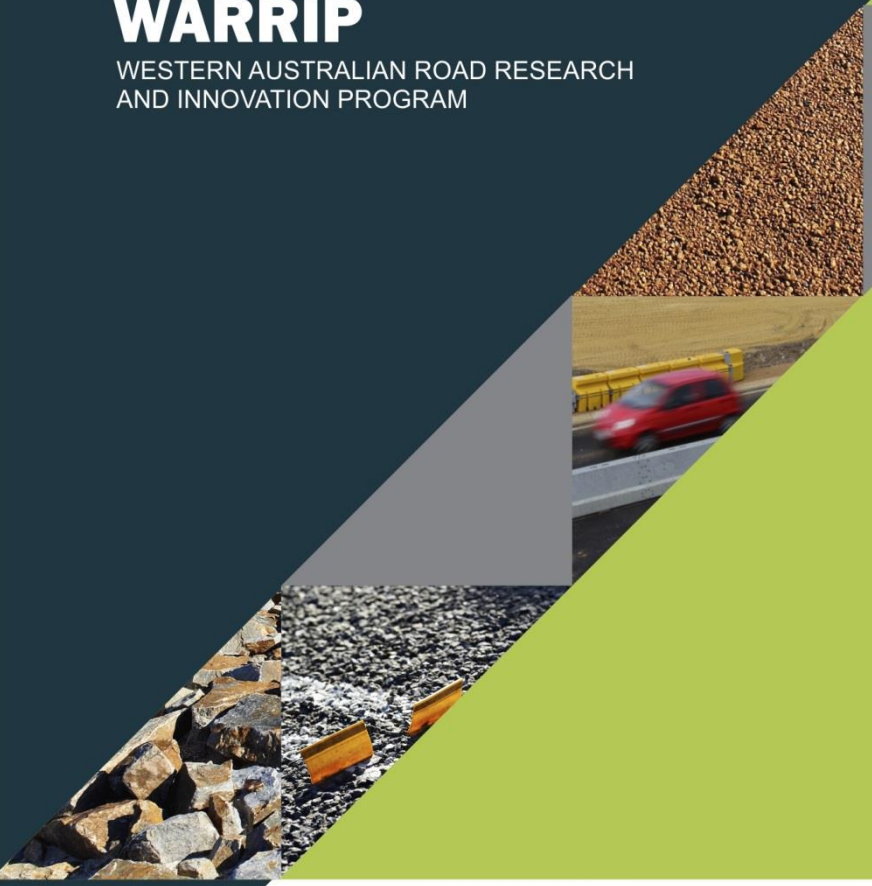
WARRIP

WESTERN AUSTRALIAN ROAD RESEARCH AND INNOVATION PROGRAM



Implementing Increased Use of Reclaimed Asphalt Pavement (RAP)

RAP Management Practice

9 May 2018

AN INITIATIVE BY:

THE GOVERNMENT OF WESTERN AUSTRALIA

mainroads WESTERN AUSTRALIA

arrb AUSTRALIAN ROAD RESEARCH BOARD

Content

- Welcome
- Project scope
- Austroads
- Current RAP management process in WA
- Monthly data
- Variability during processing
- RAP management practice
- Discussion of trial process
- Summary of discussion

Project scope

Milestone	Completion Date
Develop detailed project plan	Feb 2018
Literature review	Mar 2018
Evaluation of measured variability over time and between suppliers	Mar 2018
Develop MRWA best practice RAP management position	Mar 2018
Consultation with industry	**May 2018**
Evaluation of measured variability from single stockpile from single supplier before and after implementation of best practice RAP management	Jun 2018
Develop MRWA minimum plant capability position	Aug 2018
Consultation with industry	Sept 2018
Set up, coordinate and testing of RAP trial	Jan 2019
Develop MRWA specifications and supporting technical documentation	Apr 2019
Consultation with industry	**May 2019**
Finalise contract report	Jun 2019

Austroads Process

- Project TT1817 (2016)
  - mix design requirements to ensure asphalt mixes with high RAP contents will provide adequate performance
  - Project Report AP – R517 - 16
- Learnings resulted in publication of Test Method T193 *Design of Bituminous Binder Blends to a Specified Viscosity Value*
- Method T193 based on DSR complex viscosity (η*) test result at 60°C and angular frequency of 1 rad/s

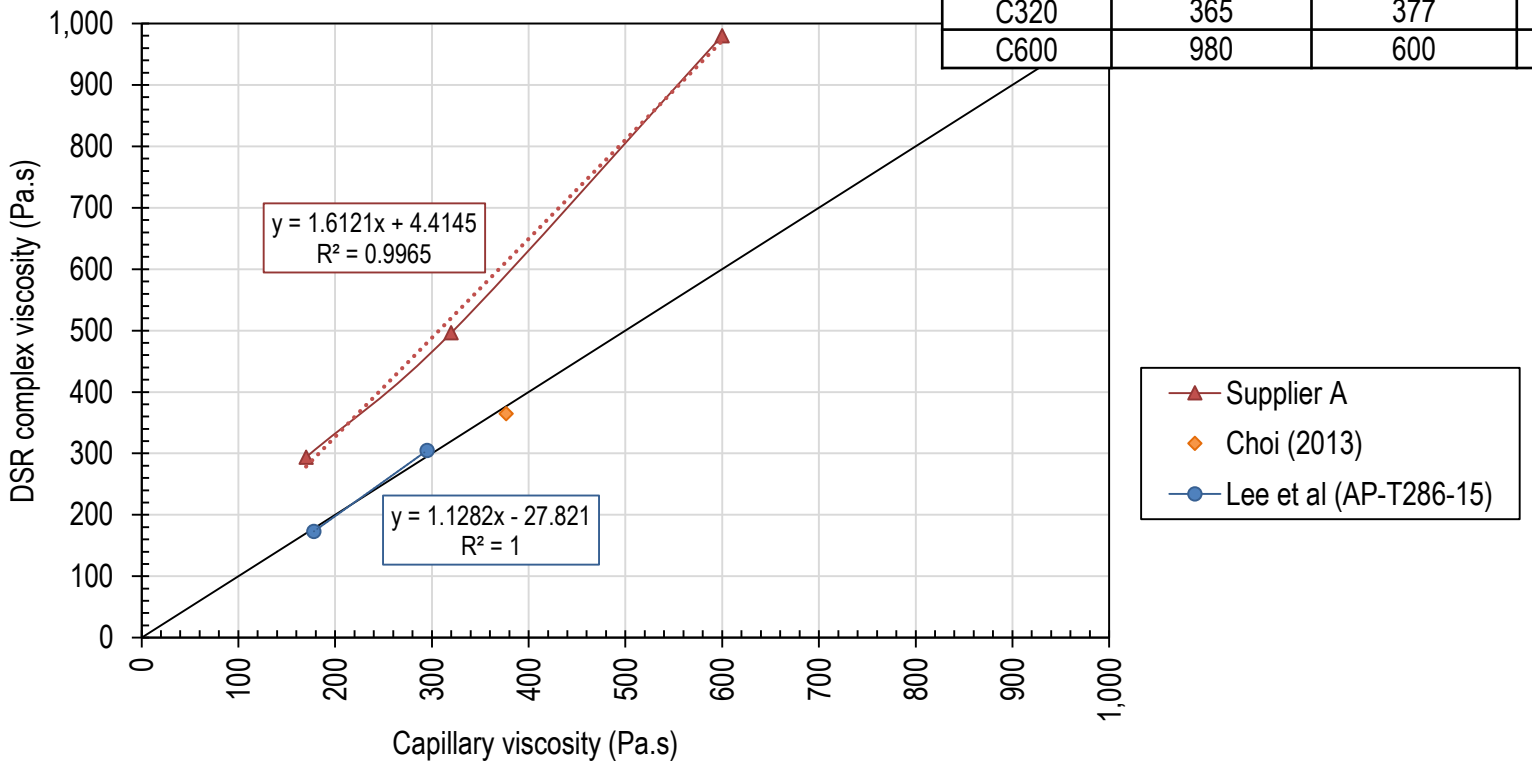
Austroads Process (cont.)

- DSR viscosity considered similar to that of viscosity measured at the same temperature with the viscometer

$$VBI_i = \frac{3 + log\vartheta_i}{6 + \vartheta_i} \Rightarrow VBI_\beta = \sum_{i=1}^{n} x_i \cdot VBI_i \Rightarrow \mu = 10^{\left(\frac{3 \cdot VBI_\beta}{1 - VBI_\beta} - 3\right)}$$

DSR complex viscosity versus capillary viscosity

Virgin Binder	DSR complex viscosity (Pa.s)	Capillary viscosity (Pa.s)	Source
C170	294	170	Supplier A
C170	173	178	Lee et al (AP-T286-15)
C320	496	320	Supplier A
C320	305	295	Lee et al (AP-T286-15)
C320	365	377	Choi (2013)
C600	980	600	Supplier A



Current RAP management process in WA

Raw RAP stockpile

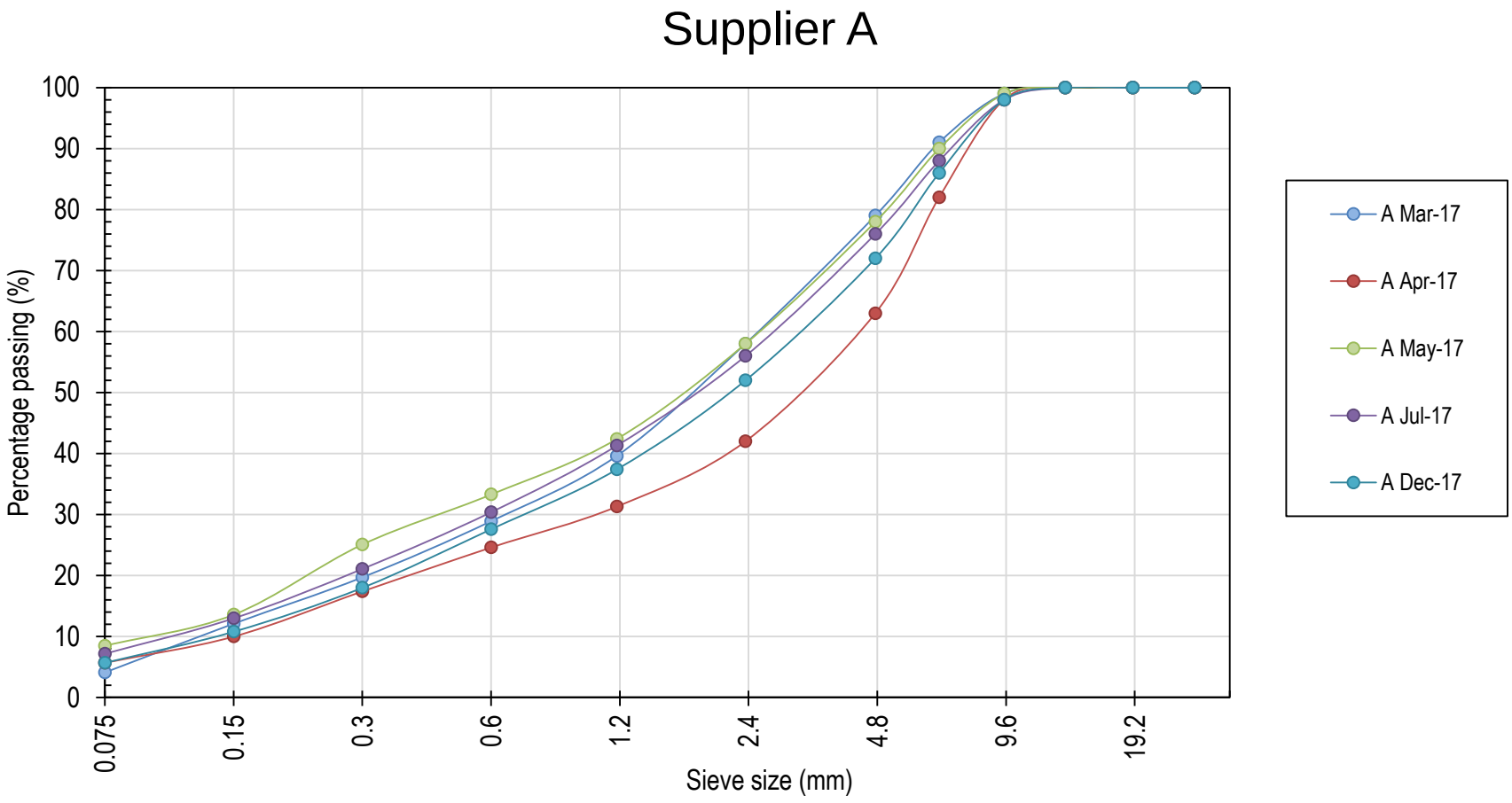
Crush and screen

Processed RAP stockpile

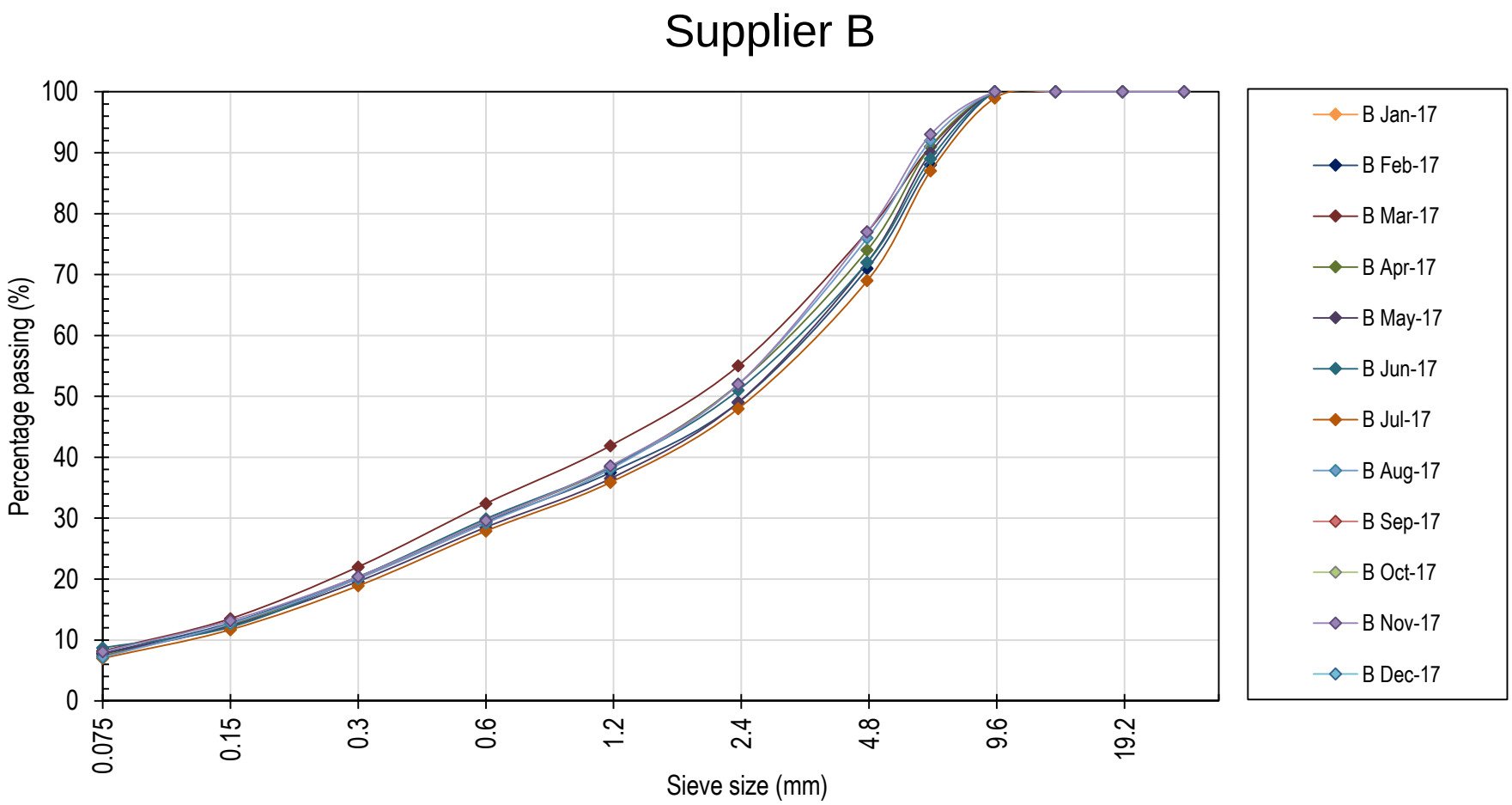
Monthly data

- Three asphalt suppliers within Perth metro area
- Sample from processed RAP stockpiles during 2017
- Aim to measure variability of processed RAP
- Discuss
  - Particle size distribution (PSD)
  - Binder content
  - Moisture content
  - DSR complex viscosity
  - Binder blend (AGPT/T193)

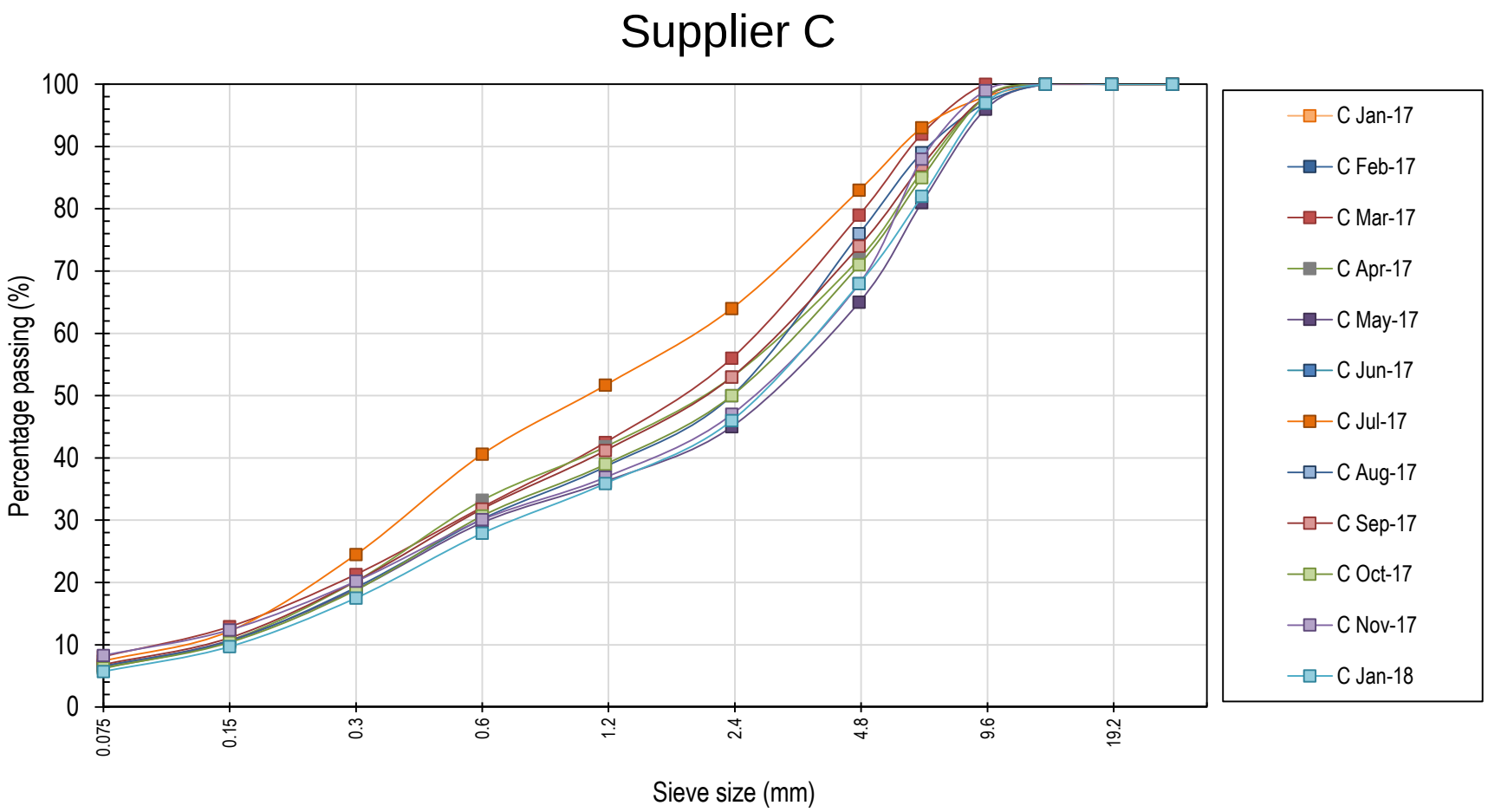
Monthly data – PSD



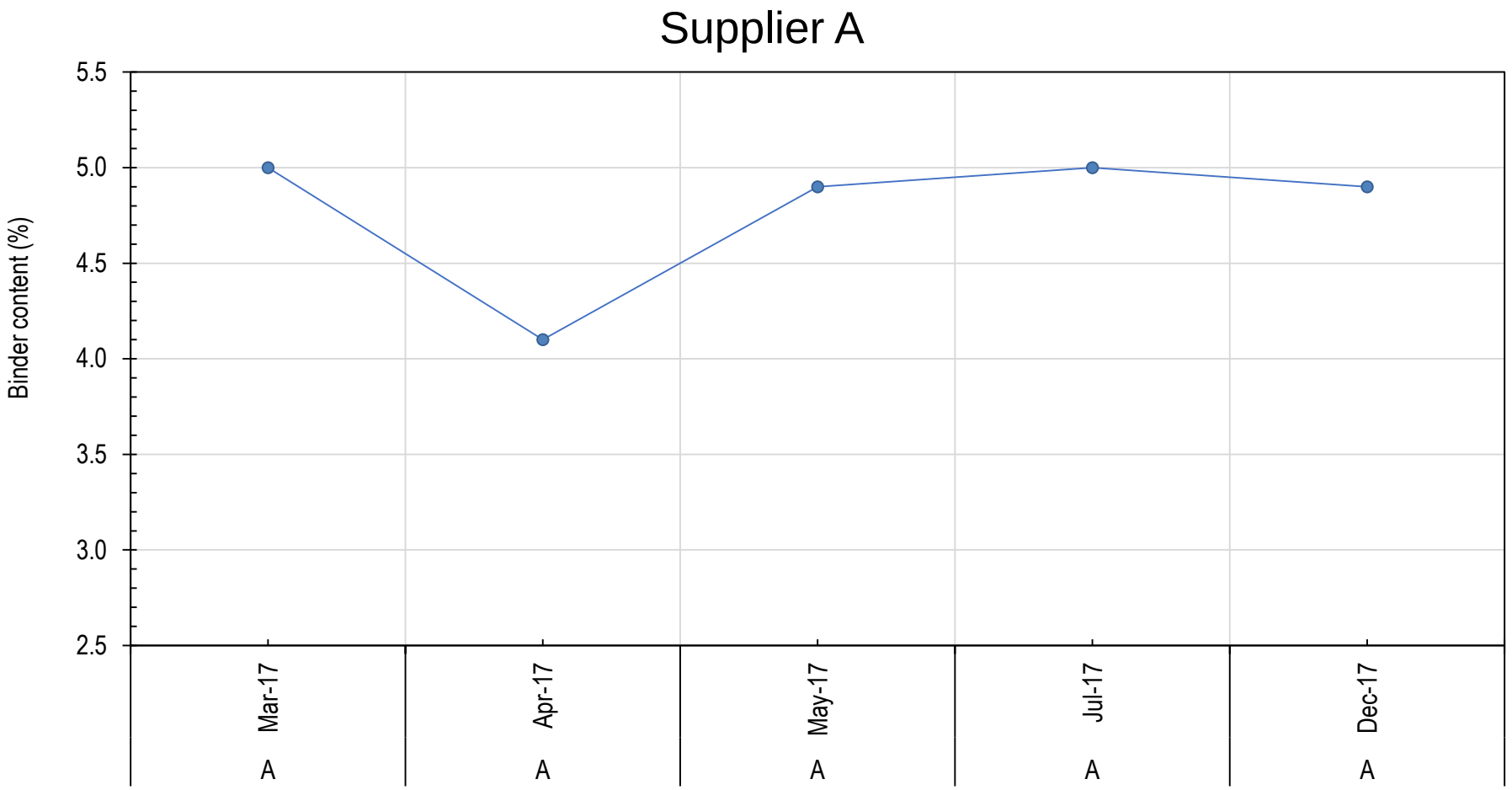
Monthly data – PSD



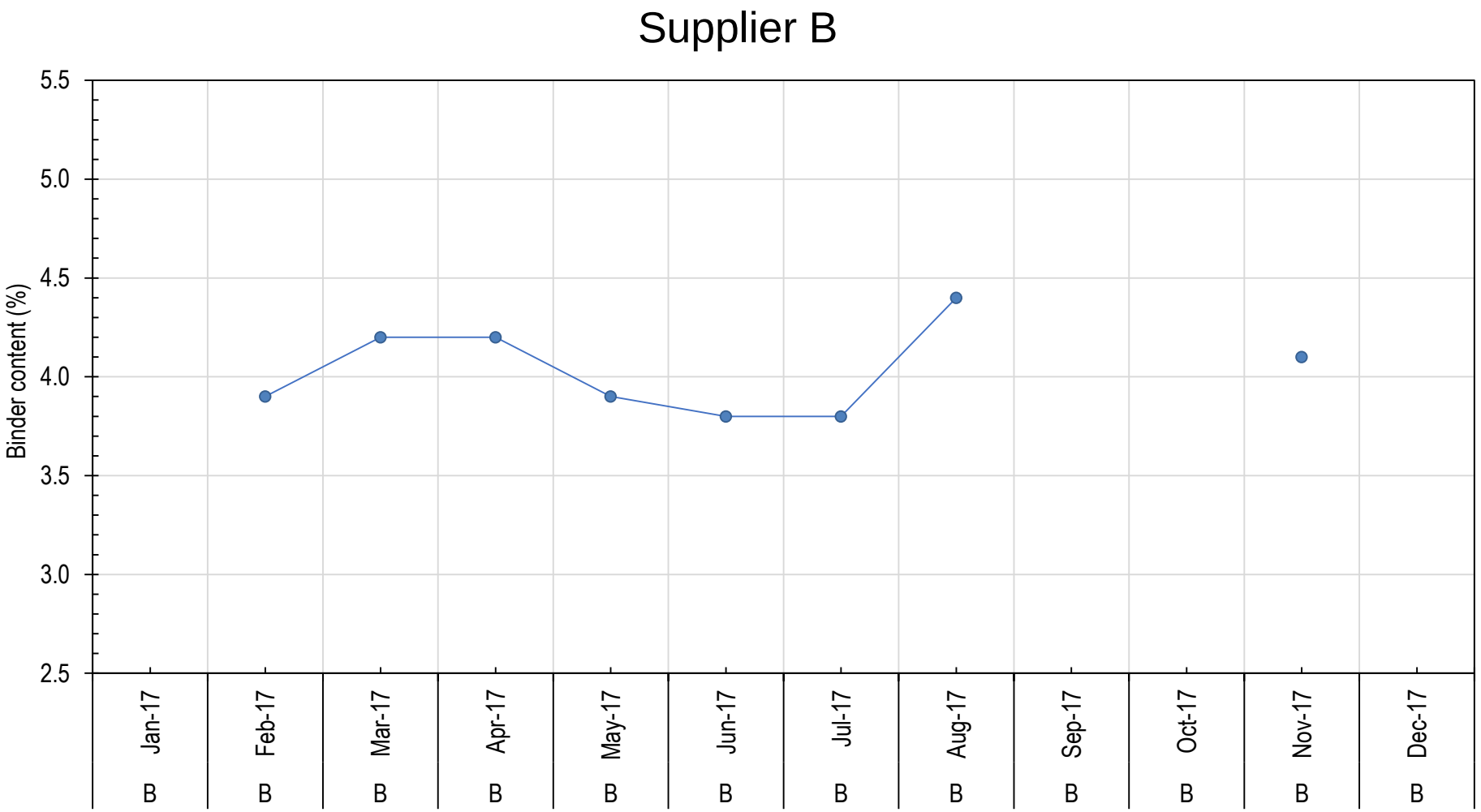
Monthly data – PSD



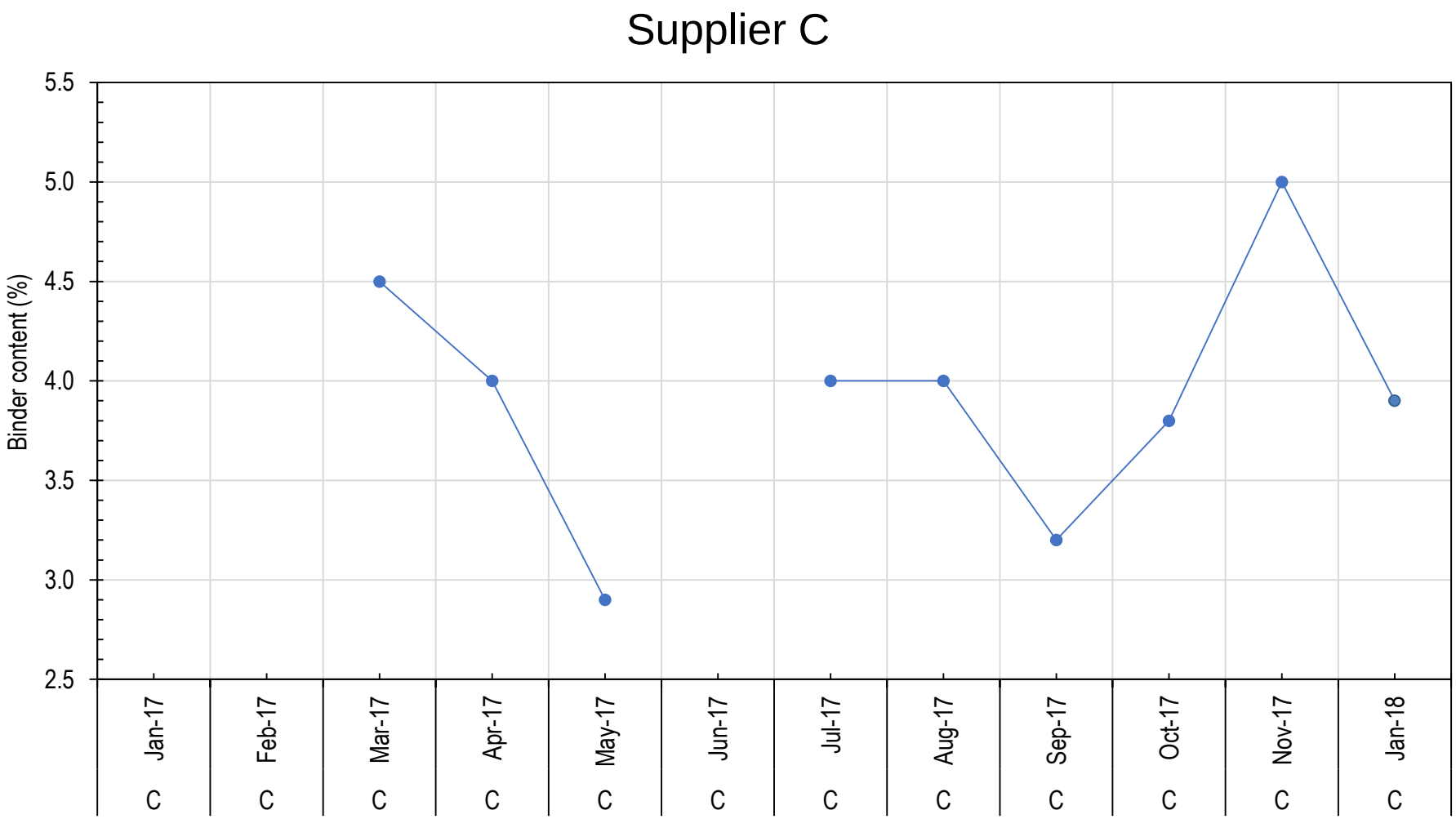
Monthly data – Binder content



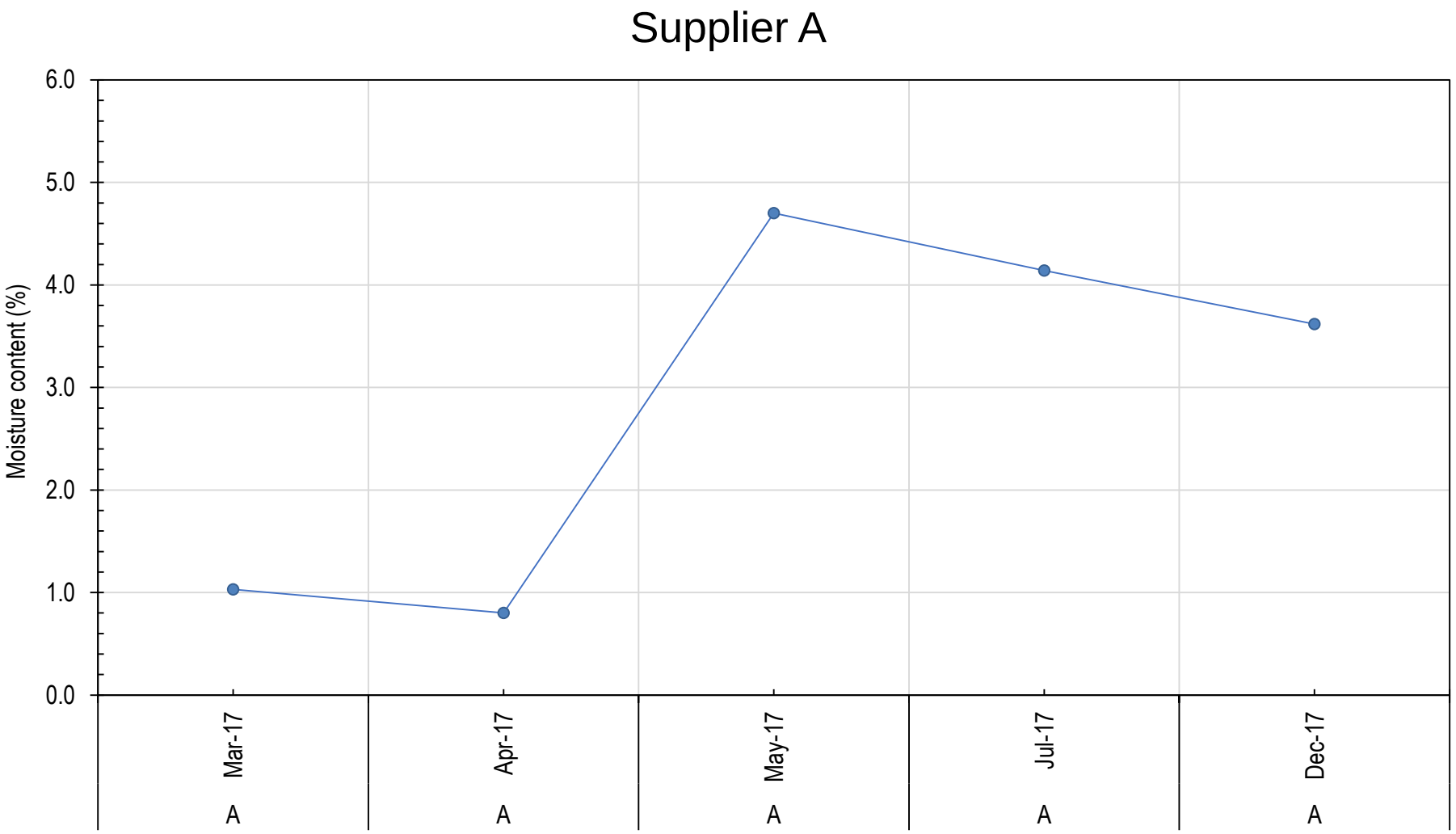
Monthly data – Binder content



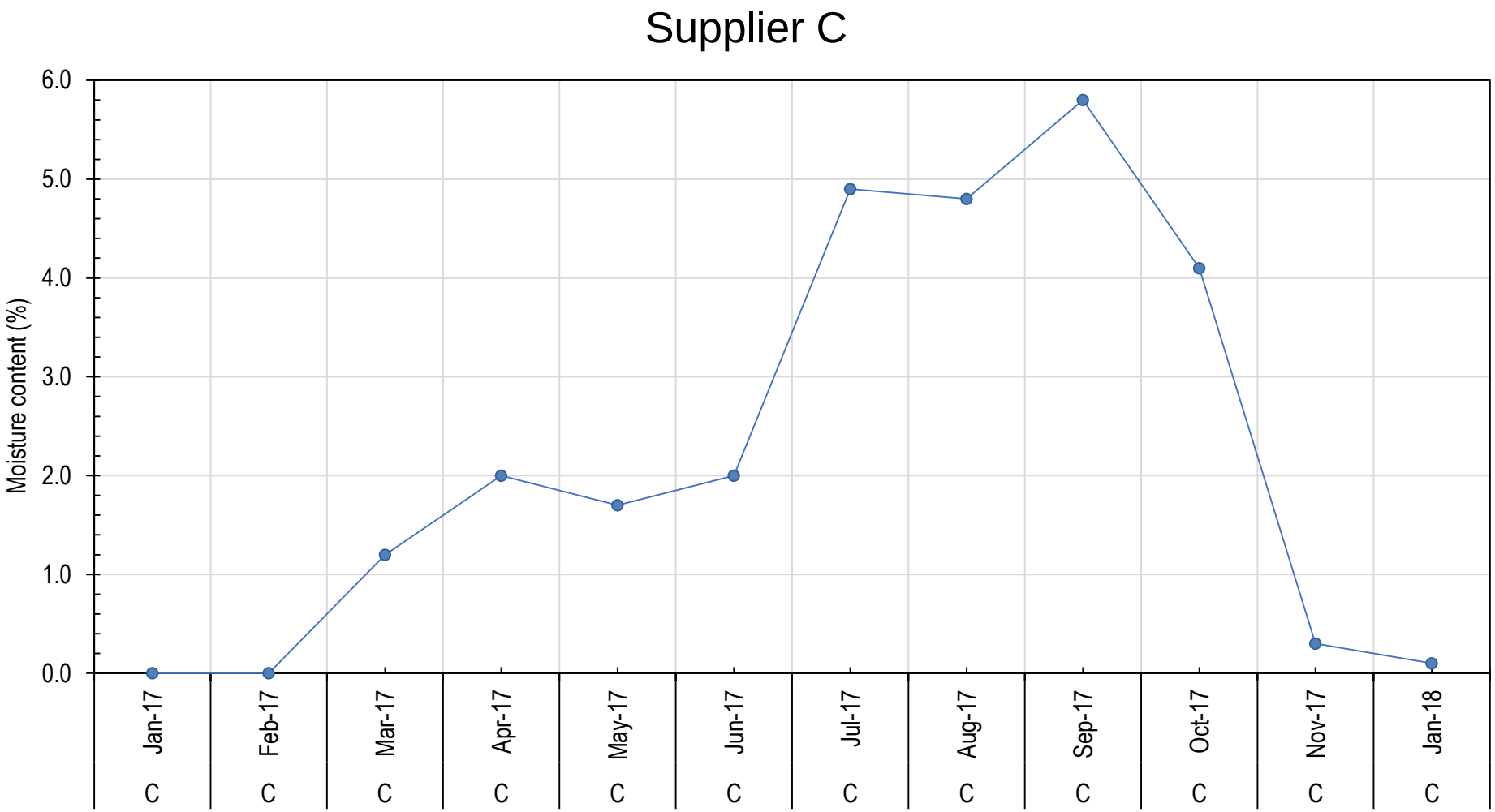
Monthly data – Binder content



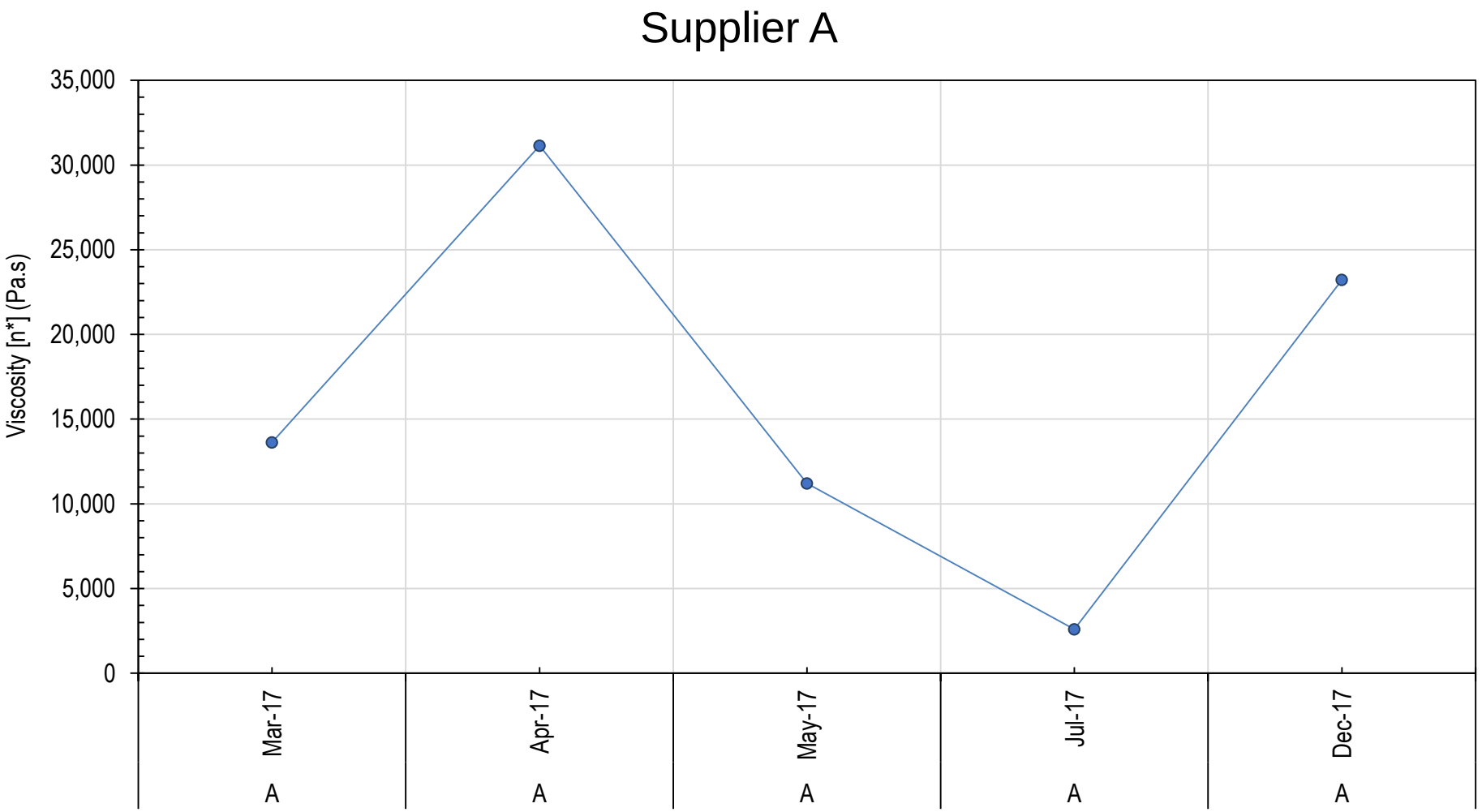
Monthly data – Moisture content



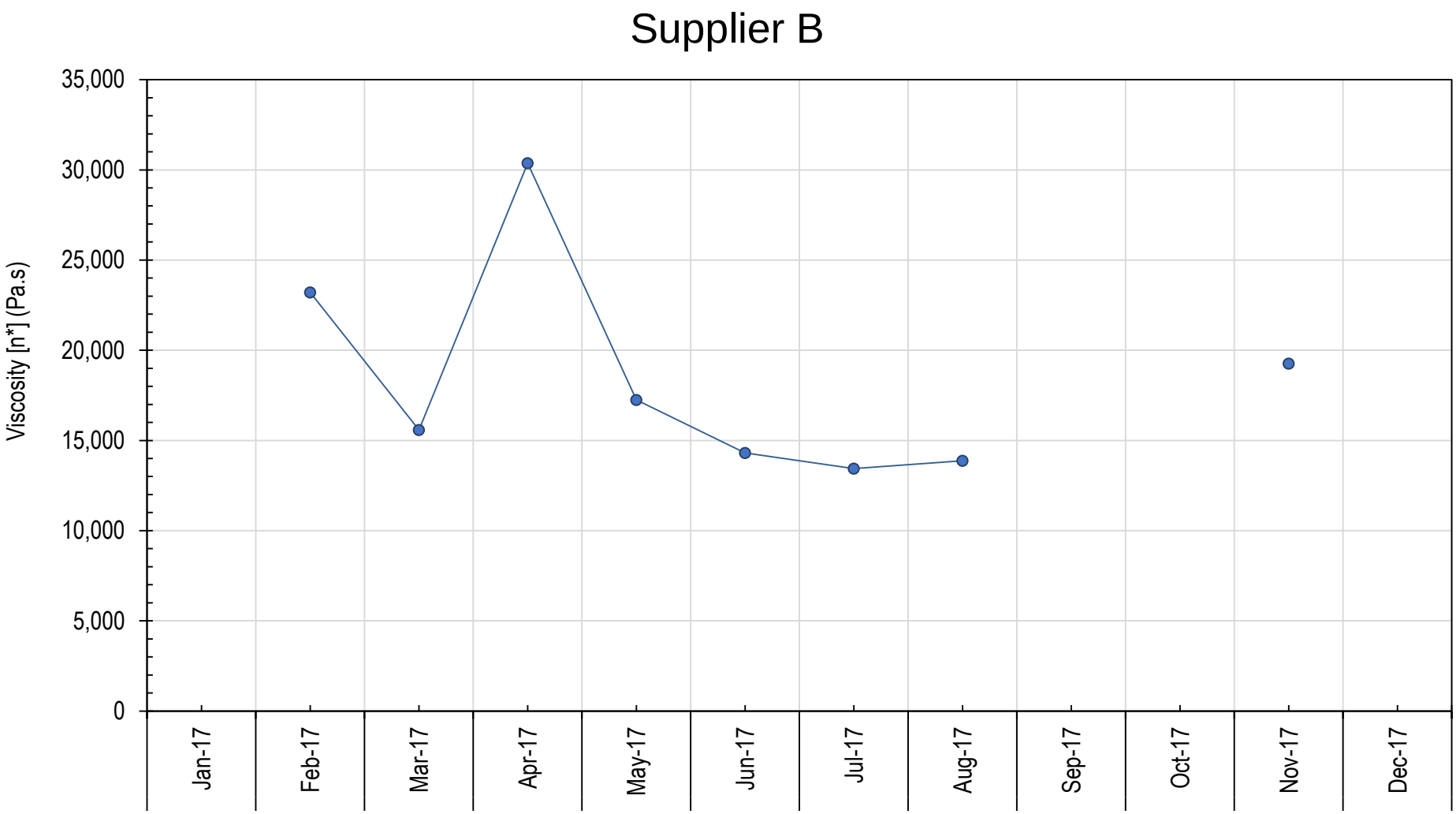
Monthly data – Moisture content



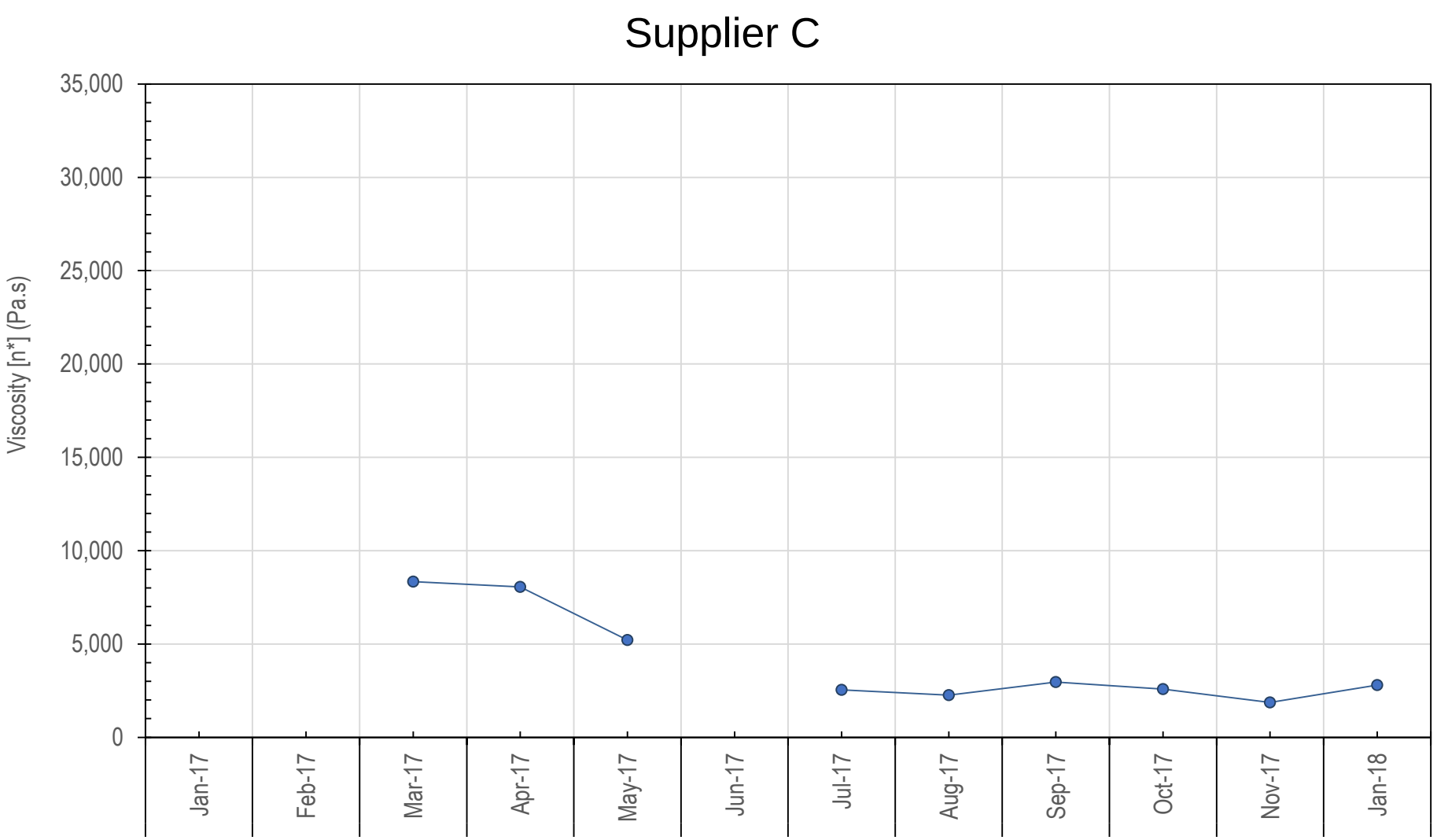
Monthly data – DSR complex viscosity



Monthly data – DSR complex viscosity



Monthly data – DSR complex viscosity



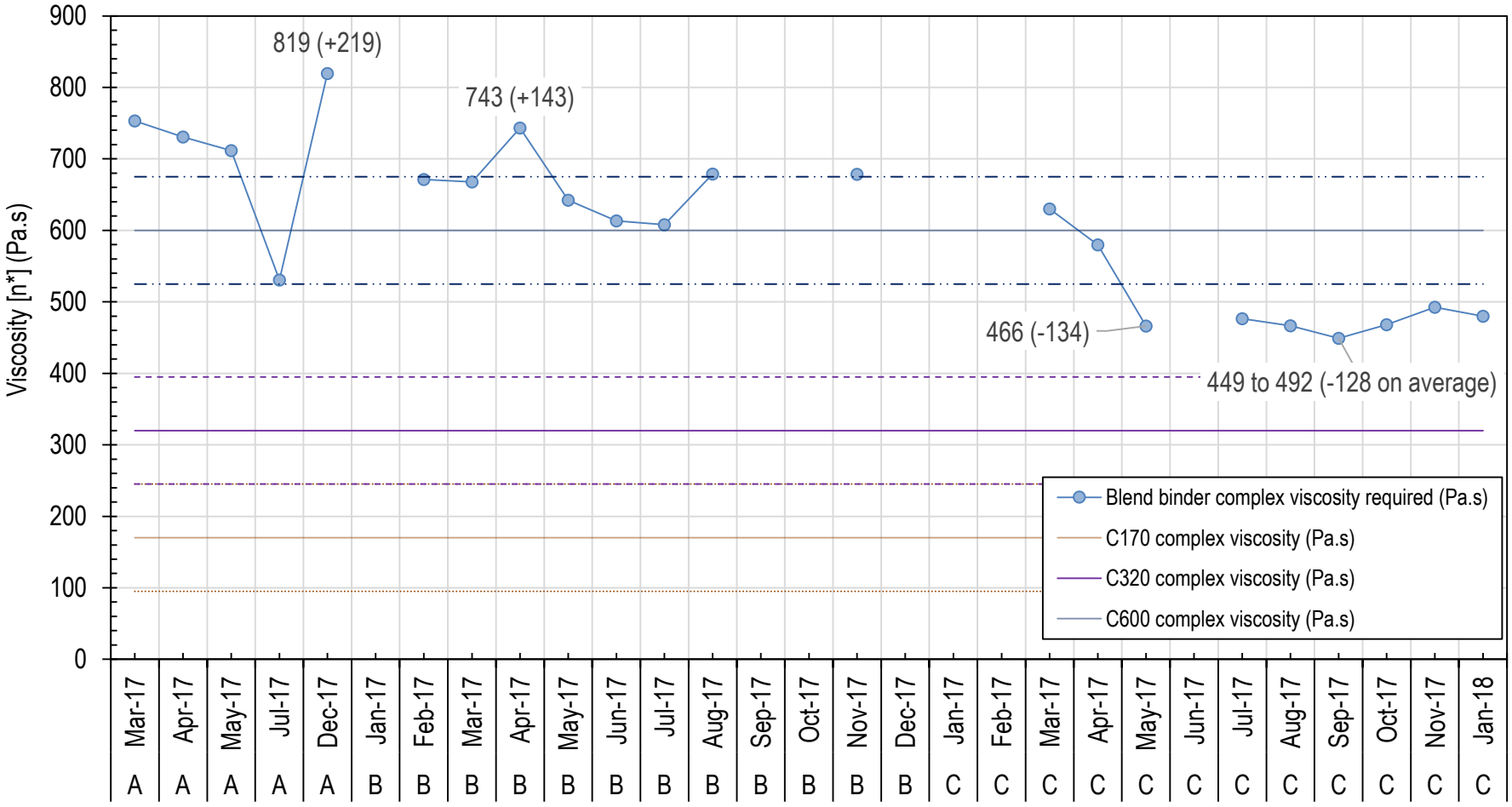
Monthly data – Binder blend

- Scenario 1
  - RAP content 25%, variable binder content
  - Target binder content of asphalt mix containing RAP at 4.8%
  - C320 virgin binder, DSR complex viscosity of 320 Pa.s
  - No low viscosity oil added
  - *Blend aim for DSR complex viscosity of 600 Pa.s (C600)*

Monthly data – Binder blend (continued)

Supplier	Month sampled	RAP Binder content (%)	RAP binder proportion (x_{RAP})	ϑ_{RAP} (Pa.s)	VBI_{RAP} (Pa.s)	C320 proportion (x_{C320})	$VBI_{ß}$	μ (Pa.s)
A	Mar-17	5.00	0.260	13,630	0.704	0.740	0.662	753
A	Apr-17	4.10	0.214	31,145	0.714	0.786	0.662	731
A	May-17	4.90	0.255	11,205	0.701	0.745	0.661	712
A	Jul-17	5.00	0.260	2,603	0.681	0.740	0.656	531
A	Dec-17	4.90	0.255	23,215	0.711	0.745	0.663	819
B	Feb-17	3.90	0.203	23,205	0.711	0.797	0.660	671
B	Mar-17	4.20	0.219	15,575	0.706	0.781	0.660	668
B	Apr-17	4.20	0.219	30,370	0.714	0.781	0.662	743
B	May-17	3.90	0.203	17,240	0.707	0.797	0.659	642
B	Jun-17	3.80	0.198	14,305	0.705	0.802	0.659	613
B	Jul-17	3.80	0.198	13,440	0.704	0.802	0.658	608
B	Aug-17	4.40	0.229	13,880	0.704	0.771	0.660	679
B	Nov-17	4.10	0.214	19,265	0.708	0.786	0.660	678
C	Mar-17	4.50	0.234	8,339	0.698	0.766	0.659	630
C	Apr-17	4.00	0.208	8,059	0.697	0.792	0.658	580
C	May-17	2.90	0.151	5,217	0.691	0.849	0.654	466
C	Jul-17	4.00	0.208	2,541	0.681	0.792	0.654	477
C	Aug-17	4.00	0.208	2,259	0.679	0.792	0.654	467
C	Sep-17	3.20	0.167	2,956	0.683	0.833	0.653	449
C	Oct-17	3.80	0.198	2,581	0.681	0.802	0.654	468
C	Nov-17	5.00	0.260	1,871	0.676	0.740	0.655	492
C	Jan-18	3.90	0.203	2,802	0.682	0.797	0.654	480

Monthly data – Binder blend (continued)



+ = higher than aimed 600 Pa.s
- = lower than aimed 6000 Pa.s

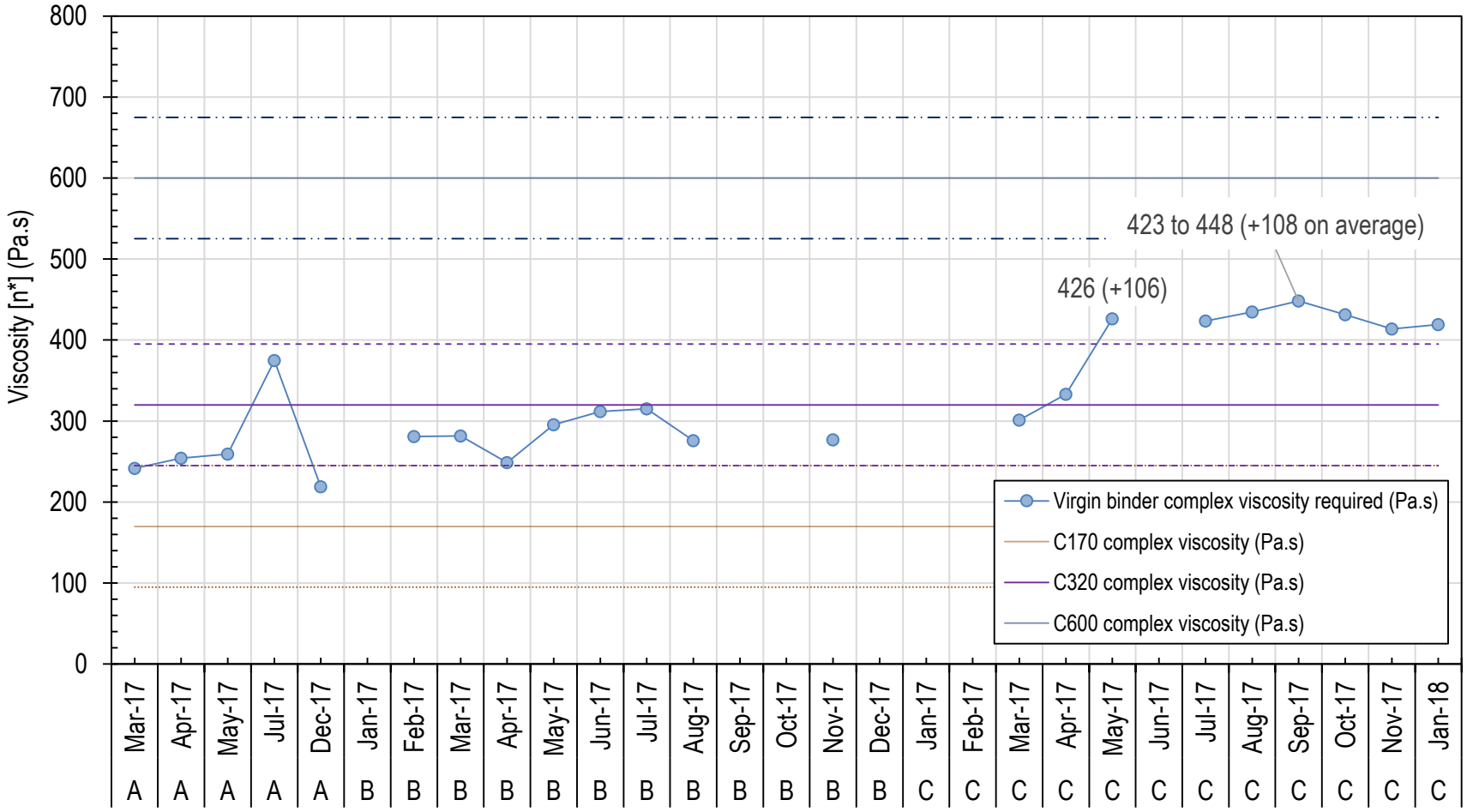
Monthly data – Binder blend

- Scenario 2
  - RAP content 25%, variable binder content
  - Target binder content of asphalt mix containing RAP at 4.8%
  - Blend adhere to C600 (DSR complex viscosity of 600 Pa.s)
  - No low viscosity oil added
  - *DSR complex viscosity of virgin binder required*

Monthly data – Binder blend (continued)

Supplier	Month sampled RAP	RAP Binder content (%)	RAP binder proportion (x)	RAP Mean complex viscosity (Pa.s)	RAP VBI (Pa.s)	Virgin binder prop. (x)	Virgin binder mean complex viscosity (Pa.s)	Virgin binder VBI (Pa.s)	VBIß	u
A	Mar-17	5.00	0.260	13,630	0.704	0.740	242	0.642	0.658	600
A	Apr-17	4.10	0.214	31,145	0.714	0.786	254	0.643	0.658	600
A	May-17	4.90	0.255	11,205	0.701	0.745	259	0.643	0.658	600
A	Jul-17	5.00	0.260	2,603	0.681	0.740	375	0.650	0.658	600
A	Dec-17	4.90	0.255	23,215	0.711	0.745	219	0.640	0.658	600
B	Feb-17	3.90	0.203	23,205	0.711	0.797	281	0.645	0.658	600
B	Mar-17	4.20	0.219	15,575	0.706	0.781	282	0.645	0.658	600
B	Apr-17	4.20	0.219	30,370	0.714	0.781	249	0.643	0.658	600
B	May-17	3.90	0.203	17,240	0.707	0.797	295	0.646	0.658	600
B	Jun-17	3.80	0.198	14,305	0.705	0.802	312	0.647	0.658	600
B	Jul-17	3.80	0.198	13,440	0.704	0.802	315	0.647	0.658	600
B	Aug-17	4.40	0.229	13,880	0.704	0.771	276	0.645	0.658	600
B	Nov-17	4.10	0.214	19,265	0.708	0.786	277	0.645	0.658	600
C	Mar-17	4.50	0.234	8,339	0.698	0.766	301	0.646	0.658	600
C	Apr-17	4.00	0.208	8,059	0.697	0.792	333	0.648	0.658	600
C	May-17	2.90	0.151	5,217	0.691	0.849	426	0.652	0.658	600
C	Jul-17	4.00	0.208	2,541	0.681	0.792	423	0.652	0.658	600
C	Aug-17	4.00	0.208	2,259	0.679	0.792	435	0.653	0.658	600
C	Sep-17	3.20	0.167	2,956	0.683	0.833	448	0.653	0.658	600
C	Oct-17	3.80	0.198	2,581	0.681	0.802	431	0.653	0.658	600
C	Nov-17	5.00	0.260	1,871	0.676	0.740	414	0.652	0.658	600
C	Jan-18	3.90	0.203	2,802	0.682	0.797	419	0.652	0.658	600

Monthly data – Binder blend (continued)



+ = higher than aimed 320 Pa.s
- = lower than aimed 320 Pa.s

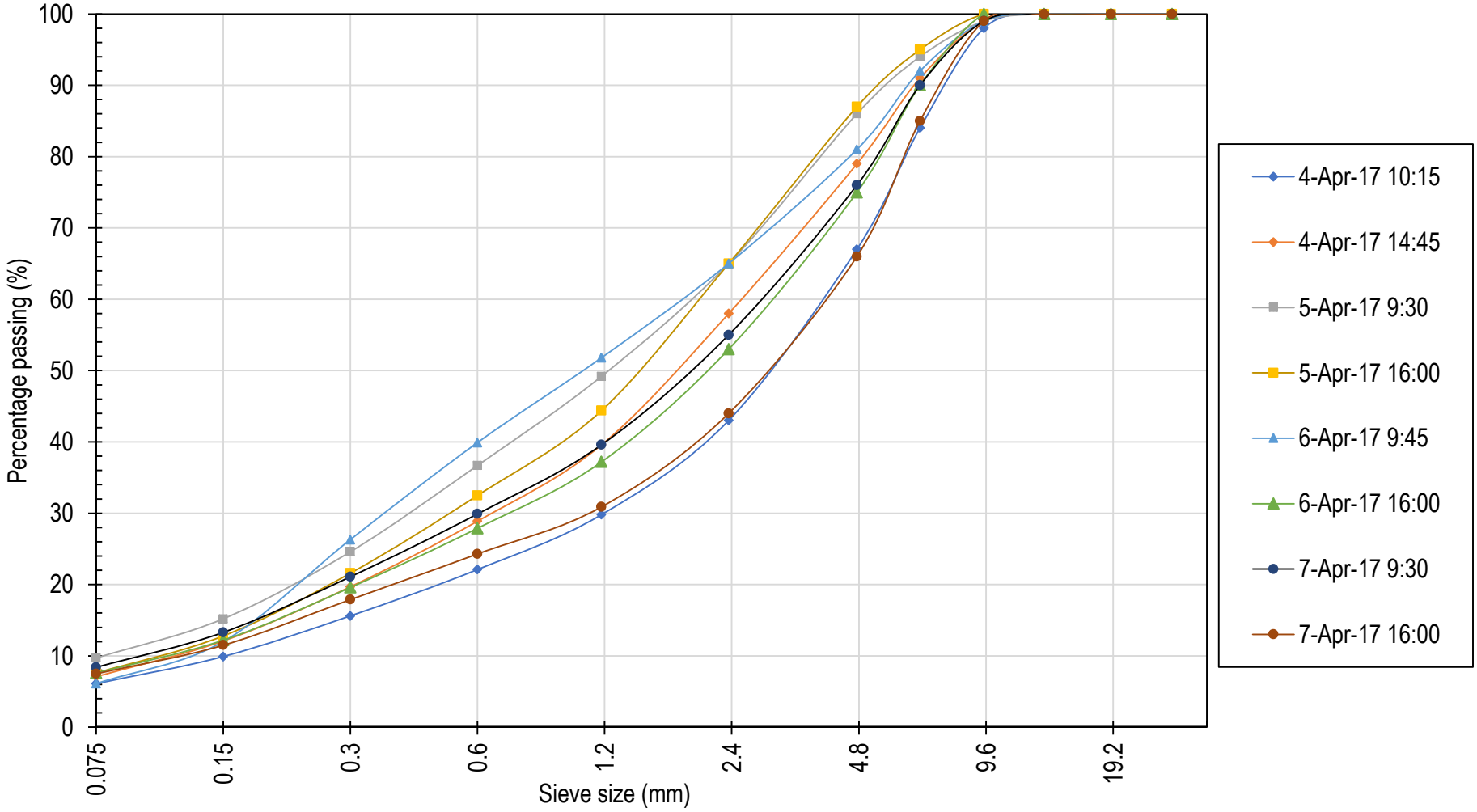
Variability during processing

- One asphalt supplier within Perth metro area
- RAP material sampled immediately after going through the crushing and screening process
- Over four days, 4 April to 7 April 2017, in the morning and afternoon
- Aim to measure variability of raw RAP
- Discuss
  - Particle size distribution (PSD)
  - Binder content
  - DSR complex viscosity
  - Binder blend (AGPT/T193)

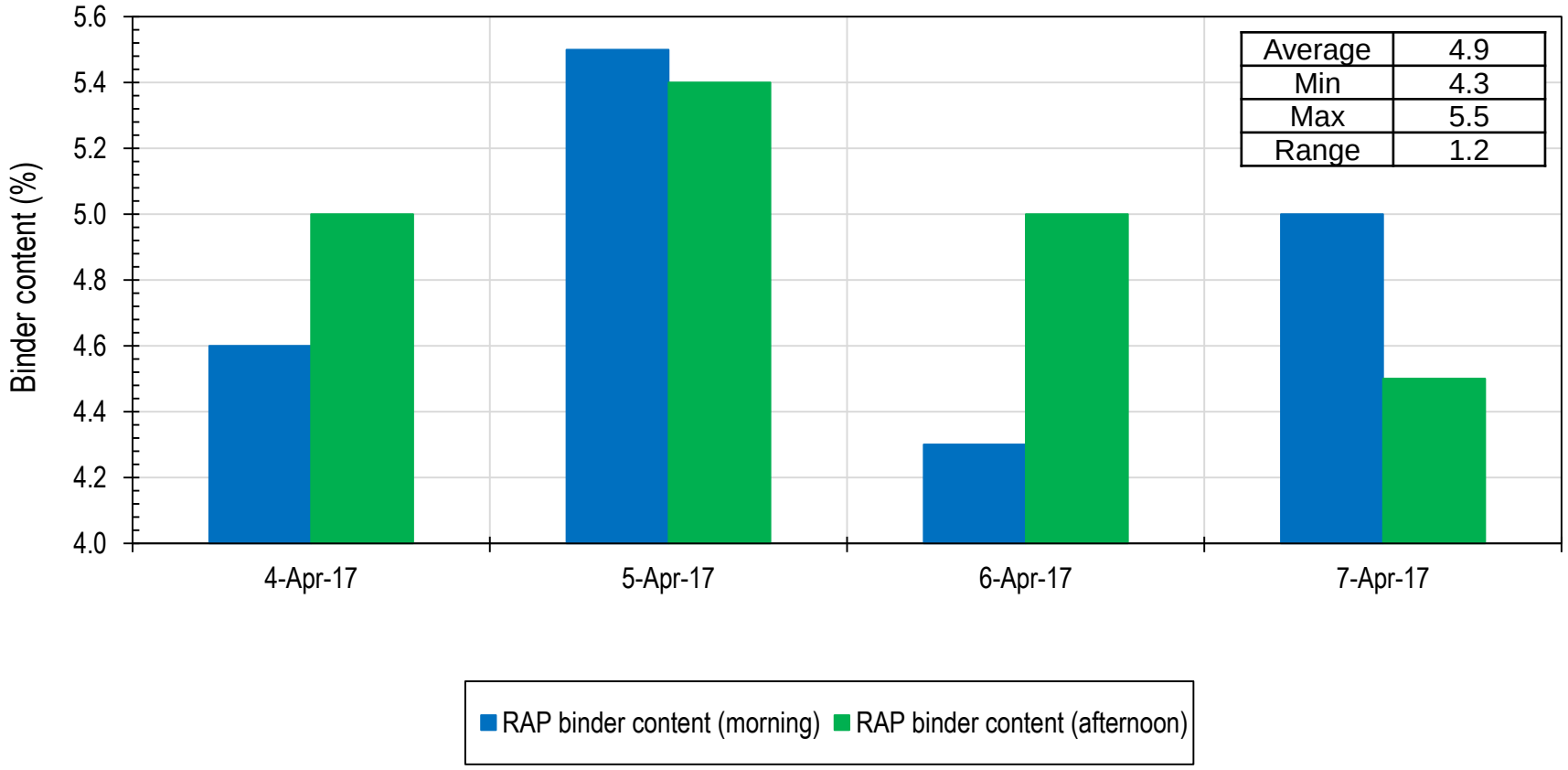
Variability during processing - PSD

Date	4-Apr-17		5-Apr-17		6-Apr-17		7-Apr-17		Avg	Min	Max	Range
Time	10:15	14:45	9:30	16:00	9:45	16:00	9:30	16:00				
Sieve size	Percentage passing (%)											
26.5	100	100	100	100	100	100	100	100	100	100	100	0
19	100	100	100	100	100	100	100	100	100	100	100	0
13.2	100	100	100	100	100	100	100	100	100	100	100	0
9.5	98	99	99	100	99	100	99	99	99	98	100	2
6.7	84	91	94	95	92	90	90	85	90	84	95	11
4.75	67	79	86	87	81	75	76	66	77	66	87	21
2.36	43	58	65	65	65	53	55	44	56	43	65	22
1.18	30	40	49	44	52	37	40	31	40	30	52	22
0.6	22	29	37	33	40	28	30	24	30	22	40	18
0.3	16	20	25	22	26	20	21	18	21	16	26	11
0.15	10	12	15	13	12	12	13	12	12	10	15	5
0.075	6.1	7.1	9.7	7.6	6.1	7.6	8.4	7.5	7.5	6.1	9.7	4

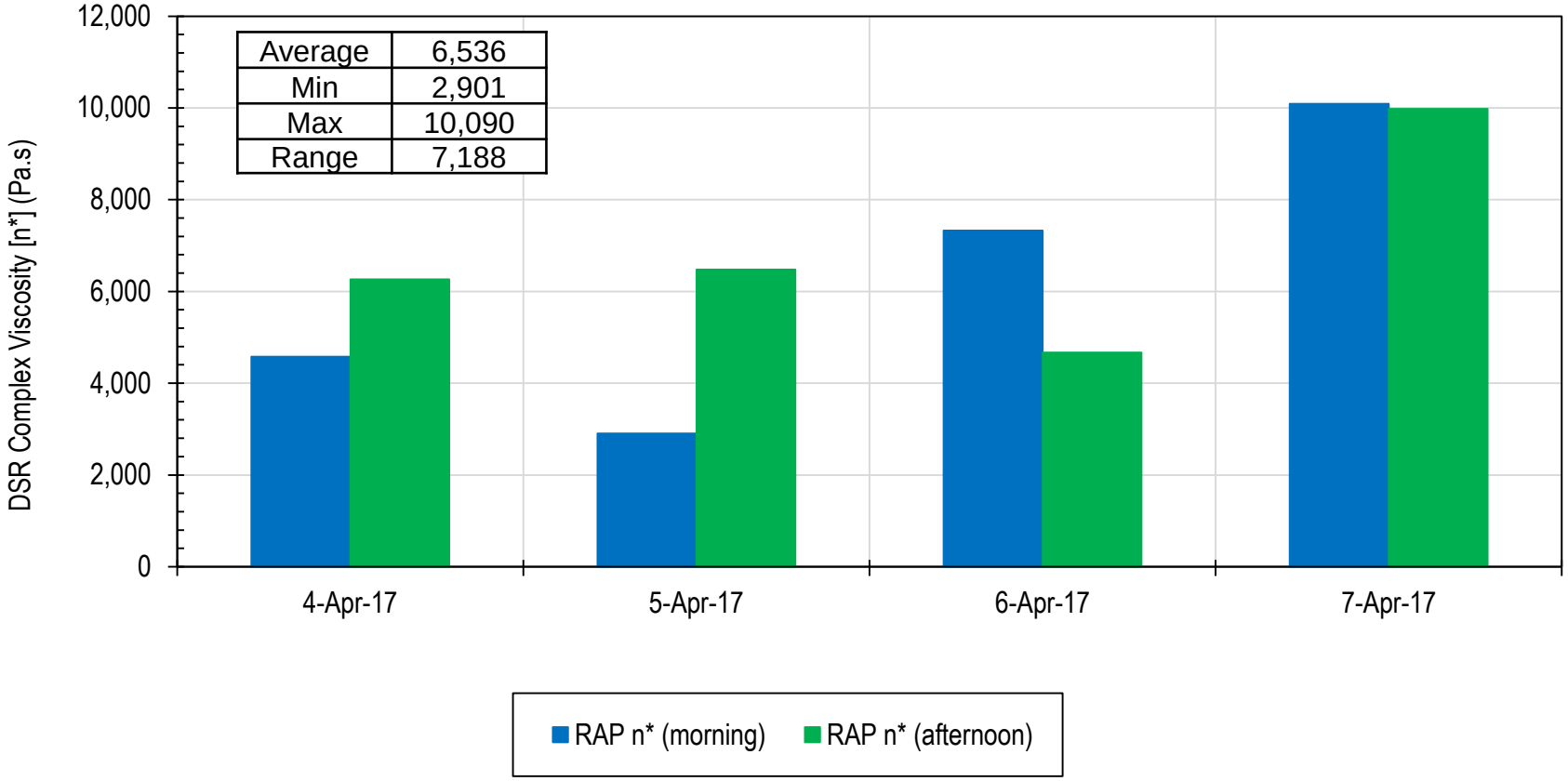
Variability during processing - PSD



Variability during processing – Binder content



Variability during processing – DSR complex viscosity

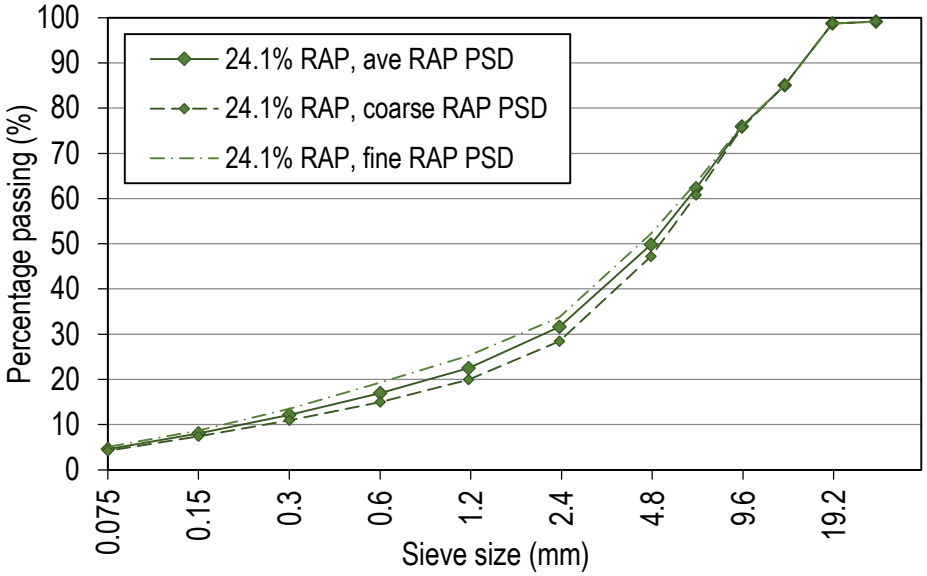


Variability during processing – Binder blend

- Assumptions
  - RAP content 24.1%, with average binder content of 4.9% and average DSR complex viscosity of 6537 Pa.s
  - Target binder content of the asphalt mix containing RAP at 4.6%
  - C320 virgin binder with DSR complex viscosity of 490 Pa.s
  - C600 target DSR complex viscosity of 980 Pa.s
  - No low viscosity oil added
  - Aggregate fraction proportions as per the mix design.

Variability during processing – Binder blend (continued)

- Effect of variable PSD



	24.1% RAP, average RAP PSD	24.1% RAP, coarse RAP PSD	24.1% RAP, fine RAP PSD	
Sieve size (mm)	Percentage passing			Range
26.5	99	99	99	0.0
19	99	99	99	0.0
13.2	85	85	85	0.0
9.5	76	76	76	0.5
6.7	62	61	63	2.7
4.75	50	47	52	5.1
2.36	32	28	34	5.3
1.18	22	20	25	5.3
0.6	17	15	19	4.3
0.3	12	11	13	2.6
0.15	8	7	9	1.3
0.075	4.6	4.2	5.1	0.9

Variability during processing – Binder blend (continued)

- Effect of variable binder content

				n* (Pa.s)	VBI (Pa.s)
RAP	24.1	%	C320	490	0.655
Target BC of mix	4.6	%	C600	980	0.666

RAP BC (%)		RAP binder prop. (x)	RAP n* (Pa.s)	VBI_{RAP} (Pa.s)	C320 prop (x)	$VBI_{ß}$	u (Pa.s)
Average	4.9	0.257	6,537	0.694	0.743	0.665	900
Minimum	4.3	0.225	6,537	0.694	0.775	0.664	833
Maximum	5.5	0.288	6,537	0.694	0.712	0.666	971

Variability during processing – Binder blend (continued)

- Effect of variable DSR complex viscosity

RAP	24.1	%
Target BC of mix	4.6	%

	n* (Pa.s)	VBI (Pa.s)
C320	490	0.655
C600	980	0.666

RAP n* (Pa.s)		RAP BC (%)	RAP binder prop. (x)	VBI_{RAP} (Pa.s)	C320 prop. (x)	$VBI_{ß}$	u (Pa.s)
Average	6,537	4.9	0.257	0.694	0.743	0.665	900
Minimum	2,902	4.9	0.257	0.683	0.743	0.662	753
Maximum	10,090	4.9	0.257	0.700	0.743	0.666	987

RAP management practice – documents reviewed

Jurisdiction	Documents reviewed
Austroads	• Maximising the Re-use of Reclaimed Asphalt Pavement: Binder Blend Characterisation (Austroads 2013) • Maximising the Re-use of Reclaimed Asphalt Pavement Outcomes of Year Two: RAP Mix Design (Austroads 2015c) • Maximising the Use of Reclaimed Asphalt Pavement in Asphalt Mix Design (Austroads 2016) • Guide to Pavement Technology Part 4B: Asphalt (Austroads 2014) • Maximising the Use of Reclaimed Asphalt Pavement in Mix Design (Austroads 2016)
Western Australia (Main Roads)	• Specification 510 Asphalt Intermediate Course (Main Roads 2017a) • Specification 511 Materials for Bituminous Treatments (Main Roads 2017b)
New South Wales (Roads and Maritime Services)	• QA Specification 3153 Reclaimed Asphalt Pavement Material (RMS 2011) • QA Specification R116 Heavy Duty Dense Graded Asphalt (RMS 2013a) • QA Specification R117 Light Duty Dense Graded Asphalt (RMS 2013b)
Northern Territory (Department of Infrastructure, Planning and Logistics)	• Standard Specification for Roadworks (DIPL 2017)

RAP management practice (continued)

- Australian documents reviewed

Jurisdiction	Documents reviewed
Queensland (Department of Transport and Main Roads)	• MRTS30 Asphalt Pavements (TMR 2017a) • MRTS102 Reclaimed Asphalt Pavement Material (TMR 2017b)
South Australia (Department of Planning, Transport and Infrastructure)	• Specification R27 Supply of Asphalt (DPTI 2016)
Victoria (VicRoads)	• Section 407 Hot Mix Asphalt (VicRoads 2017)
New Zealand (New Zealand Transport Agency)	• M10 Specification for Dense Graded and Stone Mastic Asphalts (NZTA 2014b) • M10 Notes to the Specification for Dense Graded and Stone Mastic Asphalts (NZTA 2014a)
AAPA	• Draft Reclaimed Asphalt Pavement (RAP) Management Plan (September 2017)

RAP management practice (continued)

- Reviewed in terms of
  - Source
  - Processing / fractionating
  - Storage and stockpiling
  - Inspection, test plans and auditing
- Possibly adopt from others in Australasia?
  - Project quality plan to monitor consistency of grading, binder properties and incoming RAP if >10% RAP in mix

RAP management practice (continued)

- International documents reviewed

Region	Documents reviewed
Europe	• EN 13108-8:2016 *Bituminous Mixtures: Materials Specification, Reclaimed Asphalt*
Germany	• *Recycling of Asphalt* (DAV 2011) • TL Asphalt-StB 07 *Technical Delivery Specification for Bituminous Mixtures for the Construction of Traffic Area Pavements* (FGSV 2013b) • ZTV Asphalt-StB 07 Additional Terms of Contract and Guidelines for the Construction of Road Surfacing from Asphalt (FGSV 2013a)
Japan	• Information Series 139 *High RAP Asphalt Pavement: Japan Practice – Lessons Learned* (NAPA 2015c)
South Africa	• TRH 21 *Use of Reclaimed Asphalt in the Production of Asphalt* (Sabita 2016)

RAP management practice (continued)

- International documents reviewed

Region	Documents reviewed
United Kingdom	• MCHW Series 900 *Road Pavements – Bituminous Bound Materials* (Highways Agency 2008) • RN43 *Best Practice Guide for Recycling into Surface Course* (Carswell et al. 2010)
United States of America	• *Reclaimed Asphalt Pavement Management: Best Practice* (West 2010) • *Reclaimed Asphalt Pavement in Asphalt Mixtures: State of the Practice* (FHWA 2011) • NCHRP Report 752 *Improved Mix Design, Evaluation, and Materials Management Practices for Hot Mix Asphalt with High Reclaimed Asphalt Pavement Content* (West, Willis & Marasteanu 2013) • Information Series 138 *Asphalt Pavement Industry Survey on Recycled Material and Warm-Mix Asphalt Usage 2015* (NAPA 2015a) • Quality Improvement Series 129 *Best Practices for RAP and RAS Management* (NAPA 2015b)

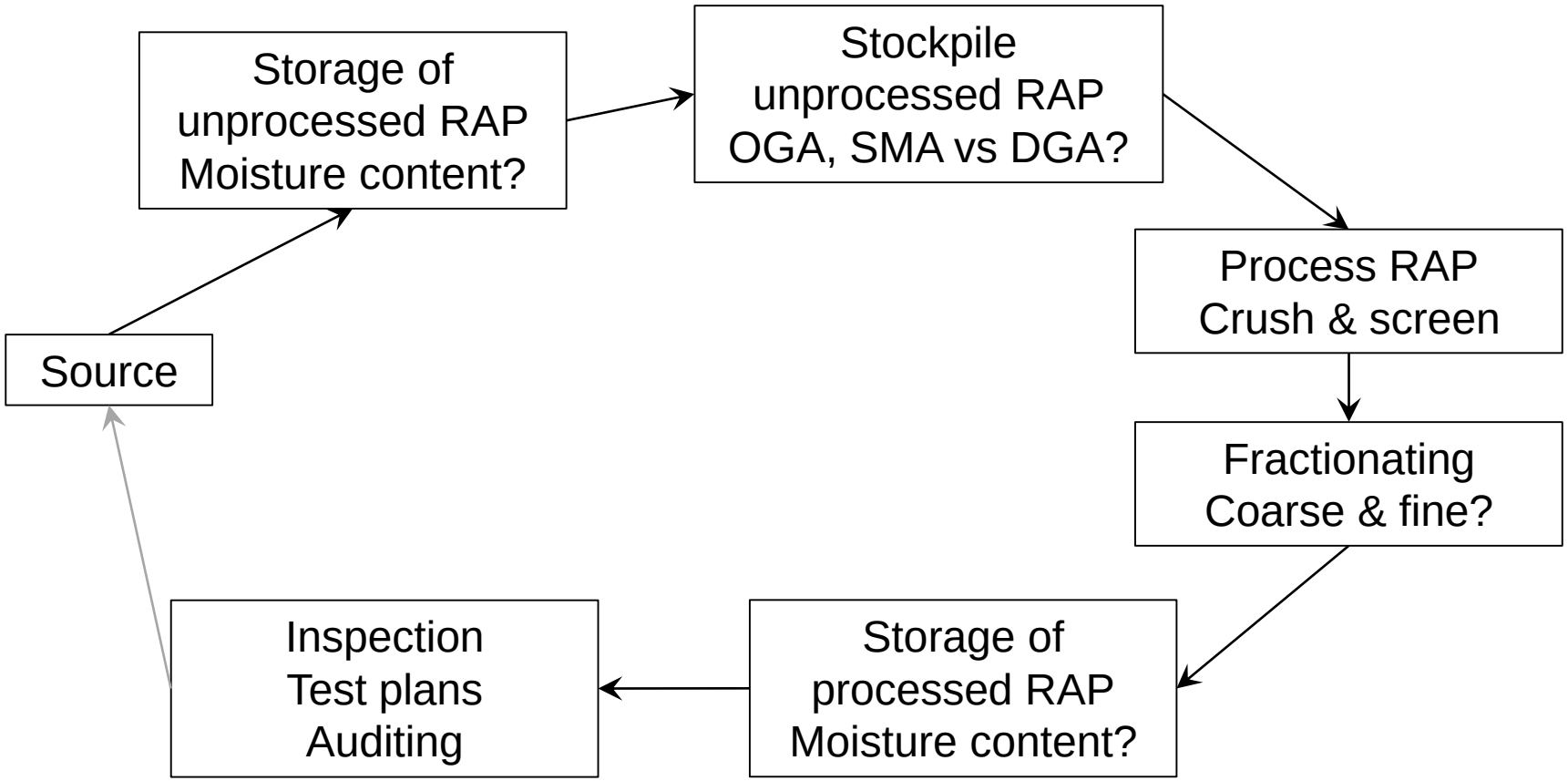
RAP management practice (continued)

- Reviewed in terms of
  - Source
  - Processing / fractionating
  - Storage and stockpiling
  - Inspection, test plans and auditing
- Possibly adopt from others?
  - Crush and screen to -13mm to +5mm and -5mm sizes
  - Unprocessed RAP stored in arc-shaped uniformly layered stockpiles
  - Processed RAP in conical or small, low sloped piles

RAP management practice (continued)

- For consideration
  - Separation of raw RAP into mix types
  - Fractionating into coarse and fines
  - Stockpiling process raw and processed RAP
  - Unprocessed RAP stored in arc-shaped uniformly layered stockpiles
  - Processed RAP in conical or small, low sloped piles
  - Inspection, test plans and auditing

Discussion of trial process



Discussion (2nd screen)

- Possibly adopt from others in Australasia?
  - Project quality plan to monitor consistency of grading, binder properties and incoming RAP if >10% RAP in mix

- Possibly adopt from others?
  - Crush and screen to -13mm to +5mm and -5mm sizes
  - Unprocessed RAP stored in arc-shaped uniformly layered stockpiles
  - Processed RAP in conical or small, low sloped piles

Summary of discussion

- Action items:

Thank you for your time and participation