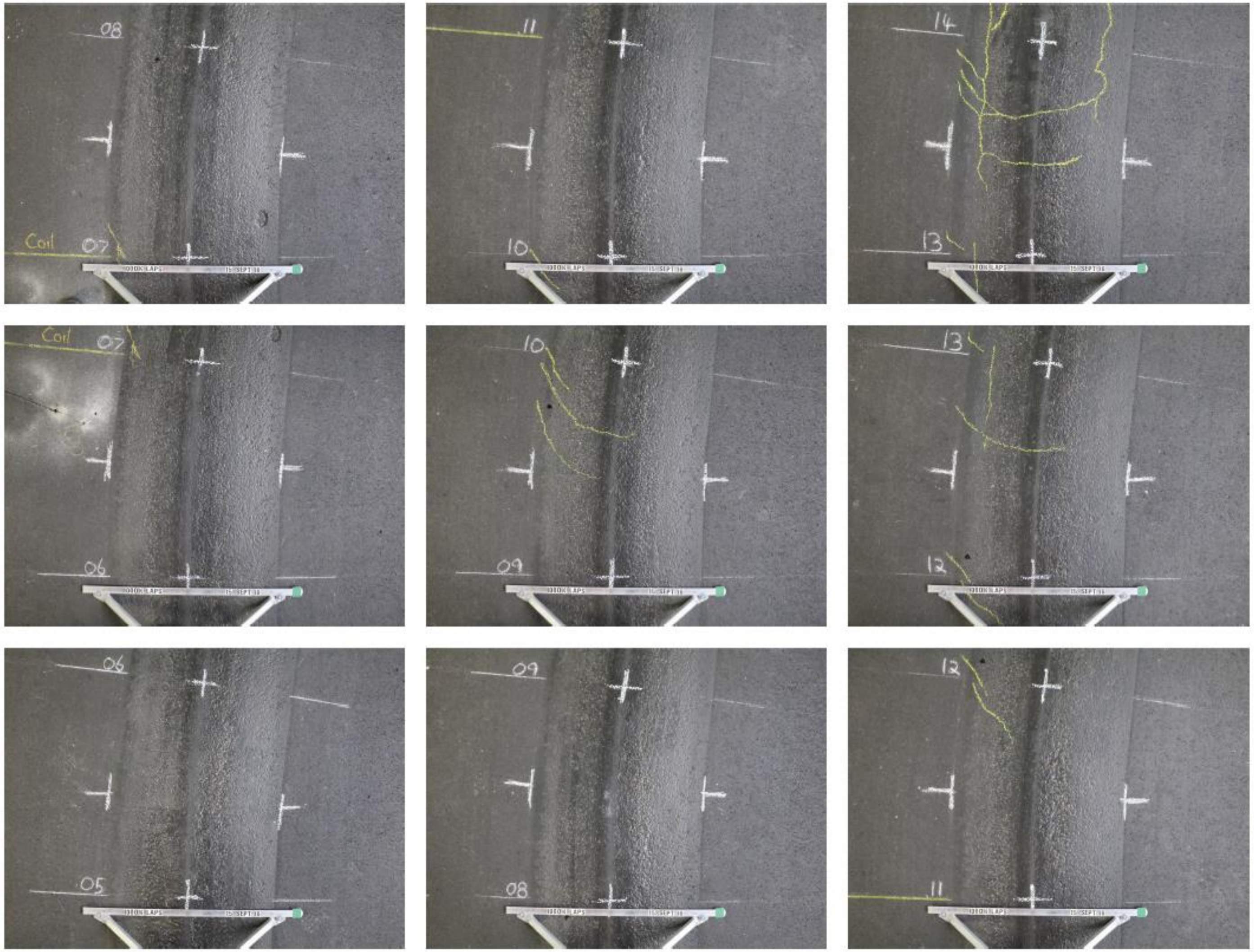

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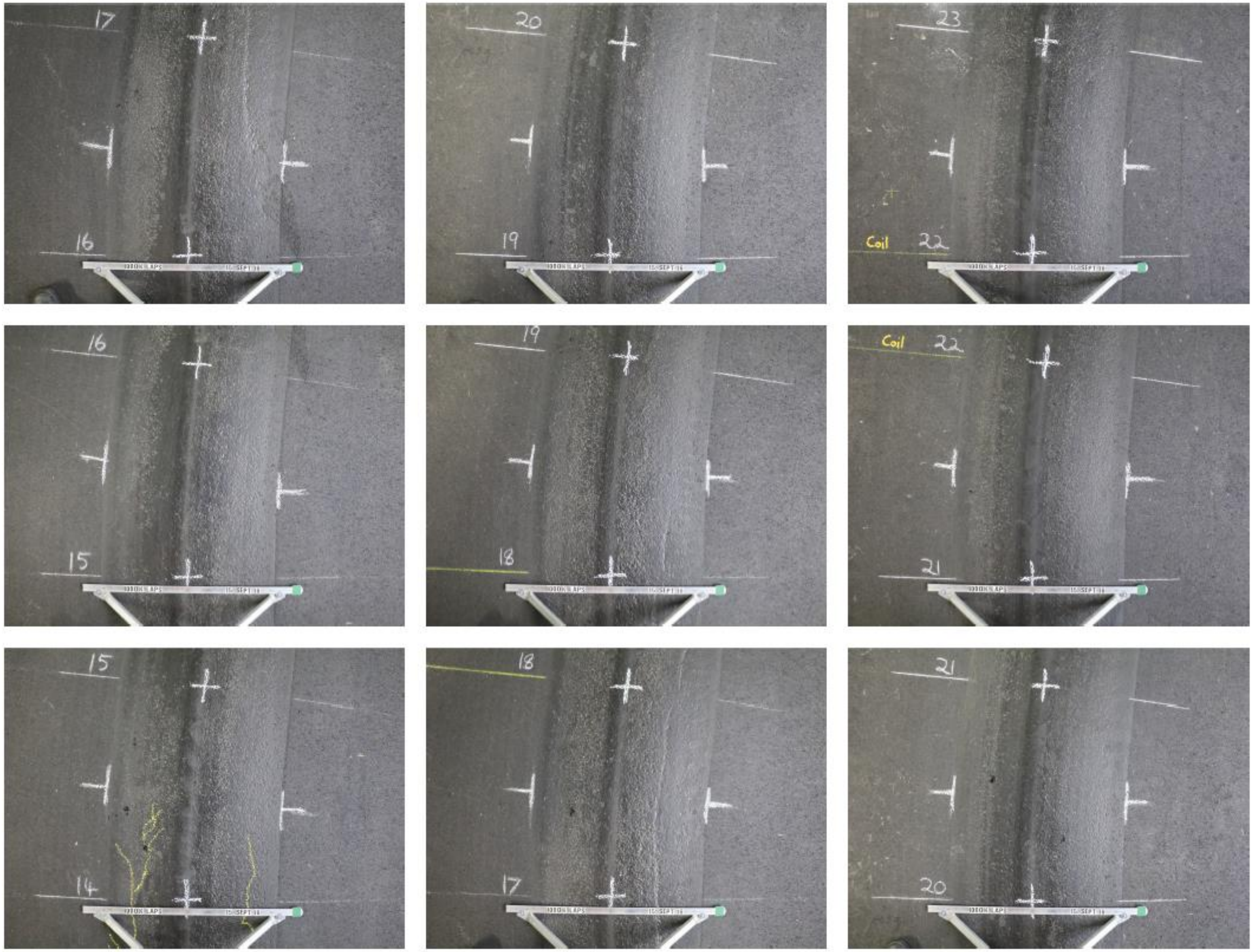

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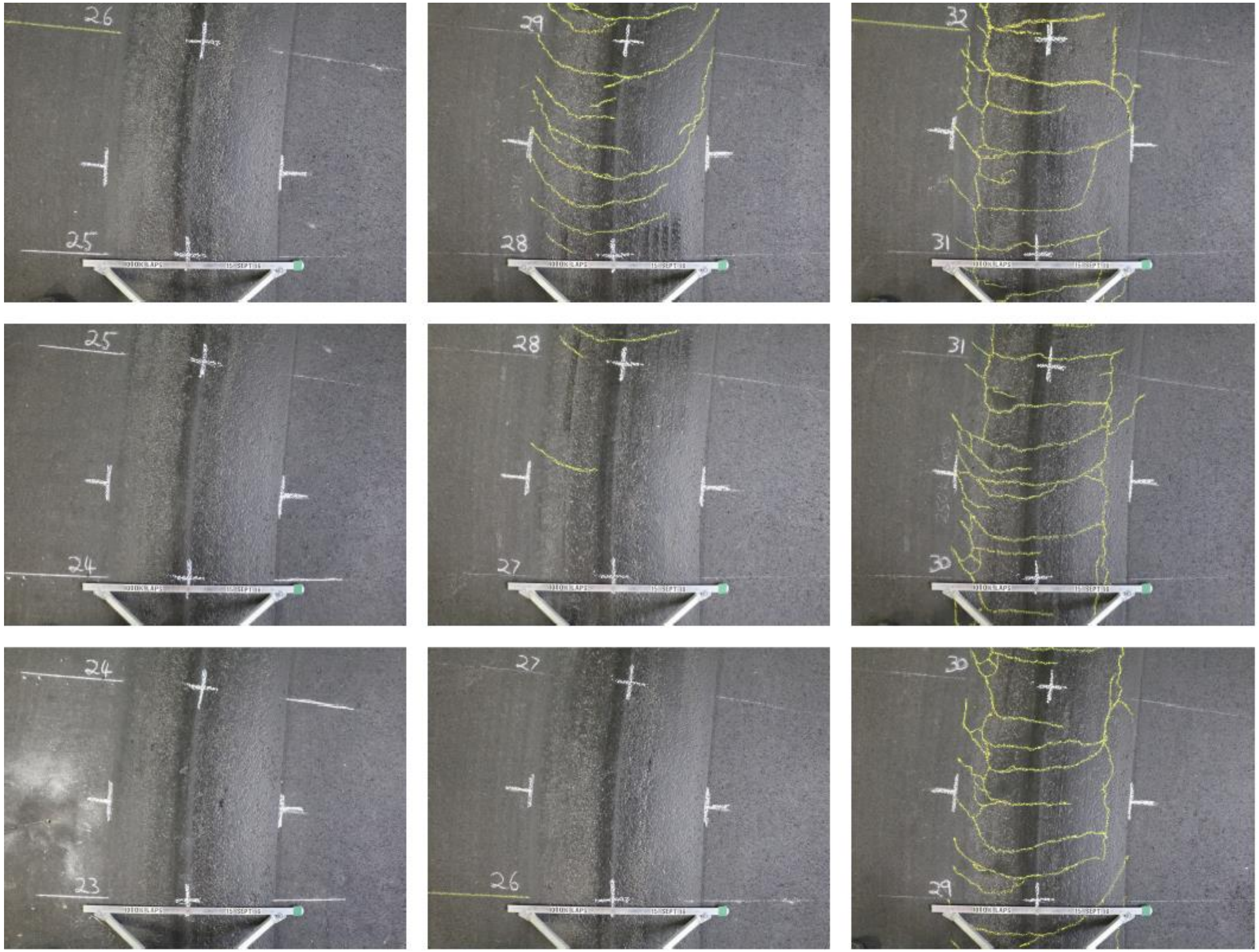

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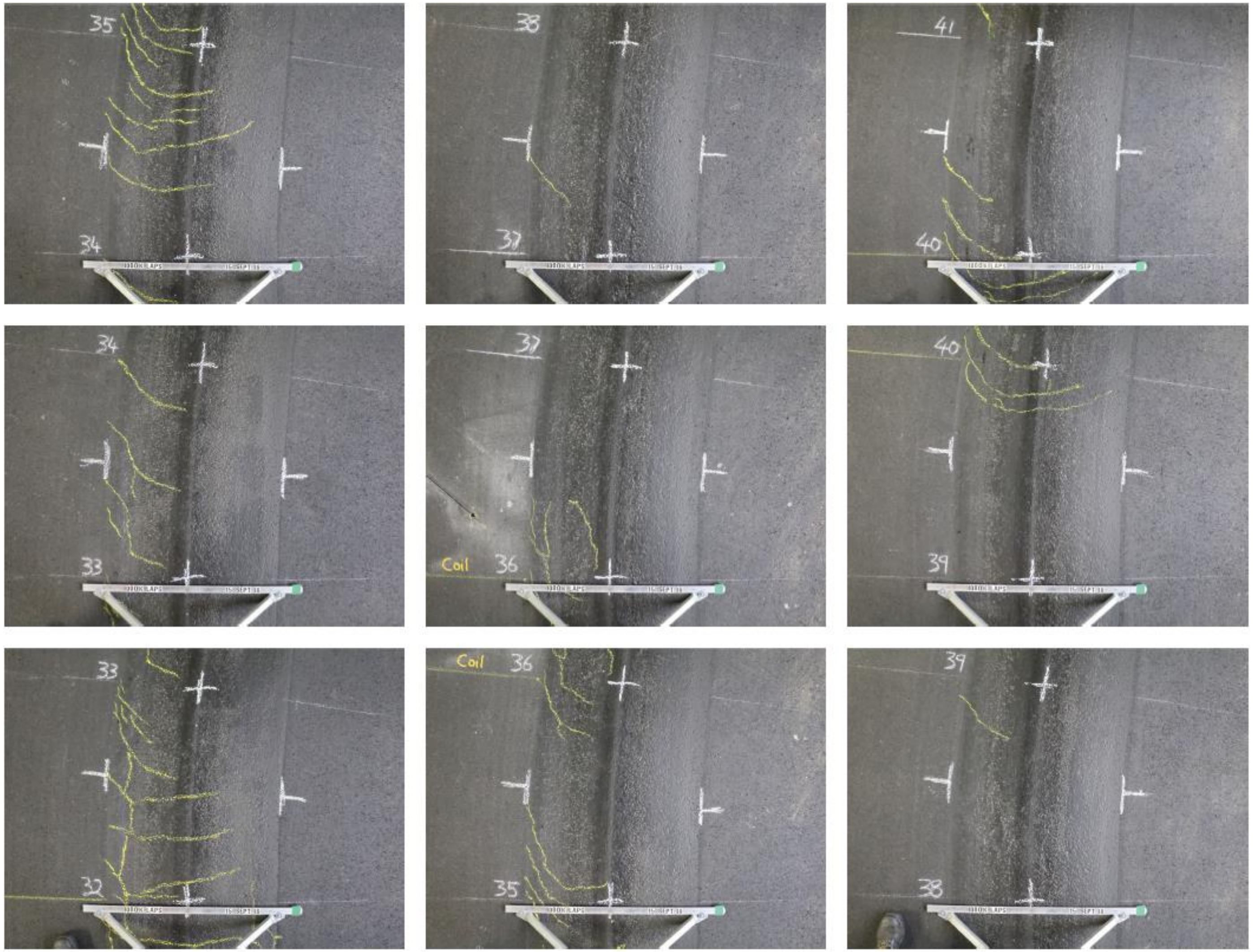

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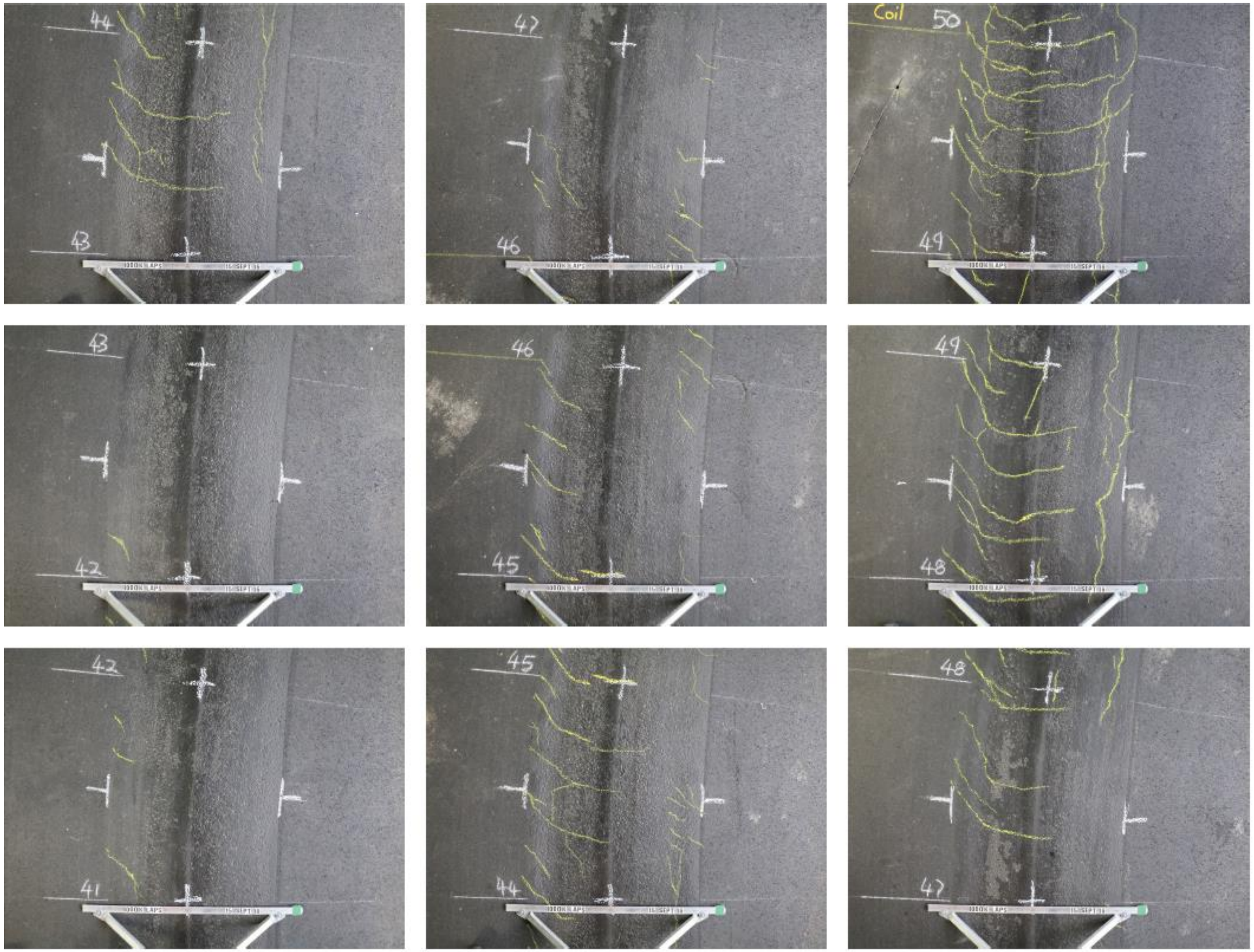

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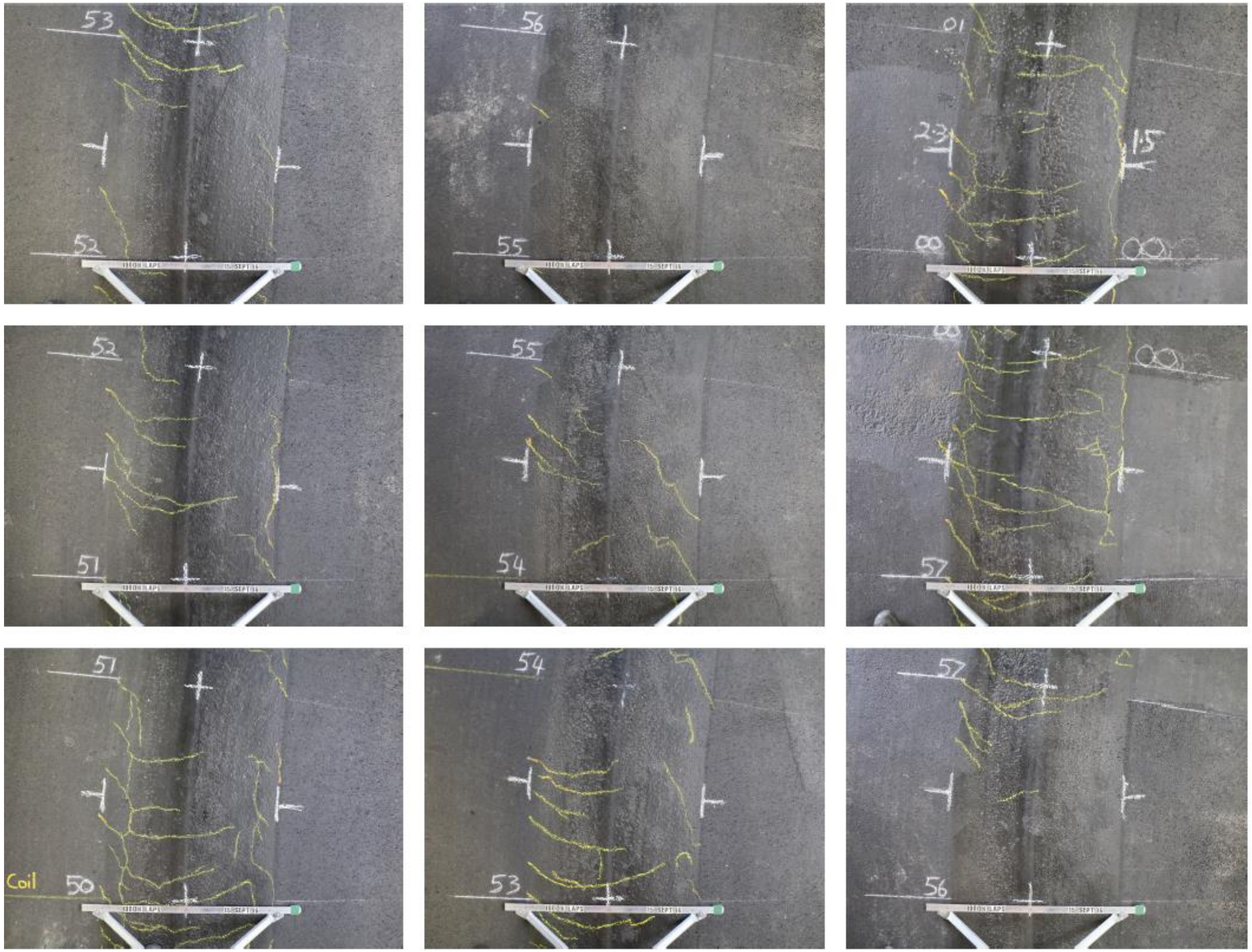

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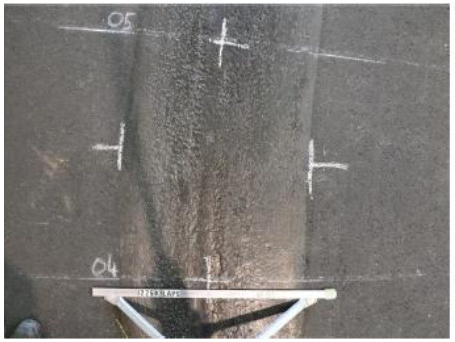

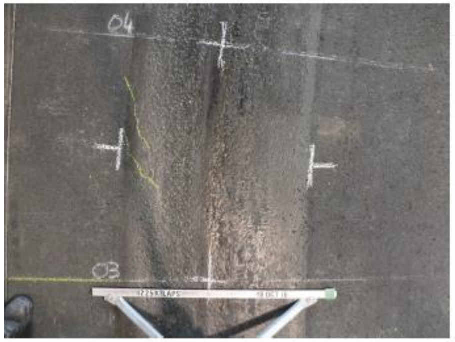

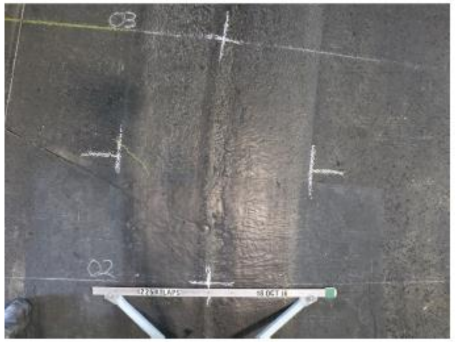

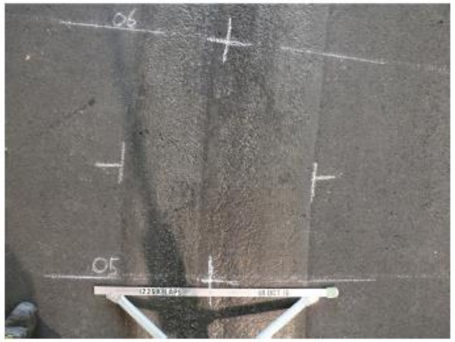

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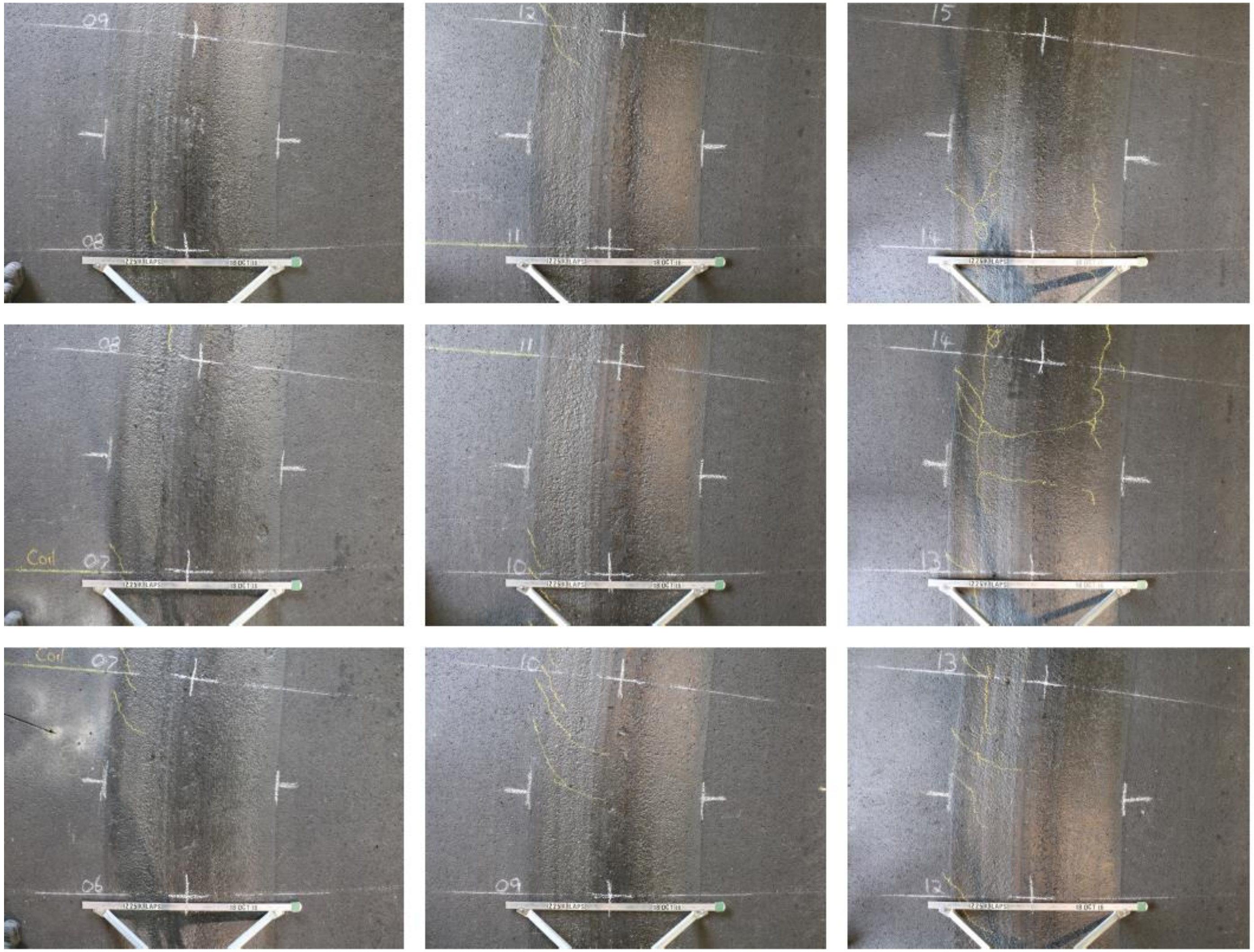

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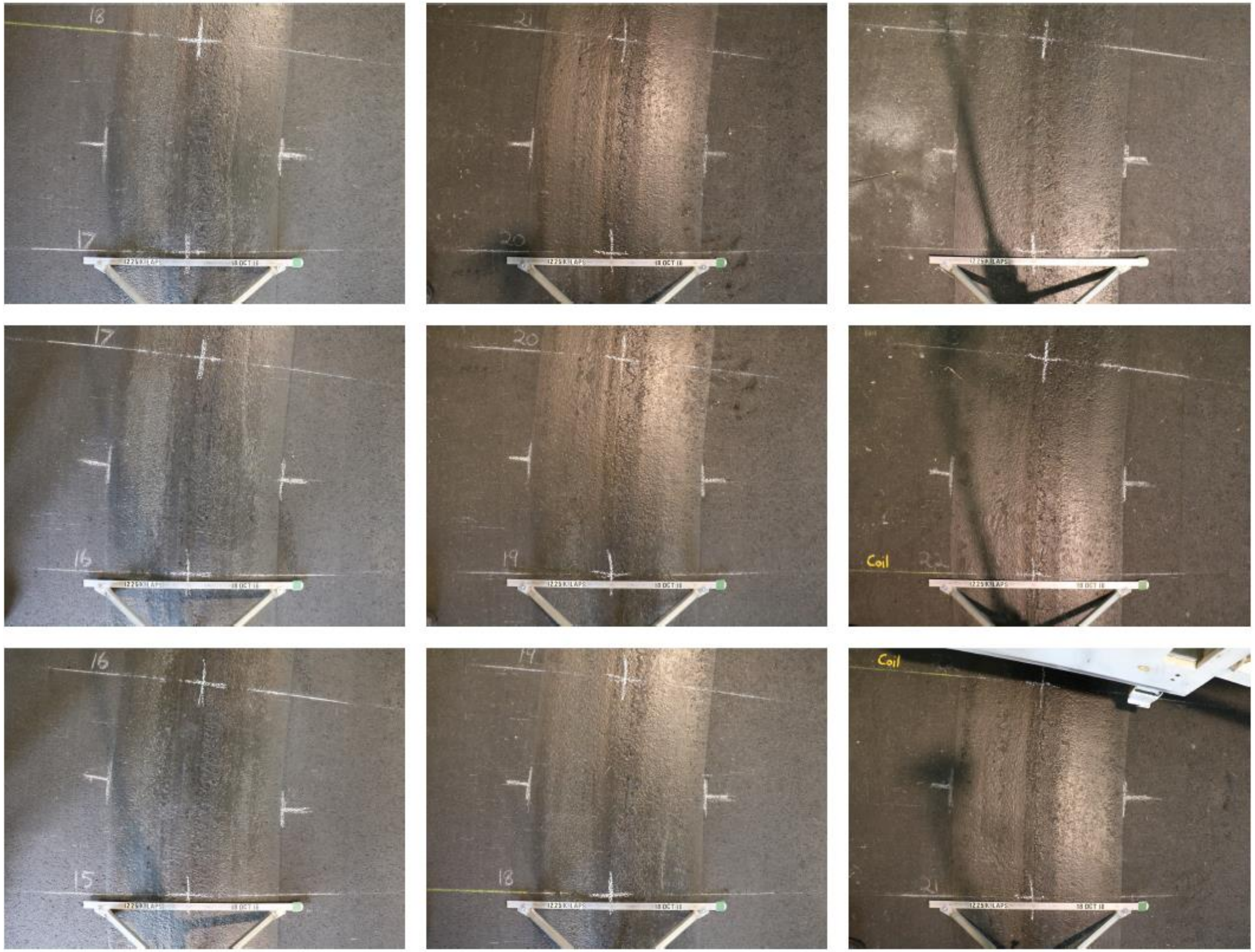

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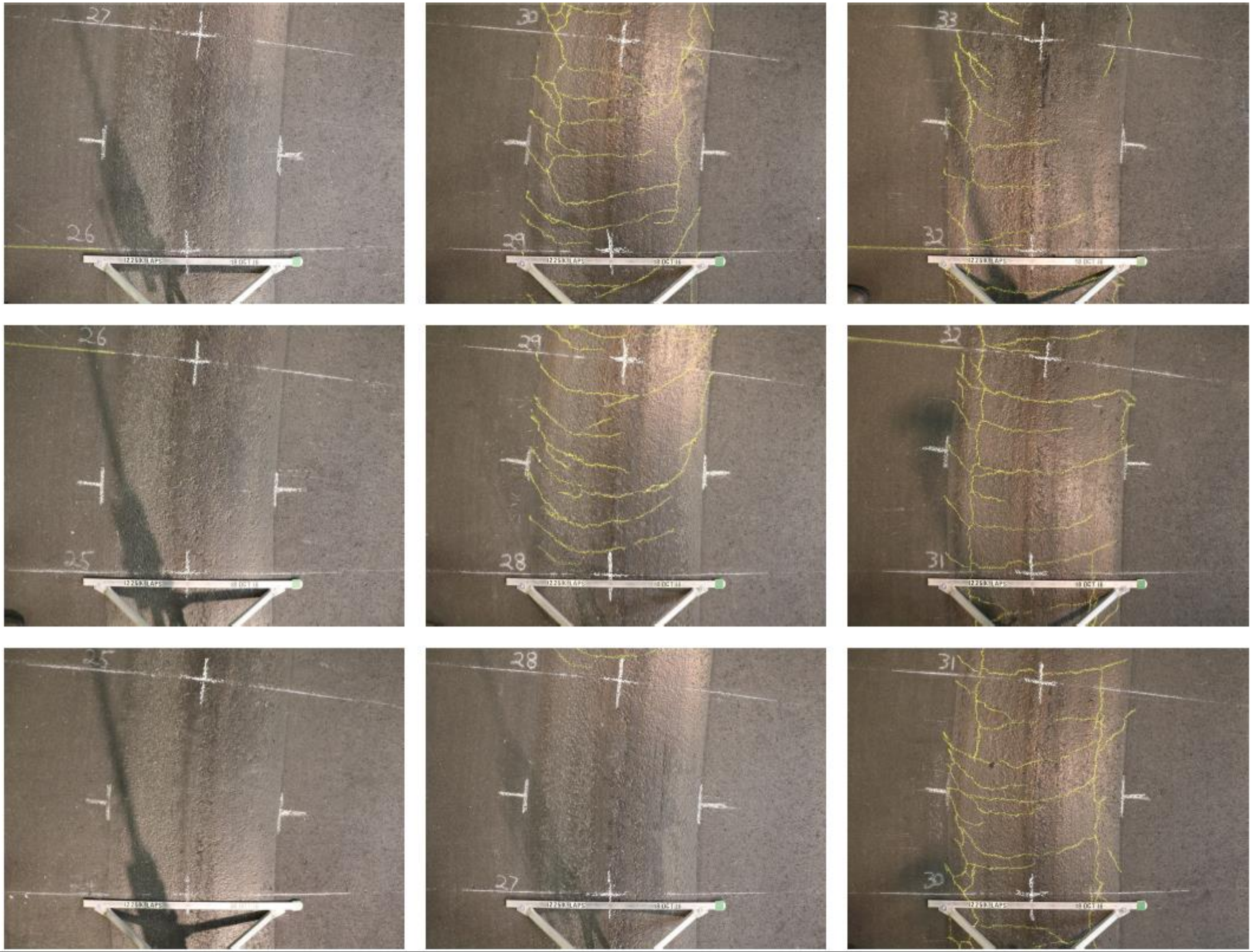

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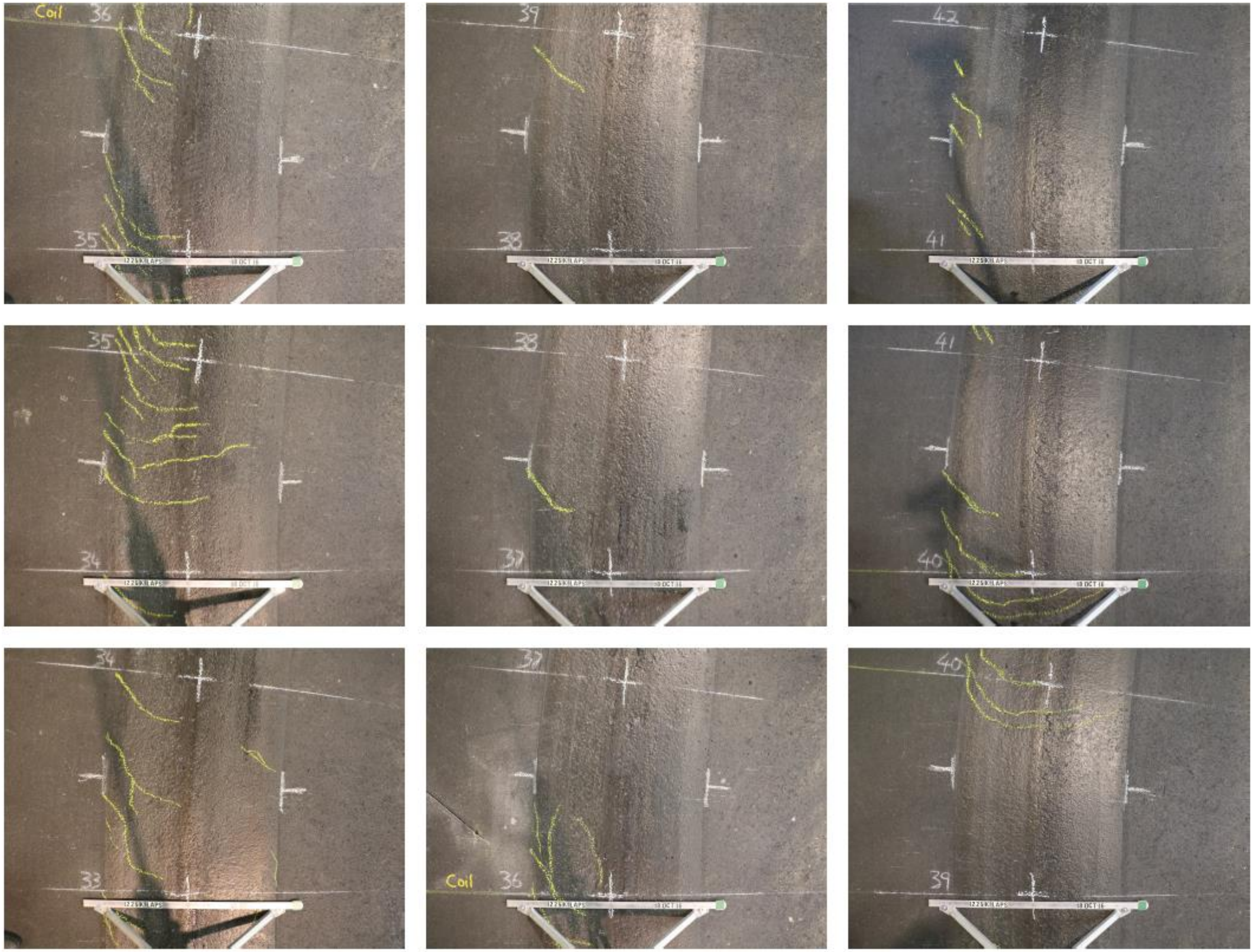

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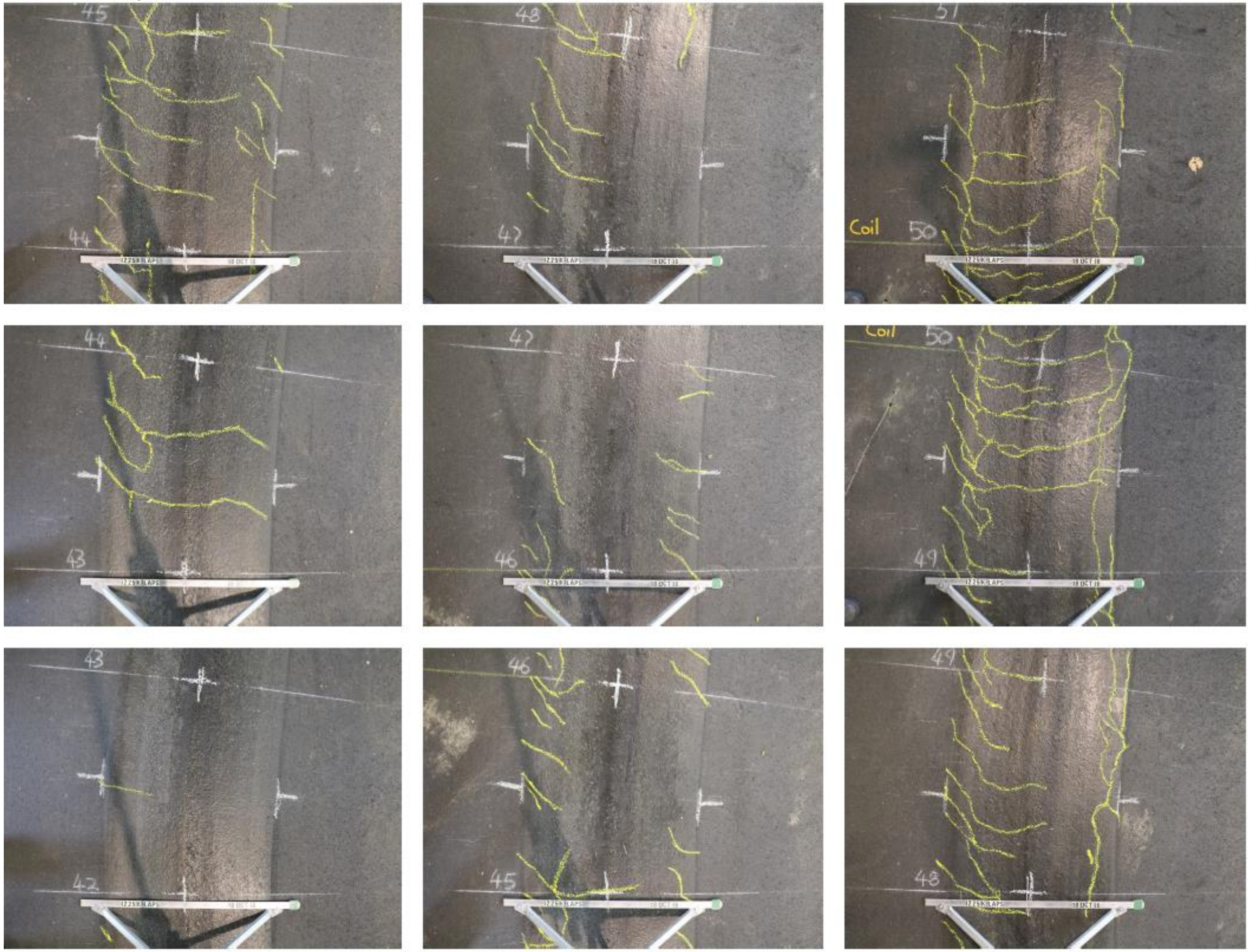

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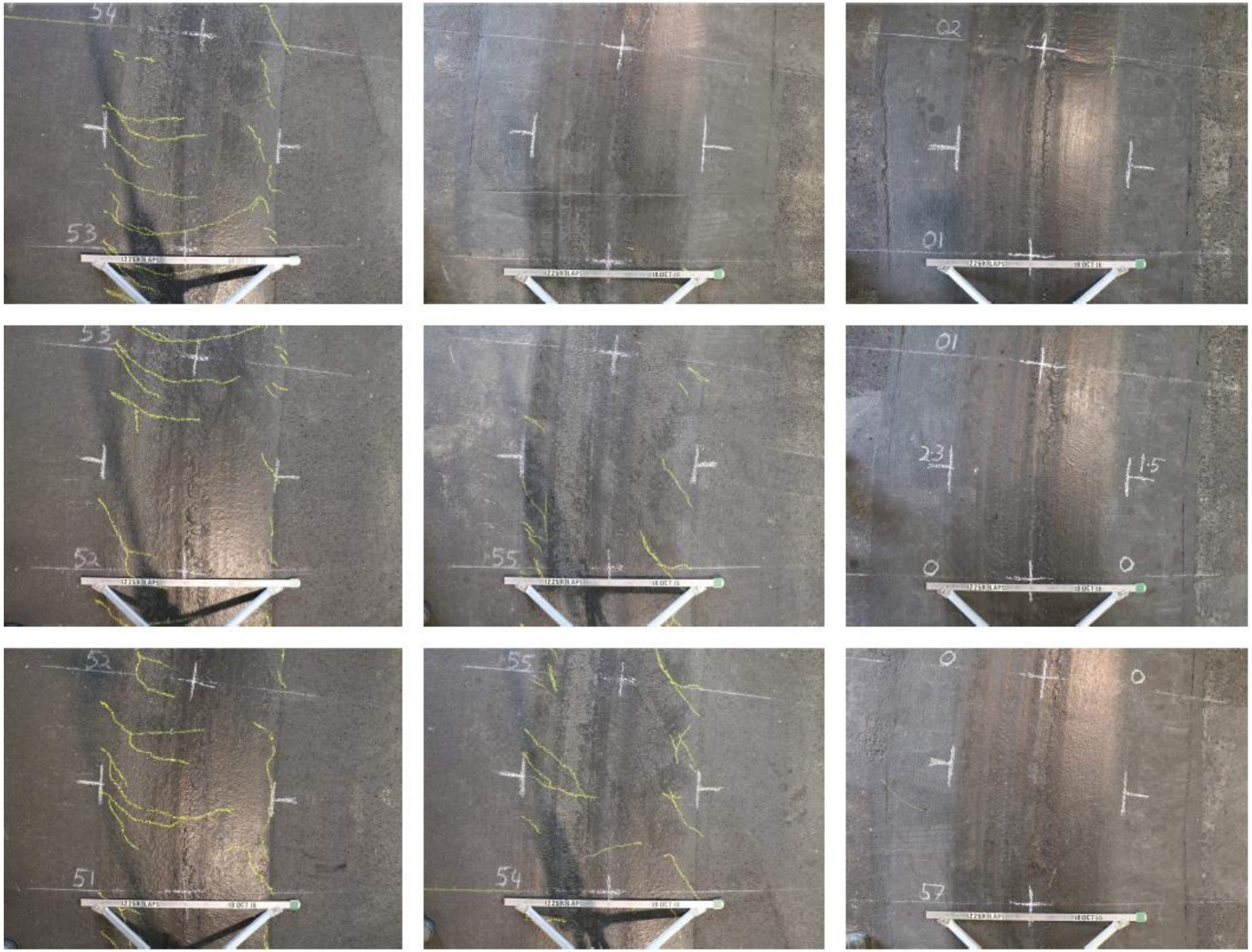

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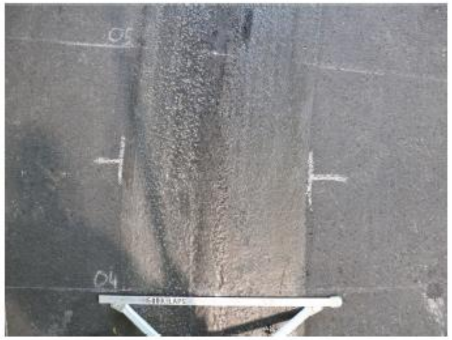
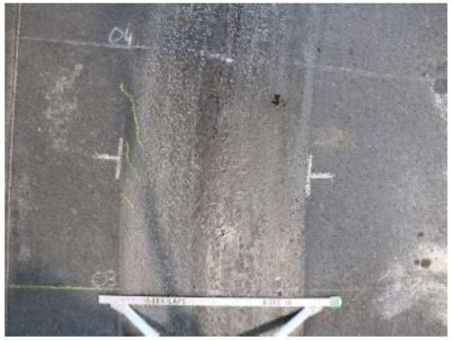
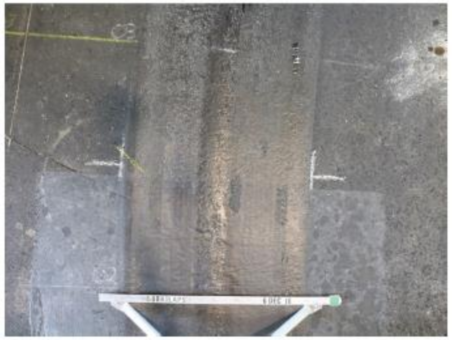
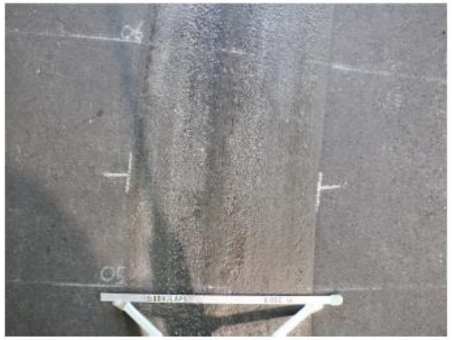


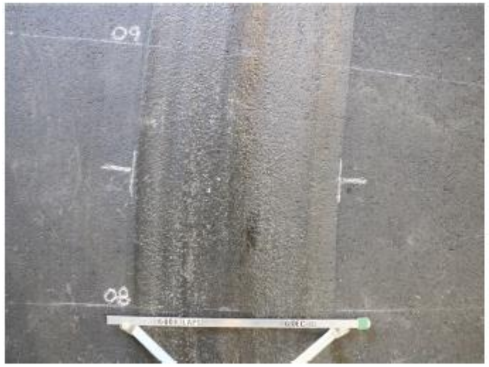


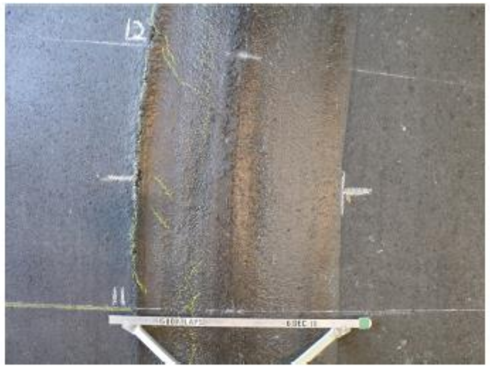


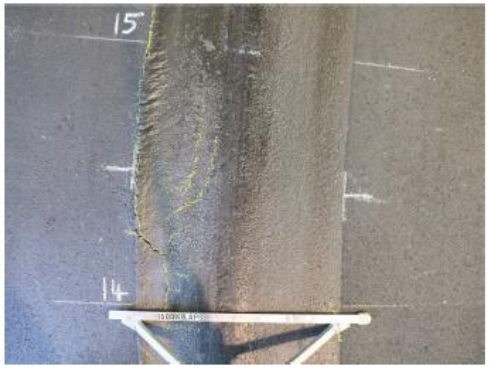


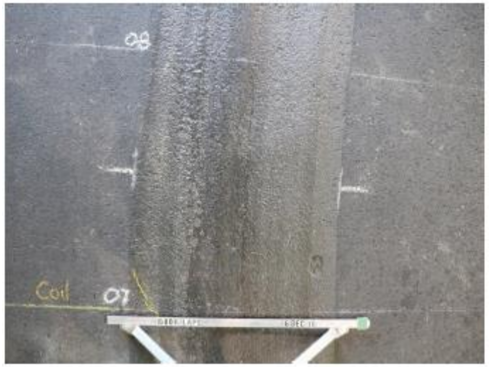
[UNCLASSIFIED]

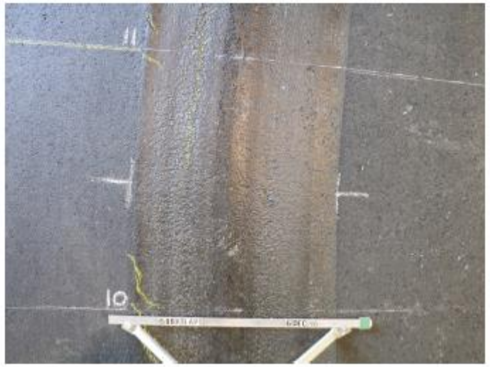
1,500,000 Laps

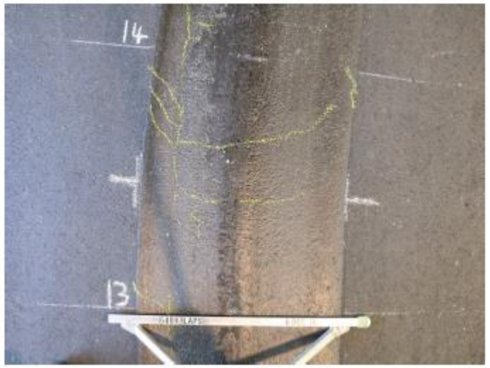


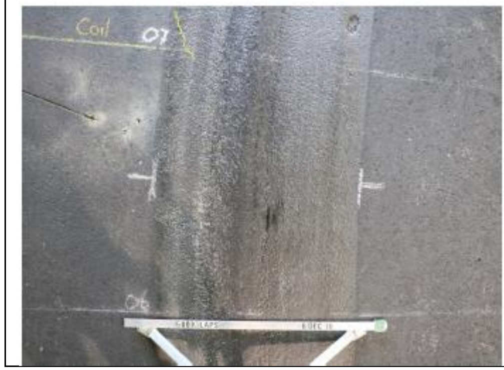


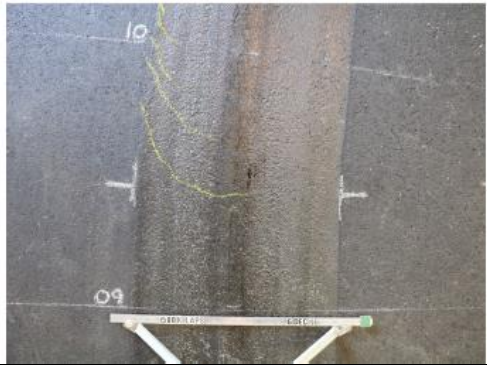


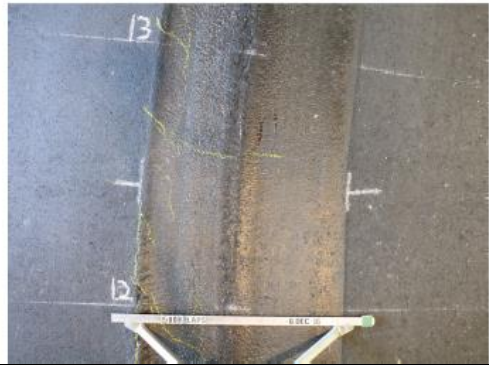












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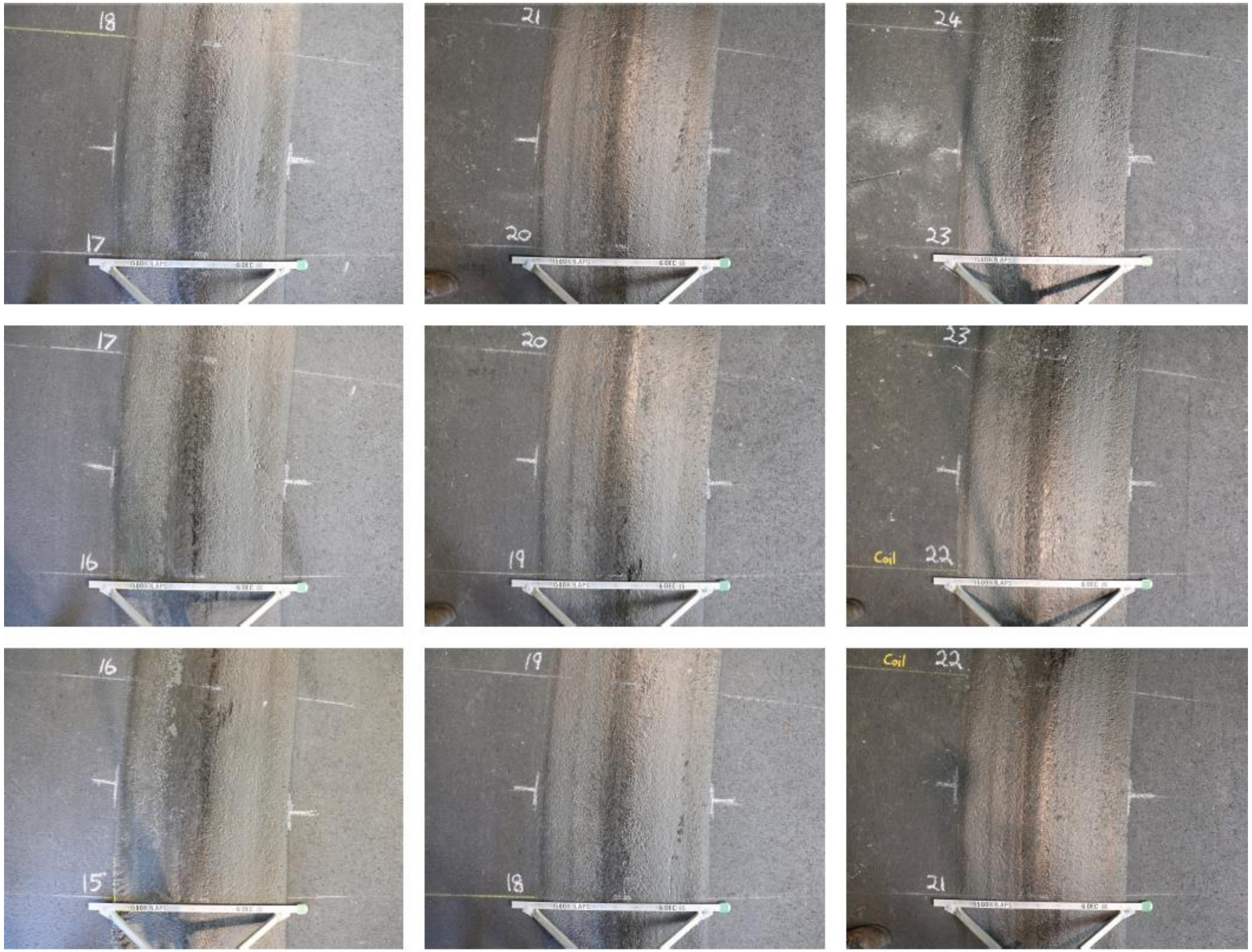

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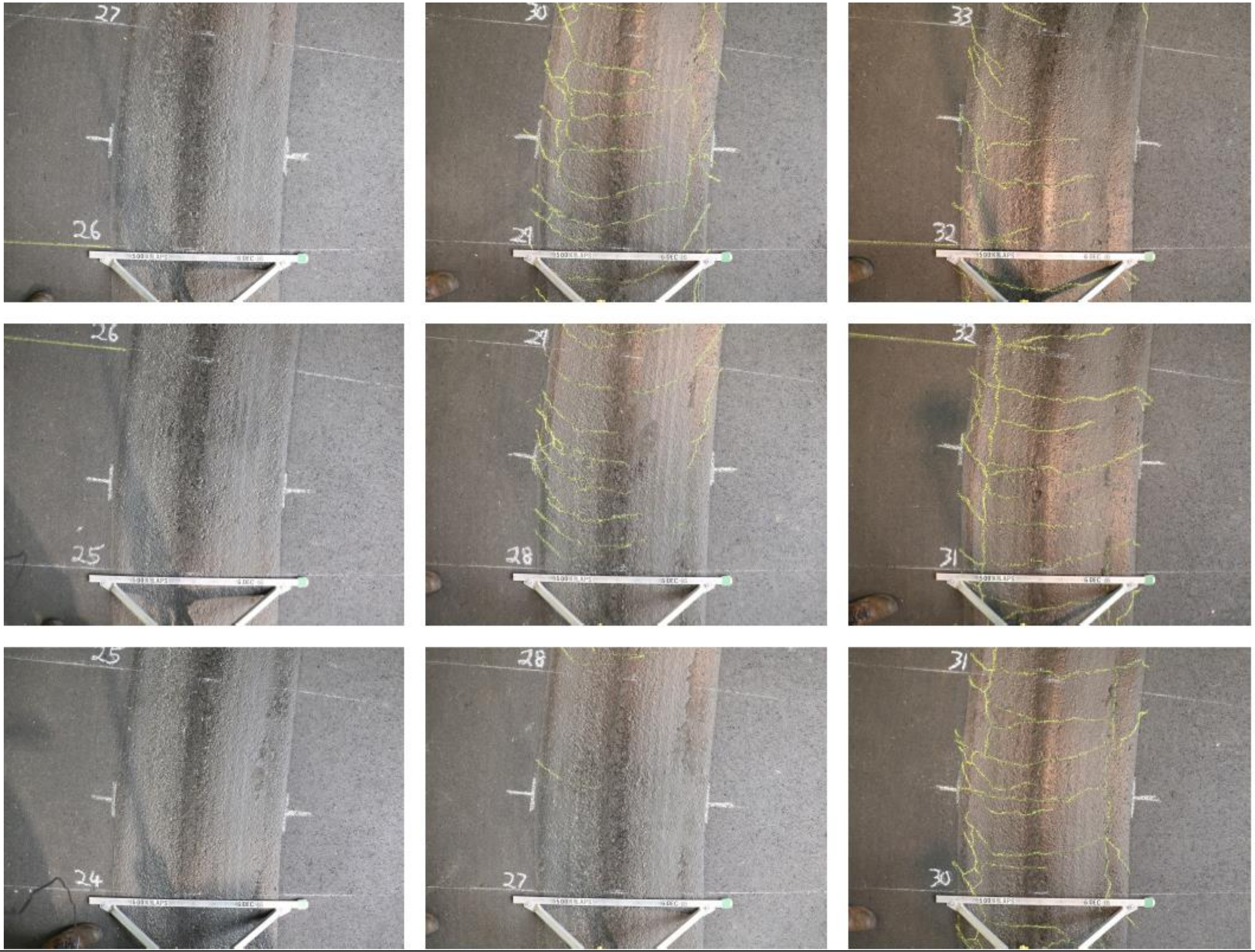

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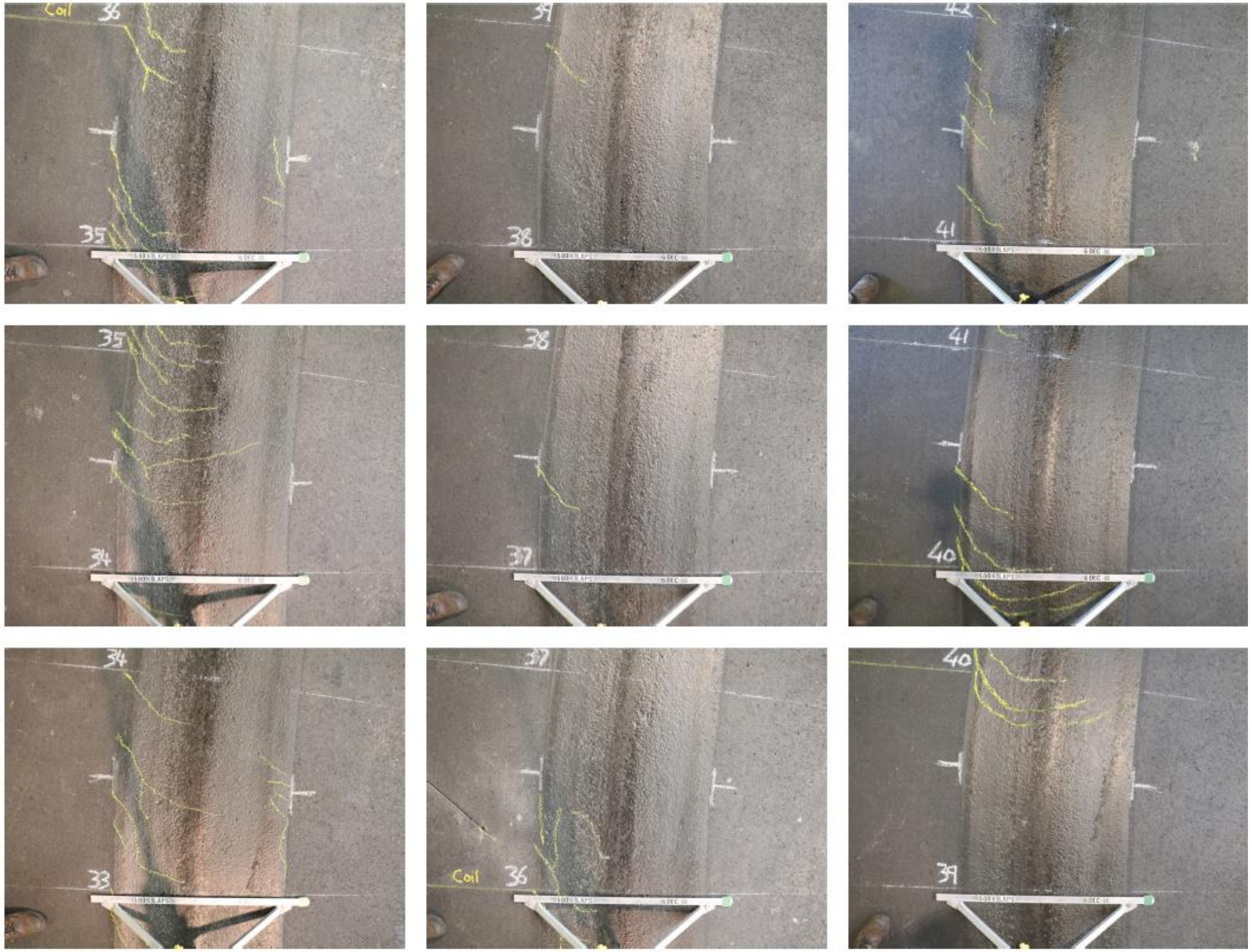

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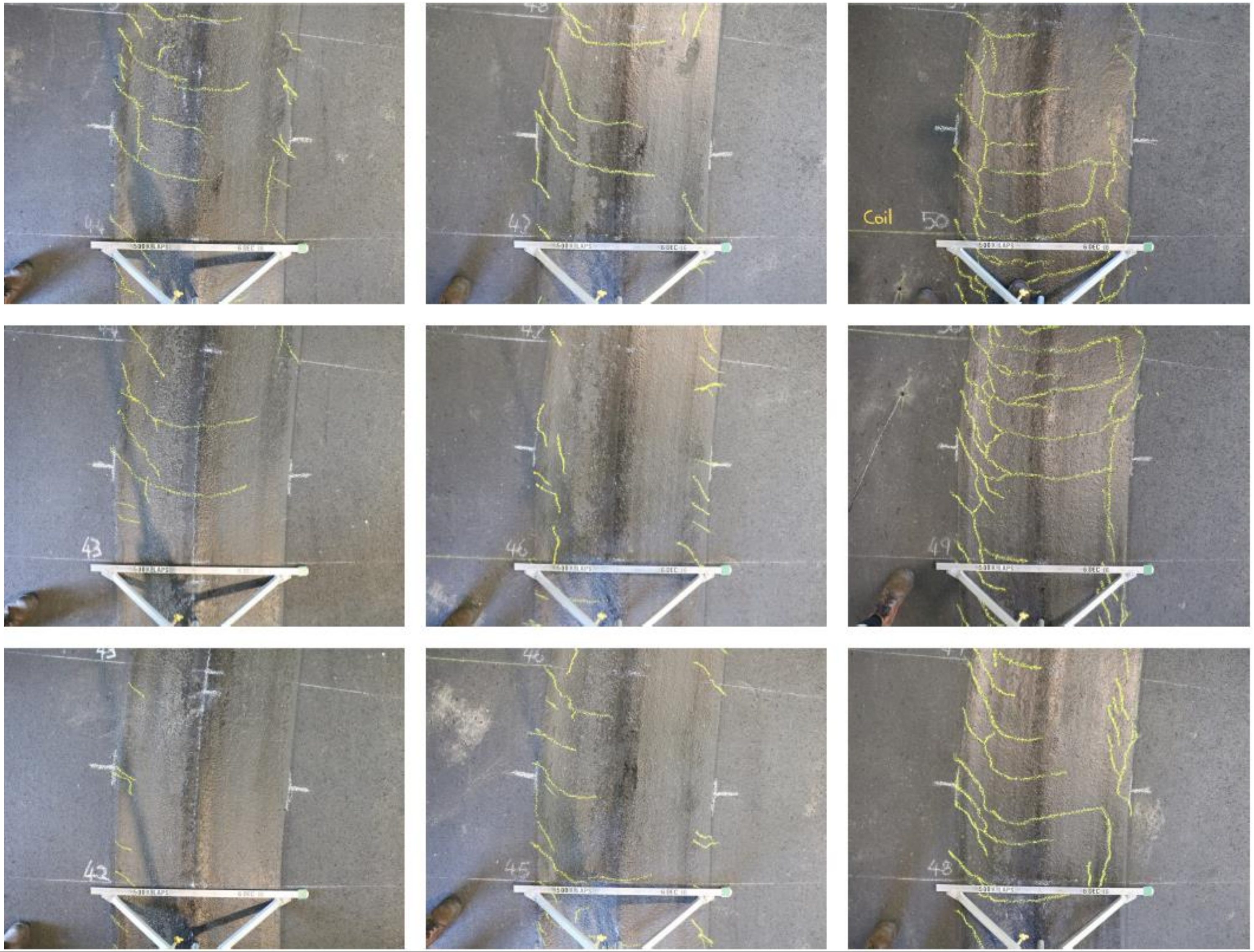

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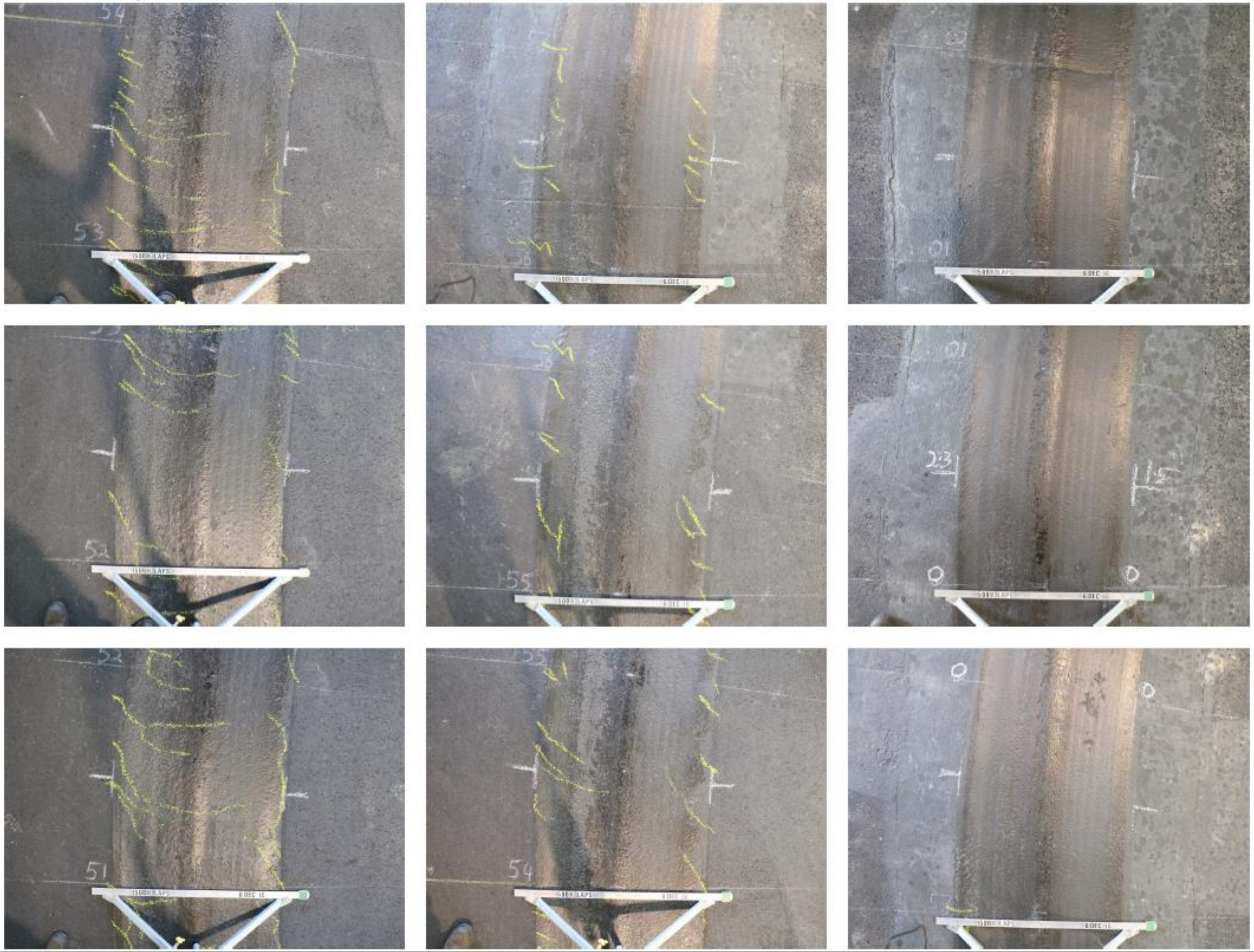

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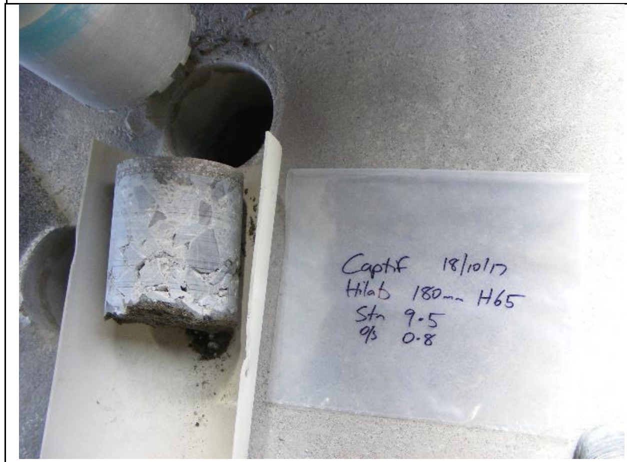
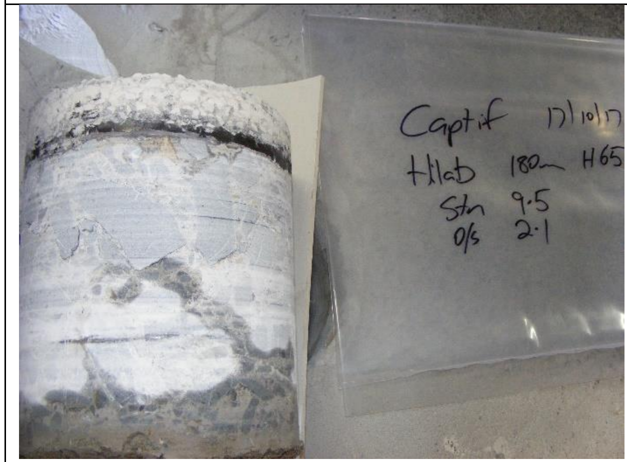
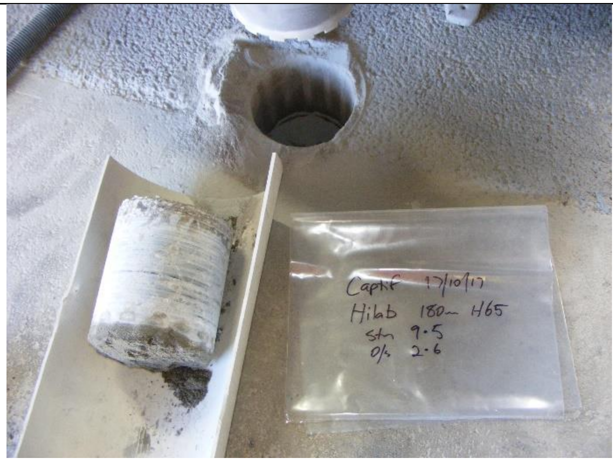
Appendix B Test post-mortem photos

Appendix A – Core Photos

Station 9.5 - Section A







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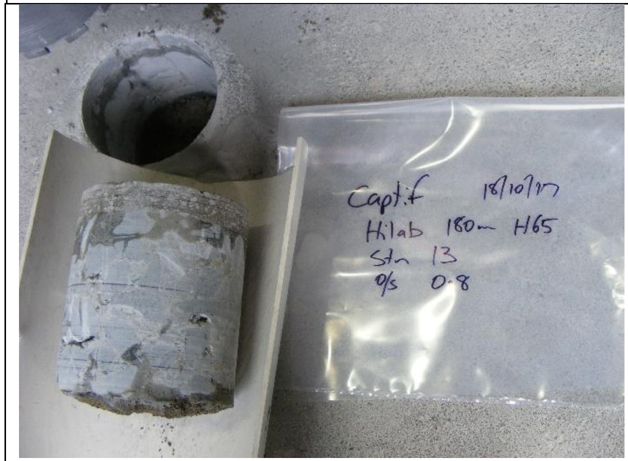
Station 13 - Section A



Station 17 - Section B		
		

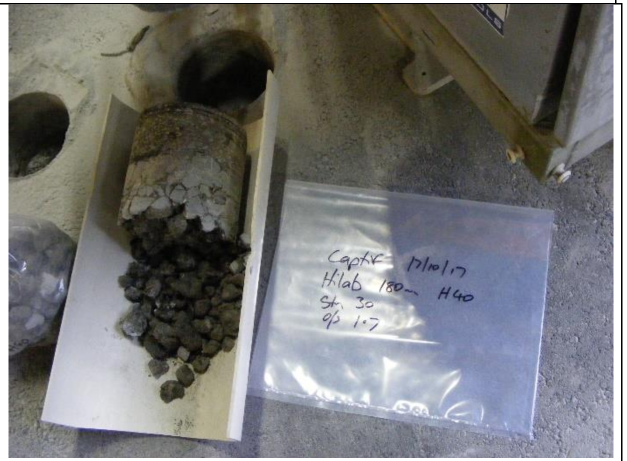
Station 19.5 - Section B		
		

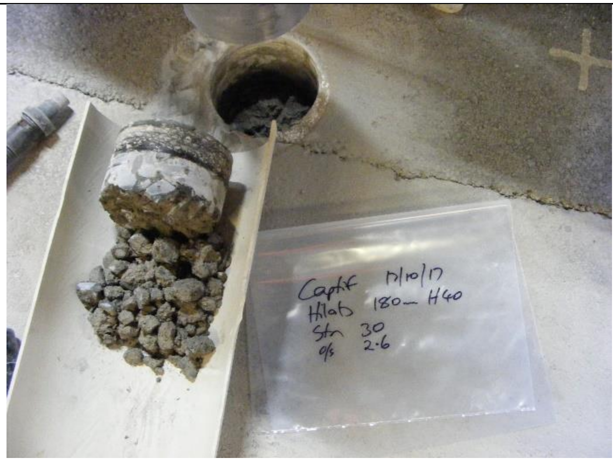
Station 20 - Section B		
		
		

[UNCLASSIFIED]

Station 24 - Section B

Station 30 - Section C





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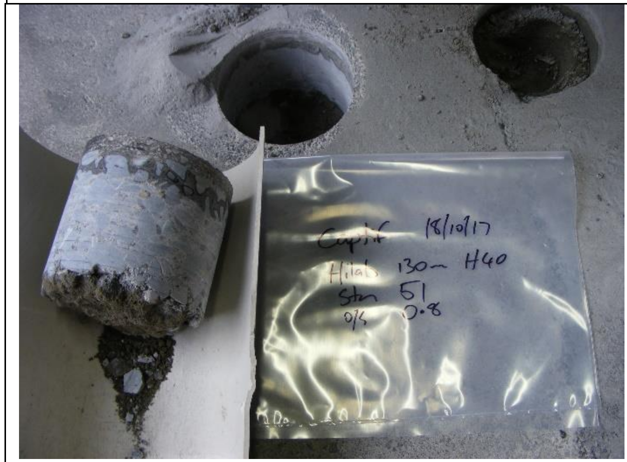
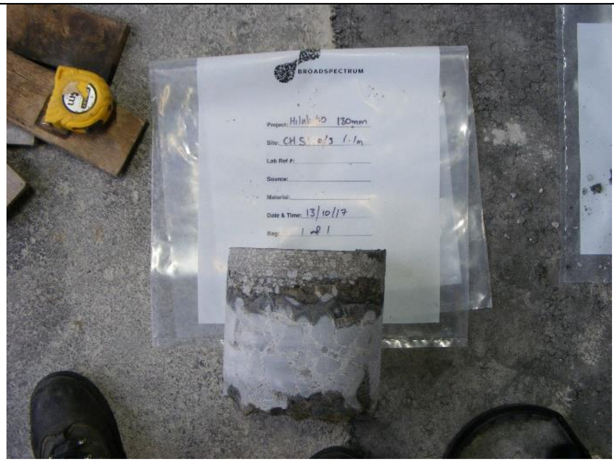
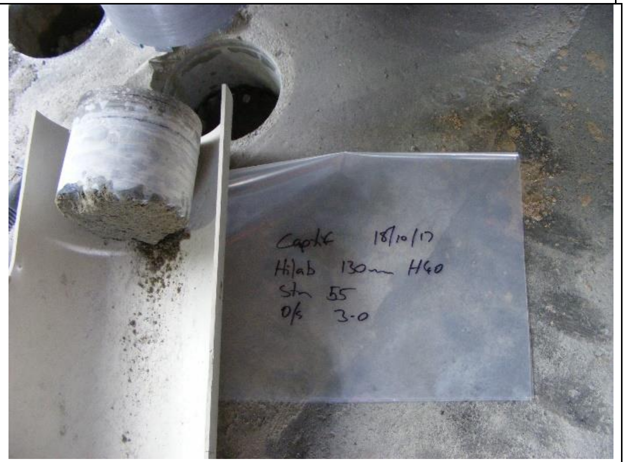
Station 39 - Section C		
		
		

[UNCLASSIFIED]

Station 41 - Section C

Station 51 - Section D		
		
		

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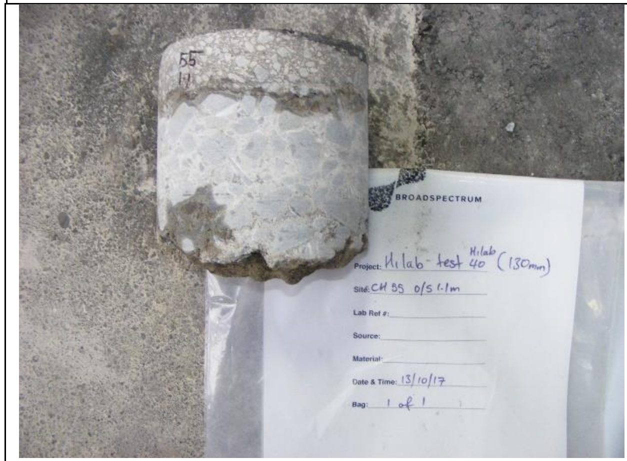
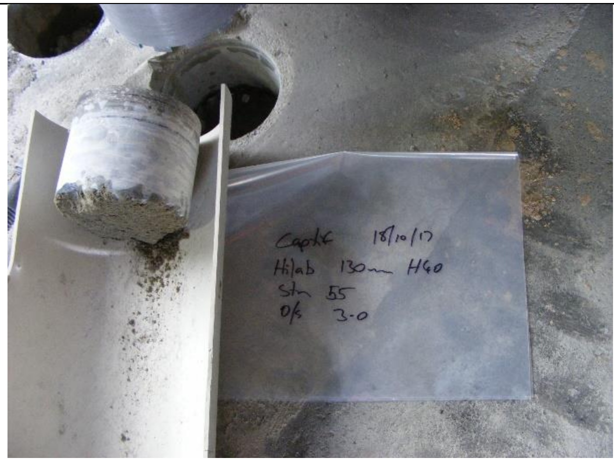
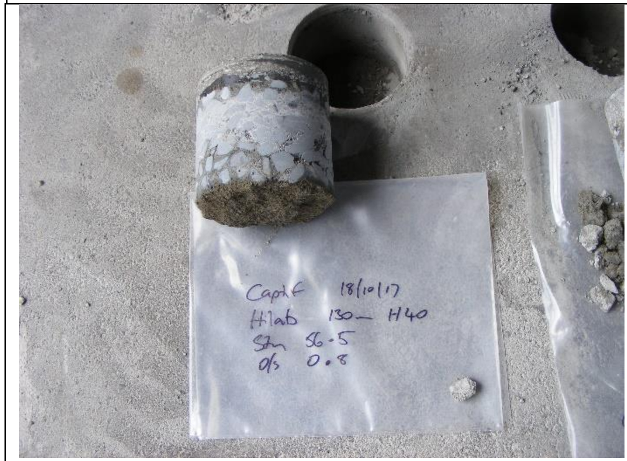
Station 55 - Section D





Station 56.5 - Section D		
		
		

[UNCLASSIFIED]

Appendix C – Post-mortem ITS and Beam Tests

Road Science
Leading Transport Technology

CHRISTCHURCH LABORATORY

397 Mcleans Island Rd, Harewood. P O Box 11 326, Christchurch
Phone: (03) 359 0757, Fax (03) 359 1909

Laboratory N°: C17/3772E
Report Date: 12-Jan-2018
Page 1 of 1 pages

TEST REPORT

Client:	New Zealand Transport Agency
Client Address:	NZTA CAPTIF, 2 Mcleans Island Road, Harewood, Christchurch
Client Ref:	HILAB-Section A
Job Location:	CAPTIF
Material:	HILAB
Material Source:	Not Advised
Sample Date:	04-Dec-2017
Sampled By:	Rob Craw
Sampling method:	Not Applicable
Test Date:	14-Dec-2017

Test Methods: Determination of the Indirect Tensile Strength and Unconfined Compressive Strength of Modified and Unmodified Aggregate Samples — DCLTM1:2013

Results:

Sample Details

Precompaction Curing Time	Not Advised
Compaction Method	Not Advised
Compactive Effort	Not Advised
Rate of Axial Compression (mm/min)	1.0
Curing conditions	Not Applicable

Test Details

Sample	1.2-9.5	1.8-4.7	2.1-4.7	2.6-9.5
Soaking Status	Unsoaked		Unsoaked	
Diameter of Specimen (mm)	191.97	188.00	190.45	192.01
Height of Specimen (mm)	208.23	183.40	184.71	198.20
Water Content as Compacted (%)	N/A	N/A	N/A	N/A
Water Content after Testing (%):	3.77	3.16	3.49	3.98
Dry Density as Compacted (t/m³)	N/A	N/A	N/A	N/A
Indirect Tensile Strength (kPa)	707	946	714	1066

Vicky Henderson

Laboratory Manager

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Road Science
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CHRISTCHURCH LABORATORY
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Phone: (03) 359 0757, Fax (03) 359 1909

Laboratory N°: C17/3772A
Report Date: 12-Jan-2018
Page 1 of 1 pages

TEST REPORT

Client: New Zealand Transport Agency
Client Address: NZTA CAPTIF, 2 Mcleans Island Road, Harewood, Christchurch
Client Ref: HILAB-Section B1
Job Location: CAPTIF
Material: HILAB
Material Source: Not Advised
Sample Date: 04-Dec-2017
Sampled By: Rob Craw
Sampling method: Not Applicable
Test Date: 14-Dec-2017

Test Methods: Determination of the Indirect Tensile Strength and Unconfined Compressive Strength of Modified and Unmodified Aggregate Samples — DCLTM1:2013

Results:

Sample Details

Precompaction Curing Time	Not Advised
Compaction Method	Not Advised
Compactive Effort	Not Advised
Rate of Axial Compression (mm/min)	1.0
Curing conditions	Not Applicable

Test Details

Sample	1.3-24 BC	1.3-24 SB	1.75-21.15 BC	1.75-21.15 SB
Soaking Status	Unsoaked		Unsoaked	
Diameter of Specimen (mm)	190.91	187.08	193.53	193.65
Height of Specimen (mm)	207.78	248.21	183.46	238.46
Water Content as Compacted (%)	N/A	N/A	N/A	N/A
Water Content after Testing (%):	3.86	4.37	2.95	3.81
Dry Density as Compacted (t/m^3)	N/A	N/A	N/A	N/A
Indirect Tensile Strength (kPa)	395	755	400	834

V Henderson

Vicky Henderson

Laboratory Manager

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Phone: (03) 359 0757, Fax (03) 359 1909

Laboratory N°: C17/3772B
Report Date: 12-Jan-2018
Page 1 of 1 pages

TEST REPORT

Client: New Zealand Transport Agency
Client Address: NZTA CAPTIF, 2 Mcleans Island Road, Harewood, Christchurch
Client Ref: HILAB-Section B2
Job Location: CAPTIF
Material: HILAB
Material Source: Not Advised
Sample Date: 04-Dec-2017
Sampled By: Rob Craw
Sampling method: Not Applicable
Test Date: 18-Dec-2017

Test Methods: Determination of the Indirect Tensile Strength and Unconfined Compressive Strength of Modified and Unmodified Aggregate Samples — DCLTM1:2013

Results:

Sample Details

Precompaction Curing Time	Not Advised
Compaction Method	Not Advised
Compactive Effort	Not Advised
Rate of Axial Compression (mm/min)	1.0
Curing conditions	Not Applicable

Test Details

Sample	2.1-24 BC	2.1-24 SB	2.25-21.3 BC	2.25-21.3 SB
Soaking Status	Unsoaked		Unsoaked	
Diameter of Specimen (mm)	190.82	190.40	193.39	191.70
Height of Specimen (mm)	186.93	246.69	202.41	205.33
Water Content as Compacted (%)	N/A	N/A	N/A	N/A
Water Content after Testing (%):	3.84	4.02	3.74	3.80
Dry Density as Compacted (t/m^3)	N/A	N/A	N/A	N/A
Indirect Tensile Strength (kPa)	368	611	484	795

VHenderson
Vicky Henderson
Laboratory Manager

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Phone: (03) 359 0757, Fax (03) 359 1909

Laboratory N°: C17/3772C
Report Date: 12-Jan-2018
Page 1 of 1 pages

TEST REPORT

Client:	New Zealand Transport Agency
Client Address:	NZTA CAPTIF, 2 Mcleans Island Road, Harewood, Christchurch
Client Ref:	HILAB-Section C
Job Location:	CAPTIF
Material:	HILAB
Material Source:	Not Advised
Sample Date:	04-Dec-2017
Sampled By:	Rob Craw
Sampling method:	Not Applicable
Test Date:	14-Dec-2017

Test Methods: Determination of the Indirect Tensile Strength and Unconfined Compressive Strength of Modified and Unmodified Aggregate Samples — DCLTM1:2013

Results:

Sample Details

Precompaction Curing Time	Not Advised
Compaction Method	Not Advised
Compactive Effort	Not Advised
Rate of Axial Compression (mm/min)	1.0
Curing conditions	Not Applicable

Test Details

Sample	**1.2-41**	**1.7-39**	**2.6-39**
Soaking Status	Unsoaked		Unsoaked
Diameter of Specimen (mm)	192.08	191.99	193.02
Height of Specimen (mm)	203.77	183.92	205.02
Water Content as Compacted (%)	N/A	N/A	N/A
Water Content after Testing (%):	3.85	2.93	2.97
Dry Density as Compacted (t/m³)	N/A	N/A	N/A
Indirect Tensile Strength (kPa)	776	572	828

V Henderson

Vicky Henderson
Laboratory Manager

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Phone: (03) 359 0757, Fax (03) 359 1909

Laboratory N°: C17/3772D
Report Date: 12-Jan-2018
Page 1 of 1 pages

TEST REPORT

Client: New Zealand Transport Agency
Client Address: NZTA CAPTIF, 2 Mcleans Island Road, Harewood, Christchurch
Client Ref: HILAB-Section D
Job Location: CAPTIF
Material: HILAB
Material Source: Not Advised
Sample Date: 04-Dec-2017
Sampled By: Rob Craw
Sampling method: Not Applicable
Test Date: 14-Dec-2017

Test Methods: Determination of the Indirect Tensile Strength and Unconfined Compressive Strength of Modified and Unmodified Aggregate Samples — DCLTM1:2013

Results:

Sample Details

Precompaction Curing Time	Not Advised
Compaction Method	Not Advised
Compactive Effort	Not Advised
Rate of Axial Compression (mm/min)	1.0
Curing conditions	Not Applicable

Test Details

Sample	1.1-55	3.0-55
Soaking Status	Unsoaked	
Diameter of Specimen (mm)	190.61	192.04
Height of Specimen (mm)	146.85	146.06
Water Content as Compacted (%)	N/A	N/A
Water Content after Testing (%):	2.41	3.99
Dry Density as Compacted (t/m³)	N/A	N/A
Indirect Tensile Strength (kPa)	941	1038

VHenderson

Vicky Henderson

Laboratroy Manager

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CHRISTCHURCH LABORATORY

397 Mcleans Island Rd, Harewood. P O Box 11 326, Christchurch
Phone: (03) 359 0757

TEST REPORT

Laboratory N°: C17/3772-Interim
Report Date: 11-Dec-17

Client: Road Science
Client Address: Private Bag 92242, Victoria Street West, Auckland, 1142
Client ref: HILAB Testing
Job location: CAPTIF
Material: HILAB
Material source: Not Advised
Sample date: 4-Dec-2017
Sampled by: Rob Craw
Test date: 4-Dec-2017

Test methods: 1 Determination of flexural tensile strength of concrete NZS 3112:Part 2:1986 Test 7

Results:

Beam Reference	Flexural Tensile Strength (MPa)	Complies With Standard
16.1 I	0.8	Yes
16.2 I	0.9	Yes
16.1 WP	1.1	Yes
16.2 WP	1.4	Yes

Notes:
1 Samples tested as received.
2 Load rate was 1mm/minute.

File: Draft Flexural Tensile Strength Report Template Issue 11, Tab: Report
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Issue: 1
Issue Date: 11 December 2017