

Road surface noise – texture relationships
Interim progress report



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1 Summary

Waka Kotahi has engaged Altissimo Consulting to investigate the relationship between surface macrotexture and CPX level. This interim report only details the measurement system, as field trials were unable to be performed in Q3&4 of FY2019-20. To facilitate these measurements a surface texture scanning laser has been installed on the CPX trailer to record the surface profile. These texture measurements will be performed simultaneously to CPX noise measurements, allowing correlations between texture and surface noise to be investigated in detail.

This report presents an overview of the intended methodology and the installation details.

1.1 Surface texture

Road surface texture is divided into three main categories:

- Microtexture: The surface texture of individual chips within the surface. The wavelength of microtexture is less than 0.5mm.
- Macrotexture: The surface texture caused by the orientation and arrangement of chips in the surface. The wavelength of macrotexture is between 0.5mm and 50mm.
- Megatexture: Longer variations in the surface with wavelengths between 50 mm and 500 mm.

The difference between microtexture and macrotexture is illustrated in Figure 1.

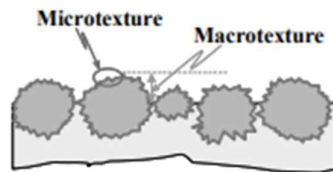


Figure 1: Macrotexture and microtexture

Macrotexture is a key factor in surface noise generation. The Mean Profile Depth (MPD) and Mean Segment Depth (MSD) is a measure of the macrotexture and is measured routinely on the NZ State Highway network. The measurement of MPD is described in ISO 13473-1:2019. The following statement is made in the 2019 version of the standard:

"The MPD now refers only to the overall value obtained after averaging all MSDs where MSD means Mean Segment Depth (earlier, MPD was used for both the mean segment depth and for mean profile depth, which might have been confusing)"

An illustration of the MPD is presented in Figure 2, using the new definition in the 2019 standard this is actually the MSD.

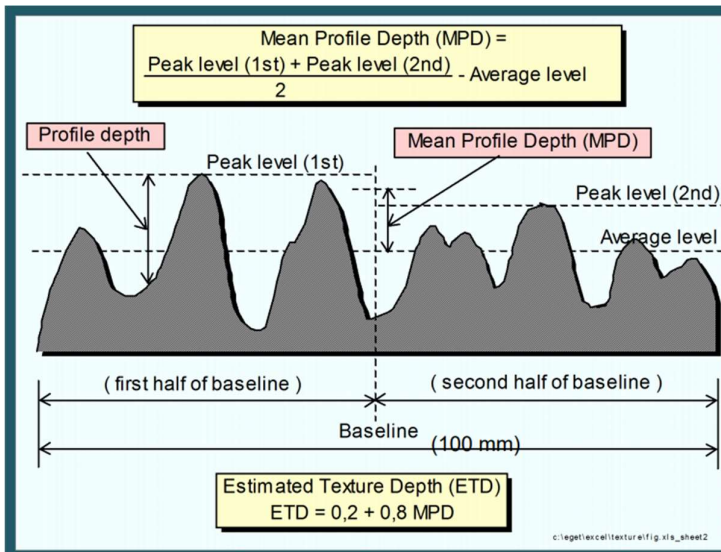


Figure 2: Calculation of MSD

The nature of the laser measurements means that the data should be cleaned and ISO 13473-1:2019 requires the following steps be completed to calculate the MSD:

- Detection and correction of drop-outs
- Resampling to 0.5mm or 1.0 mm
- Identification, removal, and reshaping
- High pass filtering at 140 mm or slope removal
- Low-pass filtering at 3mm length
- Removal of extreme outliers

1.2 Planned measurements

Extensive CPX measurements have been performed on the Western Belfast Bypass in Christchurch. This site will be used to benchmark and assess the performance of the macrotexture measurements.

The MSD and MPD measured using the CPX trailer will be compared with the results from SCRIM to ensure that general trends are similar. It is expected there will be some variations between these two measurement methodologies as the SCRIM truck measures longitudinally at five points across the lane (one of which is in the left wheel path).

Measurements will be performed on both porous asphalt and chipseal to investigate the variations between positive and negative textures, and their relationships to the measured CPX level. Positive textures refer to textures caused by the chips protruding up from the surface, whereas negative texture refers to variations caused by porosity in the surface.

All future CPX measurements will include simultaneous measurements of the surface texture using the laser, these measurements will be stored in a SQL database alongside the CPX results.

2 Measurement system overview

A SELCOM RoLine 1130 laser has been installed on the CPX trailer, this laser performs simultaneous distance measurements at up to 150 points across a line. The system can perform simultaneous measurements of these points at up to 3000Hz. This scanning rate and the current installation arrangement will yield a measurement transverse to the direction of travel every 5-10mm. The system manual provides Figure 3 that allows the line width to be calculated based on the laser height.

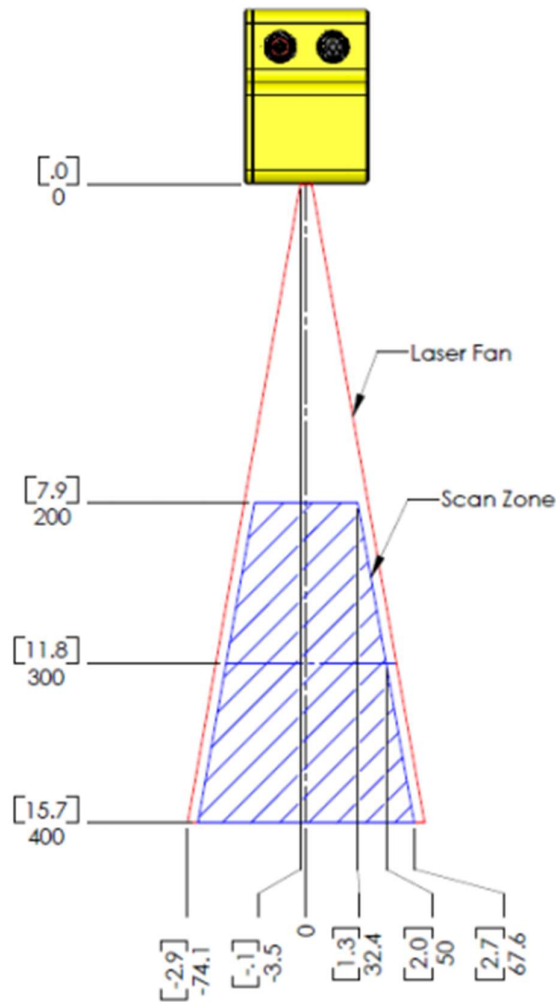


Figure 3: Laser scan zone

The current installation provides a line width of 100mm, and a corresponding measurement point spacing across this line of 0.7mm.

2.1 Mechanical fixture

The laser is mounted at the front of the trailer directly in front of the left wheel, as shown in Figure 4. The trailer is held in place by four stainless steel bolts and is rigidly fixed to the trailer chassis via a metal frame.



Figure 4: Laser mounted to front of CPX trailer

A plywood housing has been installed around the laser to protect it from potential road debris, this housing is shown below:



Figure 5: Housing for laser

2.2 Electrical installation

The location and layout of the existing CPX power supplies have been modified to accommodate an additional 40W/48V power supply that is required to operate the laser. The power supplies have been moved out of the CPX controller case into the battery case. This case now contains two batteries and three regulated power supplies (5V, 24V, 48V). These are connected to the CPX controller case via a 5-pin connection. The layout of the battery case is shown in Figure 6.

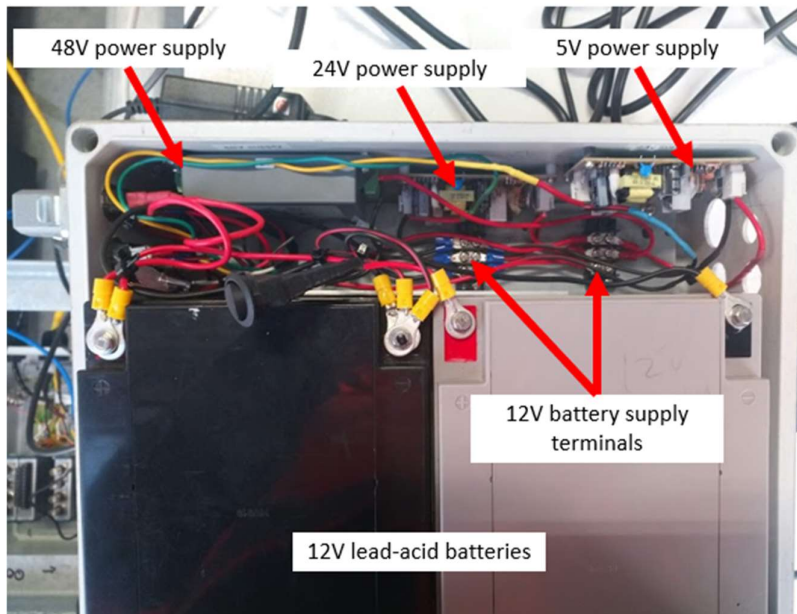


Figure 6: Layout of power supplies in battery case

A switch has been installed for each voltage supply to reduce the risk of damaging equipment when testing individual components. A key switch for the laser power supply has been included to reduce the risk of accidental activation of the laser. The switches and power connector are shown below:



Figure 7: Switches and connections for power supply

The connection between the battery case and the laser has 5-strand cable and is color coded as follows:

- Brown: Ground (negative battery terminal)
- Green: 5V regulated supply
- Red: Nominally 12V supply direct from battery
- Yellow: 24V regulated supply
- White: 48V regulated supply

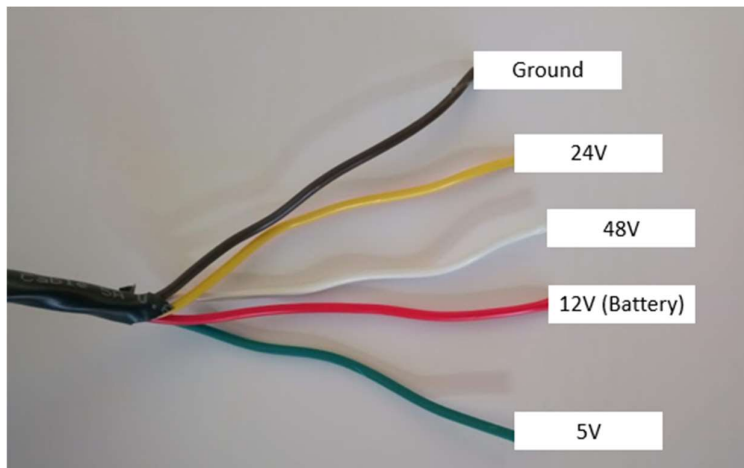


Figure 8: Power supply cable for CPX

3 Software interface

The laser connects to the CPX National Instruments chassis using an ethernet cable and communicates over TCP. A Python based driver library has been built to control and communicate with the laser, which can interface with LabView. The details of the software interface are presented in the following sections.

3.1 Laser connection to pc

The laser has an Ethernet cable for connecting to a PC and has the following Static IP address based on the lasers serial number:

- 90.0.42.19

Once connected the wired network settings for the host pc are manually set to:

- IP address: 90.0.0.2
- Subnet mask: 255.0.0.0

The laser can be tested using the manufacturers interface "kClient" which provides a graphical user interface for interacting with the laser. This interface can be downloaded and installed from:

- <https://downloads.lmi3d.com/roline-11x0-client-version-41150>

The kClient function provides an interface for interacting with the laser and provides a graphical representation of the laser measurements. An example of the visual feedback provided by this software is shown in Figure 9.

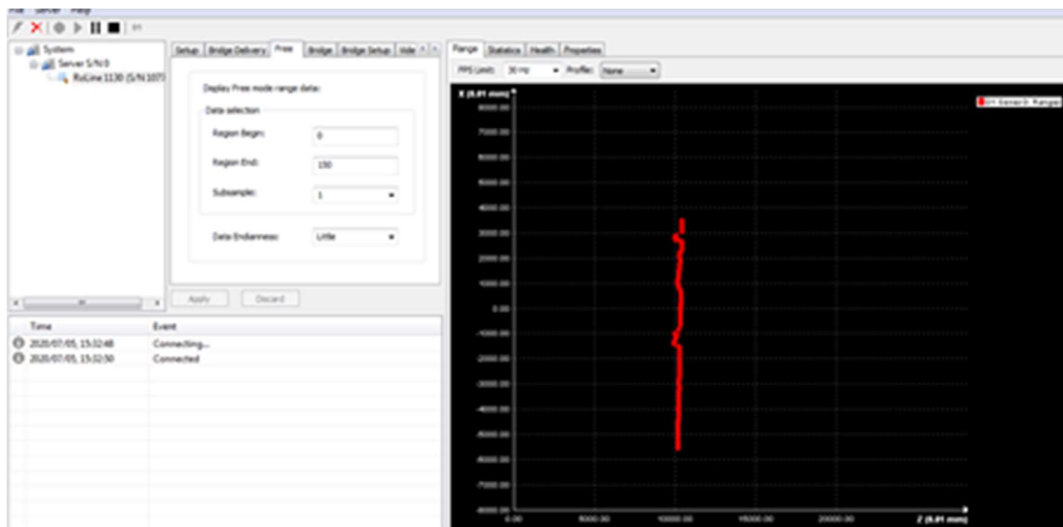


Figure 9: kClient laser interface

3.2 Control of laser

Control of the laser is performed by sending commands over a TCP Socket on Port 3190 using the FireSync Host Protocol. LabView is unable to directly interface with the laser but can utilise the system Python installation. The Python installation must be Python 3.6.0 and installed using the standard settings. This specific Python installer is available from:

- <https://www.python.org/downloads/release/python-360/>

A Python class *LaserConfigClient* has been written to manage this process. The following methods are provided:

Function	Comment / Return value
<i>LaserConfigClient</i>	
<i>get_starttime()</i>	Returns start time based on laser's internal clock
<i>enum_sensors()</i>	Returns the serial number of any connected sensors
<i>set_opmode("Free" "Bridge")</i>	Switches the laser between "Free" and "Bridge" mode. Free mode is continuous raw data from the laser, whereas bridge mode is a filtered average of the laser line.
<i>get_opmode()</i>	Returns the currently selected mode
<i>data_enable(destination_ip=data_ip, destination_port=data_port, channel=channel)</i>	Enables the incoming data ip address/port/channel and sends instructions to the laser to send data to this location
<i>start(destination_ip=data_ip, destination_port=data_port)</i>	Starts laser running
<i>stop()</i>	Tells the laser to stop transmitting data and shuts down beam

3.3 Retrieving data from laser

Data is streamed from the laser to host pc over a second TCP connection, over an arbitrary port and to any IP address on the network. A Python class *LaserDataServer* has been written to listen to the specified port, retrieve, format and store the data for later analysis.

Function	Comment / Return value
<i>LaserDataServer(ip,port,start_time)</i>	Create a data server listening for packets sent to a specific port and addressed to it. Start_time is used to convert the timestamps to an actual datetime
<i>start()</i>	Starts listening to packets on the data port
<i>stop()</i>	Stops listening for data
<i>set_database(filename)</i>	Sets the location of the SQLite database

The laser stores and reports the time since it was powered, rather than an absolute timestamp. The *LaserConfigClient* determines the start time by querying the laser and comparing this to the PC time. The start time is passed to *LaserDataServer* during initialisation. Data time offsets from the laser are converted to timestamps as the data is stored, this allows post processing to align the data with the CPX gps results.

The laser returns paired horizontal and vertical offsets in an array which is written to an *SQLite* database for each measurement run. Each database is named with the absolute start time and date (*YYYYMMHH_hhmm.db*). The horizontal offsets are required as the laser does not sample equal distances across the measurement beam.

Upon completion of a measurement the database is saved and closed. The timestamps can be used to correlate this database with specific CPX measurement data.

3.4 Python interface

The laser can be launched from a Windows terminal by running the following command:

```
python run_laser.py
```

This allow the user to activate the laser and check that the driver set is working as expected. This Python script executes the following actions in sequence:

- Instantiate a *LaserConfigClient* object and tries to connect to the laser. Returns if unsuccessful.
- Stops the laser if it is currently running
- Determines the start time of the laser
- Confirms the laser serial number matches the expected value. Returns an error if unsuccessful.
- Sets the laser to 'Free' mode rather than 'Bridge'
- Instantiate a *LaserDataServer* object with the determined start time
- Specify where the data should be stored
- Start the *LaserDataServer* to listen for incoming data
- Send the *DataEnable* command to the laser (via *LaserConfigClient*)
- Send the *Start* command to the laser (via *LaserConfigClient*)
- Continuously store incoming data to database

The script will remain open until a Control-C is received from the terminal (or a SIGTERM or SIGINT signal otherwise received).

3.5 Labview interface

Labview has an inbuilt Python module that allows the software to call a Python script and return values from this script. This module can only use Python 3.6.0, and only when this is a standard system installation. A LabView VI has been written that triggers the laser and runs it until a stop command is received:

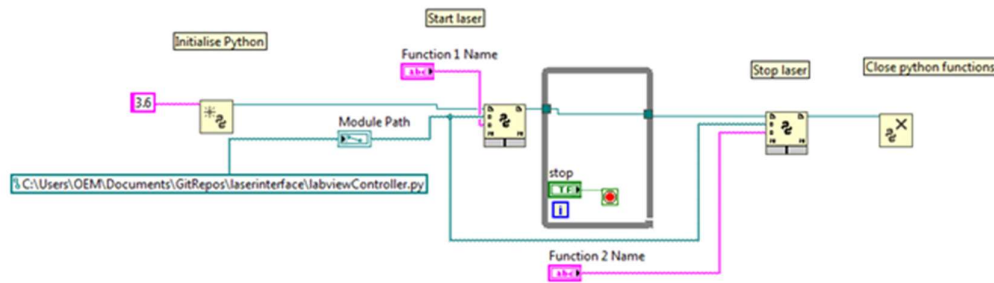


Figure 10: Labview/Python interaction script

This LabView code has been inserted into the CPX LabView system, starting the laser when the CPX measurement begins and stopping it once a measurement is completed. This has not been tested due to ongoing upgrades to the existing CPX system.

4 Analysis

The analysis of the laser results is performed in post-processing after a measurement is completed. The measured data is processed using a Python script and is visualised using the "Plotly Dash" interface. This post processing system is implemented using a Python Anaconda environment, which allows installation and management of third-party libraries, rather than the Labview's Python 3.6.0 installation.

4.1 Mean Profile Depth calculation

A simple form of the MSD calculation has been implemented and tested. This performs the MSD calculation and slope removal but currently does not implement all the steps required by ISO 13473-1:2019, the following steps need to be implemented:

- Low pass filtering
- Detection and repair of erroneous data points
- Filling of holes in data

4.2 Viewer

The results of the measurements and calculations are presented in a web browser-based interface. The MSD over a number of samples is presented in a single chart:

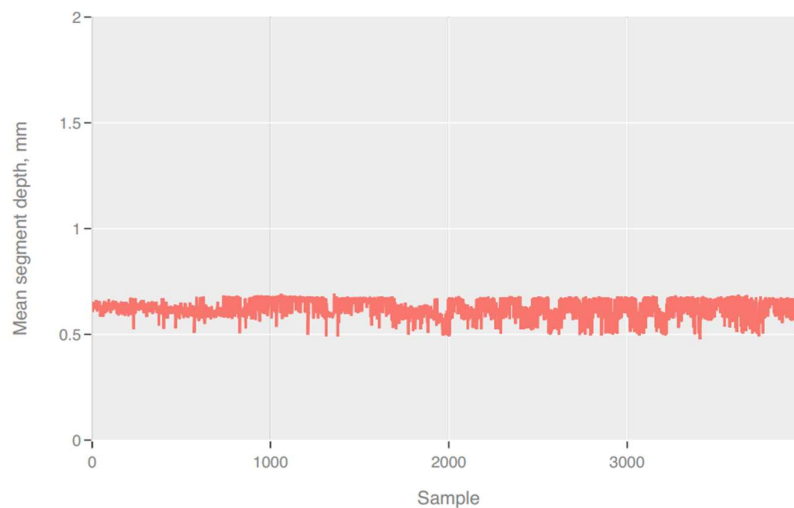


Figure 11: MSD (rotating single core sample under laser)

The user can scroll through the measurements and is presented with a visualisation of the surface as measured by the laser, which can be used to perform manual checks on the results:

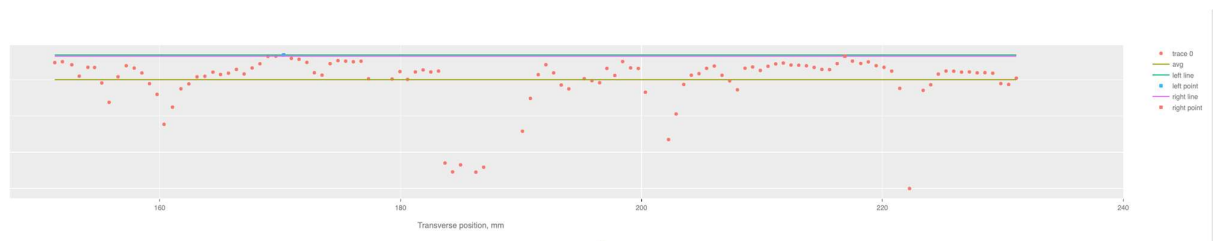


Figure 12: Surface texture chart

5 Calibration

Initial calibration using the CAPTIF test plate has been performed, this test plate is shown in Figure 13.



Figure 13: CAPTIF surface texture calibration plate

The surface of this test plate was too reflective and resulted in a large number of dropped measurement points, as shown in Figure 14.

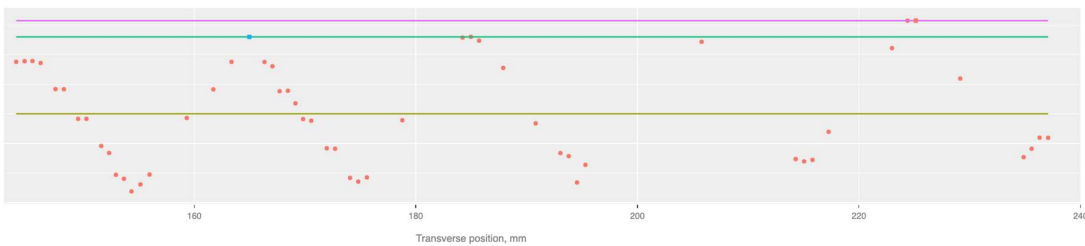


Figure 14: Results of calibration against CAPTIF test plate

A new test plate is being manufactured with both of the profiles specified by ISO 13473-1:2019 (Figure 15).

Table G.1 — Example showing a couple of useful surfaces for performance checks

Type of profile	Typical profile mm	Amplitude check?	Wavelength check?
Triangular, with 10 mm peak-bottom and 20 mm wavelength		RMS and MPD value of triangle wave (for spectrum: RMS of fundamental)	Fundamental and harmonics
Symmetrical trapezoidal with 10 mm peak-bottom and 25 mm wavelength with 10 mm base and 5 mm top level		MPD value of trapezoidal wave (for spectrum: RMS of fundamental)	Fundamental and harmonics

Note: For a triangular profile, MPD values might be sensitive to imperfections in the system's reproduction of the profile. The RMS is almost unaffected by such imperfections.

Figure 15: Test profiles for MPD laser from ISO 13473-1:2019

The laser has been tested on a core sample from Western Belfast Bypass (Figure 16). The laser did not have any dropped measurement points on this material (Figure 17), indicating the system is suitable for use on porous asphalt. The MSD for this sample was approximately 0.65mm, which is within the expected range of values at this site.



Figure 16: Core sample being measured by laser

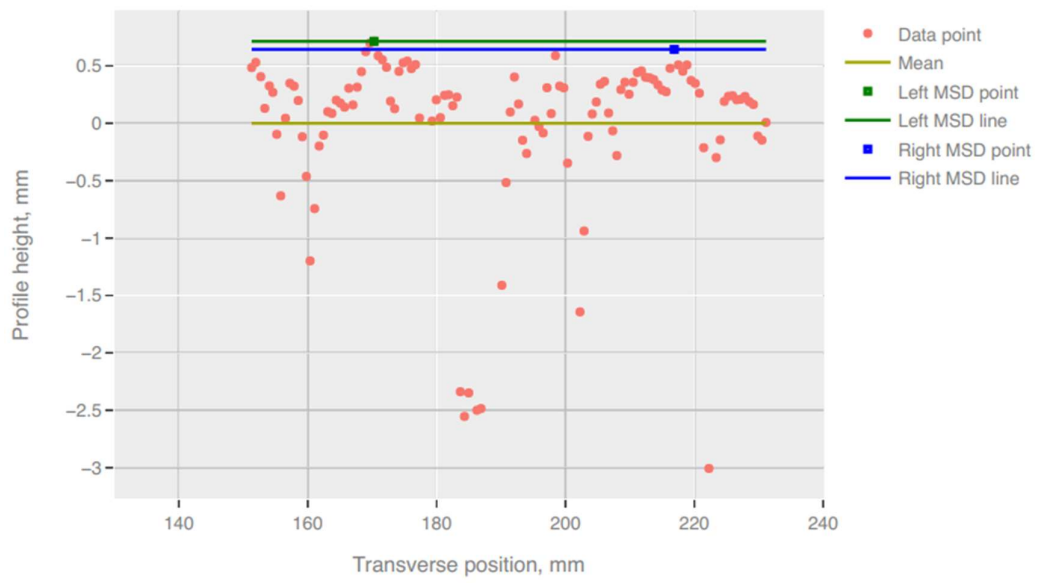


Figure 17: Measured surface profile of OGPA core sample