In Situ Structural Timber Strength Measurement Advances Using Qualitive Resistography and Quantitive Resisto-Fractometry

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flameback

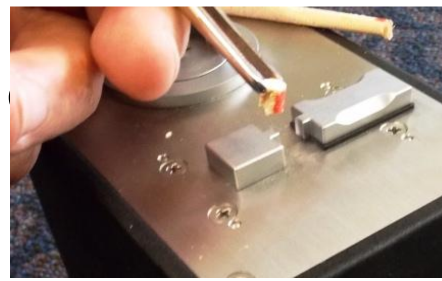
INCODO
FORENSIC BUILDING PATHOLOGY

Equipment

1 IML Resistograph PD

10 resistance readings per mm. Independent data from two motors for rotational and penetration. Bluetooth, Embedded firmware, Penetration depth to 1.00m. Bit dia 2-2.5 mm

2 IML Digital Fractometer



In compression mode takes 200 readings per mm – enables stress strain graphs to be generated from ultimate strength data.
Up to 60 MPa applied load

3 Berliner type dry wood **corer**

4.9 mm dia dendochronological dry wood corer

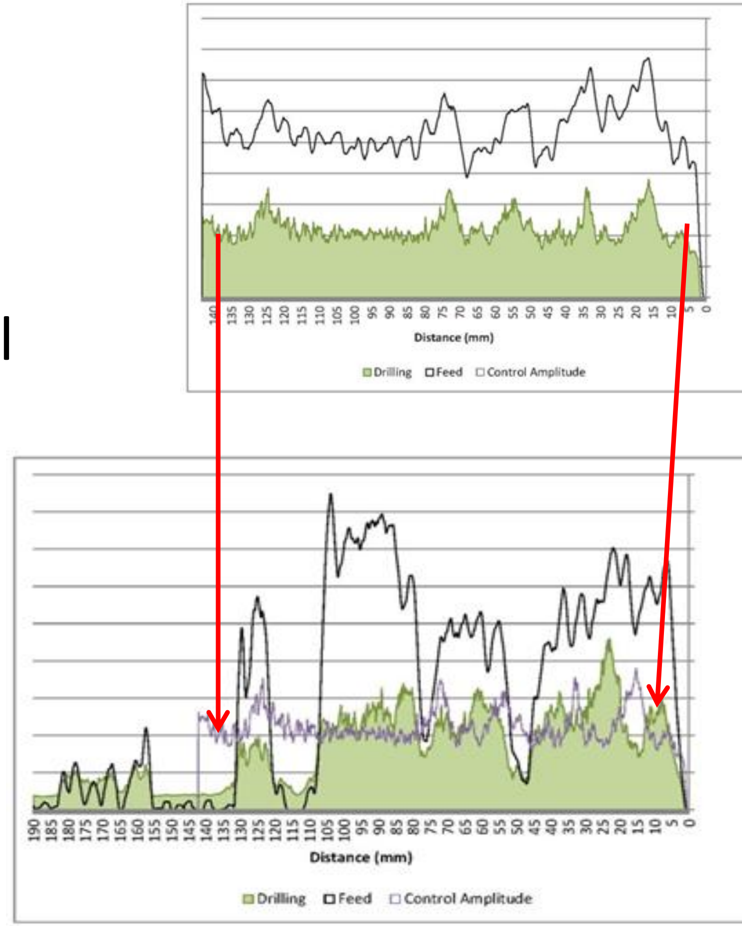
4 Integrating software

Developed by Flameback, processes resistographic and fractometric data, merges, analyses calculates averaged compression strength plus yield strength and insert results into customizable open report templates in real time

WoodChecker©
Timber Assessment Report Building Software

Qualitive **Resistography**

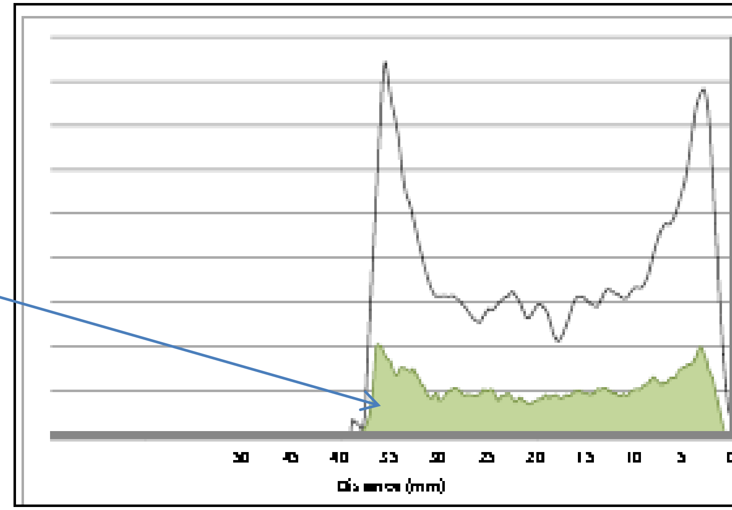
1. Take base **representative control** Resistogpraphic readings from known similar sound timber in structure
2 Ensure **appropriate** speeds of rotation and penetration set for all of test set
3 Usually 5+ controls – select 2nd lowest – must be representative
4 Digitally layer the control graph on all subsequent tests and use in identification of anomalies and indications of lower quality timber
5 Moderate results if indicated



Qualitive **Resistography**

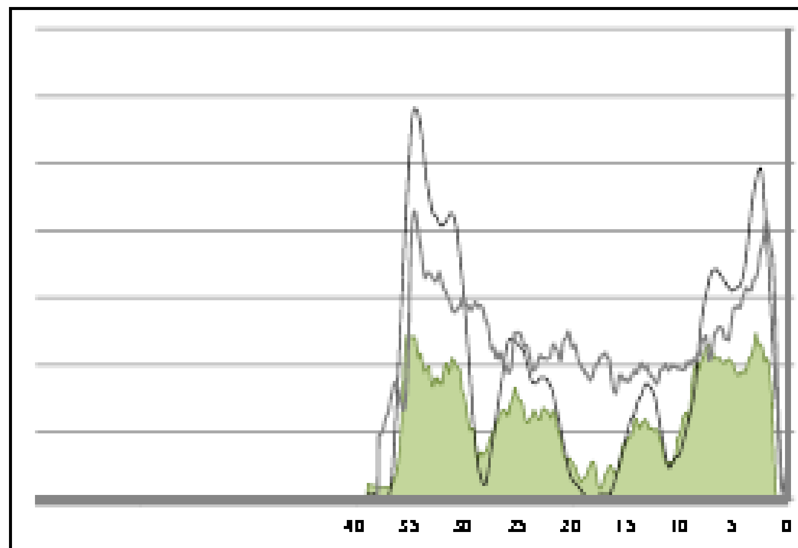
- **Applications Used**

1. Degraded framing
2. Roundwood
3. Composite board materials
4. Lined or clad structural elements
5. Determining hidden decay locations and extent



- **Applications Possible**

1. Underwater to 10 m
2. Trees
3. Historic timber structures
4. Altered use buildings
5. Earthquake code compliance
6. Forensic assessments



Quantitive **Fractometry**

- **Sequence and outline of procedure (<u>compressive strength parallel to grain methodology</u>)**

1. Extract 4.9-5.0 mm dia. drywood cores 90° to grain
2. Slice into 5 mm long pellets with scalpel or knife
3. Sequentially align pellets in Fractometer jaws with grain completely parallel with line of force.
4. Compress pellets until **ultimate** compression strength parallel to grain obtained.
5. Average results for **averaged compression strength**
6. Apply preferred formula to determine **averaged yield strength**
7. Compare against applicable construction code documents if relevant

Quantitive **Fractometry**

- **Yield Strength**

1. Considered 6 recognized formulae with 3 integrated into software to date, as selectable options
2. Yield derived by finding the **averaged** ultimate strength of **total test core sample** eg 100 x 50 mm framing results in 20 x 5 mm long samples for testing. (arithmetic average of 20 ultimate strength tests used as basis for yield strength calculation.)

Quantitive **Fractometry**

- **Current measurement options**

1. Compression strength parallel to grain
2. Bending strength parallel to grain

- **In development measurement options**

1. Tensile strength
2. Compression strength perpendicular to grain
3. Shear strength
4. …

Integrated Resisto-fractometry

- **Basic procedure (<u>compression strength parallel to grain </u>methodology test option)**

1. Resistographic microdrill test and core drill sample 20 mm apart on same timber grain plane
2. Develop standard **Resistograph** graph with *x* axis = distance and *y* axis = % amplitude
3. Develop standard **Fractometer** graph with *x* axis = distance and *y* axis = MPa parallel to grain compression strength.
4. Digitally merge graphs to overlay using software
5. Align /adjust graph overlays horizontally and vertically using software
6. Tabulate values in summary sheets

Integrated Resisto-fractometry

BLACK GRAPH

Resistogpraphic feed data component (rotation)

BLUE GRAPH

Ultimate compression strength of 5 mm sections of cores

GREEN GRAPH

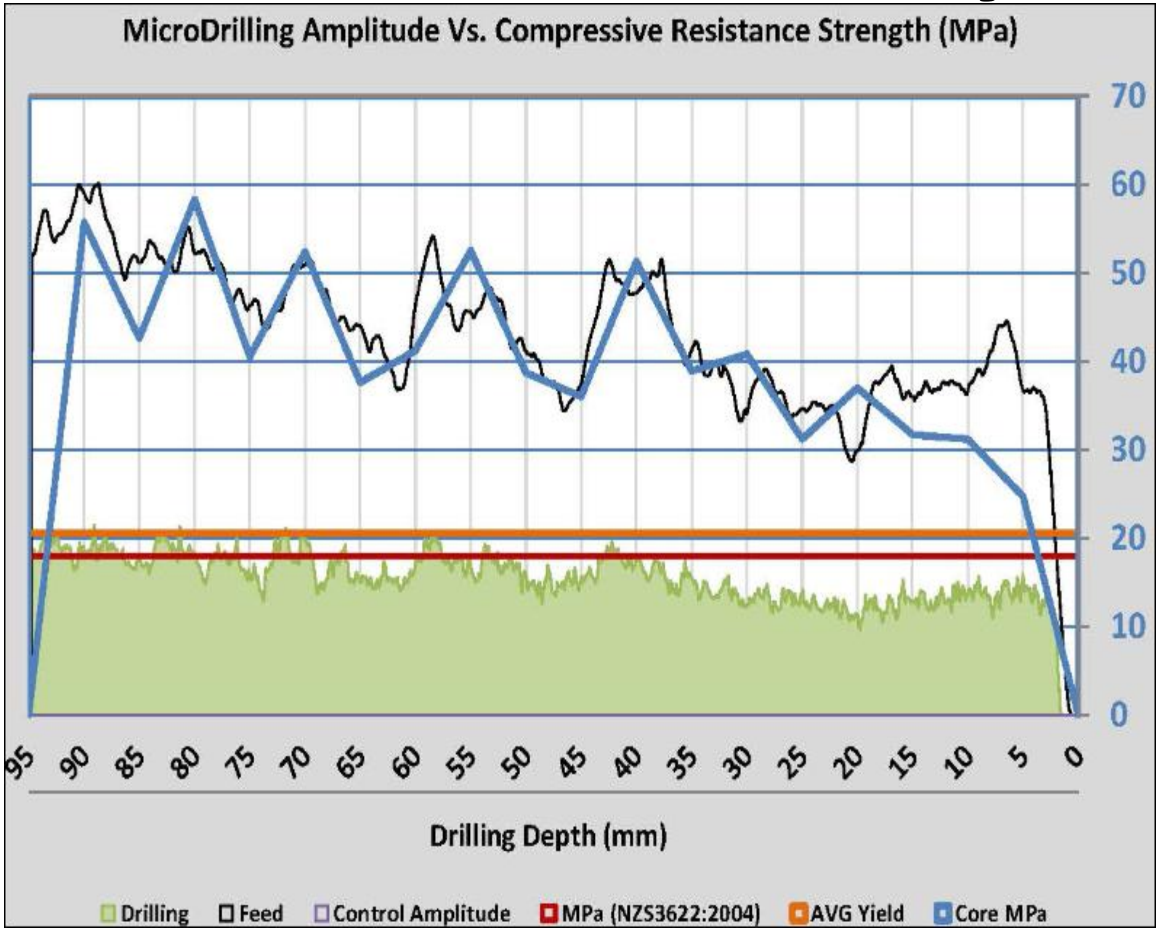
Resistographic drilling data component (penetration)

ORANGE HORIZONTAL

Averaged yield strength (using CSIRO formula)

RED HORIZONTAL

Minimum strength requirement according to local code document or defined level



TYPICAL RESISTO-FRACTOMETRIC PRESENTATION

Note : control graph omitted for clarity

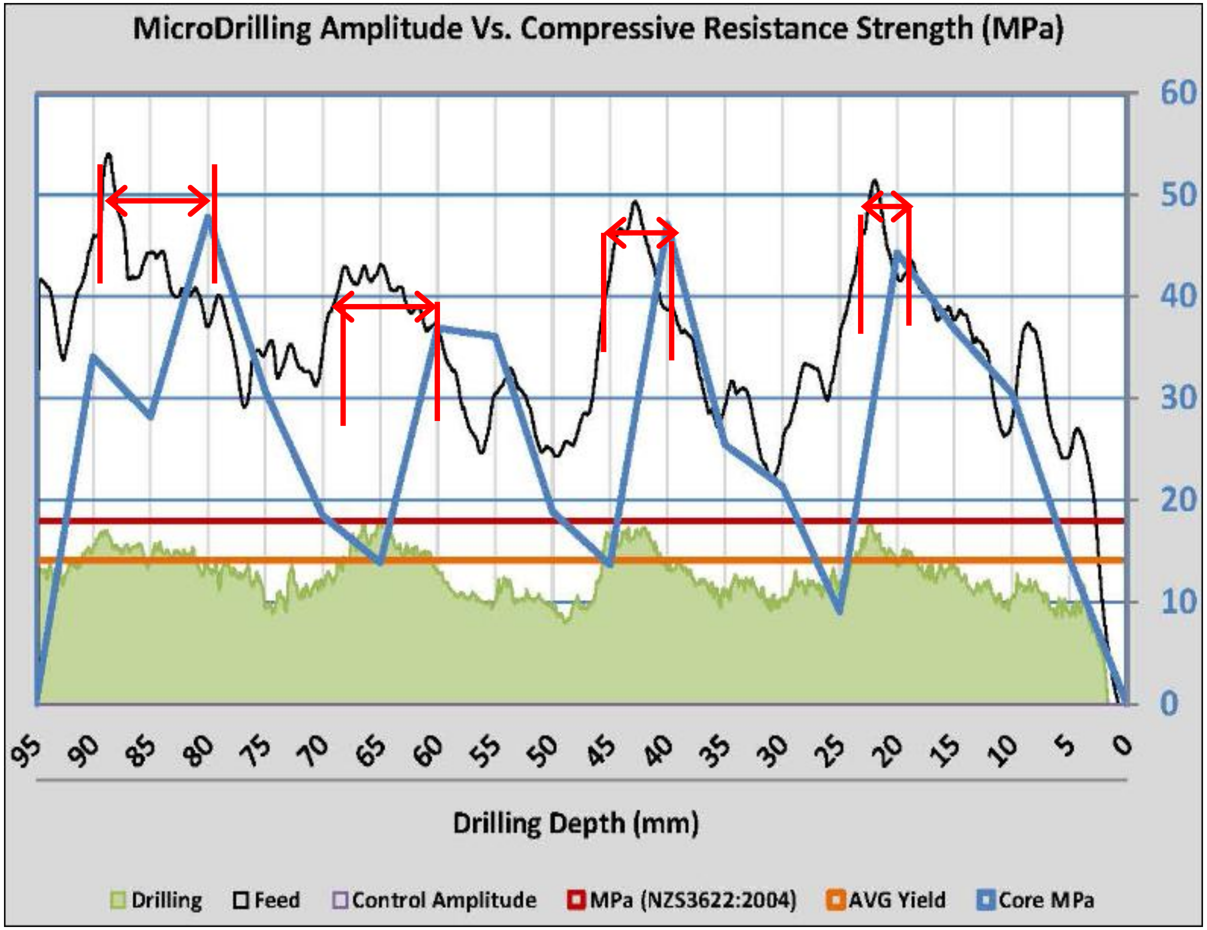
Note : Aprox 1000 resisto-fractometric tests to date

Integrated Resisto-fractometry

GRAPHIC OVERLAYS
At 0mm parallel
At 25mm offset 5mm
At 40mm offset 8 mm
At 70mm offset 10mm
At 90mm offset 10mm

Likely causes
1 Variance in drilling angles of core drill and Resistograph
2 Changes in plane of grain at depth

Corrective Action
Manipulate graphs by aligning or stretching if needed. (software feature – preference leave fractometric result ,adjust resistogpraphic graph)



GRAIN INDUCED ALIGNMENT OFFSET EXAMPLE

Integrated Resisto-fractometry

- **Structural Applications**

1. **Quantifying timber strengths generally**
2. **Assessing compliance with specific performance requirements**
3. **Providing data for structural upgrade calculations and costings**
4. **Identifying and quantifying hidden anomalies and or decay**
5. Methodologies used in field over last 9 months in New Zealand – clients include design consultants and government agencies. Applications include
   1) **Leaky home damage assessment,**
   2) **Determining degraded frame replacement extent**
   3) **Assessing stability of composite board structural walling**
   4) **Assessments of exposed and covered structural timber**
6. Proposed applications In NZ
   1) Provide timber 'strength' data for structural engineering analysis of 100,000+ older buildings that are required to demonstrate 30% compliance with current earthquake code requirements.
7. Buildings or structures of historic importance.

Integrated Resisto-fractometry

- **Software Development Features**

Note: **Focus** is <u>site inspection</u> and **object** is reports developed in <u>real time and exportable from site</u>.

1. Integrated editable report template
2. Integrated data bases
3. Equipment servicing check functions
4. Selectable timber specie function
5. Moderation of results- comments override
6. End user friendly ‘pass’, ‘warning,’ ‘fail’ indications – colour coded
7. Site plan /elevations/photographic logging of test locations or GPS enters
8. Summary sheets –sortable by chosen variable(s)

Current development program

- Statistical comparison of paired averaged Fractometer compression strength and averaged Resistograph amplitude correlation, to assess degree of confidence in Resistographic tests as indicator of compressive or other strength(s) without Fractometric checking.
- Working with Fractometer manufacturer to enable greater manipulation of samples
- Increasing software modules for **bending strength**, **compression strength perpendicular to grain**, **shear** and **tensile** strength (additional to current compression parallel to grain capability)
- Refining field "**invisibility**" of test techniques

Note : Likely require extensive specie by specie testing, factoring in variables such as MC% to derive equations.

Limitations on results

NOTE: **Starter Research Only** -

1. Small scale testing only
2. Testing largely on Pinus Radiata –some Douglas Fir
3. Limited independent auditing
4. No microbiological assessment of fungal decay in warning or fail samples.
5. No comparison with standard strength testing methodologies.

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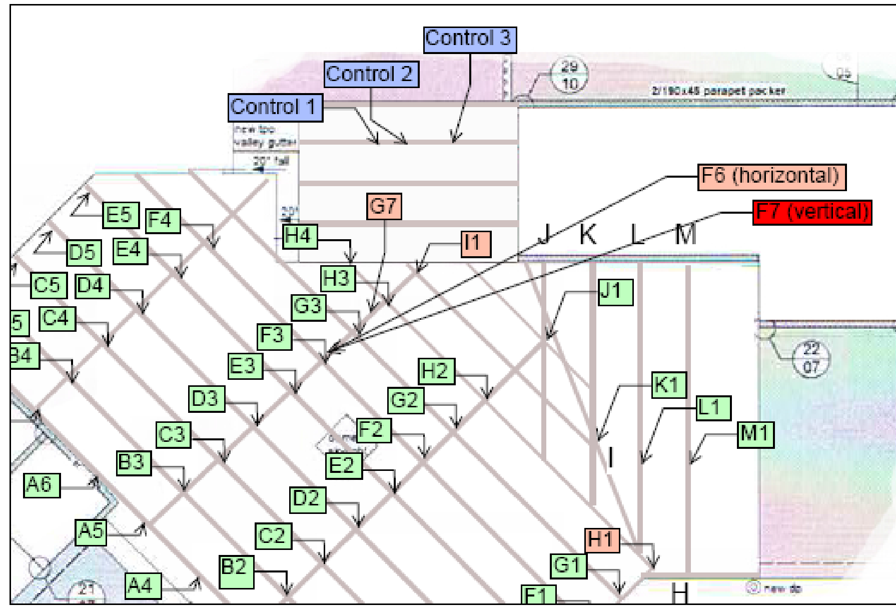
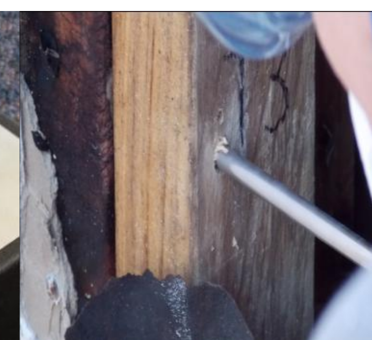
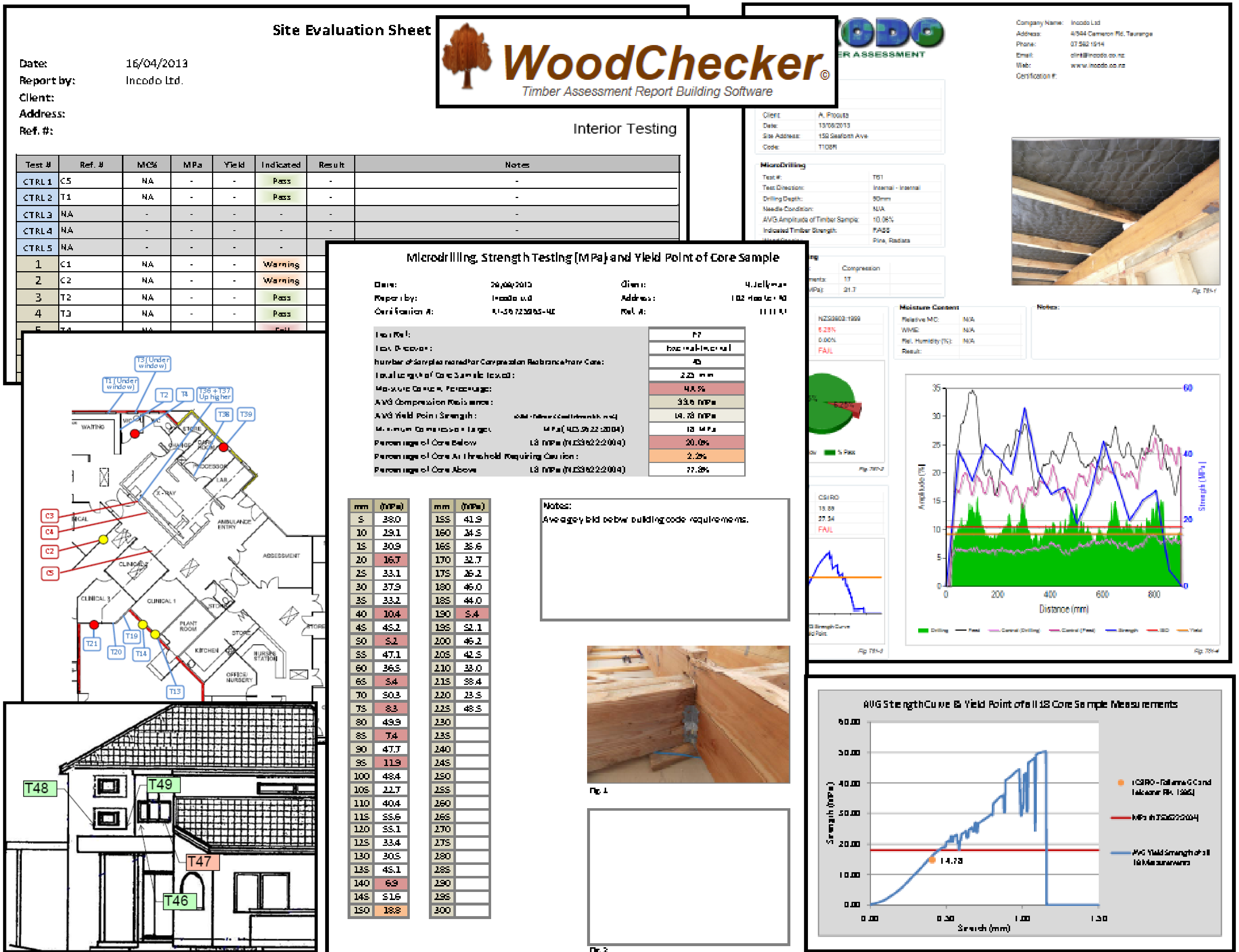
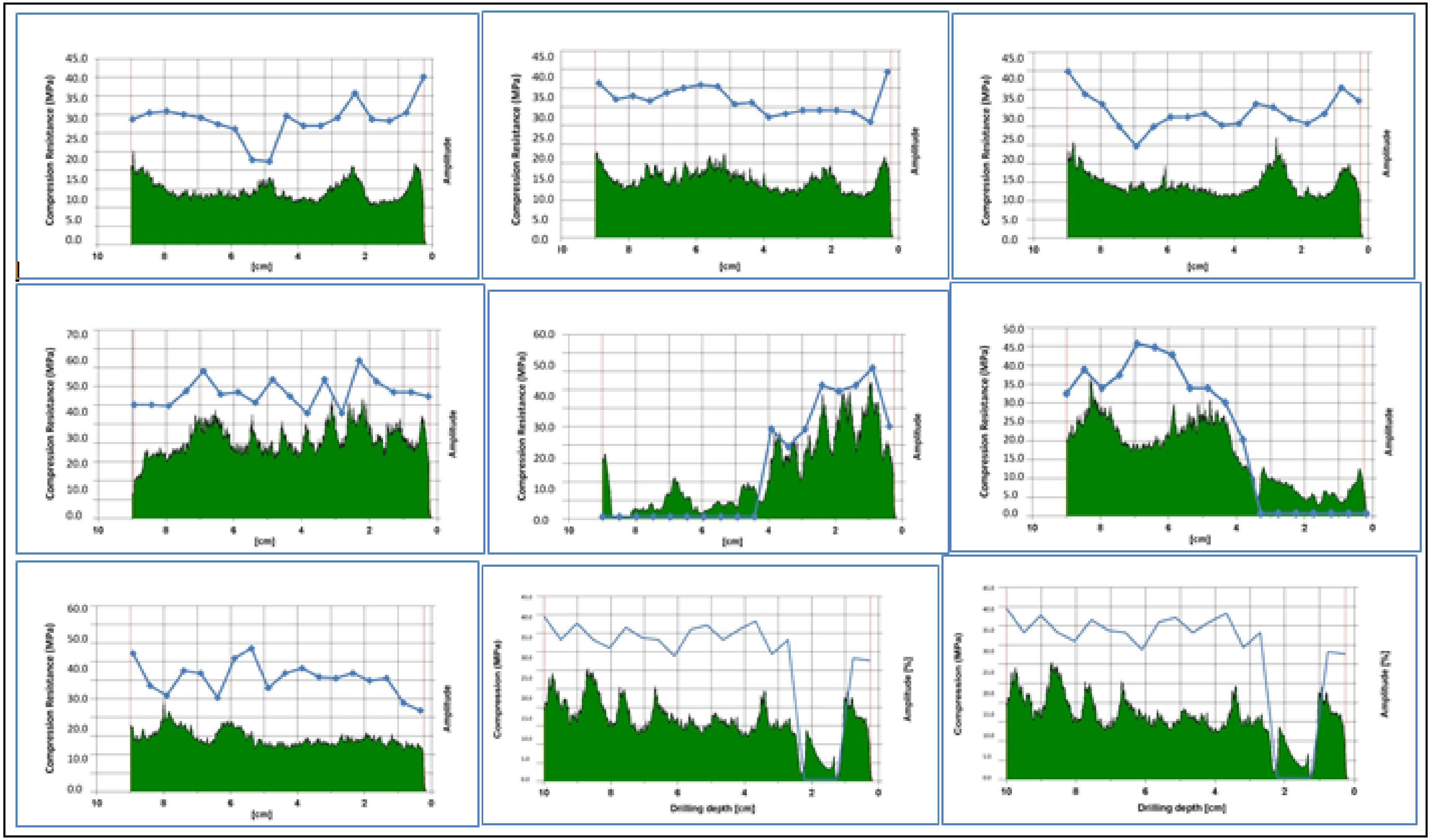


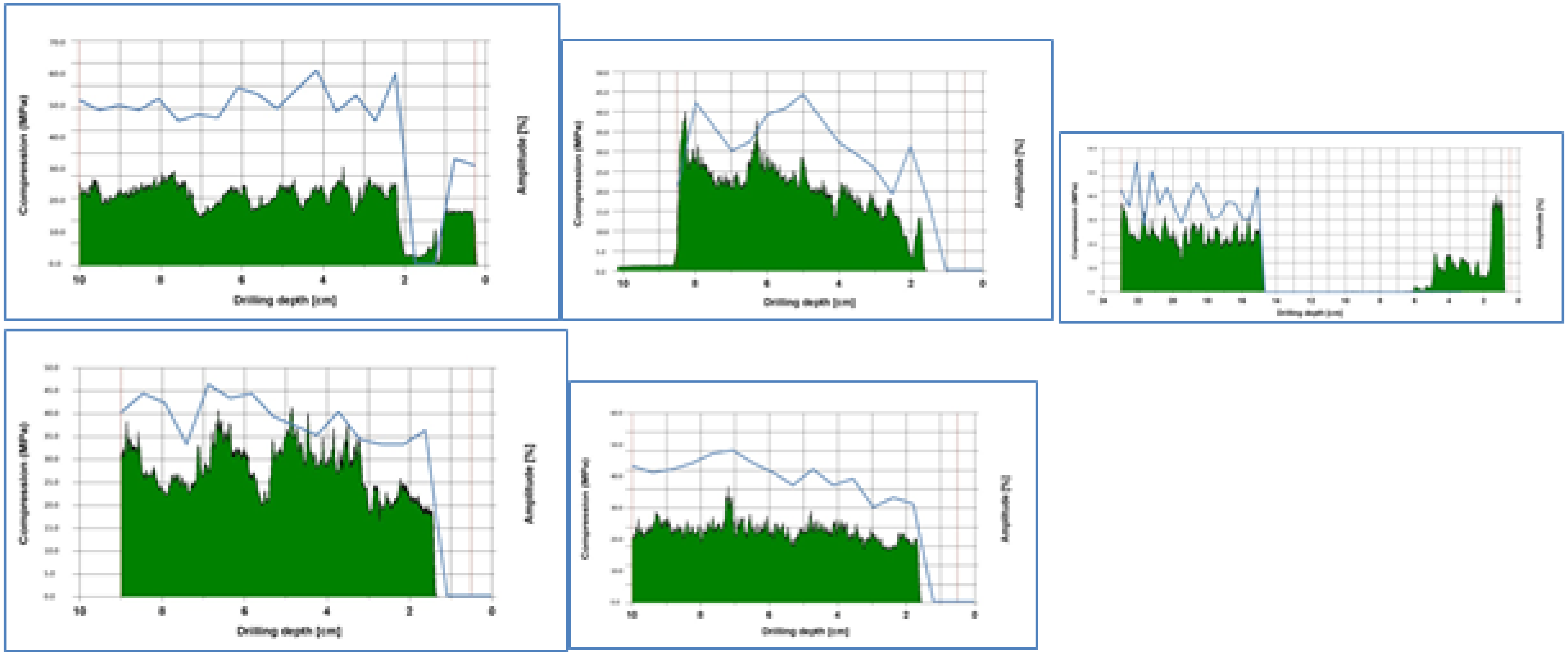




Site Evaluation Sheet
Date: 16/04/2013
Report by: Incodo Ltd.
Client:
Address:
Ref. #:
Interior Testing
Test # Ref. # MC% MPa Yield Indicated Result Notes
CTRL 1 C5 NA - - Pass -
CTRL 2 T1 NA - - Pass -
CTRL 3 NA
CTRL 4 NA
CTRL 5 NA
1 C1 NA - - Warning
2 C2 NA - - Warning
3 T2 NA - - Pass
4 T3 NA - - Pass
WoodChecker©
Timber Assessment Report Building Software
Microdrilling, Strength Testing (MPa) and Yield Point of Core Sample
Notes:
Fig. 1
Fig. 2
T48
T49
T47
T46
AVG Strength Curve & Yield Point of all 18 Core Sample Measurements
14.78
Distance (mm)



Compression Resistance (MPa)
Amplitude
[cm]
Compression (MPa)
Amplitude [%]
Drilling depth [cm]


Compression [MPa]
Amplitude [%]
Drilling depth [cm]
10
8
6
4
2
0
Compression [MPa]
Amplitude [%]
Drilling depth [cm]
10
8
6
4
2
0
Compression [MPa]
Amplitude [%]
Drilling depth [cm]
10
8
6
4
2
0
Compression [MPa]
Amplitude [%]
Drilling depth [cm]
10
8
6
4
2
0

Formula for determining degree of reliability / variance of Resistograph average amplitude (%) as indicator of average compression strength parallel to grain (MPa)

$$a = fp \pm\text{-}\ Evar$$

*For **s** specie where:*

***a** equals average amplitude percentage of Resistographic test,*

***fp** equals average compression strength parallel to grain*

***Evar** equals the statistical degree of expected variance in samples strength and*

*where Resistograph penetrative speed is **l** /mm/sec and rotational speed is **m** rpm.*

DETERMINATION OF YIELD POINT AND DUCTILITY OF TIMBER ASSEMBLIES: IN SEARCH FOR A HARMONISED APPROACH

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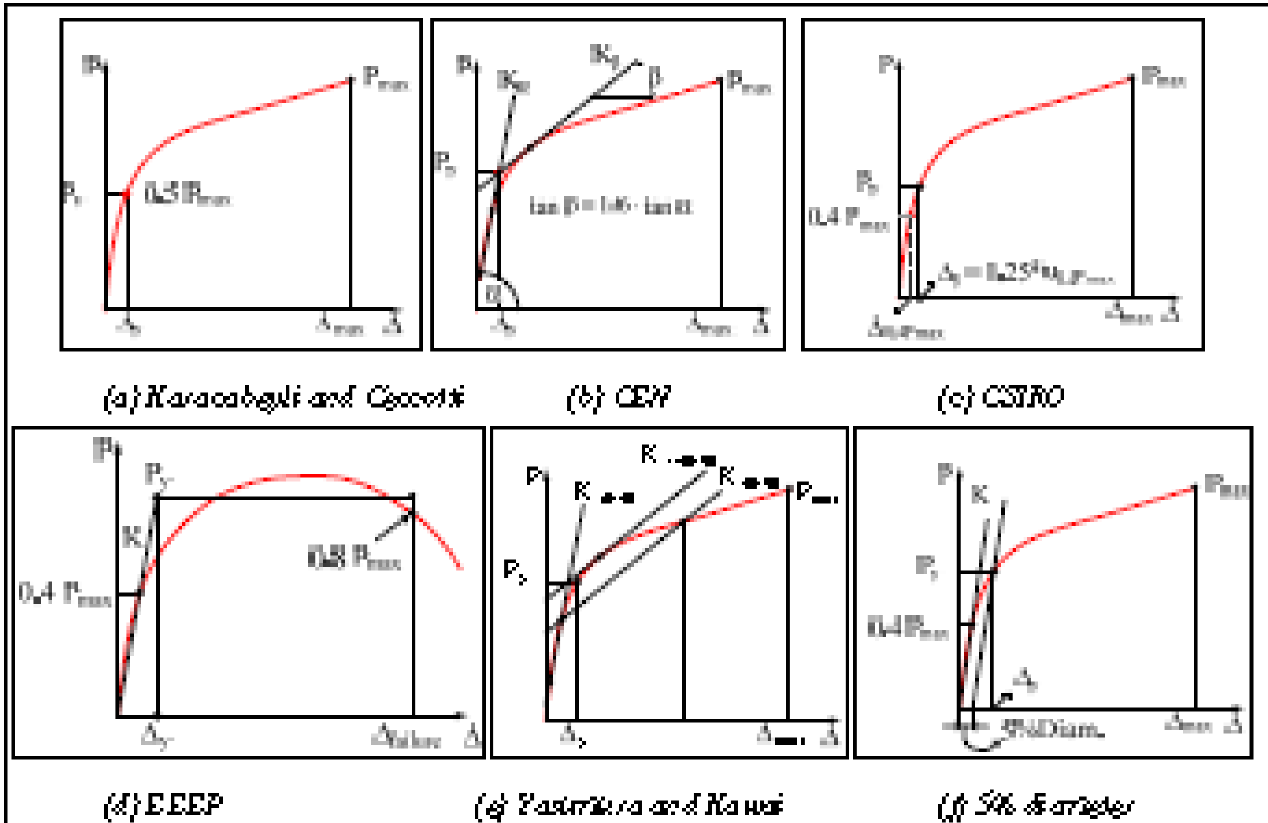

(a) Karacabeyli and Ceccotti (b) CEN (c) CSIRO

(d) EEEP (e) Yasumura and Kawai (f) 5% diameter