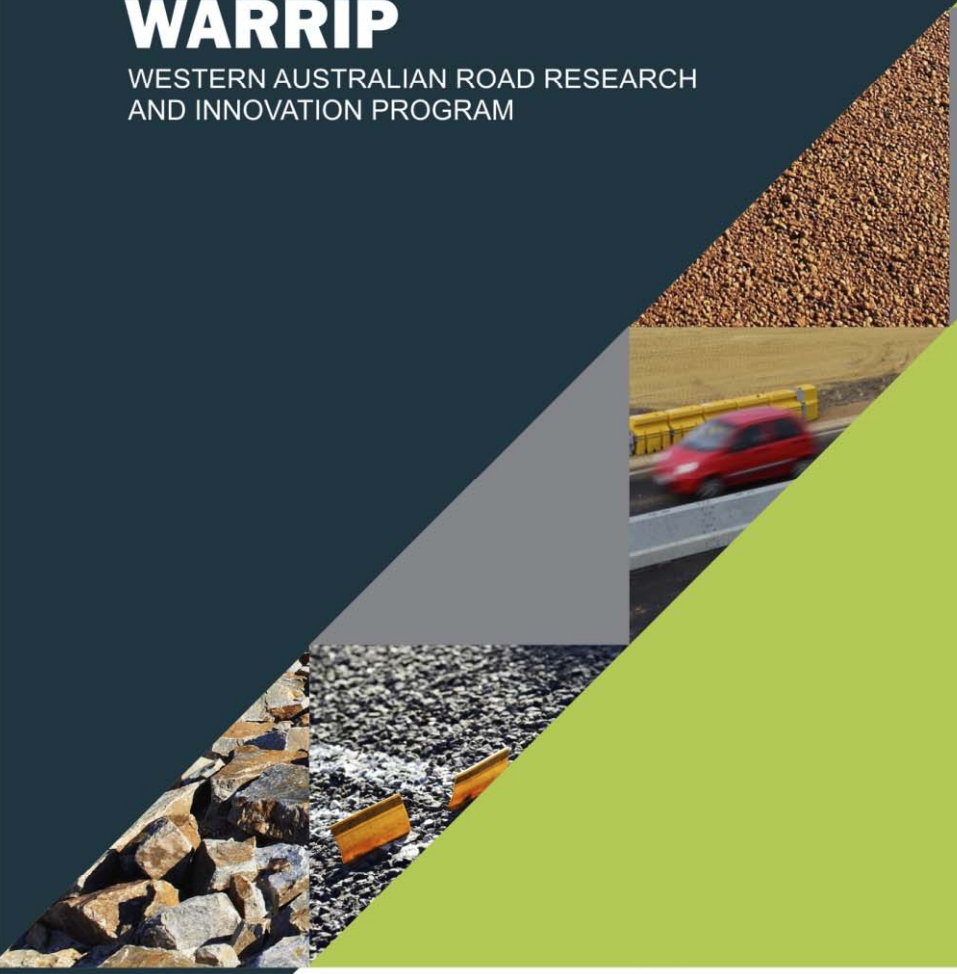
WARRIP

WESTERN AUSTRALIAN ROAD RESEARCH AND INNOVATION PROGRAM



CRUMB RUBBER DIGESTION POTENTIAL

18 June 2021

AN INITIATIVE BY:

THE GOVERNMENT OF WESTERN AUSTRALIA

mainroads WESTERN AUSTRALIA

arrb AUSTRALIAN ROAD RESEARCH BOARD

Content

- Welcome
- Main Roads Strategic Vision
- ARRB preparation of samples and engineering properties
- Curtin advanced laboratory testing
- Next Steps

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WESTERN AUSTRALIAN ROAD RESEARCH
AND INNOVATION PROGRAM

A collaborative research agreement between Main Roads WA and ARRB

Identify innovative practices and guide implementation to deliver superior technology and cost savings in road infrastructure

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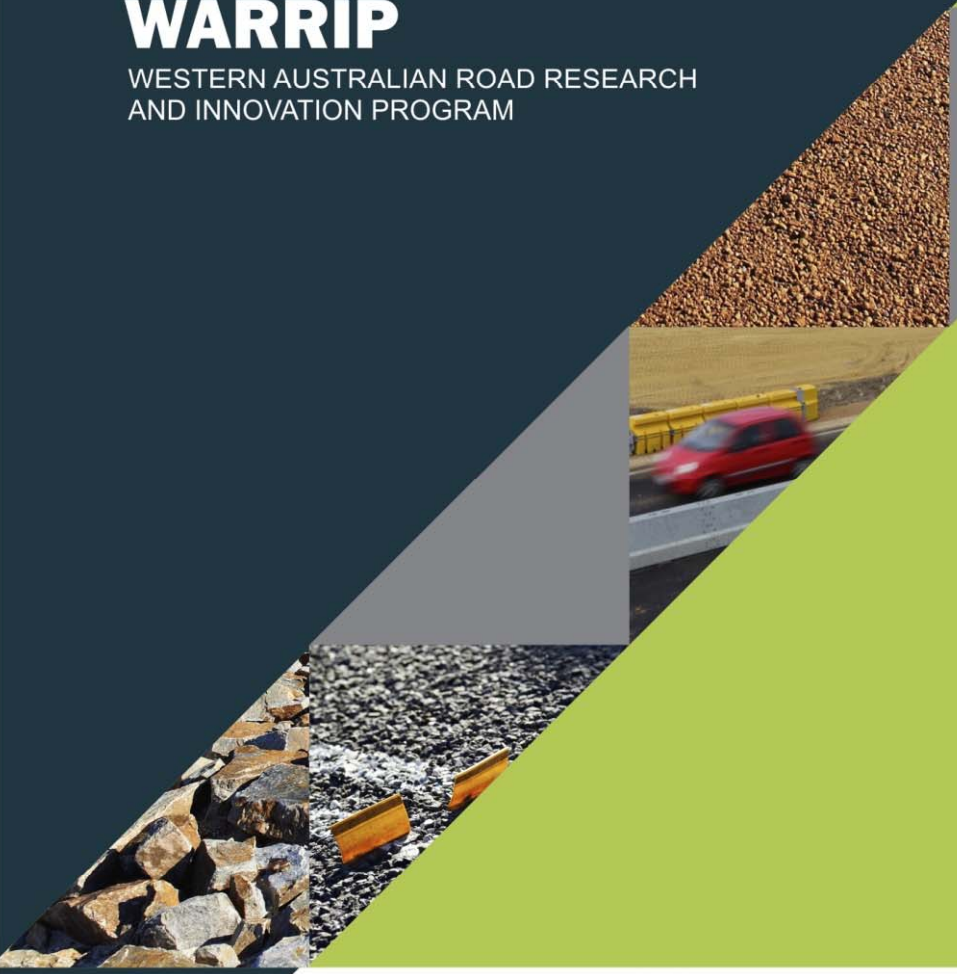

Main Roads Strategic Vision

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Overall Goals

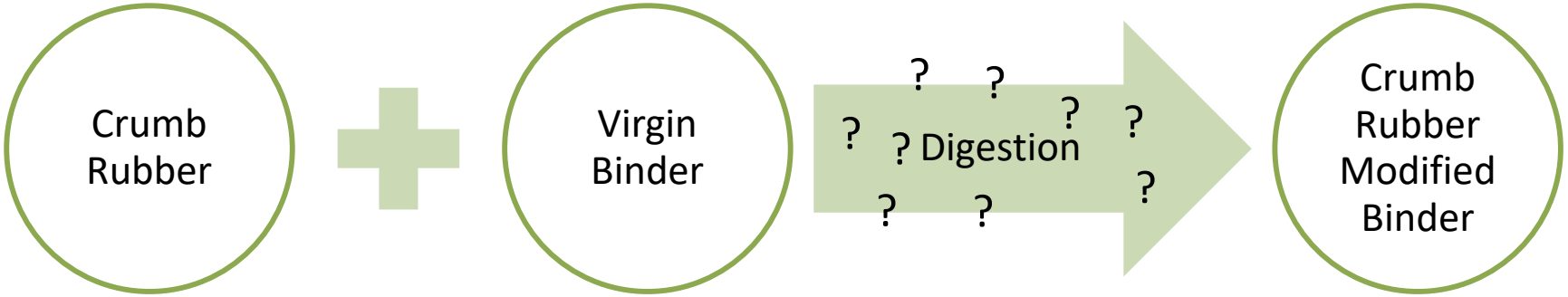
- To increase the use of recycled materials, particularly waste rubber, in road construction in line with Western Australia's 2030 Waste Avoidance and Resource Recovery Strategy
- To provide whole of life cost reductions through improved product quality, durability, and sustainability
- To build upon and expand our knowledge within the pavements area

Current Status

- ~1300 tonnes of Crumb Rubber used in 2019/20
- New WA Rubber sources coming to market
- Desire to increase use of Rubber Binders due to the significant performance property benefits

What is the Problem?

- Enormous knowledge gap
- We don't understand how Crumb Rubber Digestion works
- We don't even fully understand what "Crumb Rubber" is
  - Synthetic vs Natural Rubber
  - What is providing us with the properties we desire?



- How can we expect to understand our outputs if we don't understand how we get there!

What is this project?

- To work out what's happening during digestion!
- 8 digestion profiles
  - 2 rubber sources (Truck & Passenger)
  - 2 grading's (Size 16 & Size 30)
  - 2 digestion temperatures (165 & 190)
- Standard Binder Testing by ARRB (>380 tests)
  - Viscosity, Torsional Recovery, Softening Point, Consistency, Stress Ratio, Resilience, Compressive Limit
- Advanced Research Testing by Curtin University (>260 tests)
  - SARA, DSC, TGA, Sorption, GPC, Cryo SEM, Optical & Laser PSD
  - Advanced Analysis & Interpretation

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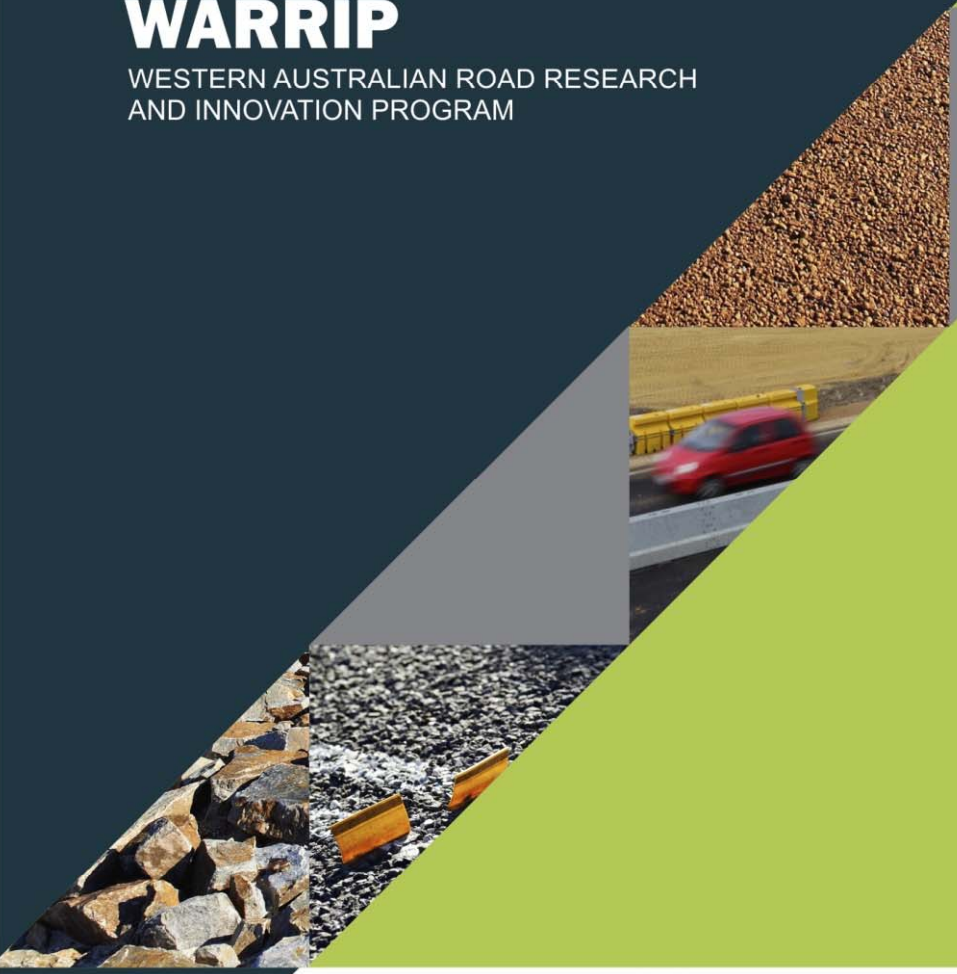

ARRB Testing

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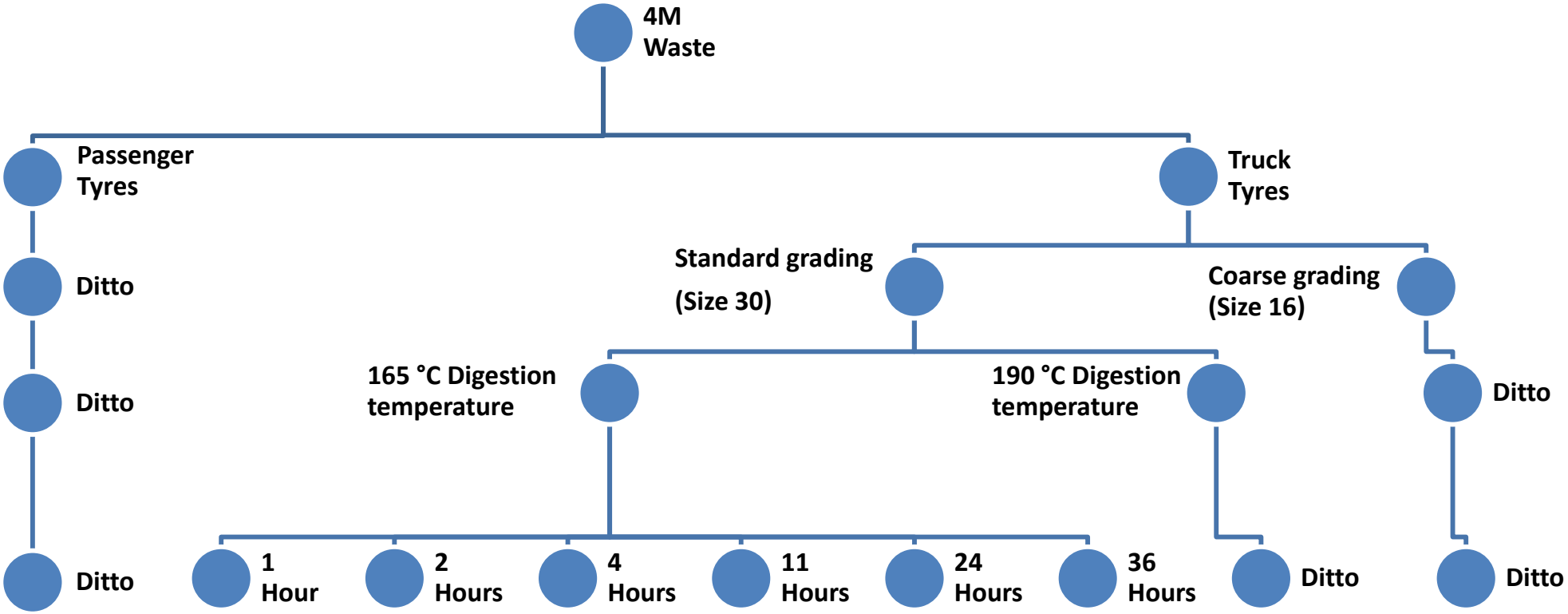
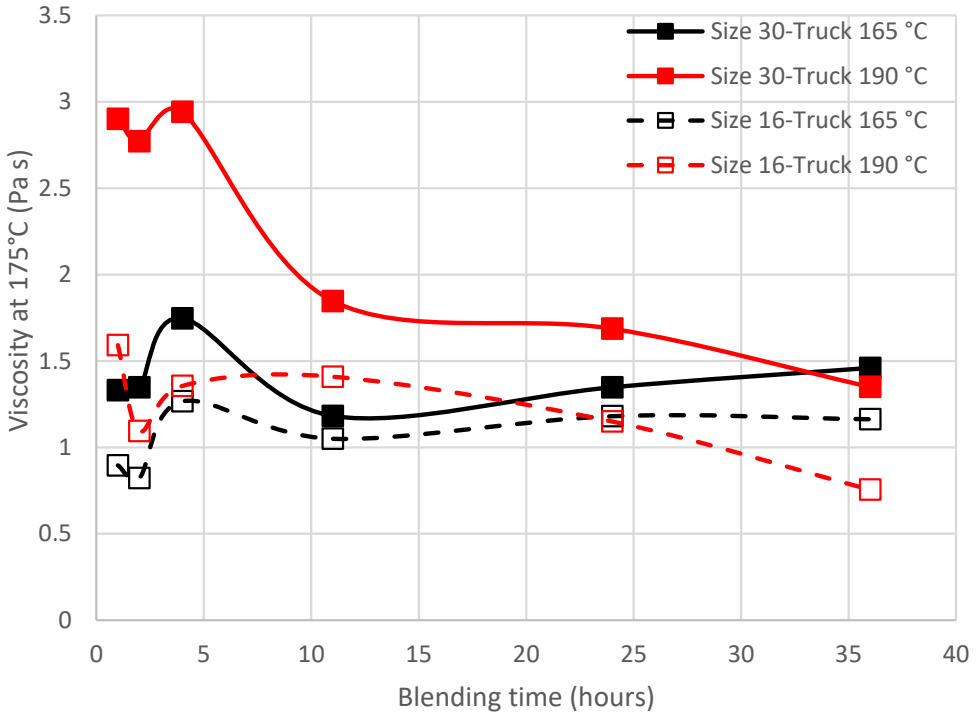
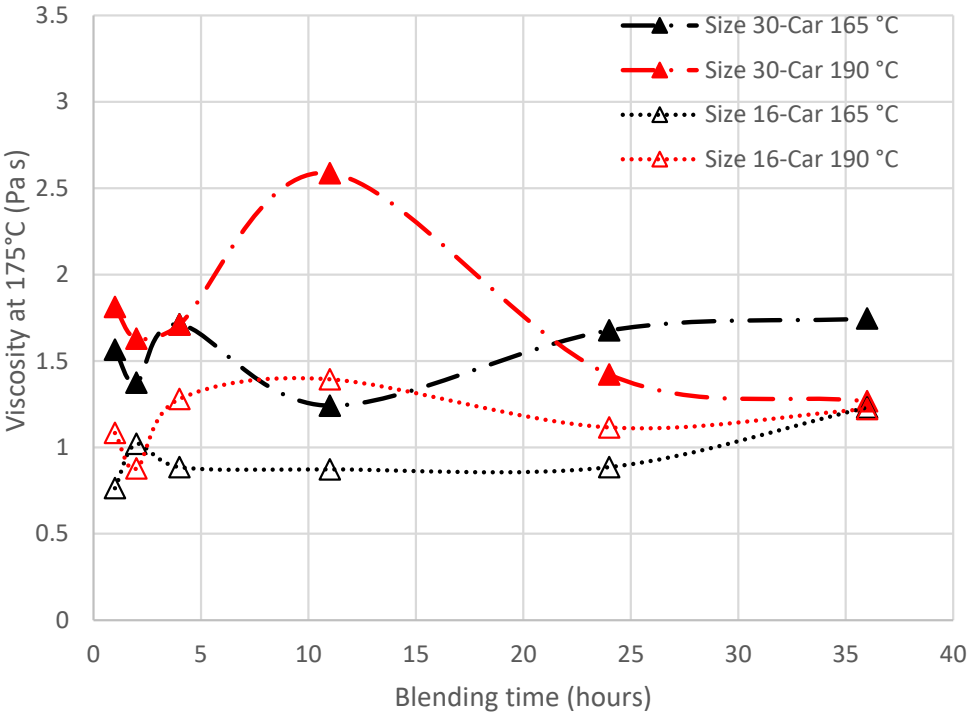
Scope and Materials



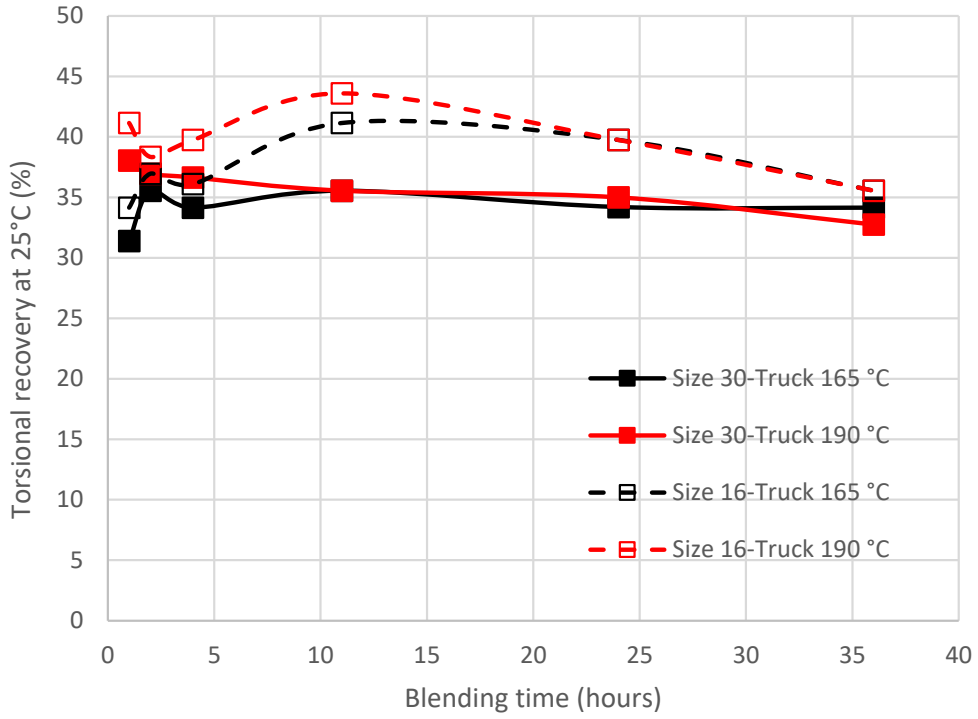
Preparation of Samples

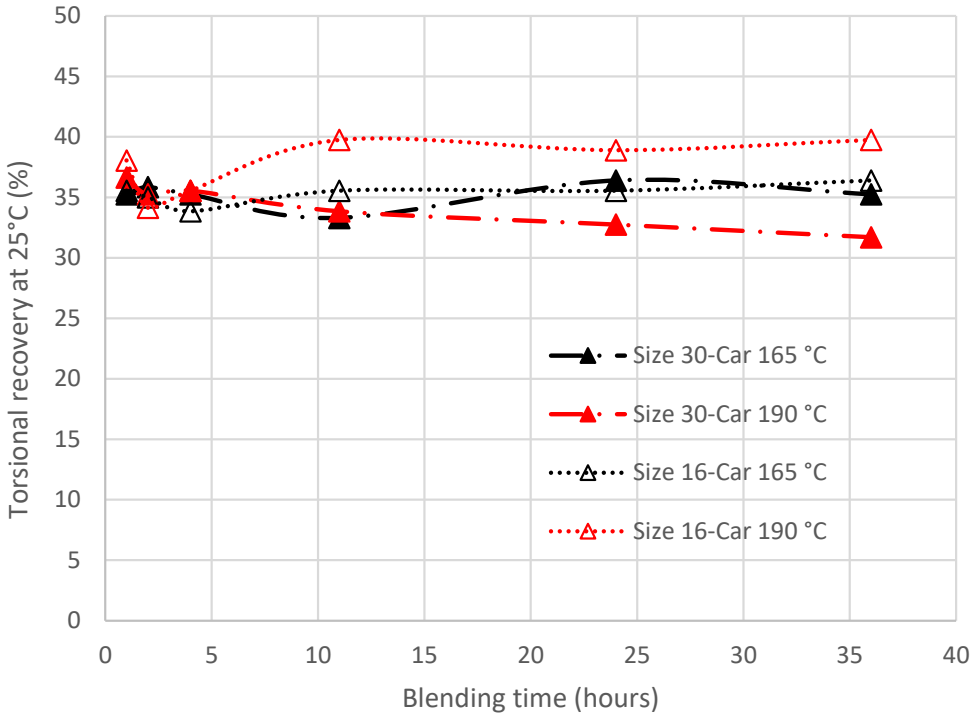
Viscosity at 175 °C



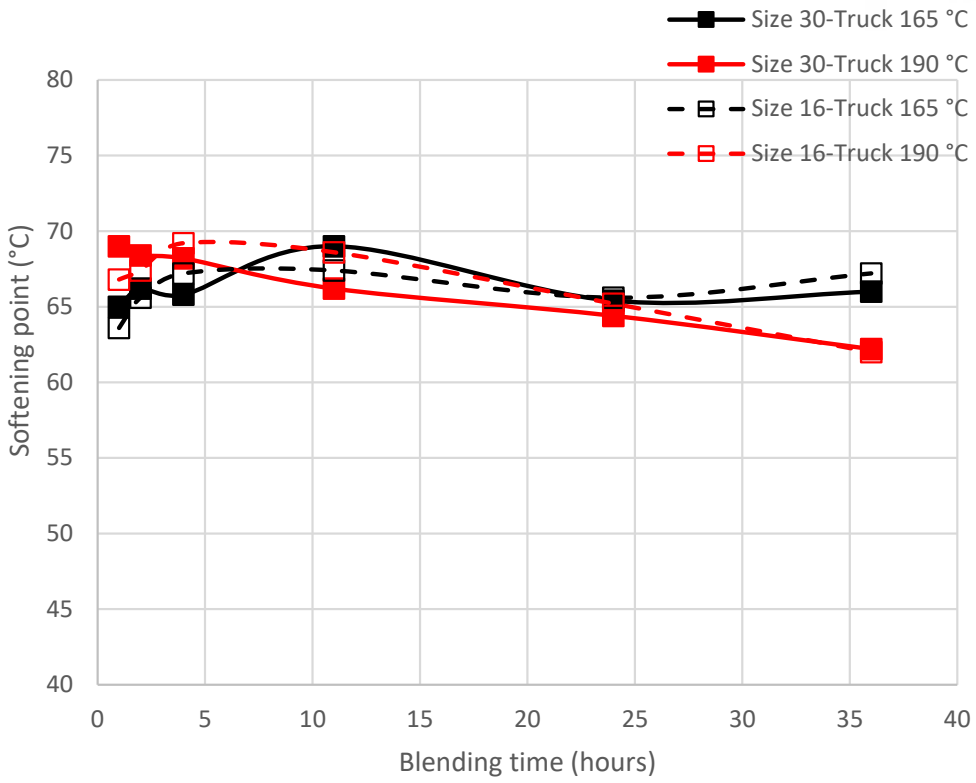


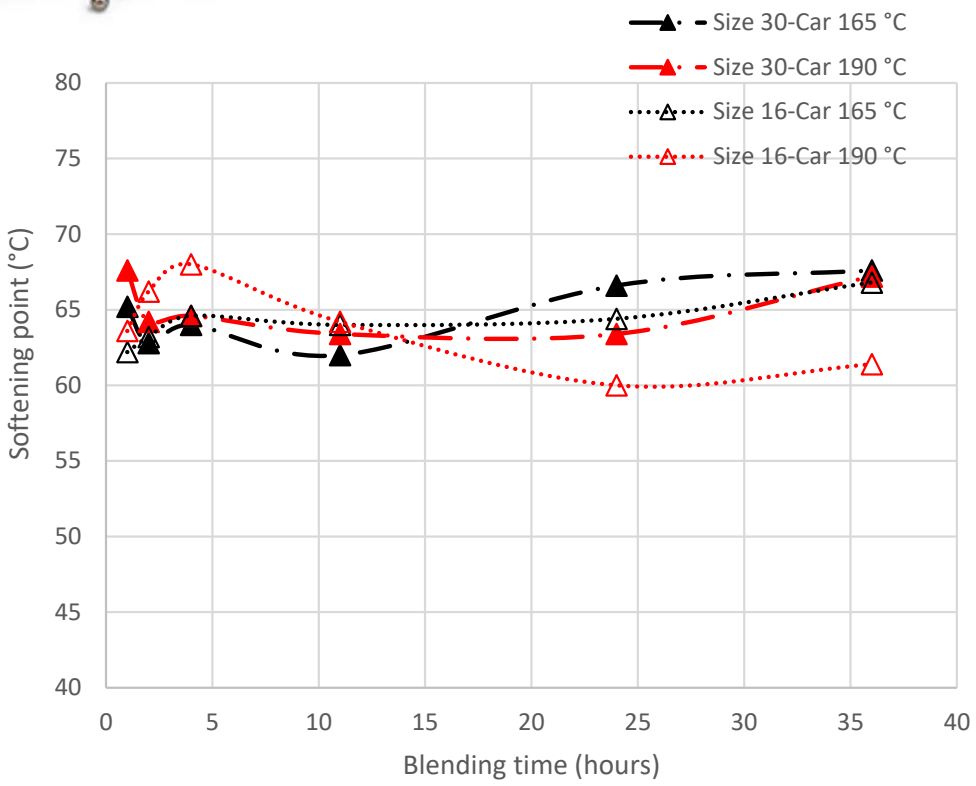
Torsional Recovery at 25 °C



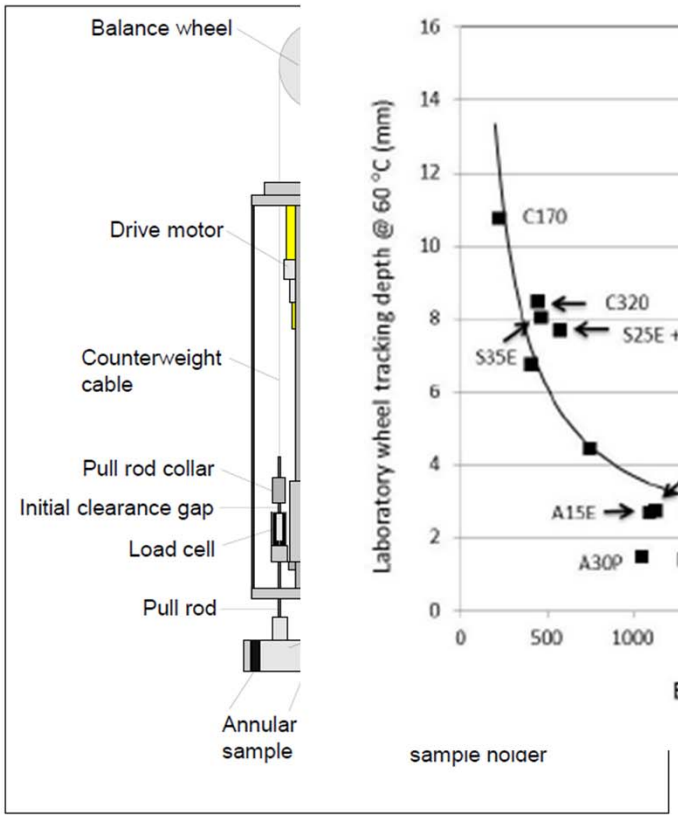


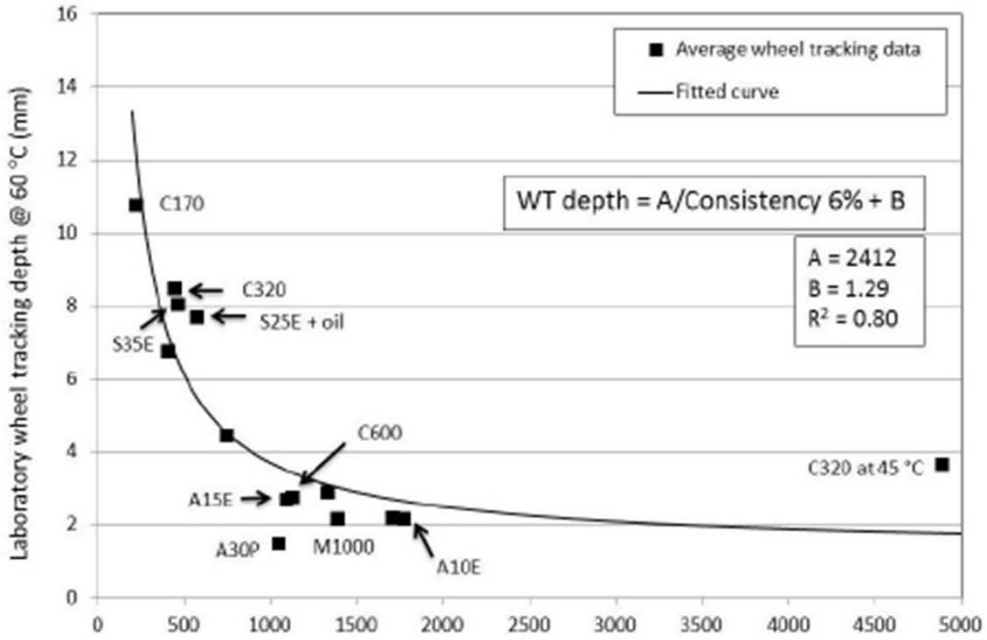
Softening Point

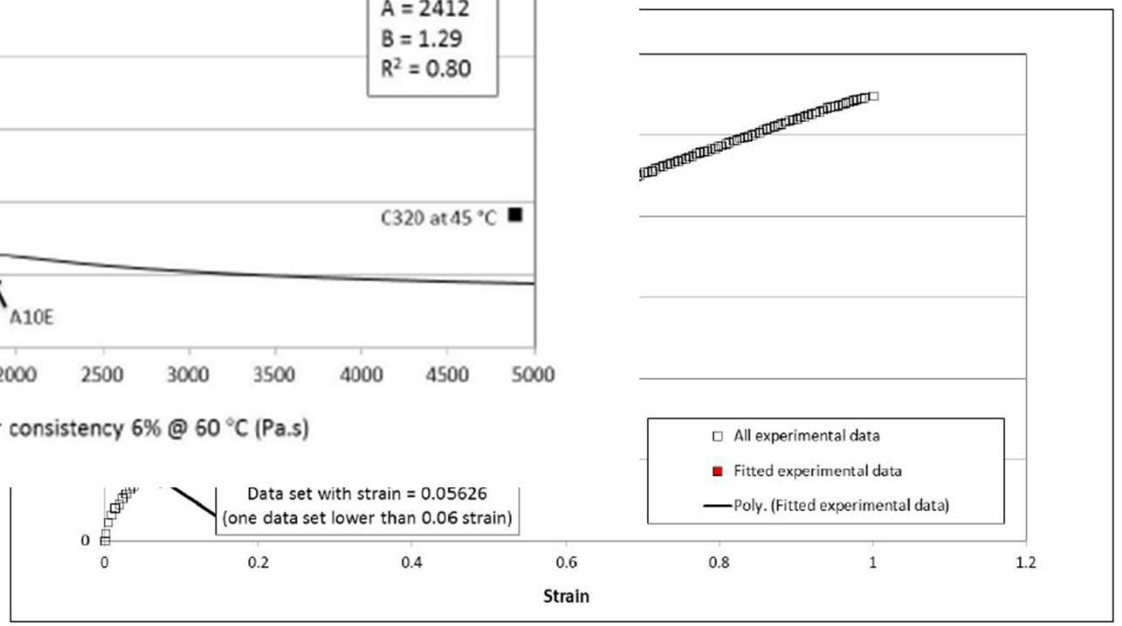




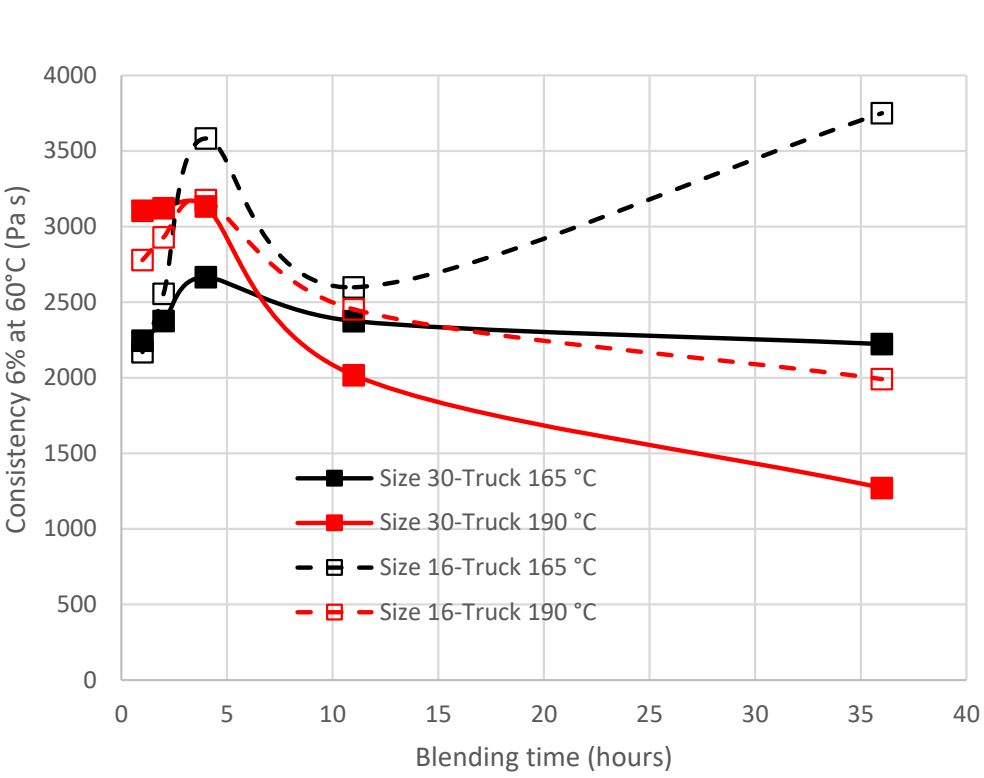
ARRB Elastometer Consistency 6% at 60 °C

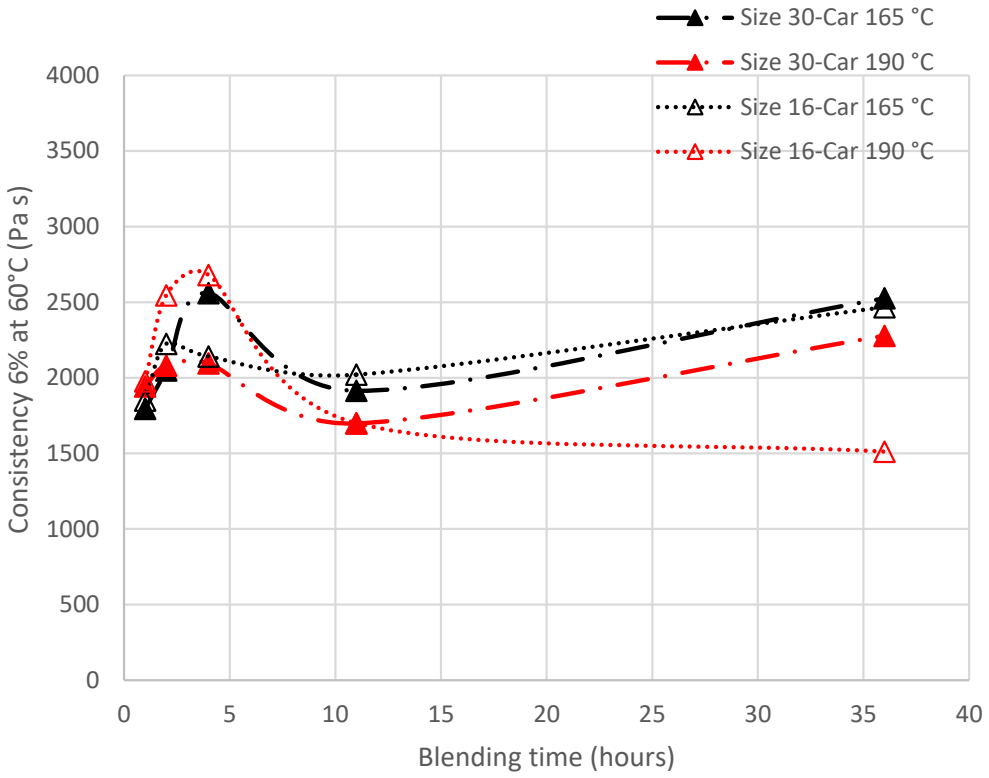




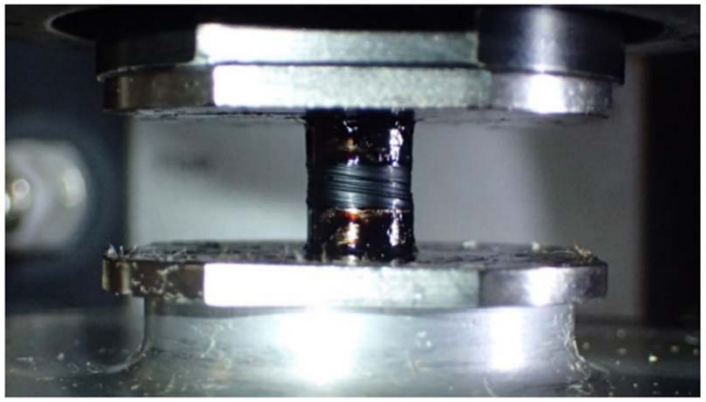


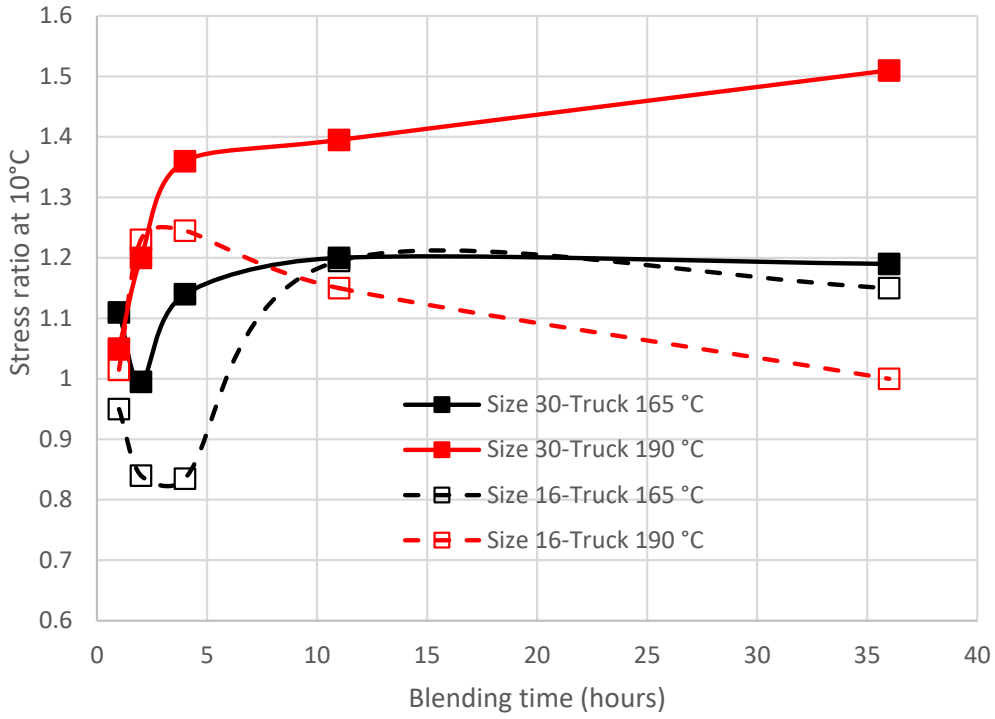
Consistency 6% at 60 °C

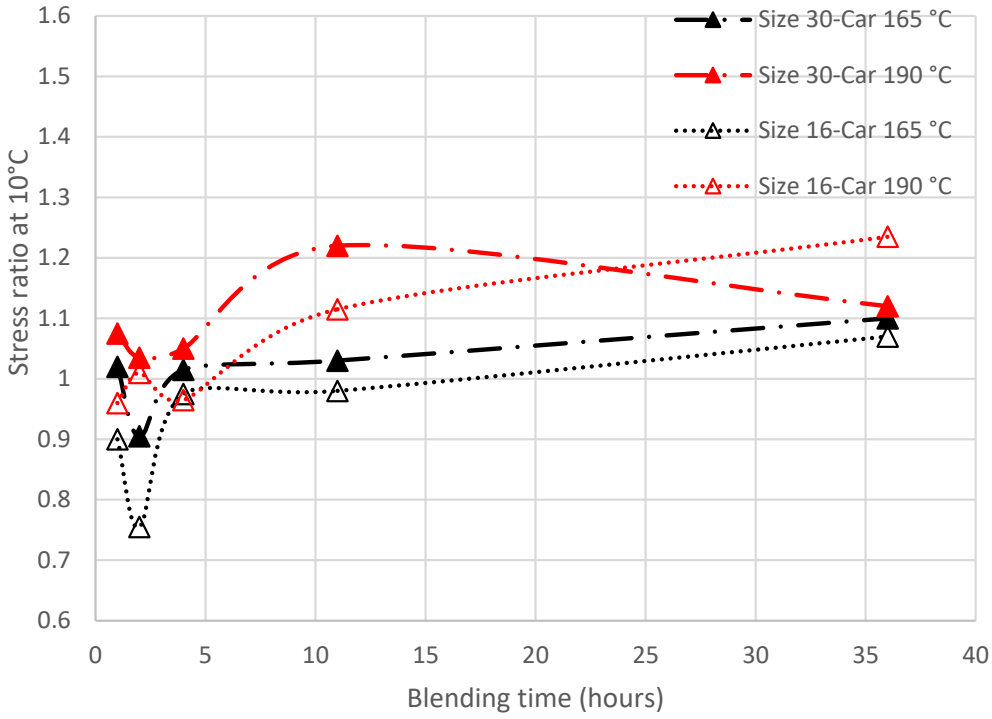




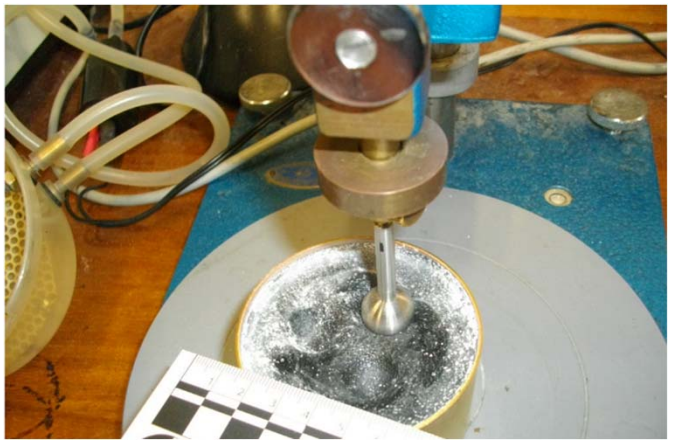
Stress Ratio 10 °C

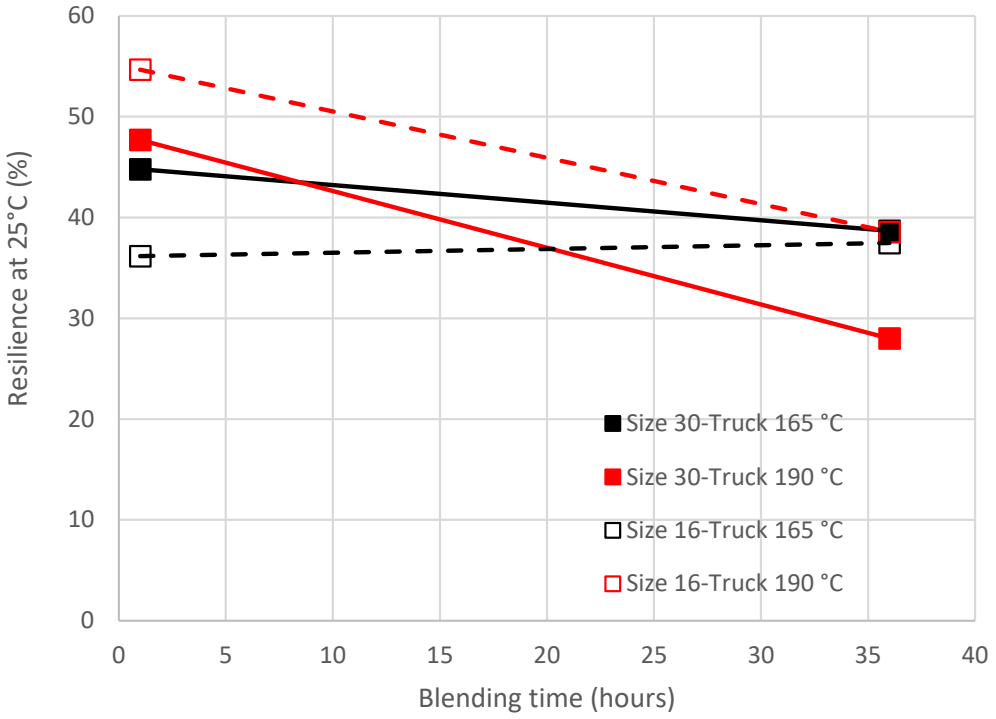


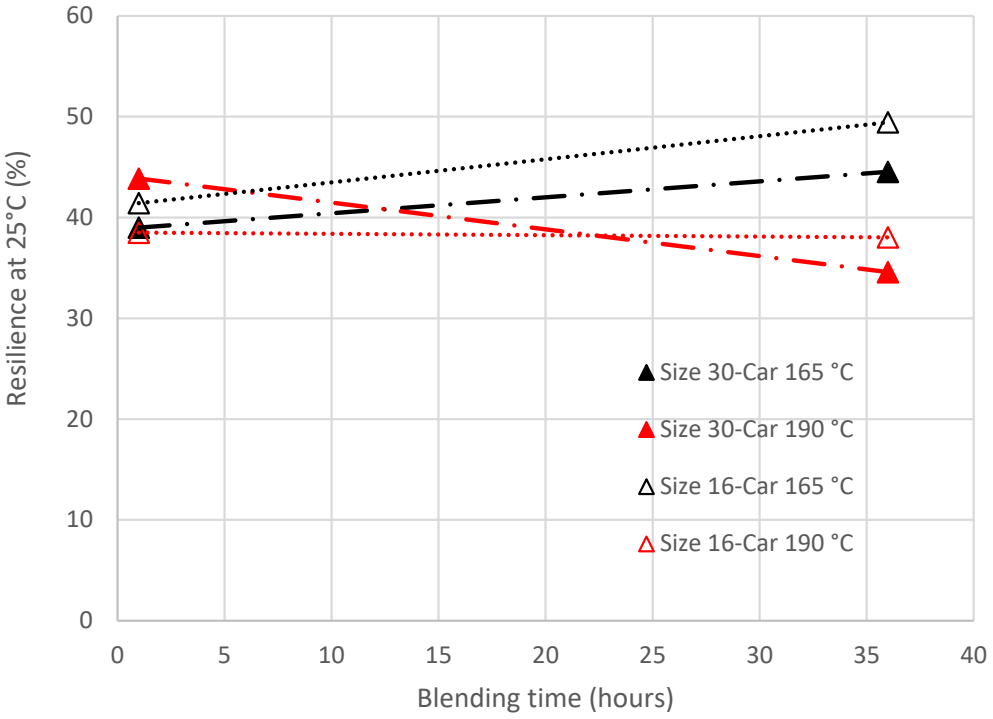




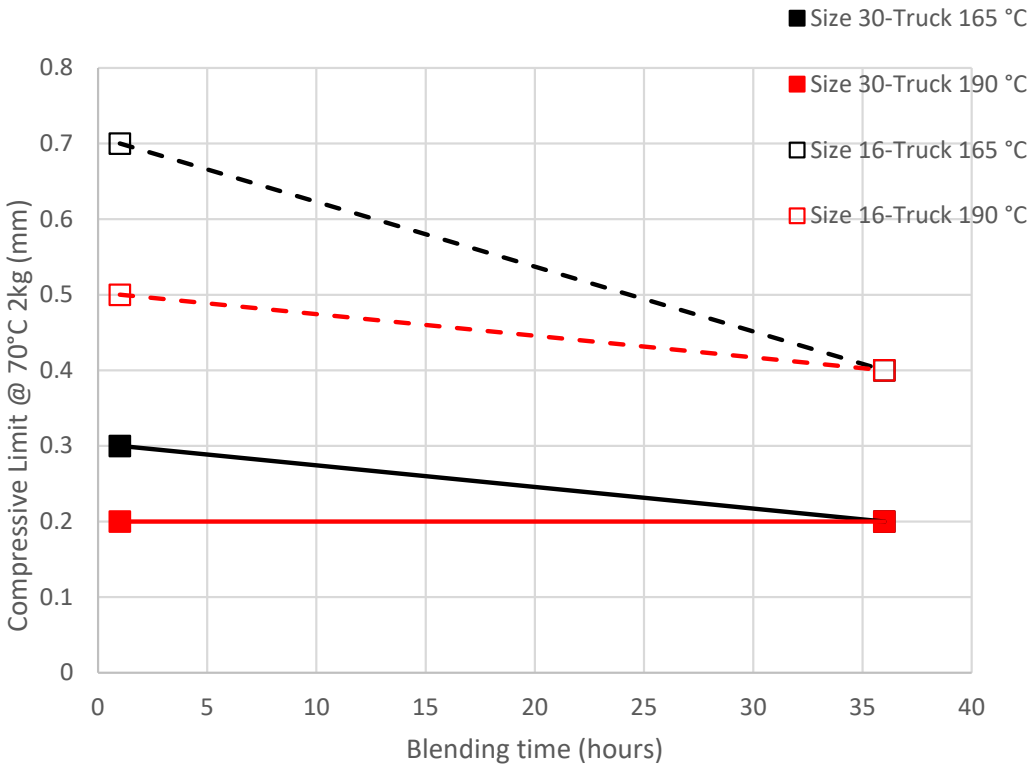
Resilience at 25°C

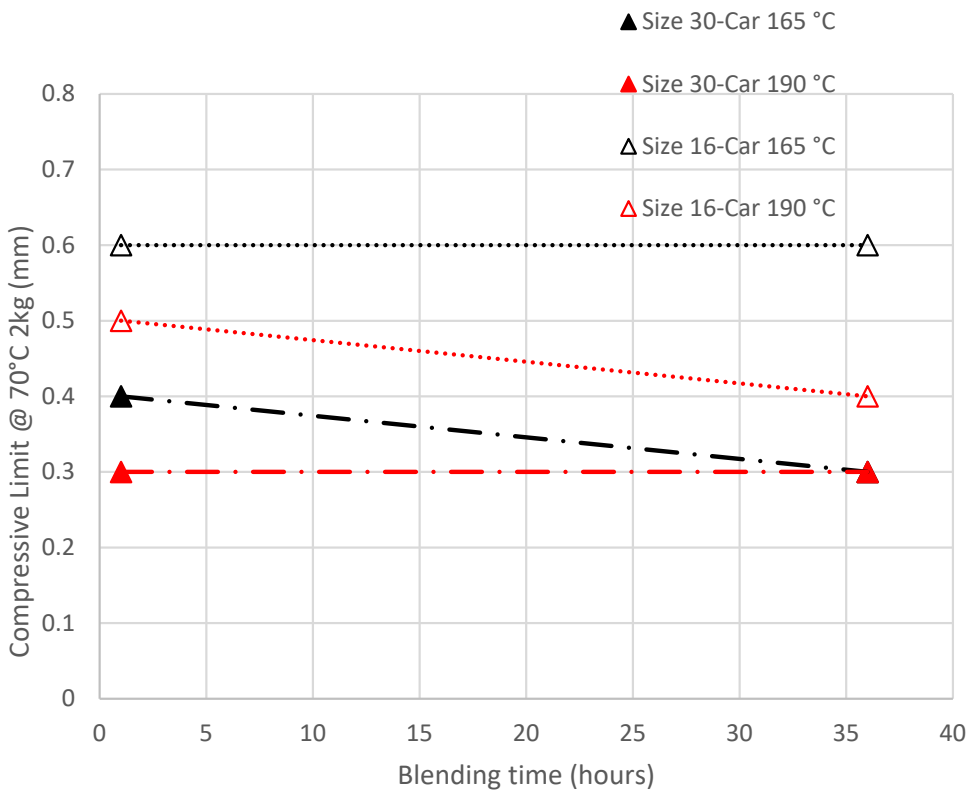






Compressive Limit





Summary

Test property	Rubber type	Size	Temperature	Time
High temperature viscosity (165 and 175 °C)	No change	Slight decrease with increasing crumb rubber size	Minor increase in initial viscosity for 190 vs 165 ° C	Slight decrease with time for 190 °C Relatively little change with time for 165 °C
Torsional Recovery/Resilience	No change	Slight increase with increase in crumb rubber size ~5%	No change	Slight reduction with time at 190 °C ~5%
Softening Point	Slight increase for truck tyres ~3-4 °C	No change	Slight increase early softening point at 190 °C ~2-4°C	190 °C decreasing slightly with time ~5 °C 165 °C little change with time
Consistency at 6%	Slight increase for truck tyres ~500 Pa.s	No change	No change	Peak occurring around 4 hours – more investigation required
Stress Ratio	Slight increase for truck tyres ~0.2%	No change	Possibly slight increase with increase in temperature ~0.1%	Slight increase with time
Compressive Limit	No change	Increase with size ~0.4mm	No change	No change (very minor 0.1mm if any)

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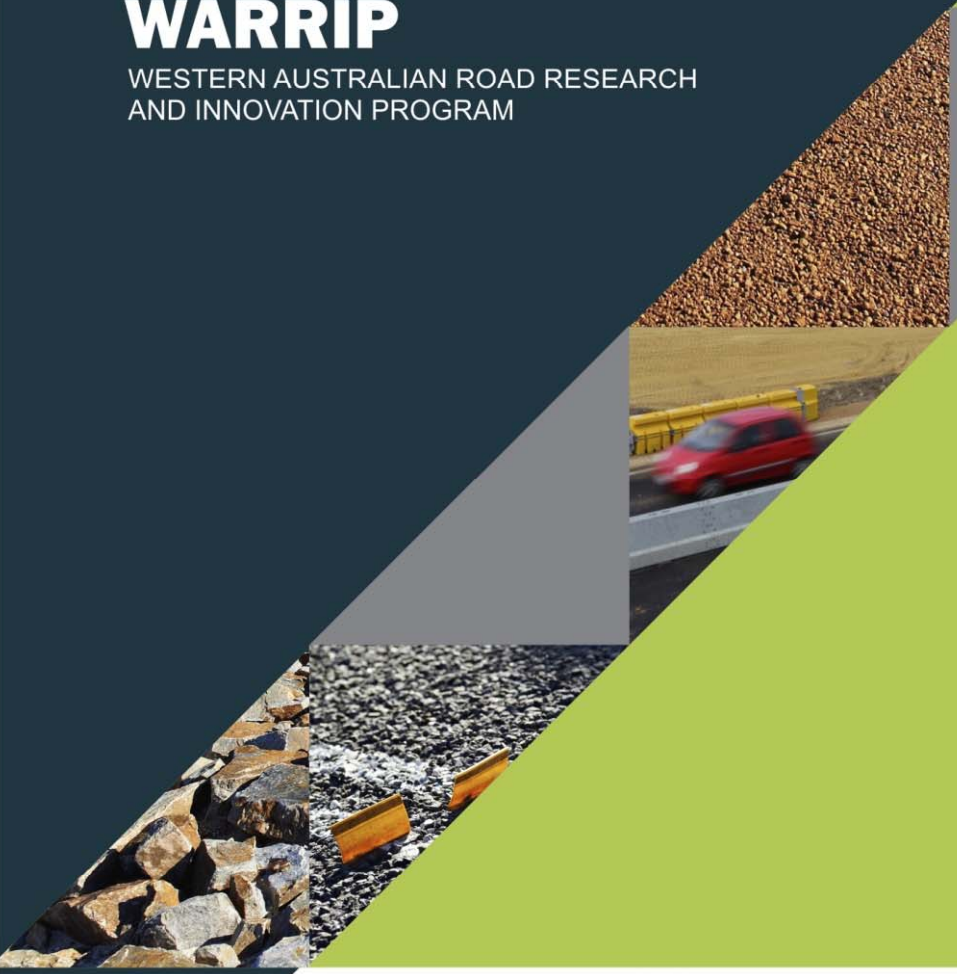

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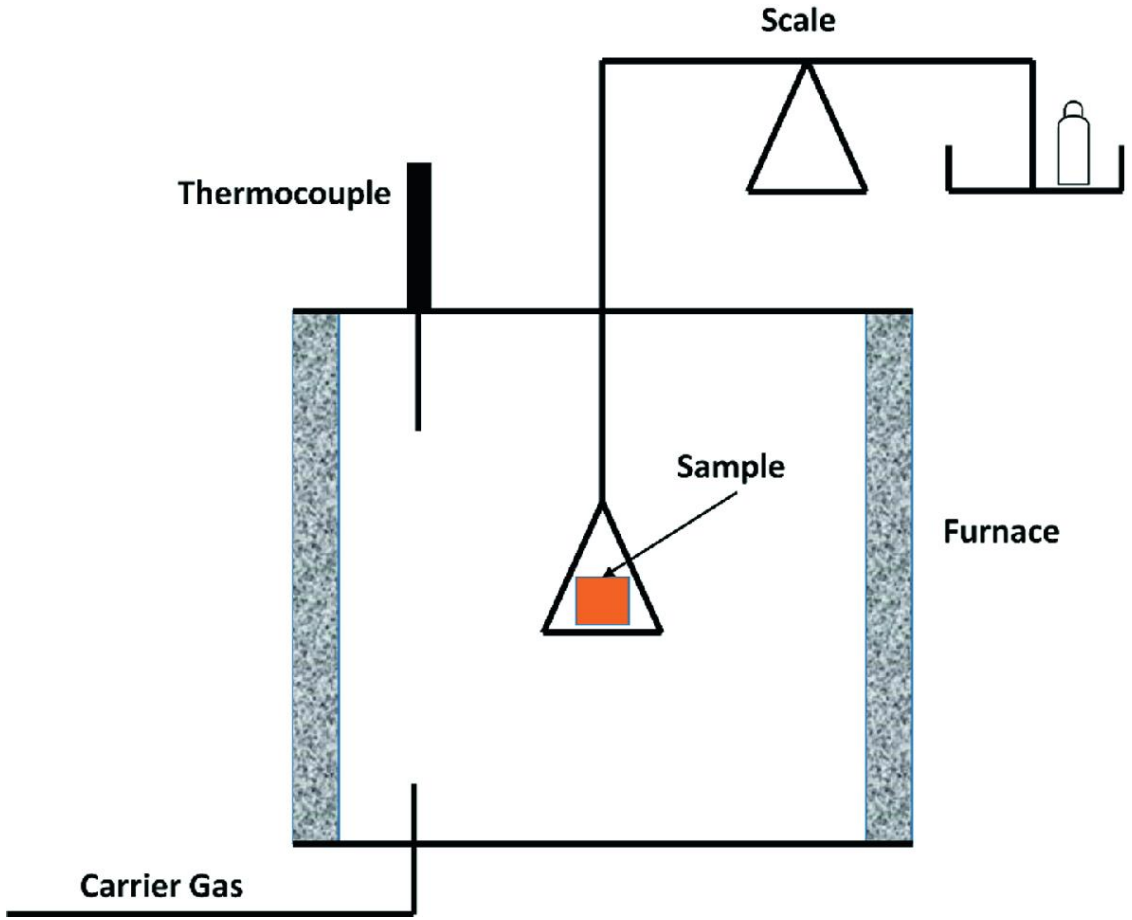
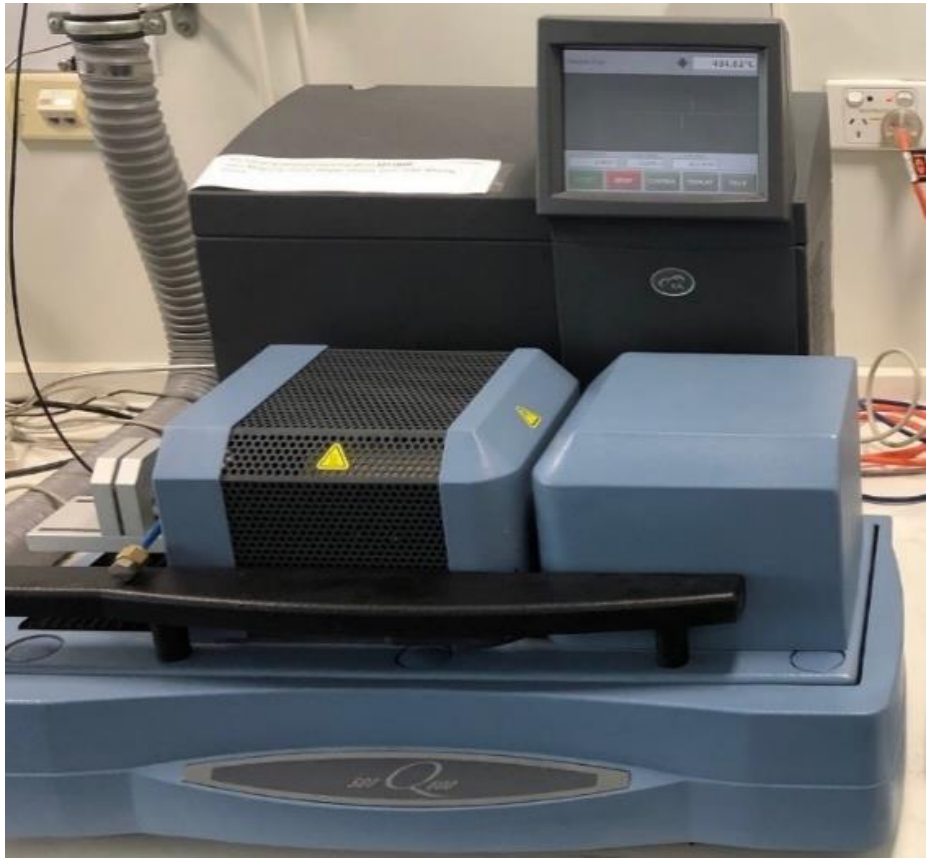
TGA & DTG





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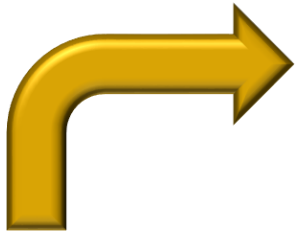
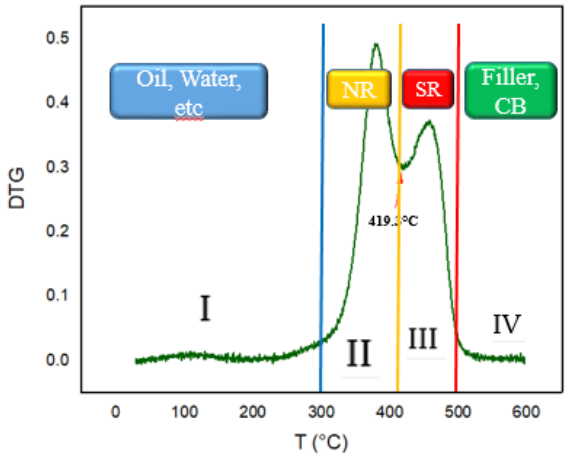
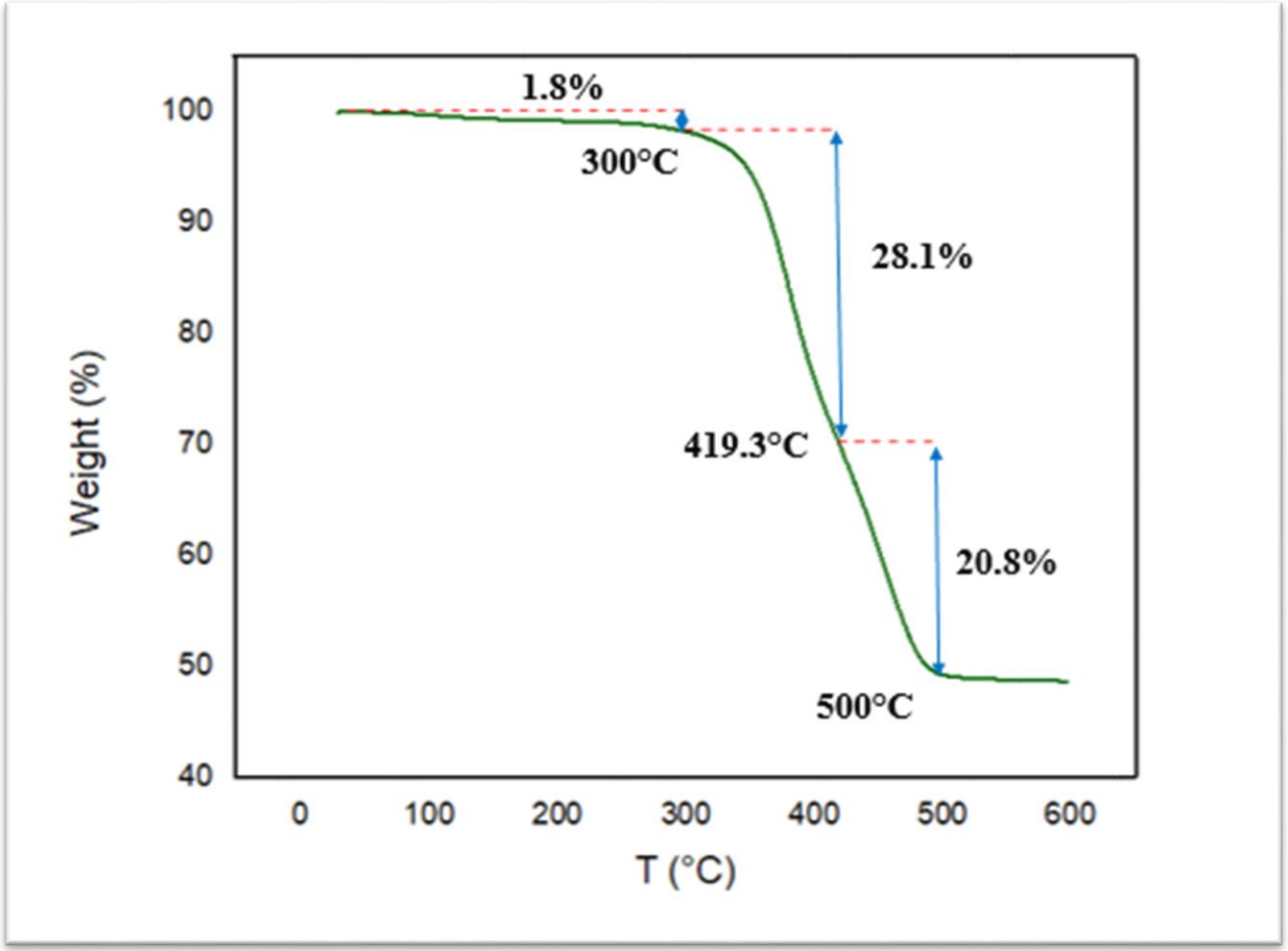
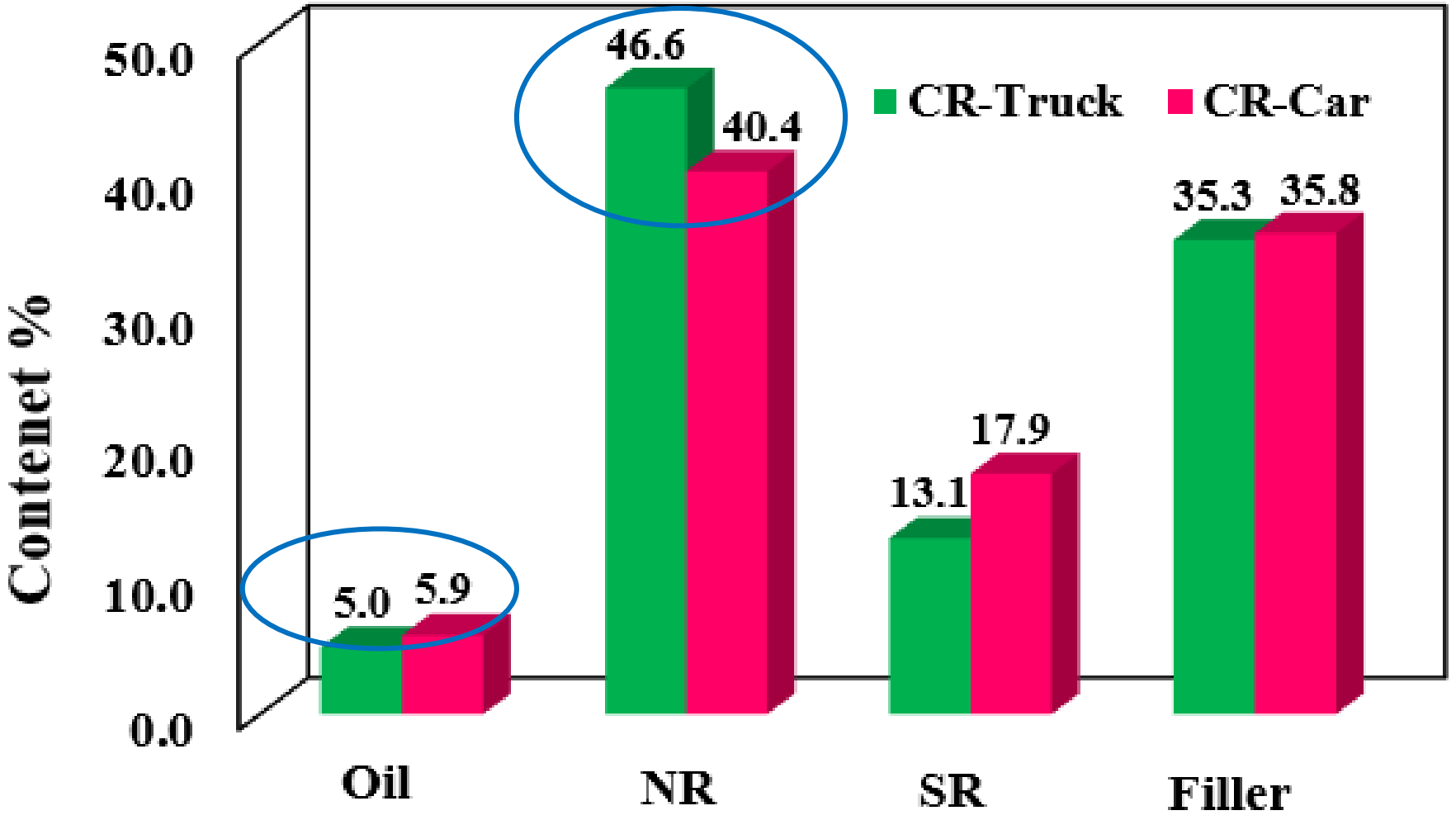
TGA analysis



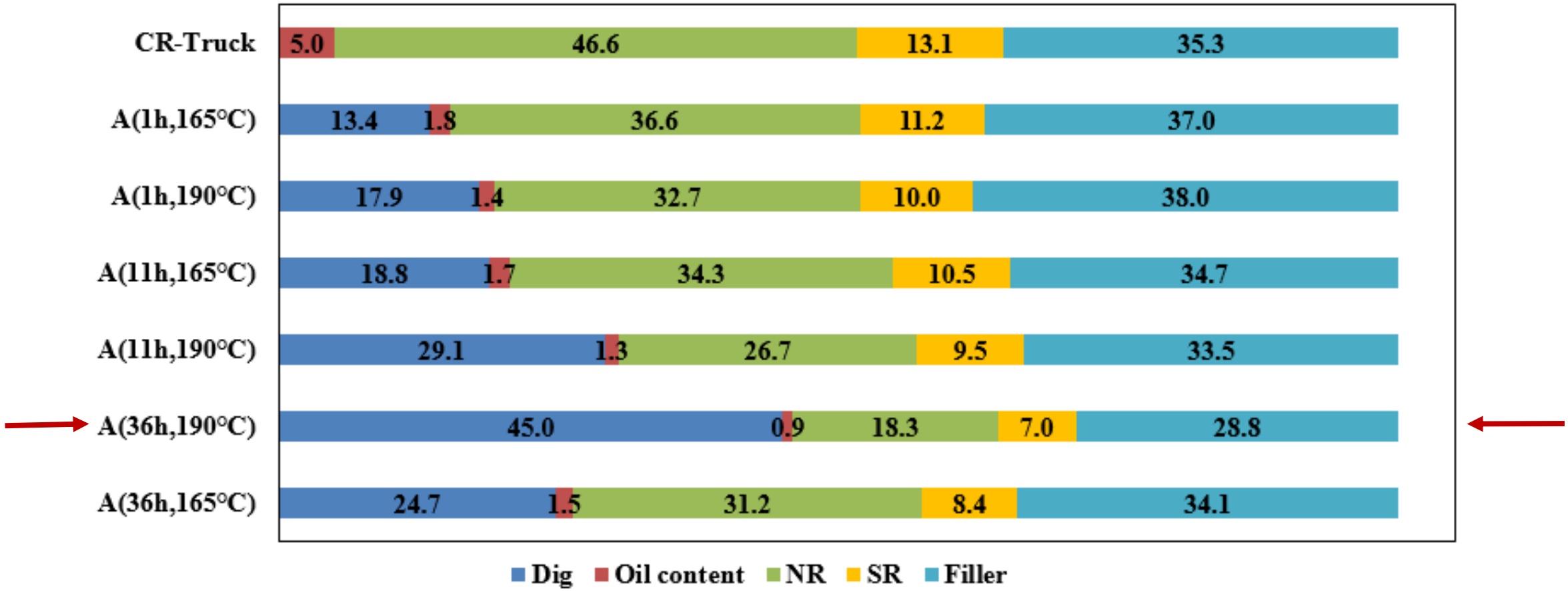




Car vs. Truck

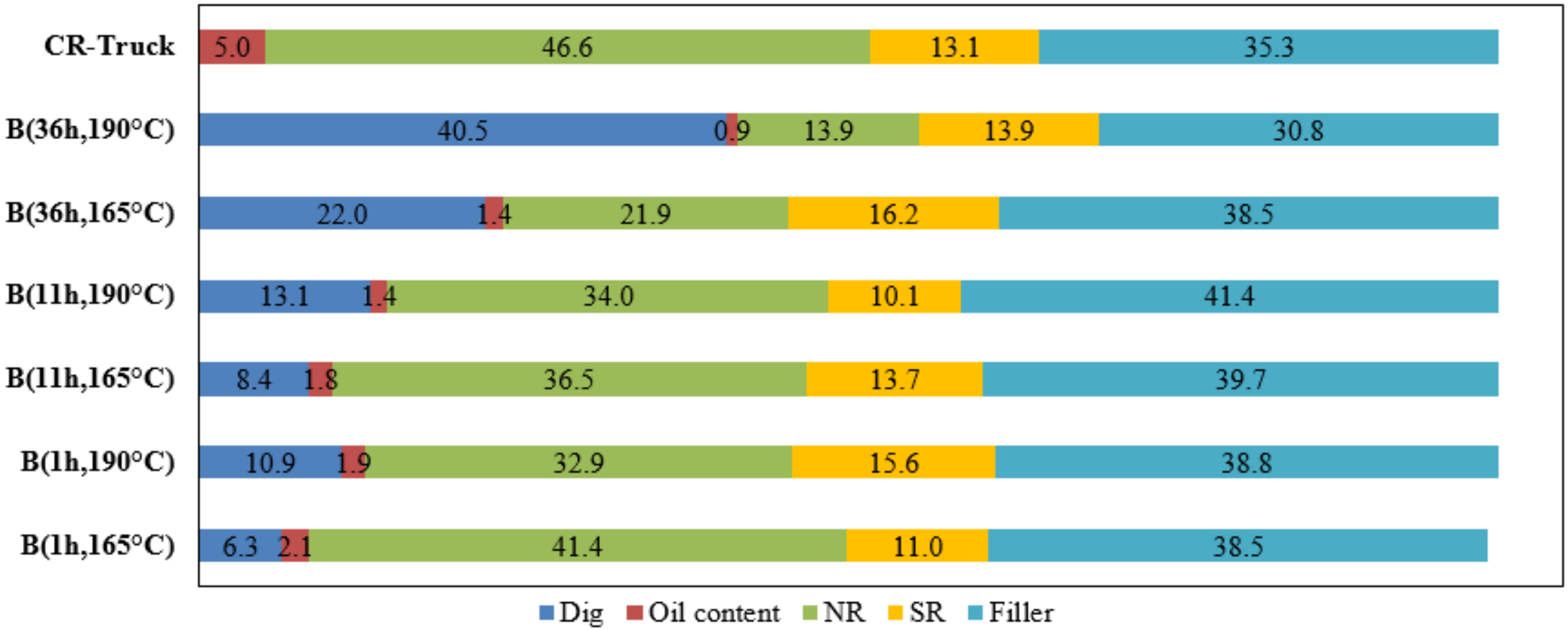


Components concentration in extracted CRM samples-A

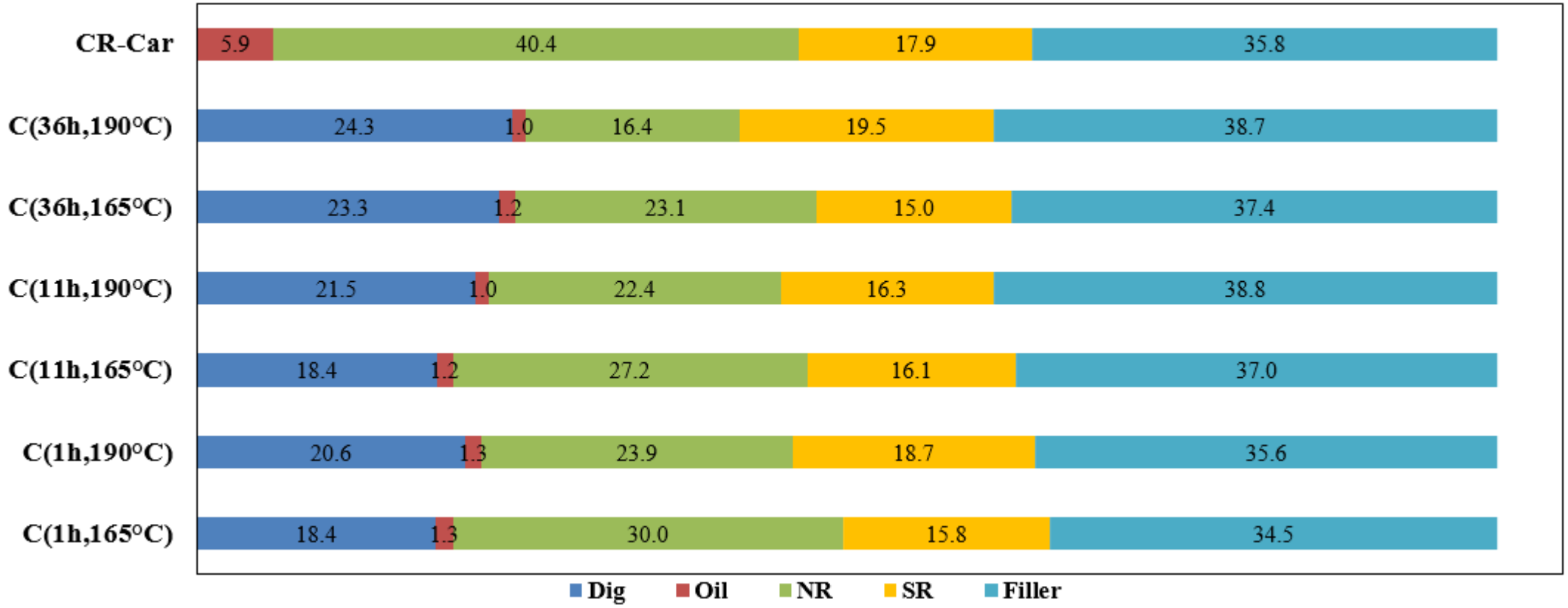


1. Yao, H., Zhou, S. & Wang, S. Structural evolution of recycled tire rubber in asphalt. *J. Appl. Polym. Sci.* **133**, (2016)

Components concentration in extracted CRM samples-B



Components concentration in extracted CRM samples-C



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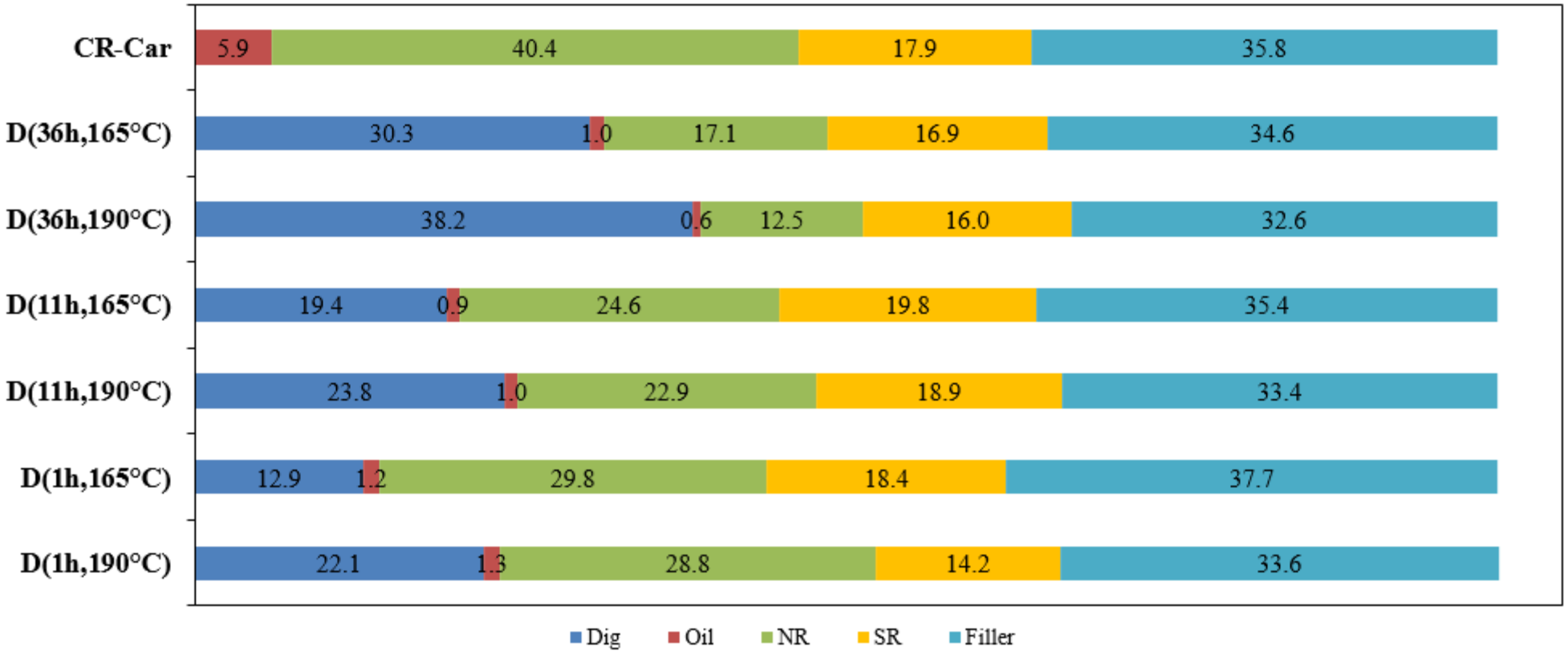
Components concentration in extracted CRM samples-D



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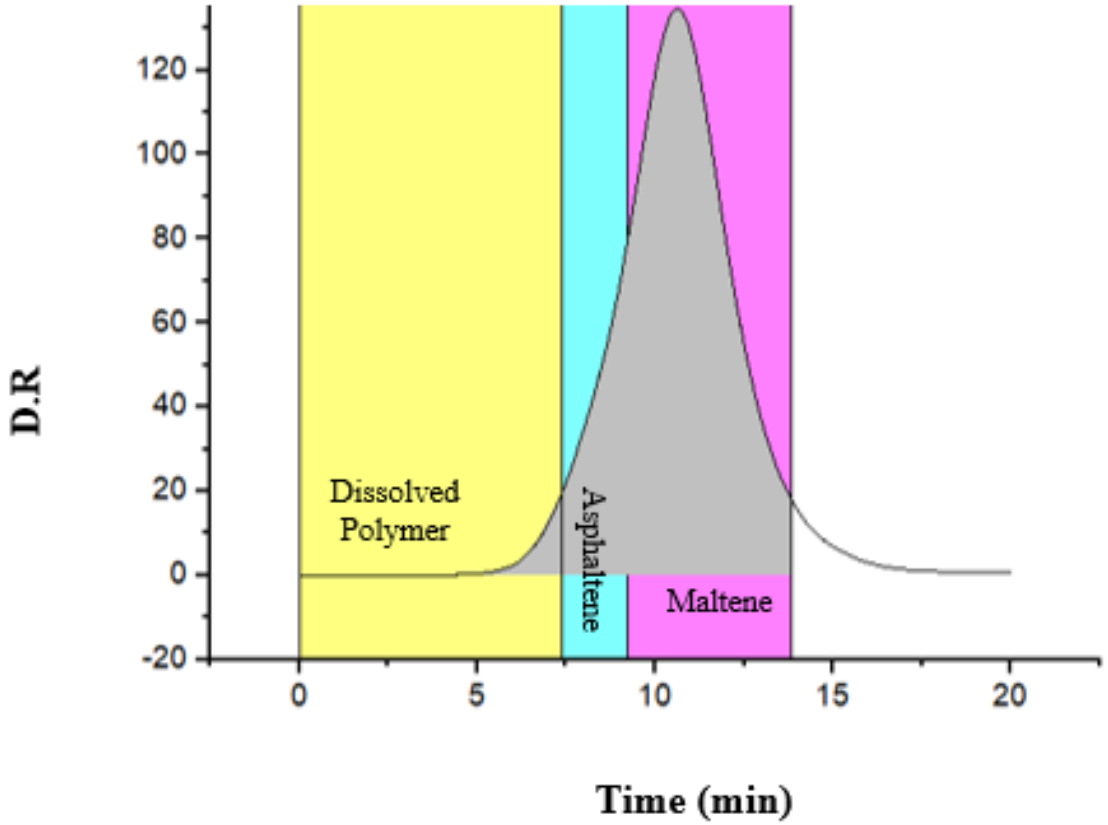
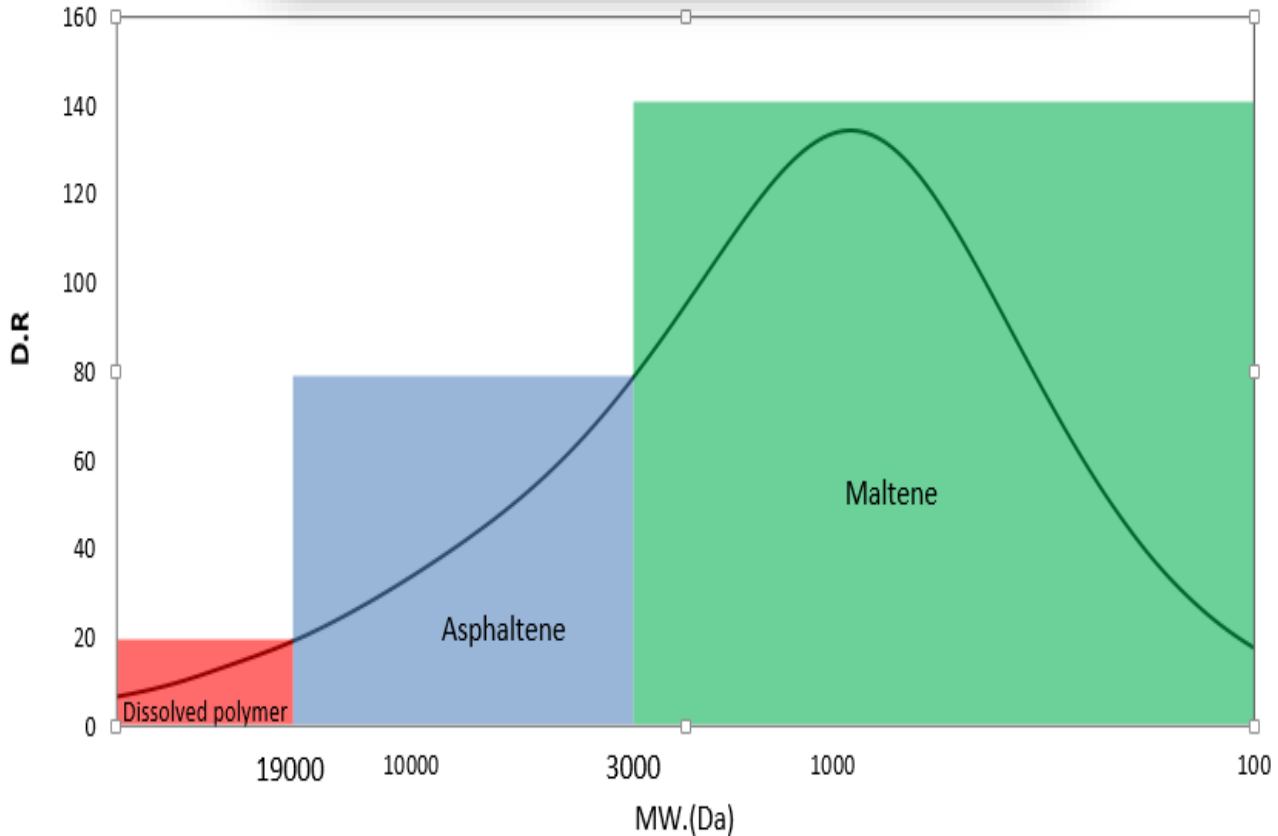
GPC – quantification

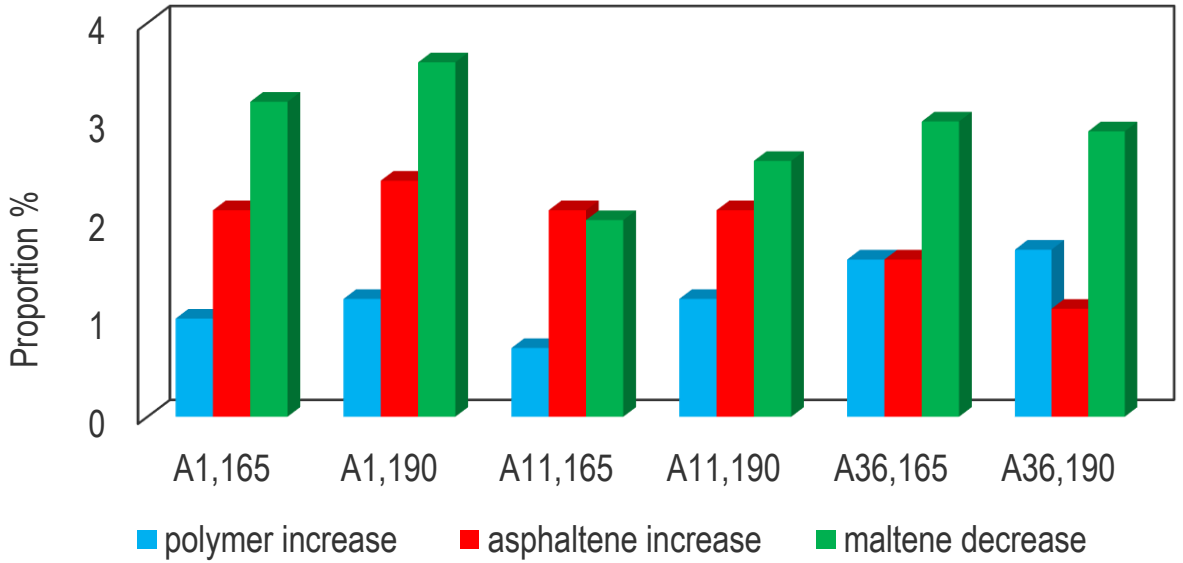
$$Dissolved\ polymer\ \% = \frac{A_{MW>1900}}{A_{MW>100}} \times 100$$

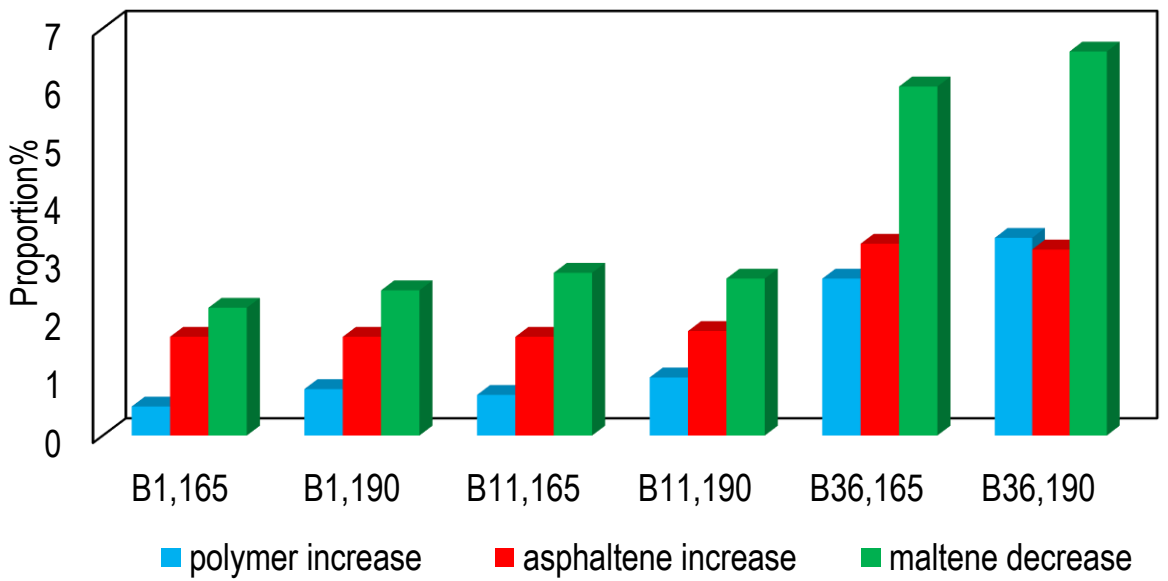
$$Apparent\ asphaltene\ \% = \frac{A_{19000>MW>3000}}{A_{MW>100}} \times 100$$

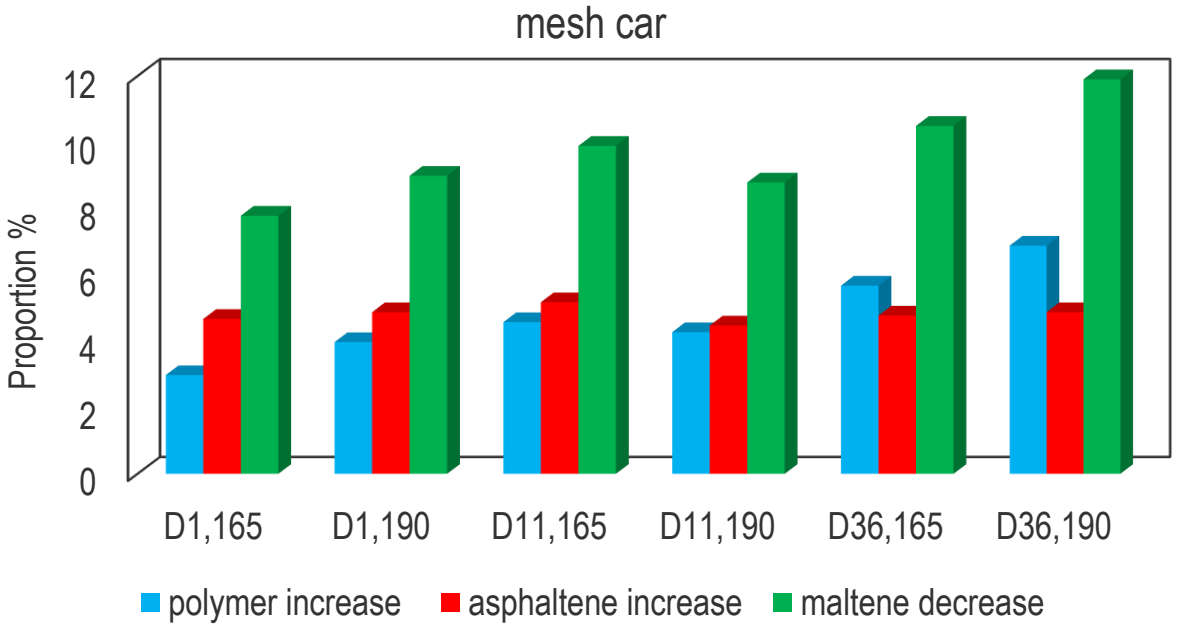
$$Maltene\ \% = \frac{A_{3000>MW>100}}{A_{MW>100}} \times 100$$

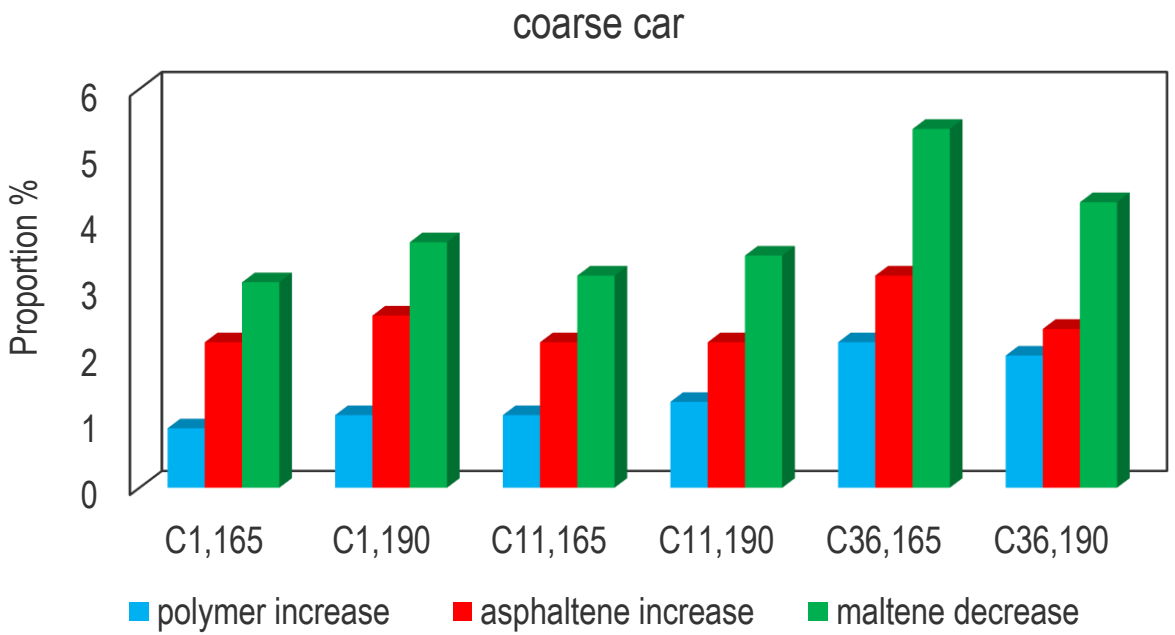




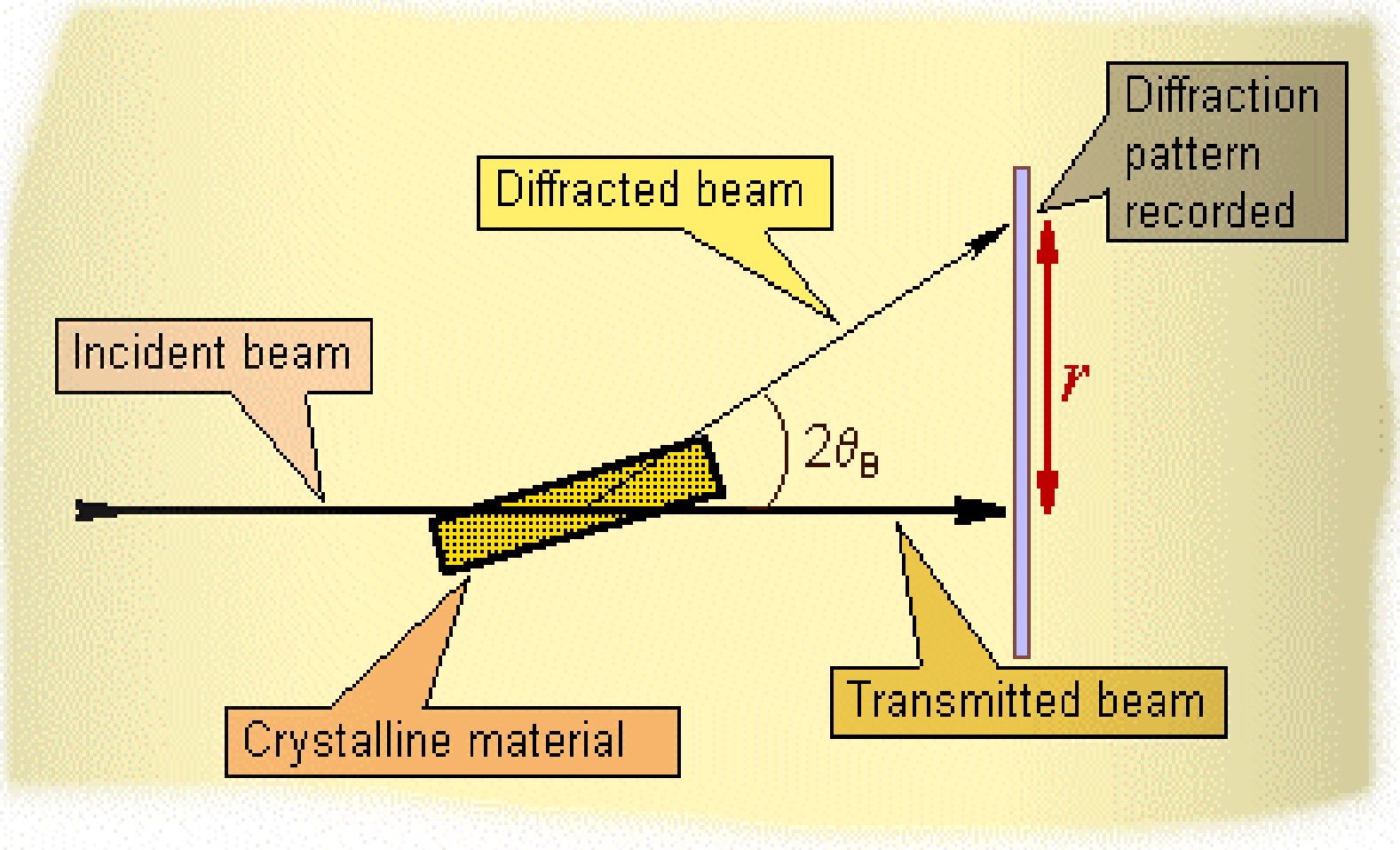

mesh truck
Proportion %
0
1
2
3
4
A1,165
A1,190
A11,165
A11,190
A36,165
A36,190
polymer increase
asphaltene increase
maltene decrease


coarse truck
Proportion%
0
1
2
3
4
5
6
7
B1,165
B1,190
B11,165
B11,190
B36,165
B36,190
polymer increase
asphaltene increase
maltene decrease


mesh car
Proportion %
0
2
4
6
8
10
12
D1,165
D1,190
D11,165
D11,190
D36,165
D36,190
polymer increase
asphaltene increase
maltene decrease


coarse car
Proportion %
0
1
2
3
4
5
6
C1,165
C1,190
C11,165
C11,190
C36,165
C36,190
polymer increase
asphaltene increase
maltene decrease

X-ray Diffraction



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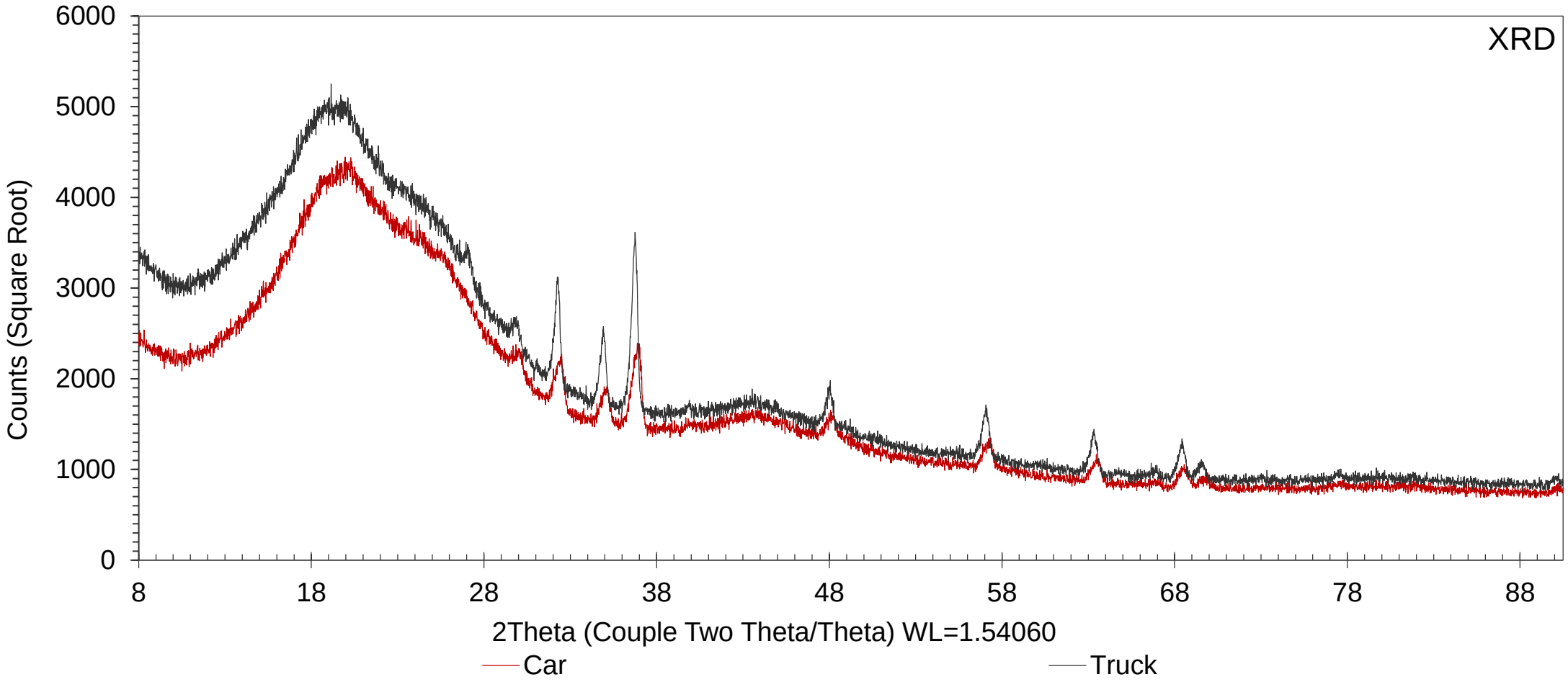
www.micro.magnet.fsu.edu/primer/java/interference/index.html

X-ray Diffraction



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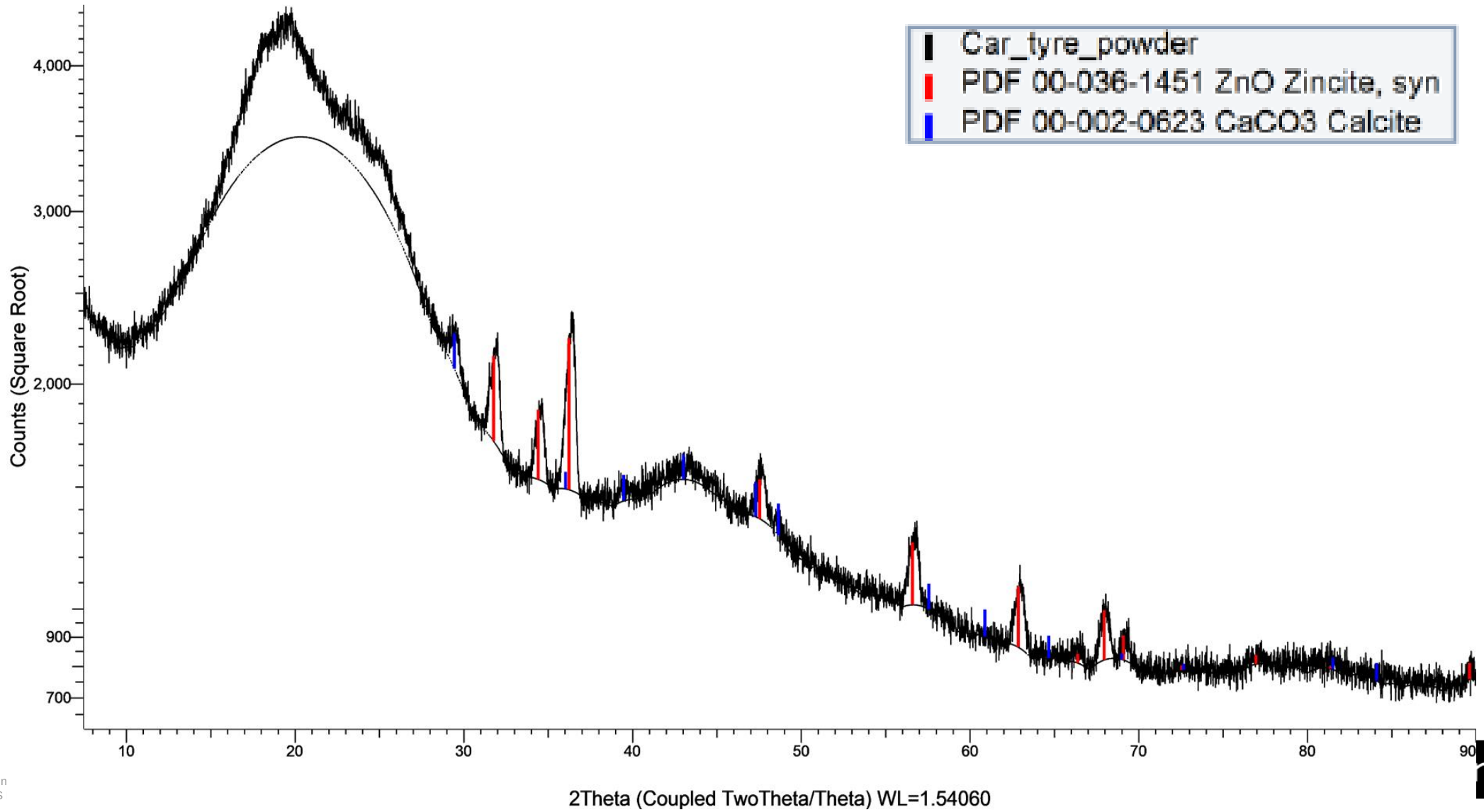
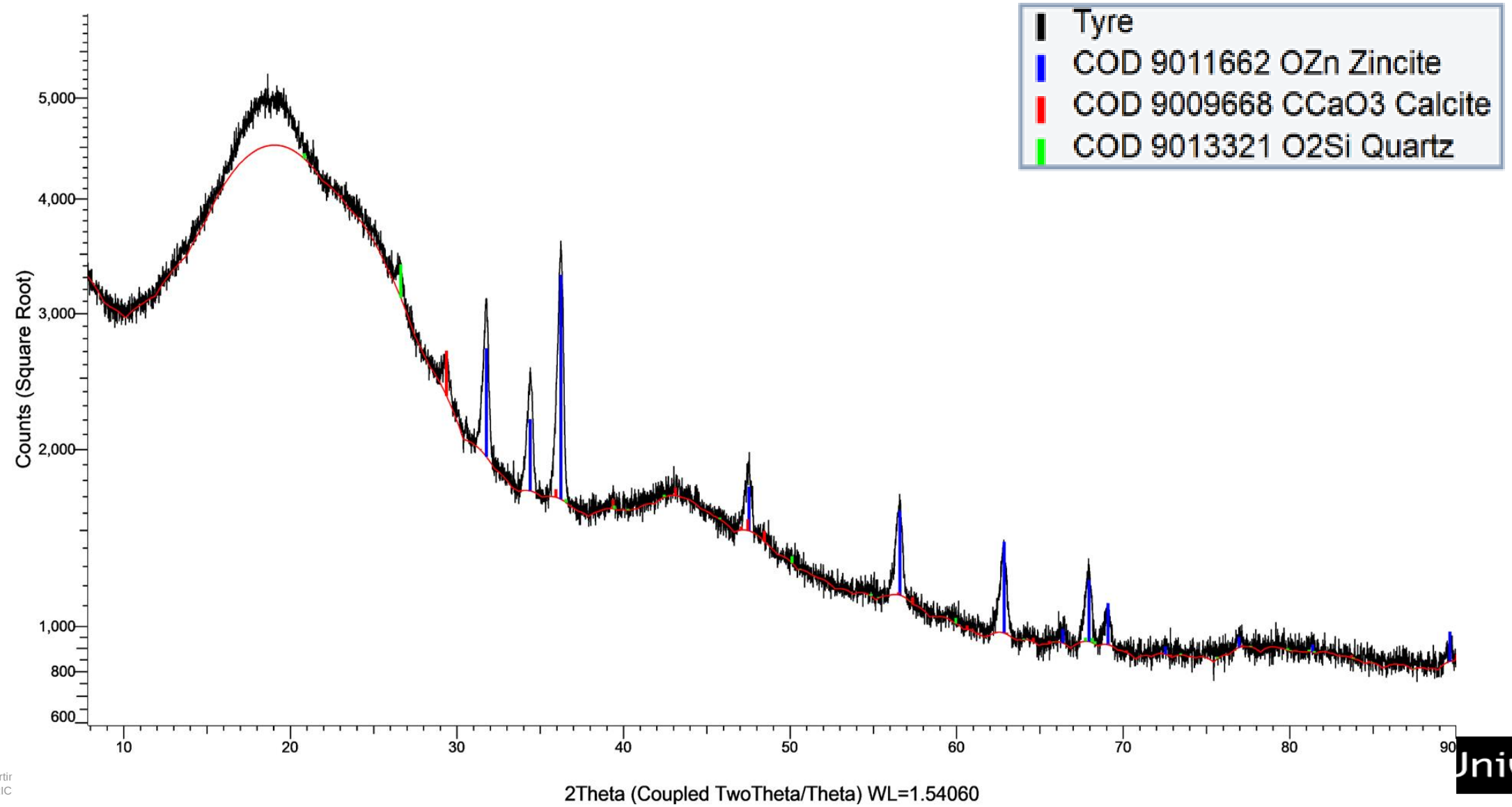
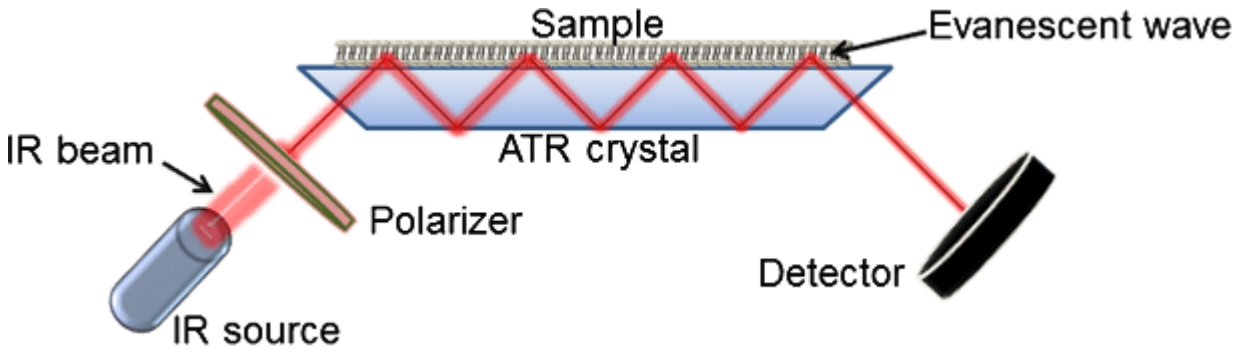
XRD for Car rubber

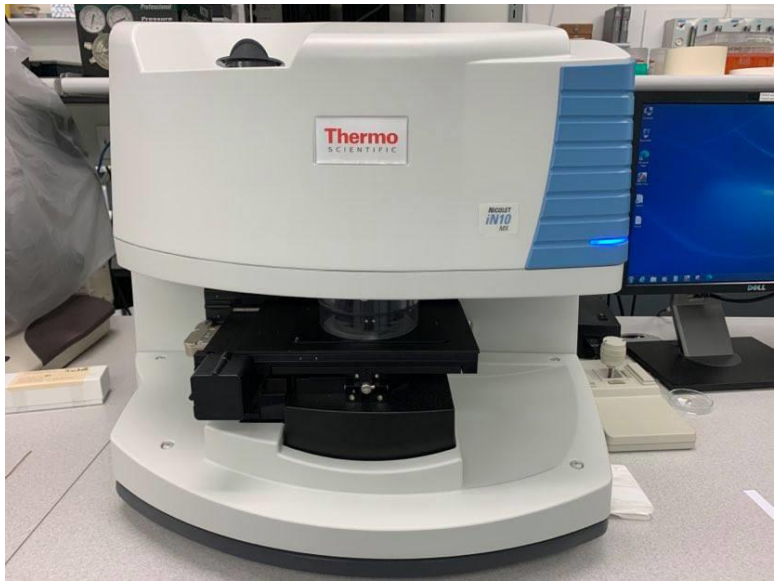


XRD for Truck rubber



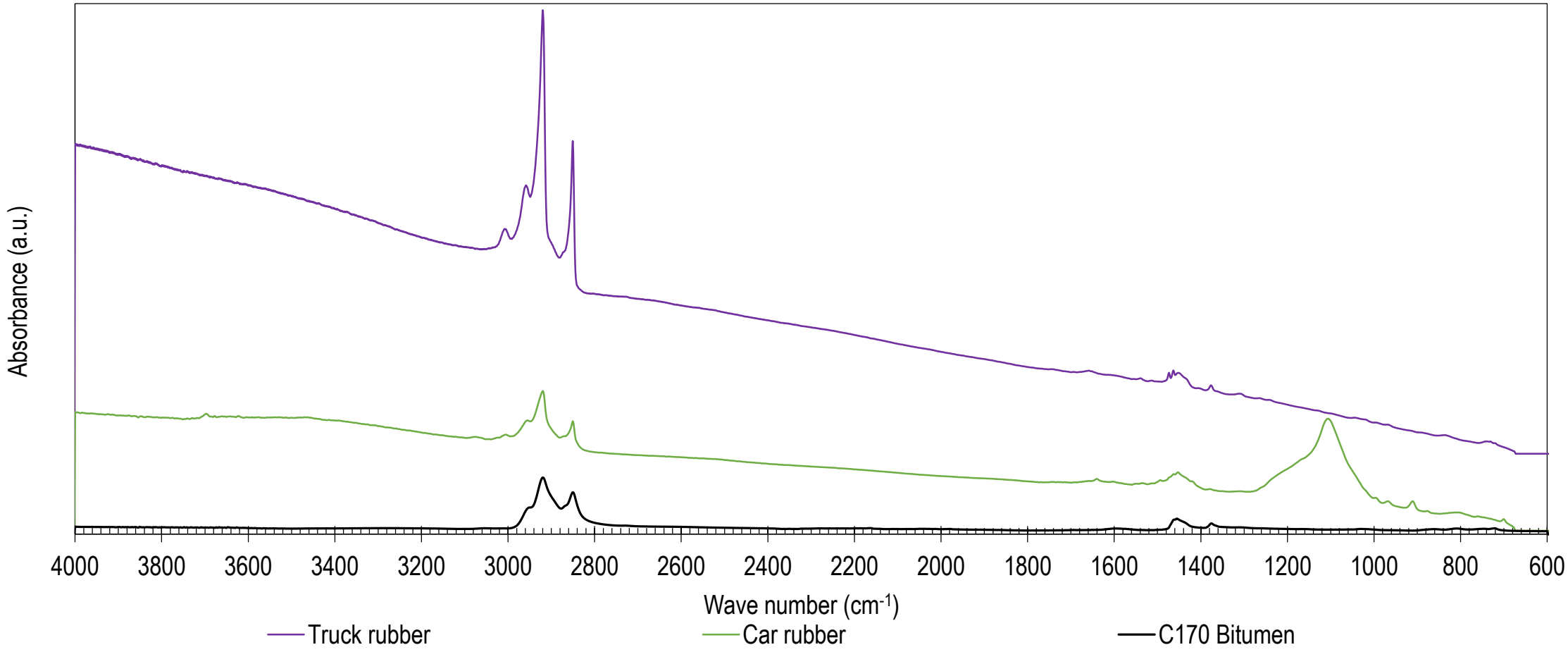
Fourier-transform infrared spectroscopy (FTIR)





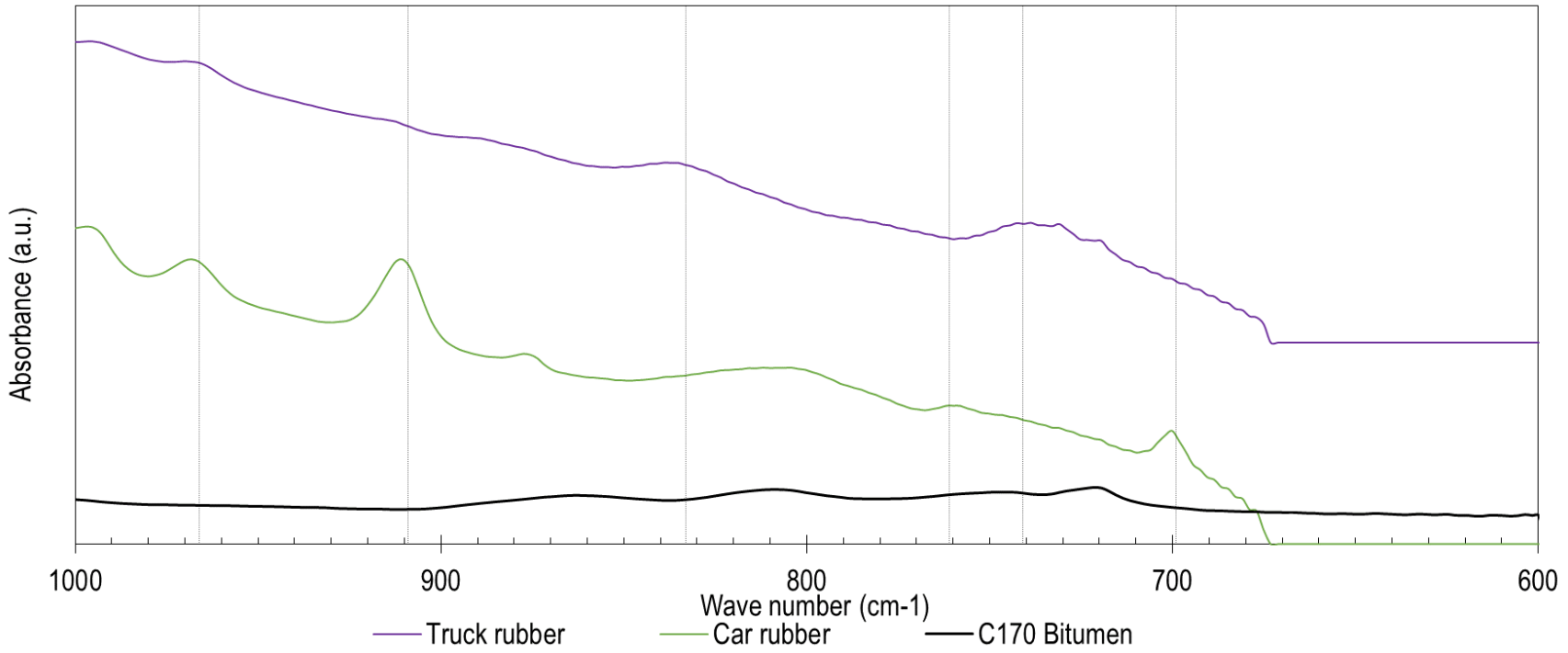
Ausili, A., et al. (2015). "Attenuated total reflectance infrared spectroscopy: A powerful method for the simultaneous study of structure and spatial orientation of lipids and membrane proteins." Biomedical Spectroscopy and Imaging **4**: 159-170.

FTIR spectra for raw bitumen, car and truck rubber



Curtin University

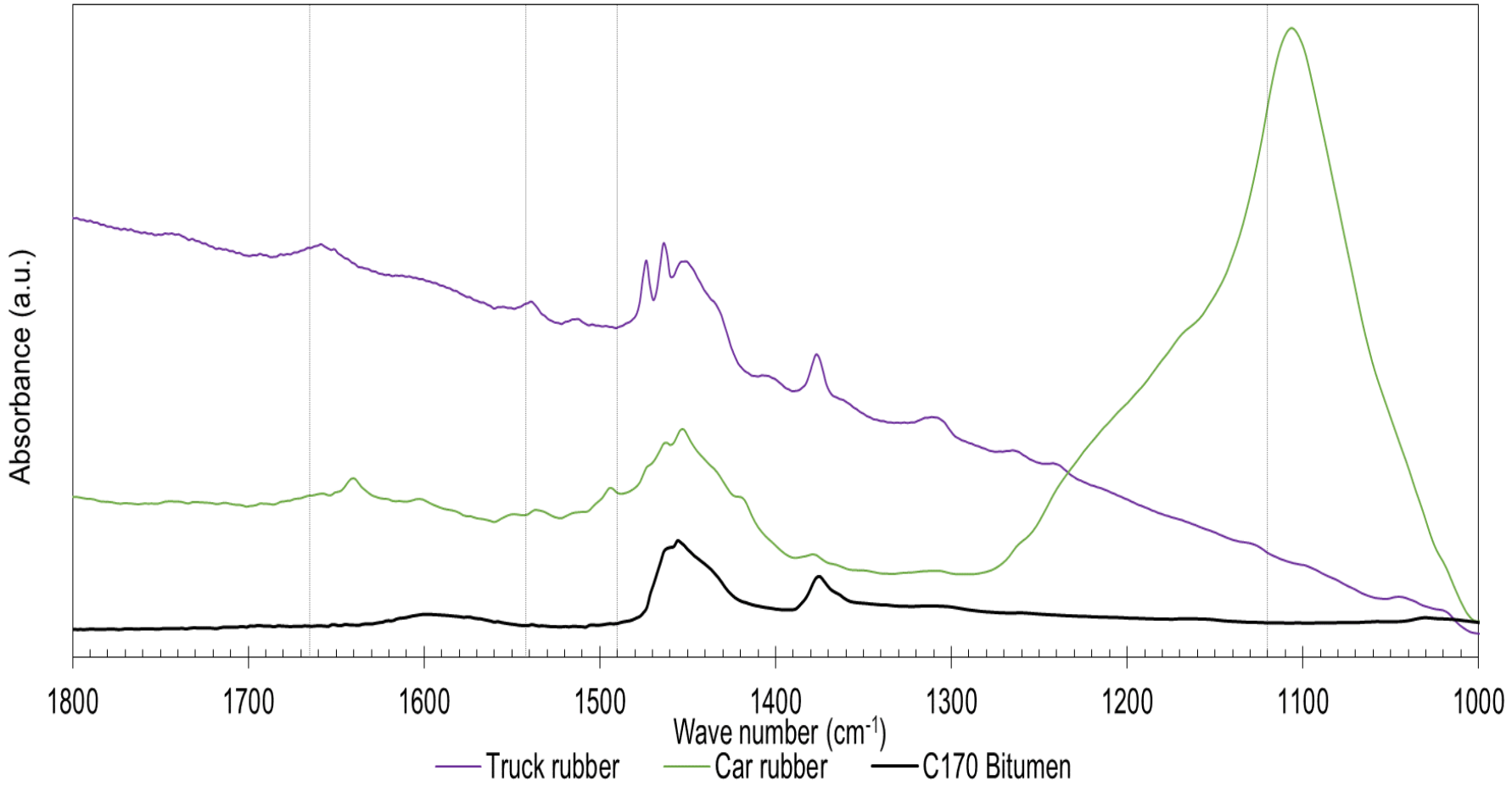
FTIR spectra for raw bitumen, car and truck rubber



Peak position (cm^{-1})	Component
699	SBR
741	SBS
761	SBR
833	NR
909	SBR, SBS (butadiene part)
965	SBS

Curtin University

FTIR spectra for raw bitumen, car and truck rubber



Peak position (cm^{-1})	Component
1120	Filler (SiO_2, CB)
1665	NR
1490	SBR

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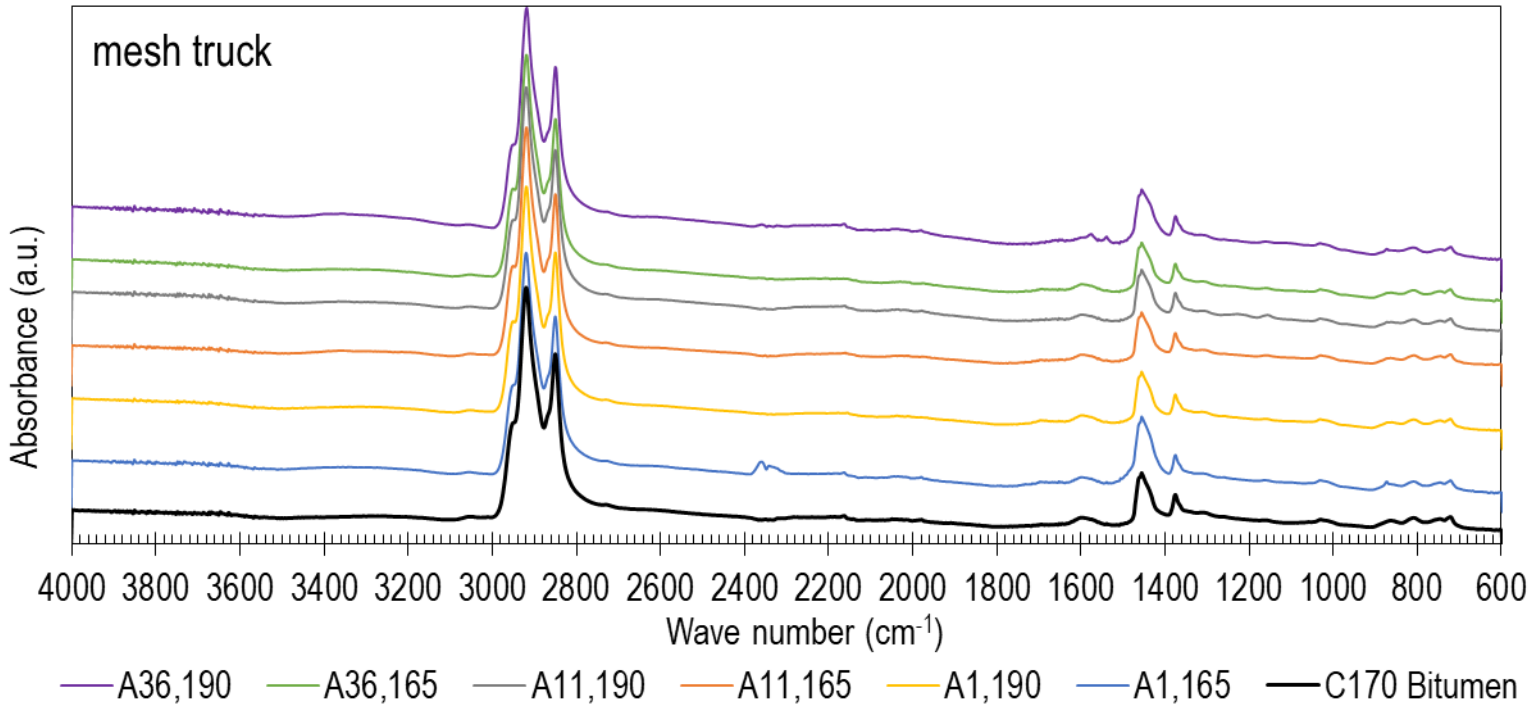
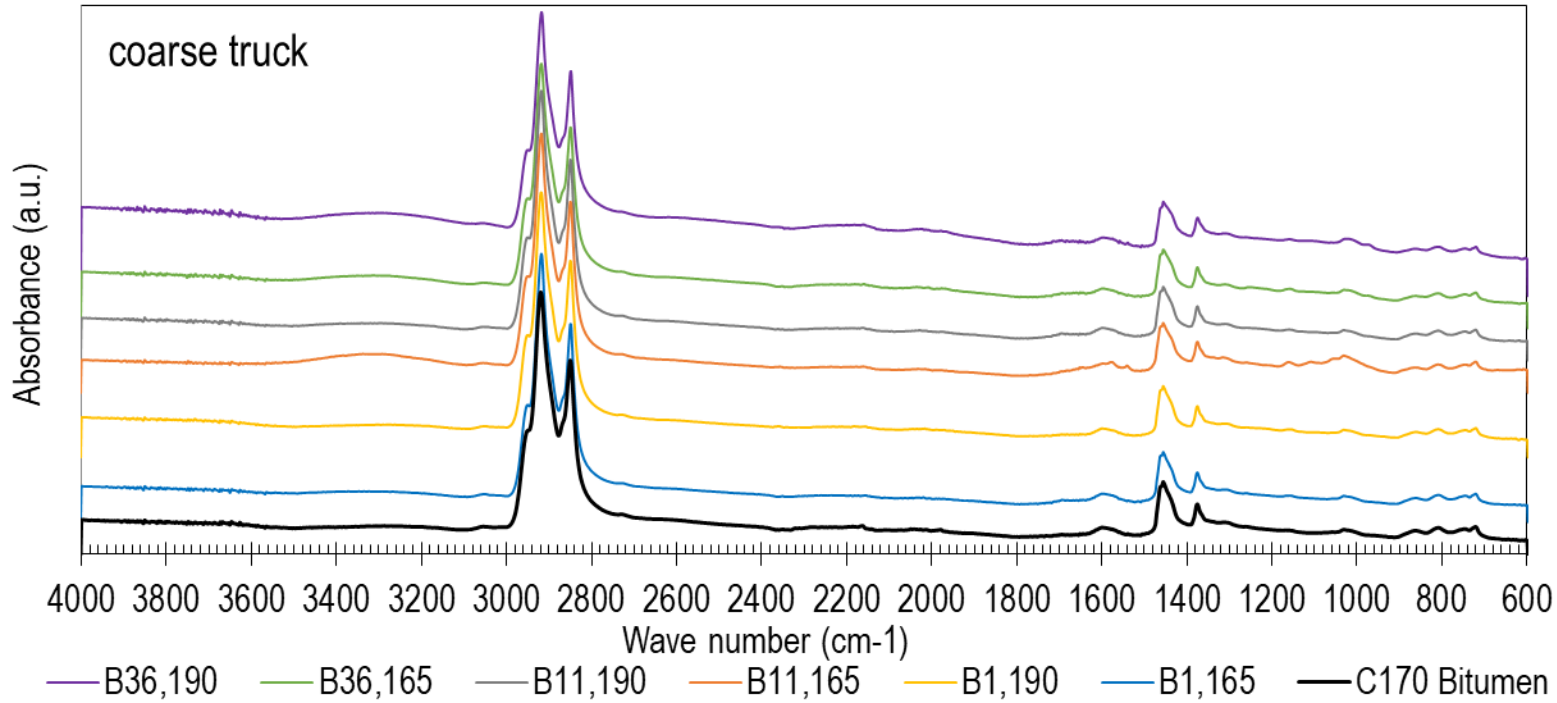
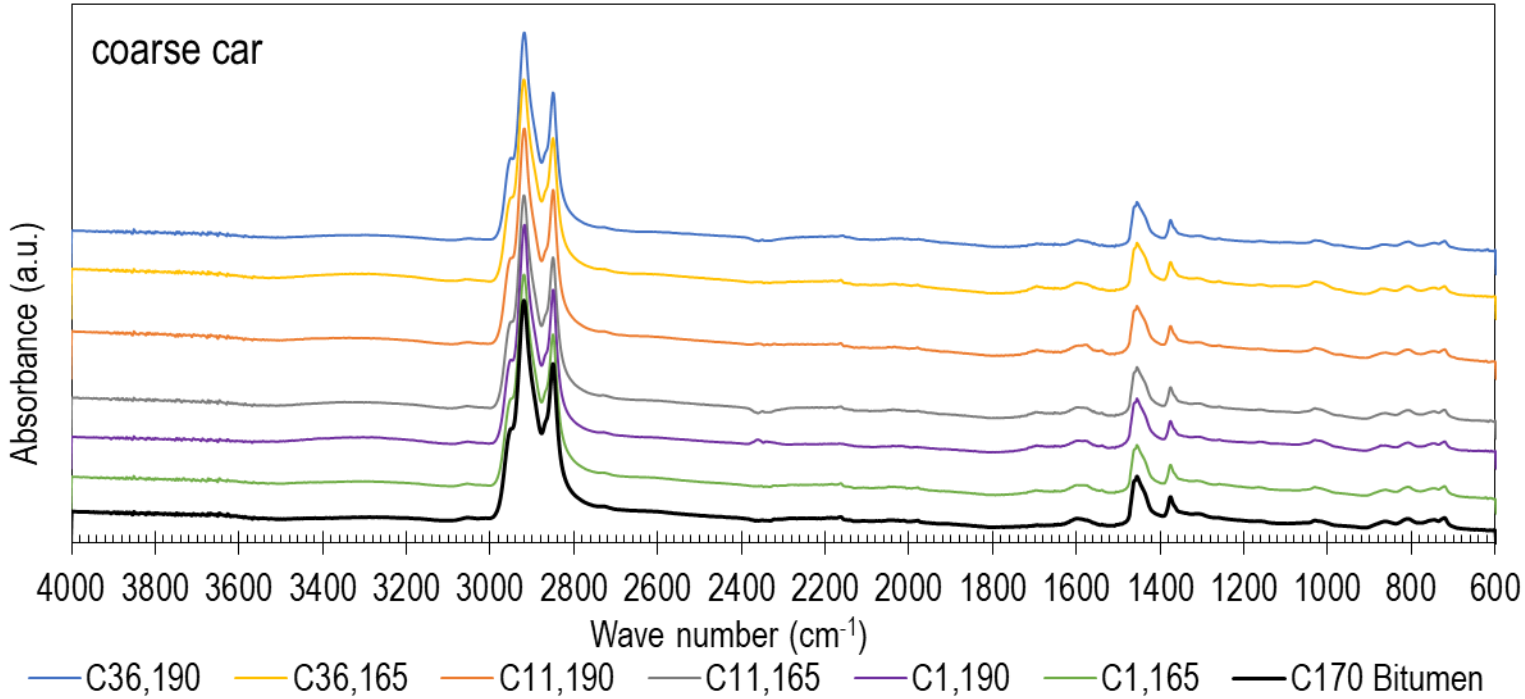
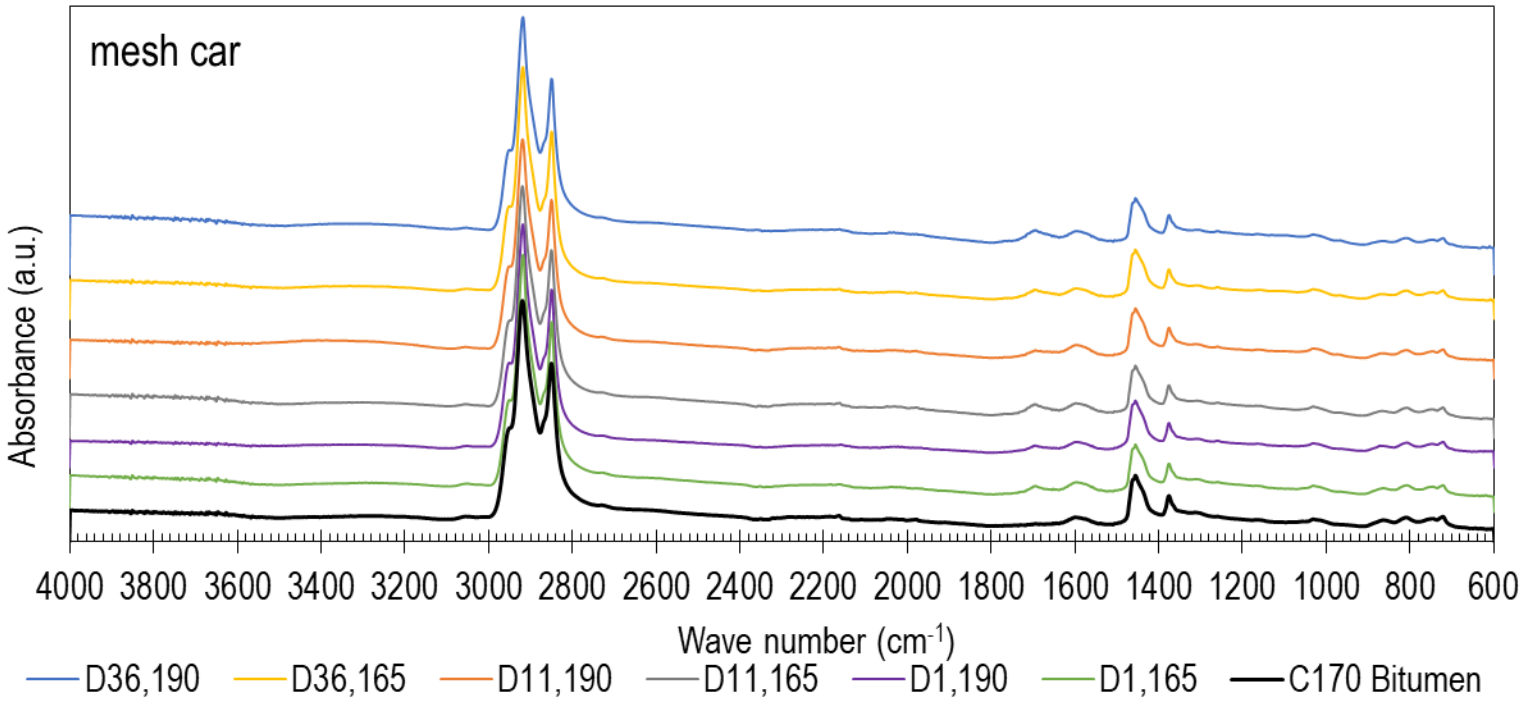
FTIR


mesh truck
Absorbance (a.u.)
4000 3800 3600 3400 3200 3000 2800 2600 2400 2200 2000 1800 1600 1400 1200 1000 800 600
Wave number (cm-1)
A36,190
A36,165
A11,190
A11,165
A1,190
A1,165
C170 Bitumen


coarse truck
Absorbance (a.u.)
4000 3800 3600 3400 3200 3000 2800 2600 2400 2200 2000 1800 1600 1400 1200 1000 800 600
Wave number (cm-1)
B36,190
B36,165
B11,190
B11,165
B1,190
B1,165
C170 Bitumen

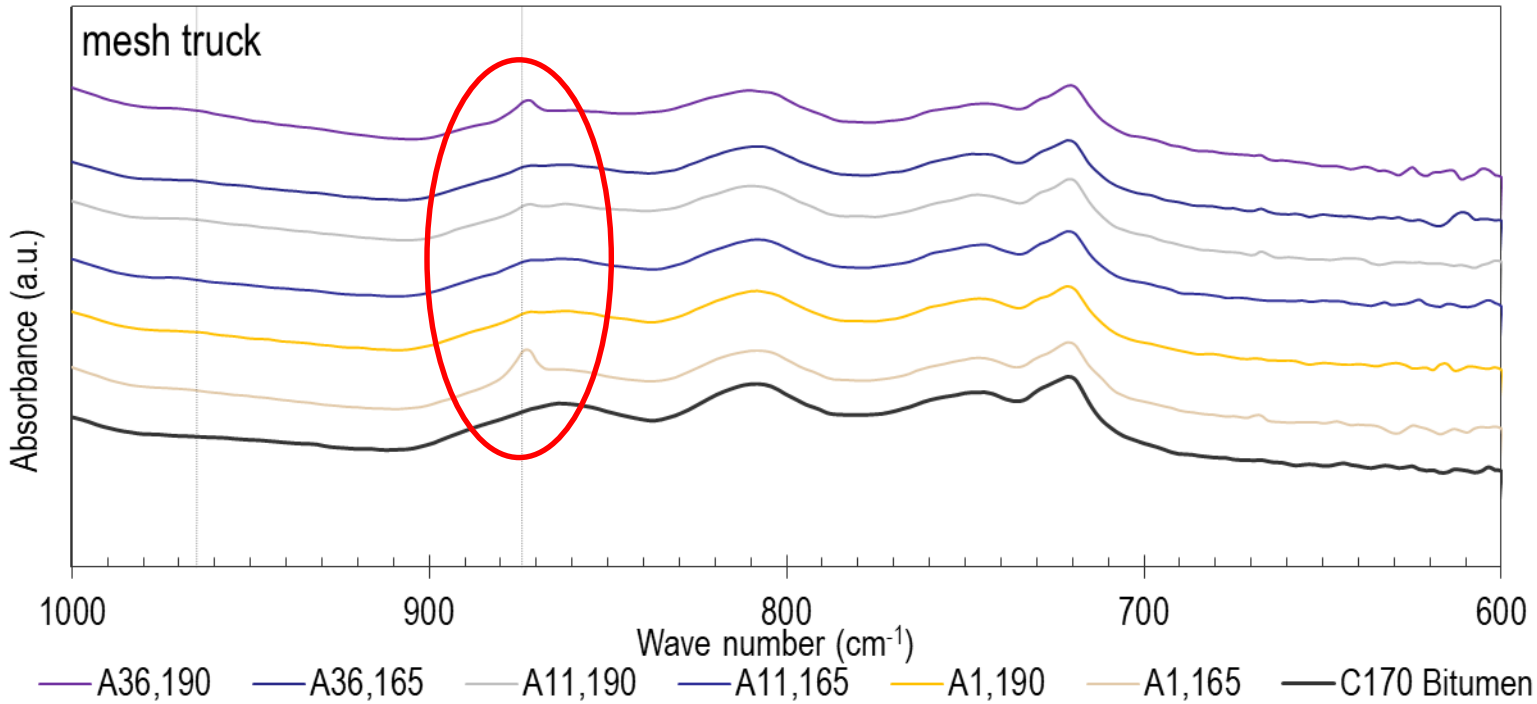
FTIR

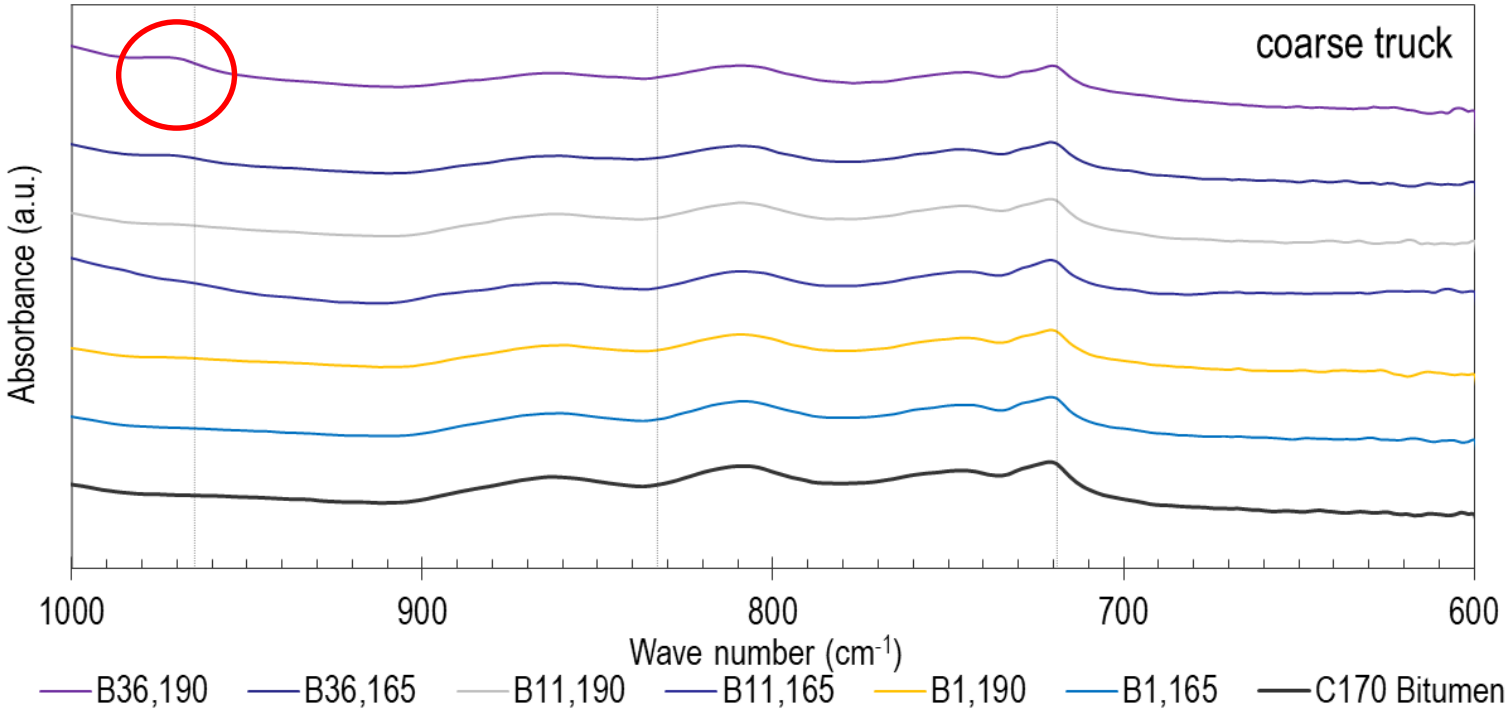


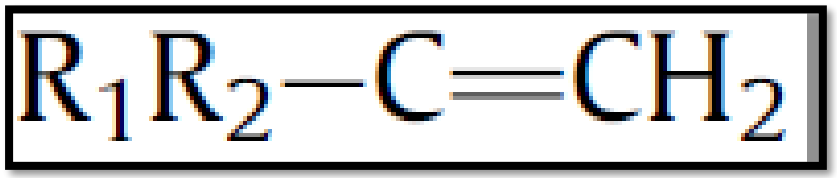


FTIR

~965 → SR



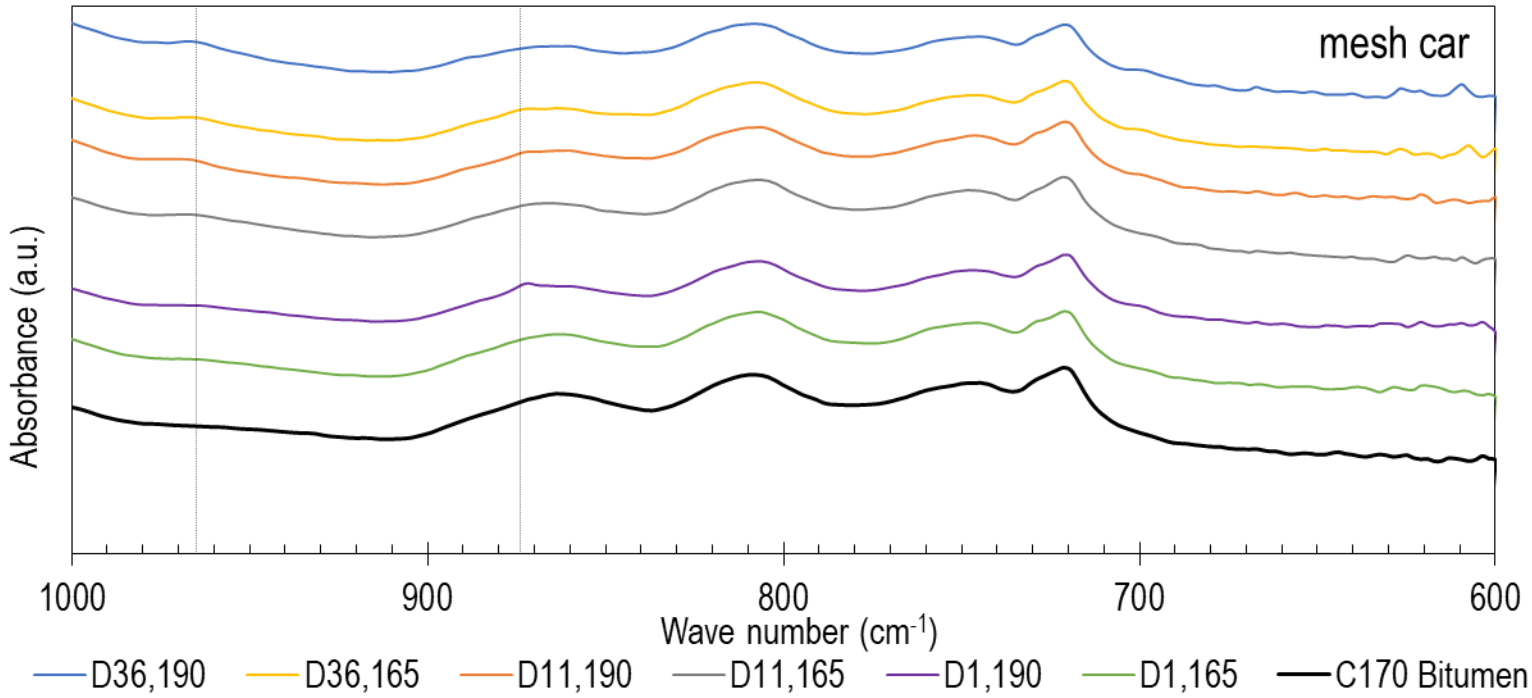


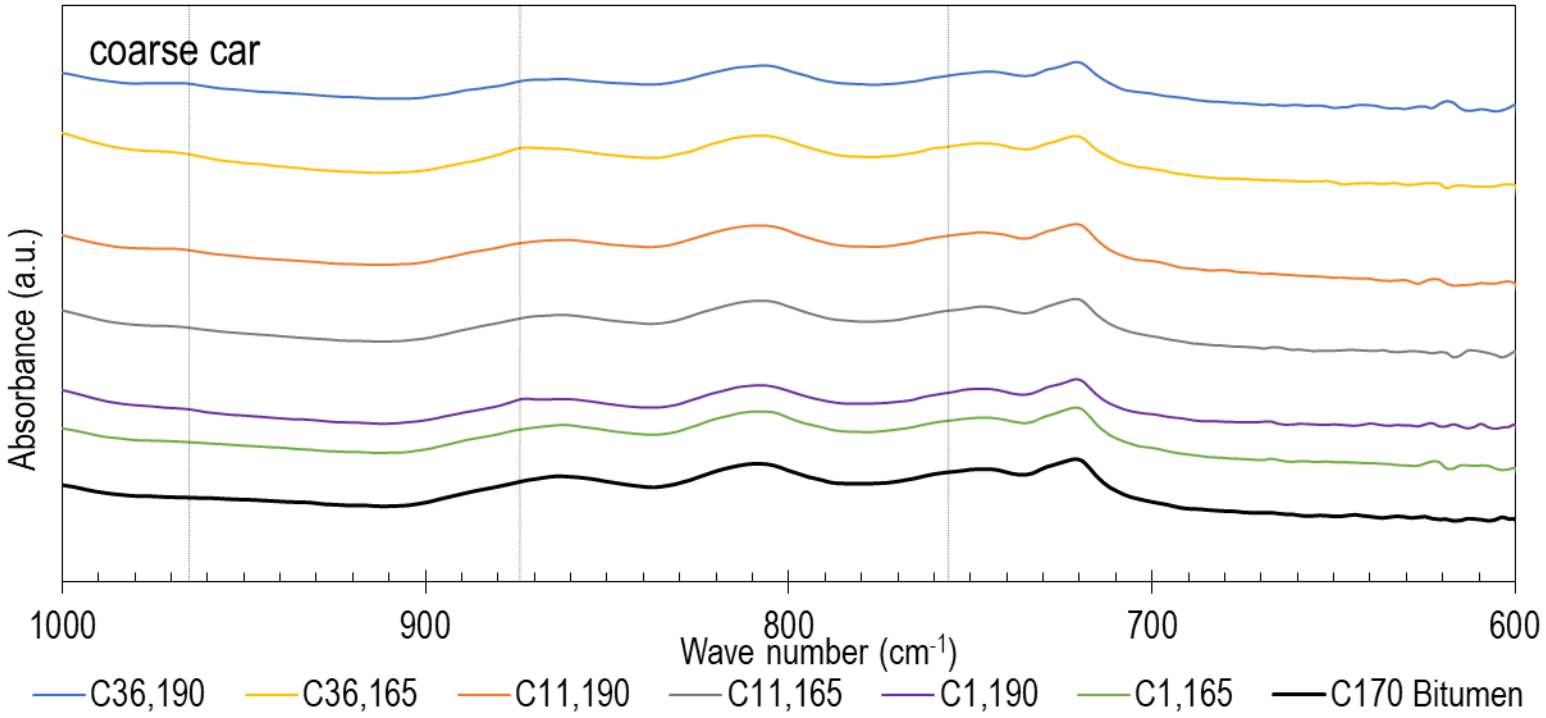


874

FTIR

~965 → SR





$R_1R_2-C=CH_2$

874

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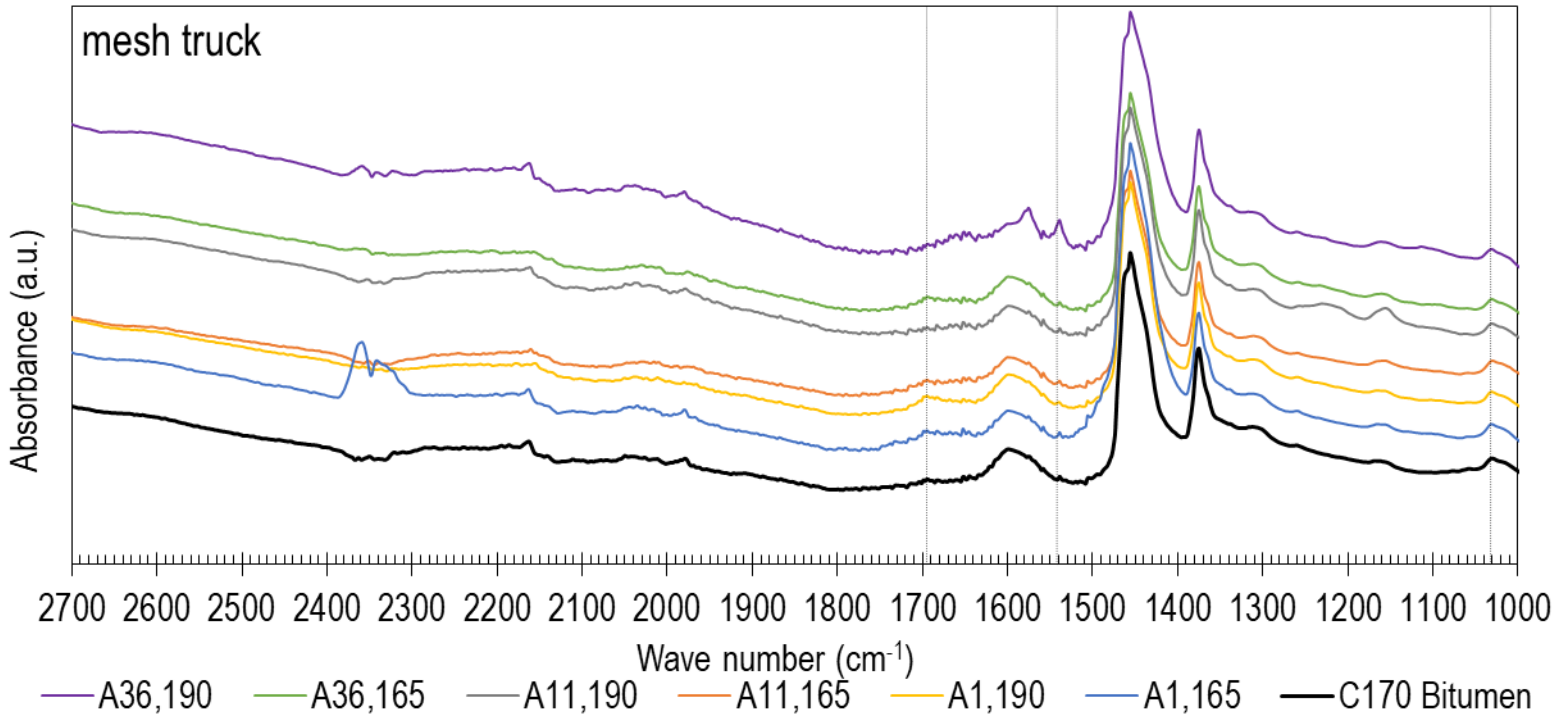
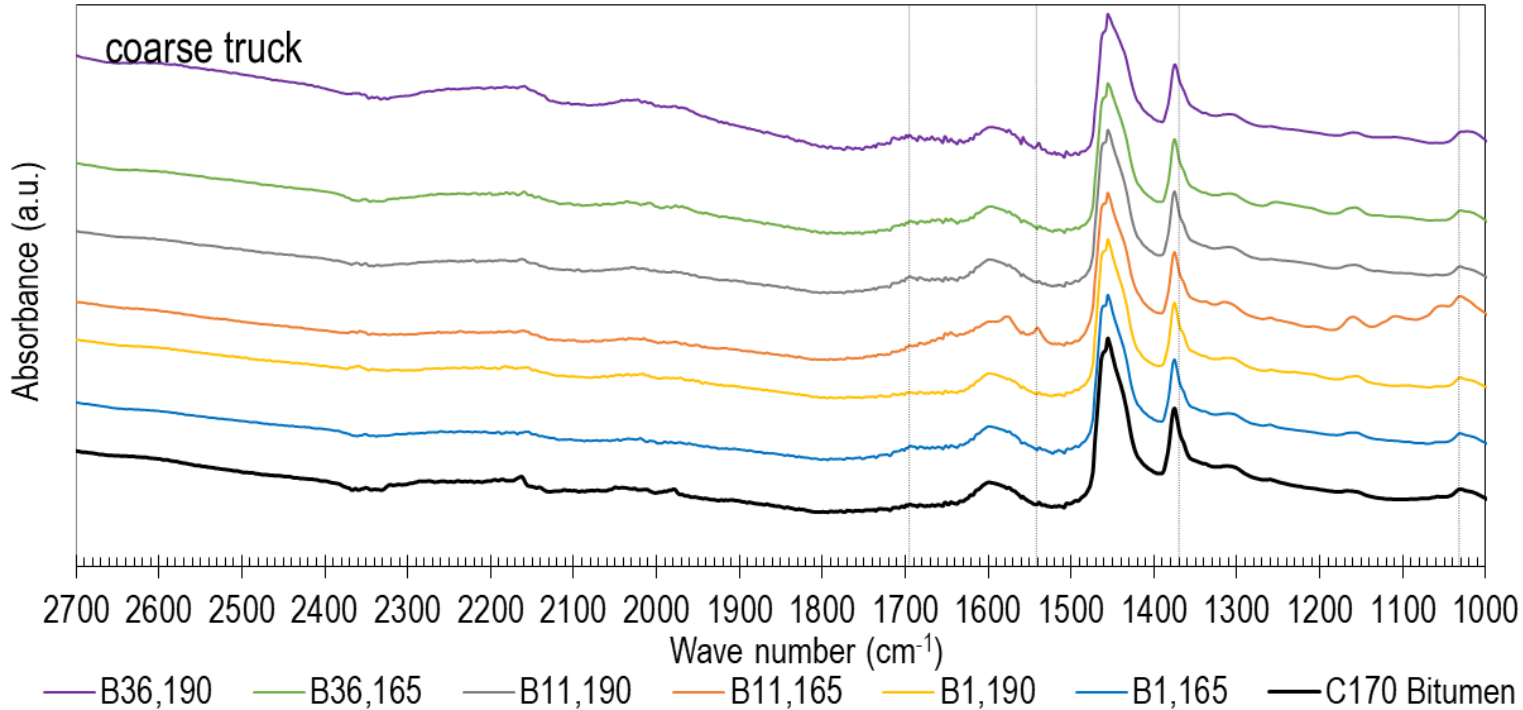
FTIR

~1700

C=O

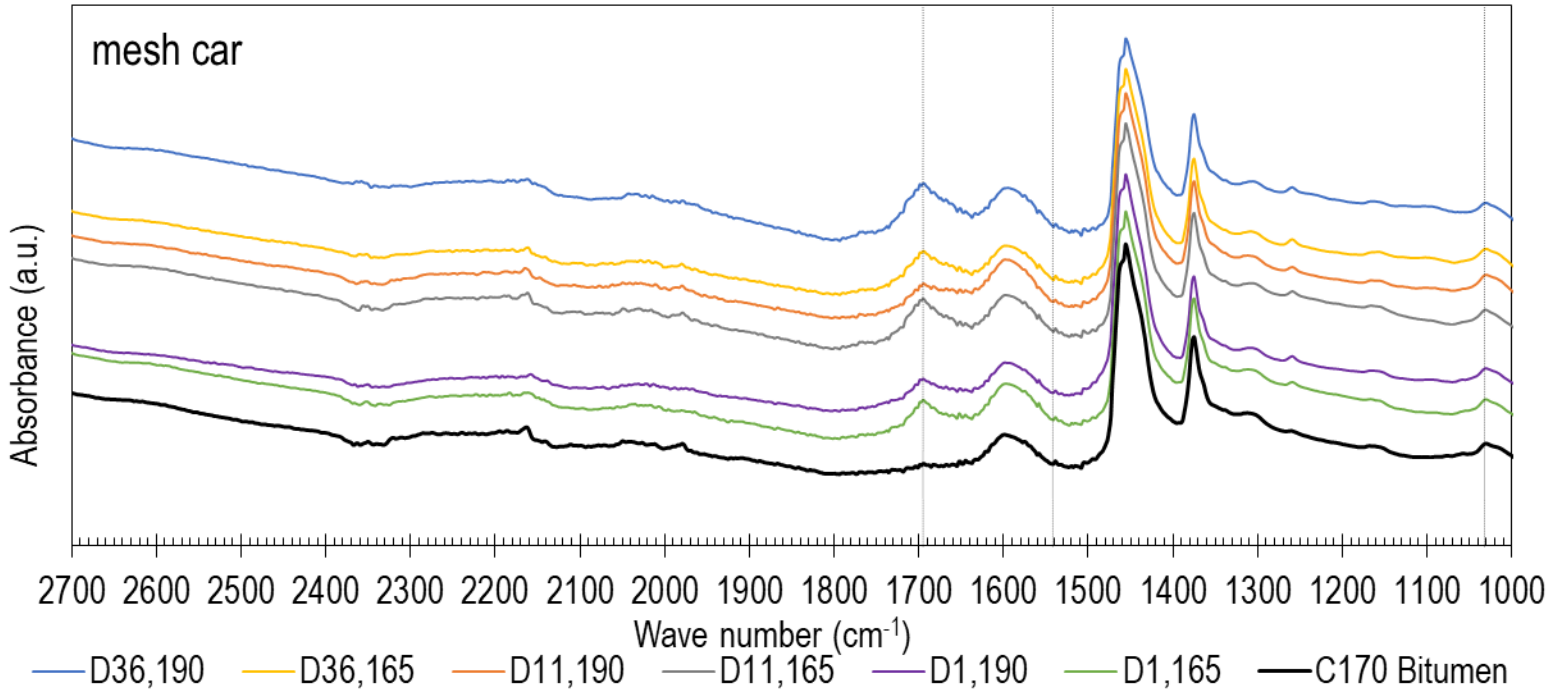

mesh truck
Absorbance (a.u.)
2700 2600 2500 2400 2300 2200 2100 2000 1900 1800 1700 1600 1500 1400 1300 1200 1100 1000
Wave number (cm-1)
A36,190
A36,165
A11,190
A11,165
A1,190
A1,165
C170 Bitumen

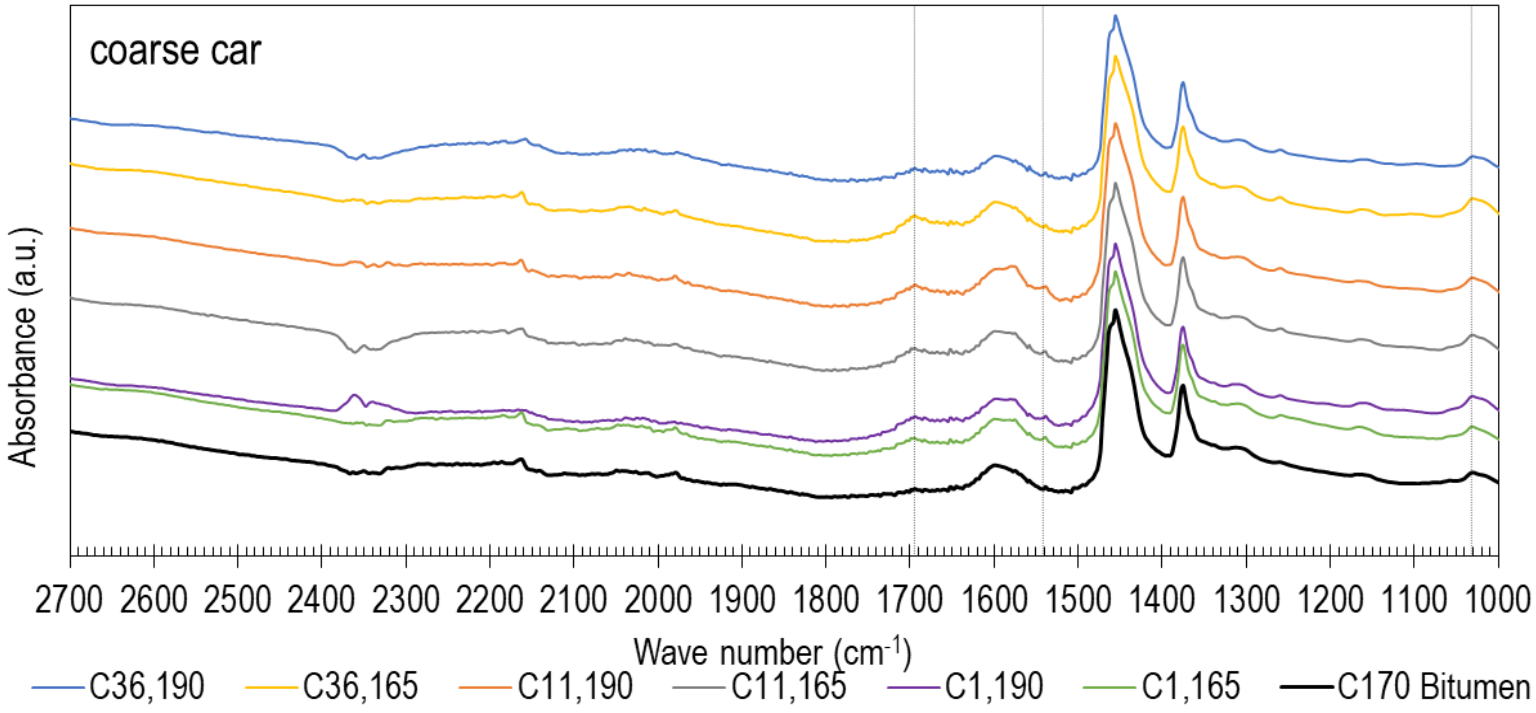

coarse truck
Absorbance (a.u.)
2700 2600 2500 2400 2300 2200 2100 2000 1900 1800 1700 1600 1500 1400 1300 1200 1100 1000
Wave number (cm-1)
B36,190
B36,165
B11,190
B11,165
B1,190
B1,165
C170 Bitumen

FTIR

~1700

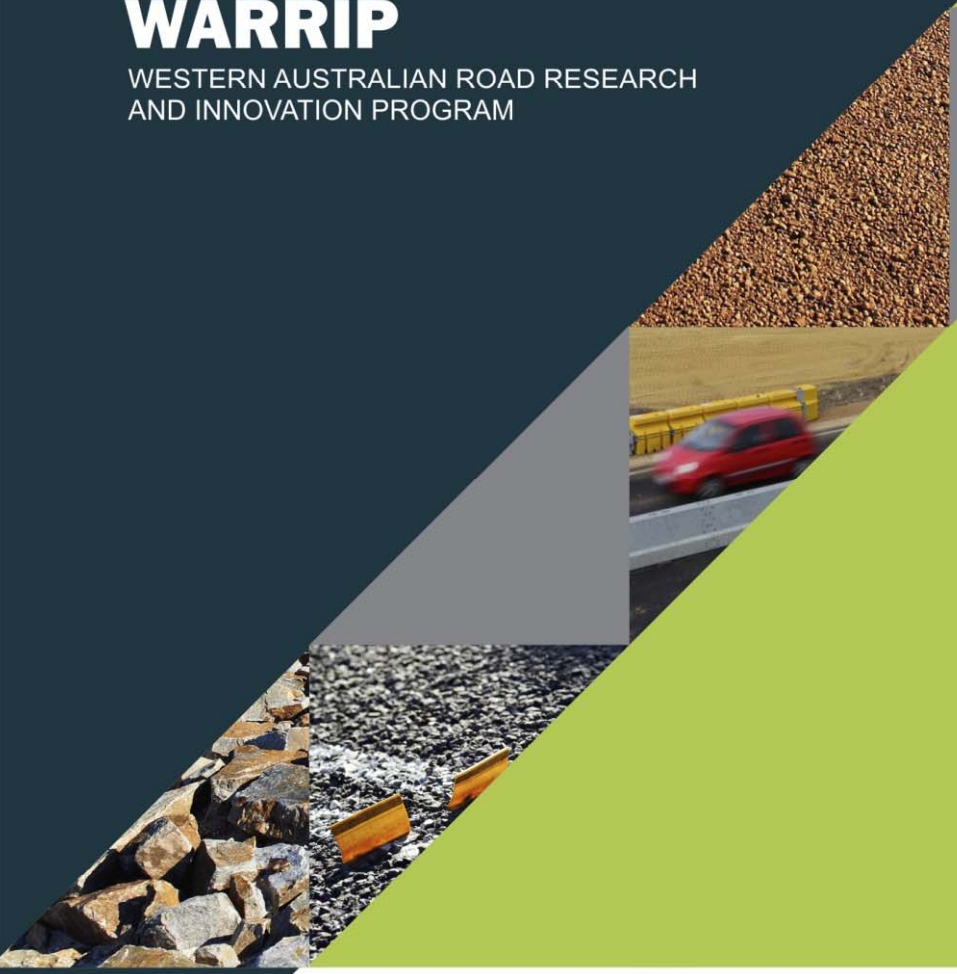
C=O





WARRIP

WESTERN AUSTRALIAN ROAD RESEARCH AND INNOVATION PROGRAM



Summary

AN INITIATIVE BY:

THE GOVERNMENT OF WESTERN AUSTRALIA

mainroads WESTERN AUSTRALIA

arrb AUSTRALIAN ROAD RESEARCH BOARD

Key Takeaways

- Standard Testing:
  - Truck & Passenger Tyre crumb appear to digest very similarly
  - Larger crumb size seems linked to slower changes to the binder
  - Lower temperatures result in slower changes to the binder
- Advanced Testing:
  - It is the natural rubber component that is digesting into the mix
  - Truck tyres have a higher NR component
  - Passenger tyres don’t digest as quickly as truck tyres
  - Crumb rubber may be reducing the aging of the binder

What questions still need answers?

- What is the impact of base binder on digestion?
- What is the impact of particle shape on digestion?
- How do these different blends impact the performance properties of downstream products such as asphalt and seals?
- Can we get more rubber into the binder (without using combining oils) by using a larger crumb?

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Thank you for your time and participation