AC Binder Characterization Containing Crumb Tire Rubber

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SUSTAINABLE MATERIALS FOR PAVEMENT INFRASTRUCTURE:
USE OF WASTE TIRES IN ASPHALT MIXTURES
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INTRODUCTION

RUBBER MODIFIED ASPHALT

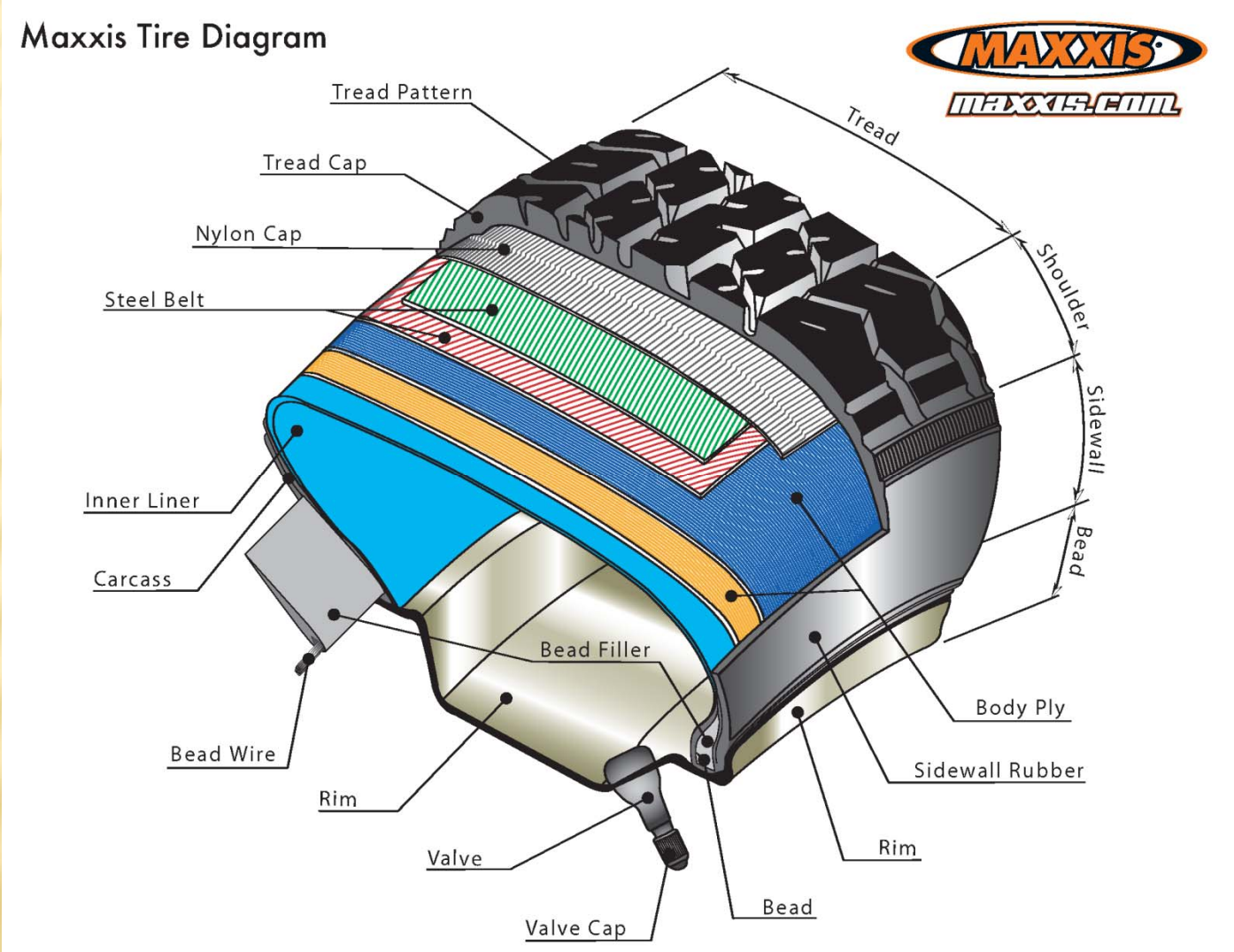
- Ground Tire Rubber (GTR) is a post consumer polymer fractionally beneficial in modification of asphalt binders.
- Benefits of modification of asphalt with GTR are similar to those achieved with virgin synthetic polymers with the exception GTR loadings are typically higher.
- Knowledge and technology for processing GTR modified binders are just as critical as with synthetic polymer modified binders e.g. SBS
- In the US, Asphalt Rubber or rubber modified bitumen/asphalt is the largest single market for recycled tires and consumes an estimated 12 million tires annually.

RUBBER MODIFIED ASPHALT

- Ground Tire Rubber (GTR) is separated into two particle sizes by class “ground” (2000µm and less) and “coarse” (greater that 2000µm)
- Rubber produced from ground whole tires contains ~ 30% reactive material for asphalt modification.
- Functional yield is dependent of tire composition and asphalt and is directly proportional to rubber source, rubber particle size and asphalt source.
- Terminal blending can be an operations challenge without adequate knowledge of asphalt chemistry, GTR source and processing.

TIRE COMPONENTS AND COMPOSITION

TYPICAL TIRE CONSTRUCTION



TYPICAL TYPES OF MATERIALS USED TO MANUFACTURE TIRES

- Synthetic Rubber
  - Styrene-Butadiene Rubber
  - Isoprene
  - Butadiene
  - Butyl Rubber
  - Halogenated Butyl Rubber
  - Ethylene Propylene Diene Monomer
- Natural Rubber
- Sulphur and sulphur compounds
- Silica
- Phenolic resin
- Oil: aromatic, naphthenic, paraffinic
- Fabric: Polyester, Nylon, Etc.
- Petroleum waxes
- Pigments: zinc oxide, titanium dioxide, etc.
- Carbon black
- Fatty acids
- Inert materials
- Steel Wire

TYPICAL TIRE COMPOSITIONS BY WEIGHT

- Passenger Tire
  - Natural rubber 14 %
  - Synthetic rubber 27%
  - Carbon black 28%
  - Steel 14 - 15%
  - Fabric, fillers, accelerators, antiozonants, etc. 16 - 17%
  - Average weight: New 25 lbs, Scrap 20 lbs.
- Truck Tire
  - Natural rubber 27 %
  - Synthetic rubber 14%
  - Carbon black 28%
  - Steel 14 - 15%
  - Fabric, fillers, accelerators, antiozonants, etc. 16 - 17%
  - Average weight: New 120 lbs., Scrap 100 lbs.

RUBBER PERCENT BY WEIGHT IN A NEW RADIAL PASSENGER TIRE

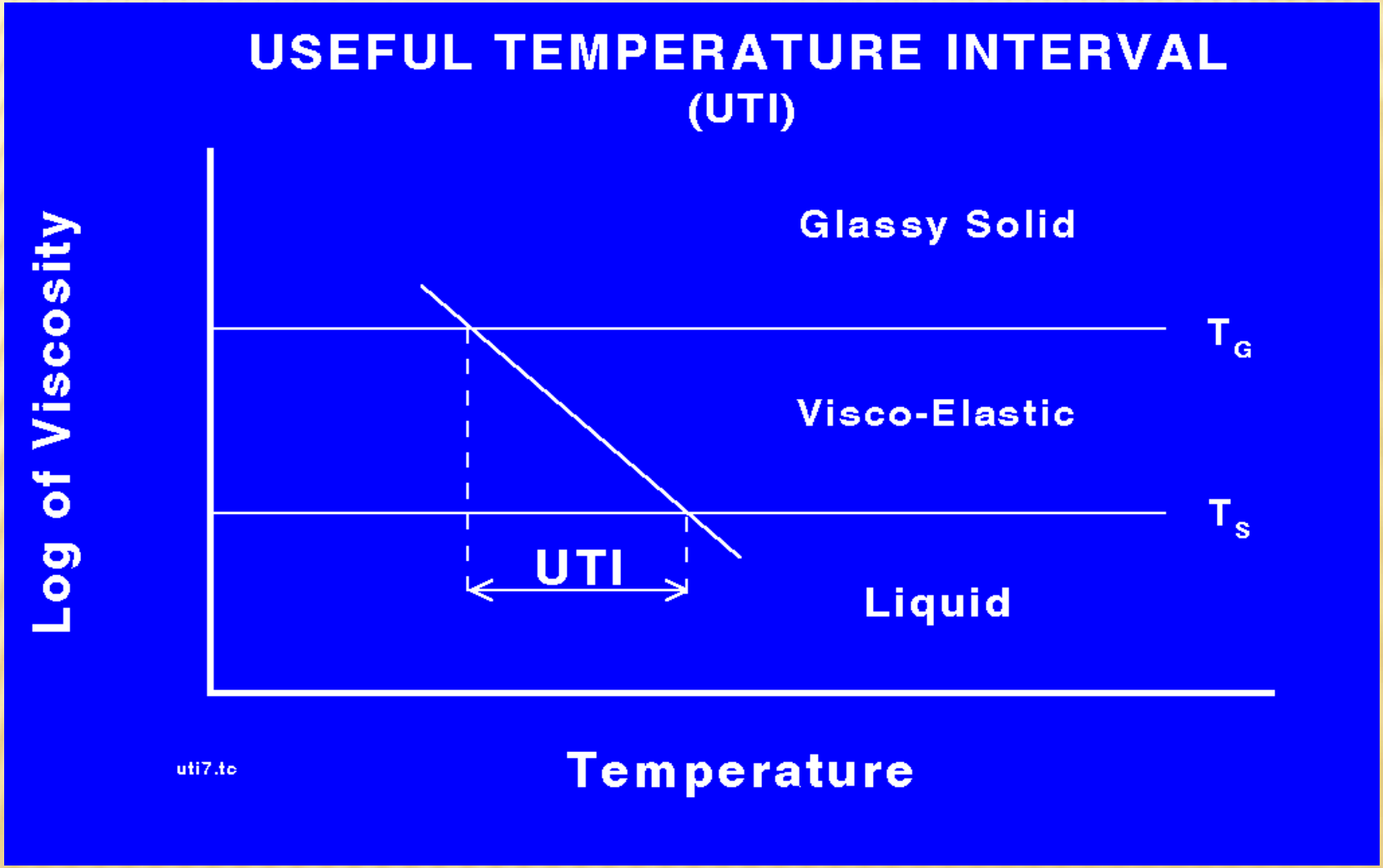
TREAD	32.6%
BASE	1.7%
SIDEWALL	21.9%
BEAD APEX	5.0%
BEAD INSULATION	1.2%
FABRIC INSULATION	11.8%
INSULATION OF STEEL CORD	9.5%
INNERLINER	12.4%
UNDERCUSHION	3.9%
	100.0%

MODIFIED ASPHALT BINDERS

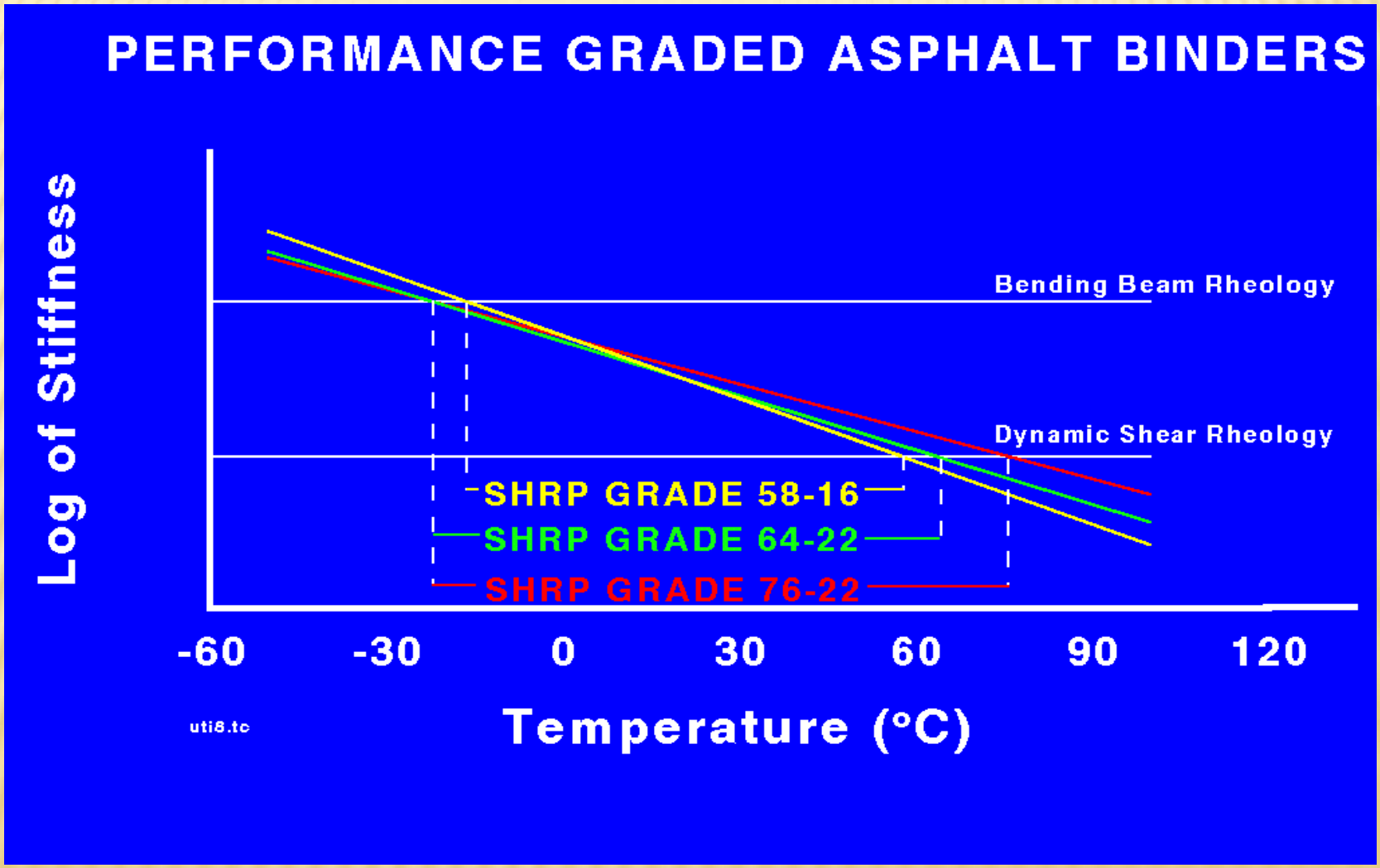
ASPHALT MODIFICATION

- Samuel Whiting
  - 1873 patent 1% natural rubber (Balata)
- France 1902
  - Rubberized asphalt
- Paving technologist improving asphalt pavements since.
- Use of synthetic polymers limited
  - Styrene-Butadiene Polymers most common
  - Rubber is a polymer of primarily the Styrene-Butadiene type

UTI – SUPERPAVE MADE SIMPLE



SUPERPAVE – UTI

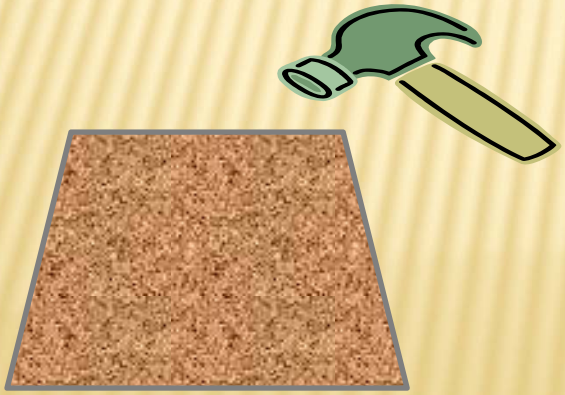


CONTINUOUS PHASE

20 Parts Natural Rubber + 80 Parts Cement

Water

Xylenes



CR ASPHALT MODIFICATION METHODS

- CR in asphalt is not a new idea.
- Three common methods of modification:
  - Wet Process
    - Rubber blended with asphalt at the asphalt mix facility
    - CR content ~ 18 – 20%
  - Dry Process
    - Rubber added to mixture either fine or coarse
    - CR content ~ 5 – 25%
  - Terminal Blend
    - Rubber blended with asphalt and stored as liquid
    - CR content ~ 5 – 15%

CRITICAL PARAMETERS

- Asphalt Source
- Asphalt Grade
- Rubber Composition — Natural/Synthetic
- Rubber Particle Size — < 30 mesh
- Rubber Grinding Method — Ambient/Cryogenic
- Blending Temperature — > 180 C
- Blending Time — > 45 min.

SPECIFICATIONS

CRM

- Historically testing has been done with pen and vis.
- Viscosity was mostly rotational or vane shear.

NEW CRM SPEC TO MATCH MSCR BINDER SPEC

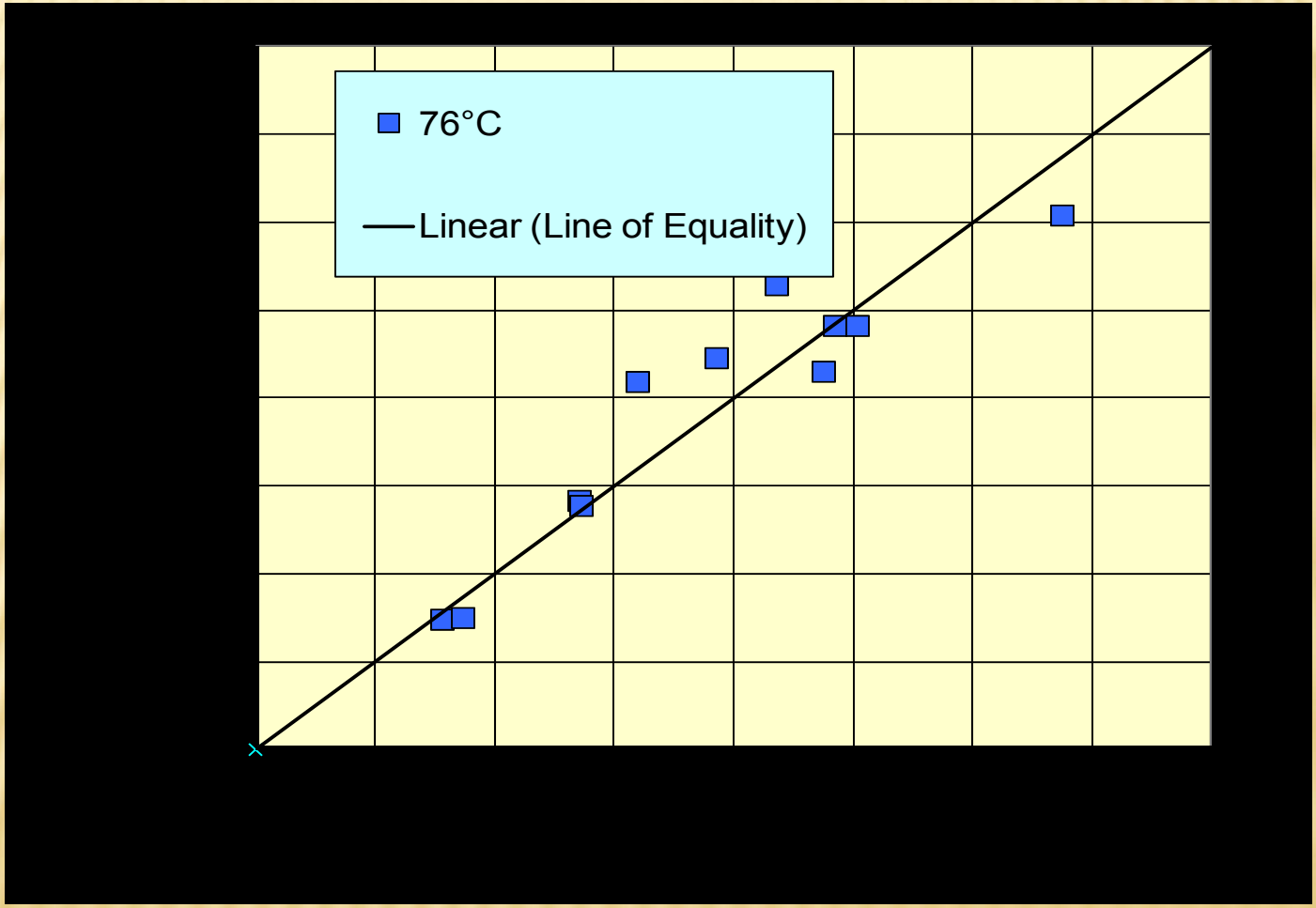
Original					
DSR G*/sinδ Min 1.0	64				
RTFOT					
64 Standard MSCR3.2 <4.0	[(MSCR3.2 – MSCR 0.1)/ MSCR 0.1] < .75	64			
64 Heavy MSCR 3.2<2.0		64			
64 Very heavy MSCR3.2 <1.0		64			
PAV					
S grade DSR G*sinδ Max 5000	28	25	22	19	16
H & V grade DSR G*sinδ Max 6000	28	25	22	19	16

Low temp BBR and DTT remain unchanged

CRM SIZES

- Rubber is delivered in different systems with supper sacks very prevalent.
- CRM comes in different sizes.

COMPARISON OF MEASUREMENTS AT 1 AND 2 MM GAPS



HOW TO HANDLE LARGER CRM

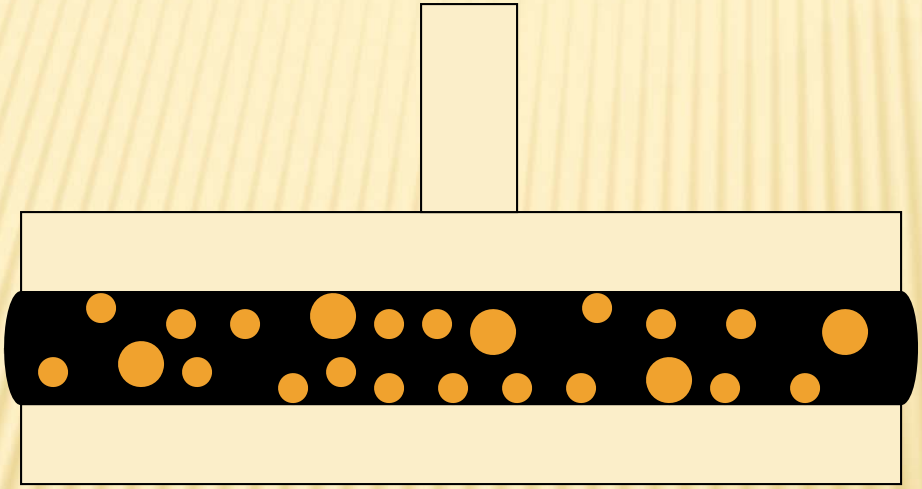
- 60 mesh material is easily handled in 1 mm gap.
- 30 mesh material may be tested at 2 mm
- 20 mesh material may require larger gaps.
- What is the limit of gap size?
- Are other geometries available to test larger particles?

4 MM GAP

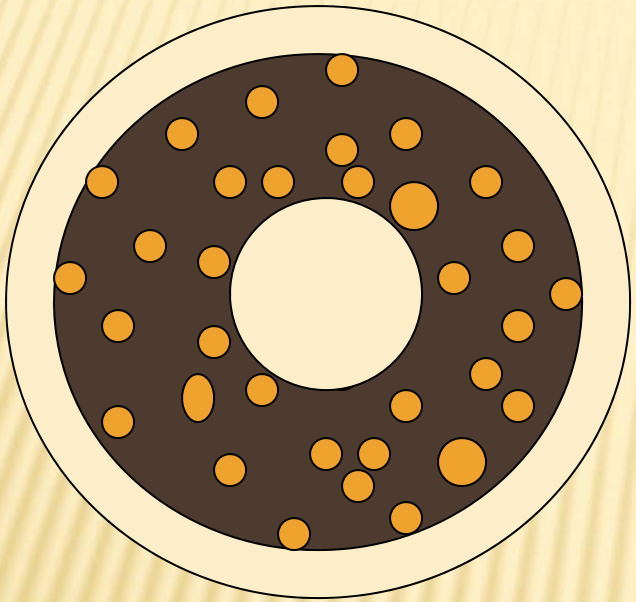
- Malvern Instruments
  - Kinexus Pro Rheometer
    - Active Heated Chamber
      - Used with 25mm parallel plates

    - Peltier Cylinder Cartridge
      - Used with Cup & Bob and Cup & Vane

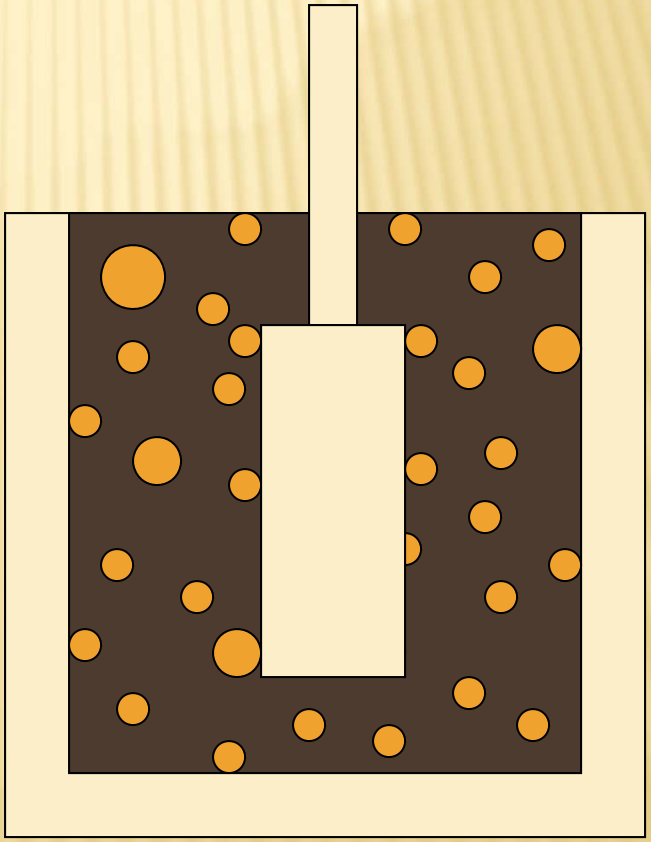
PARALLEL PLATE



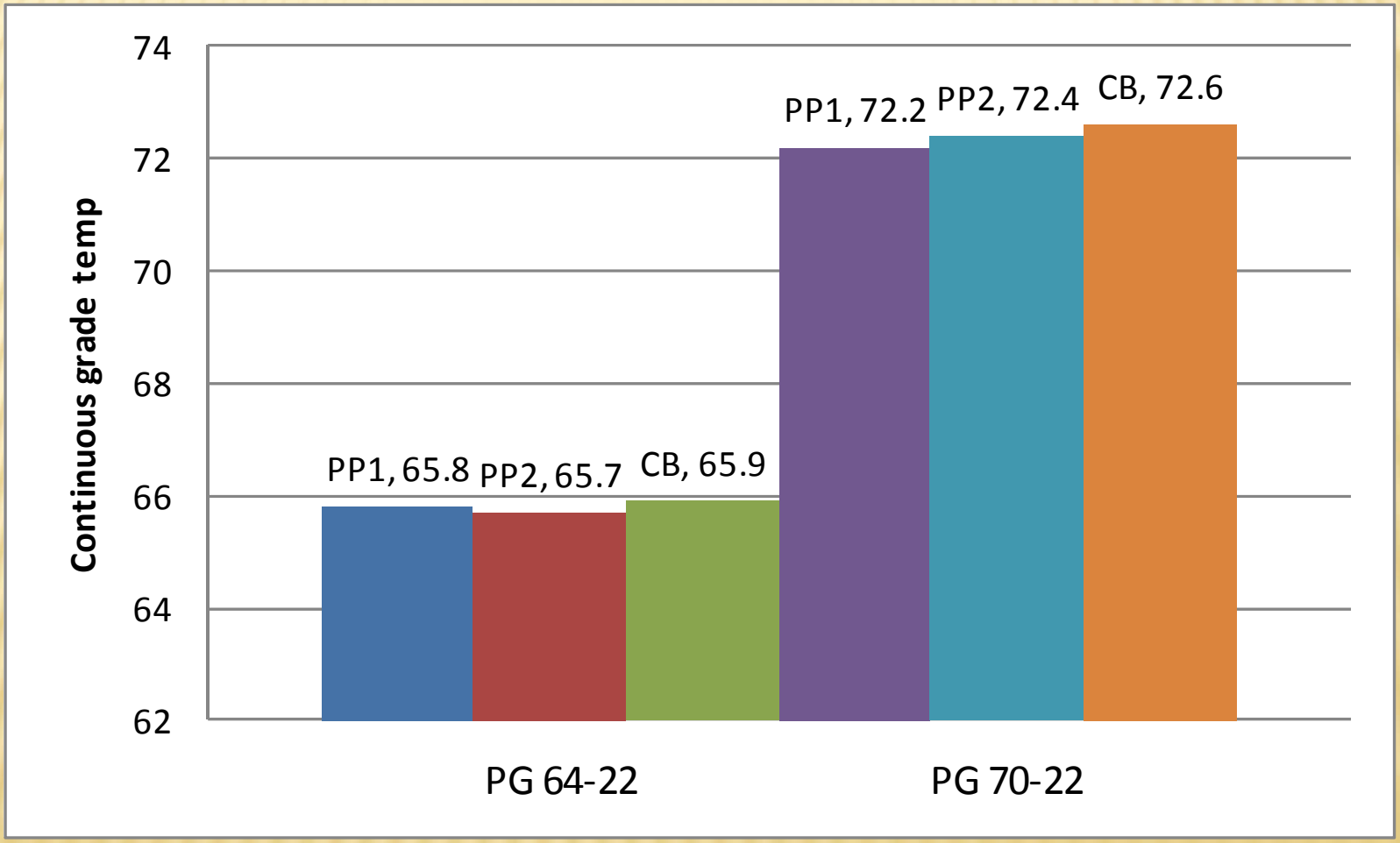
CUP & BOB



Top View



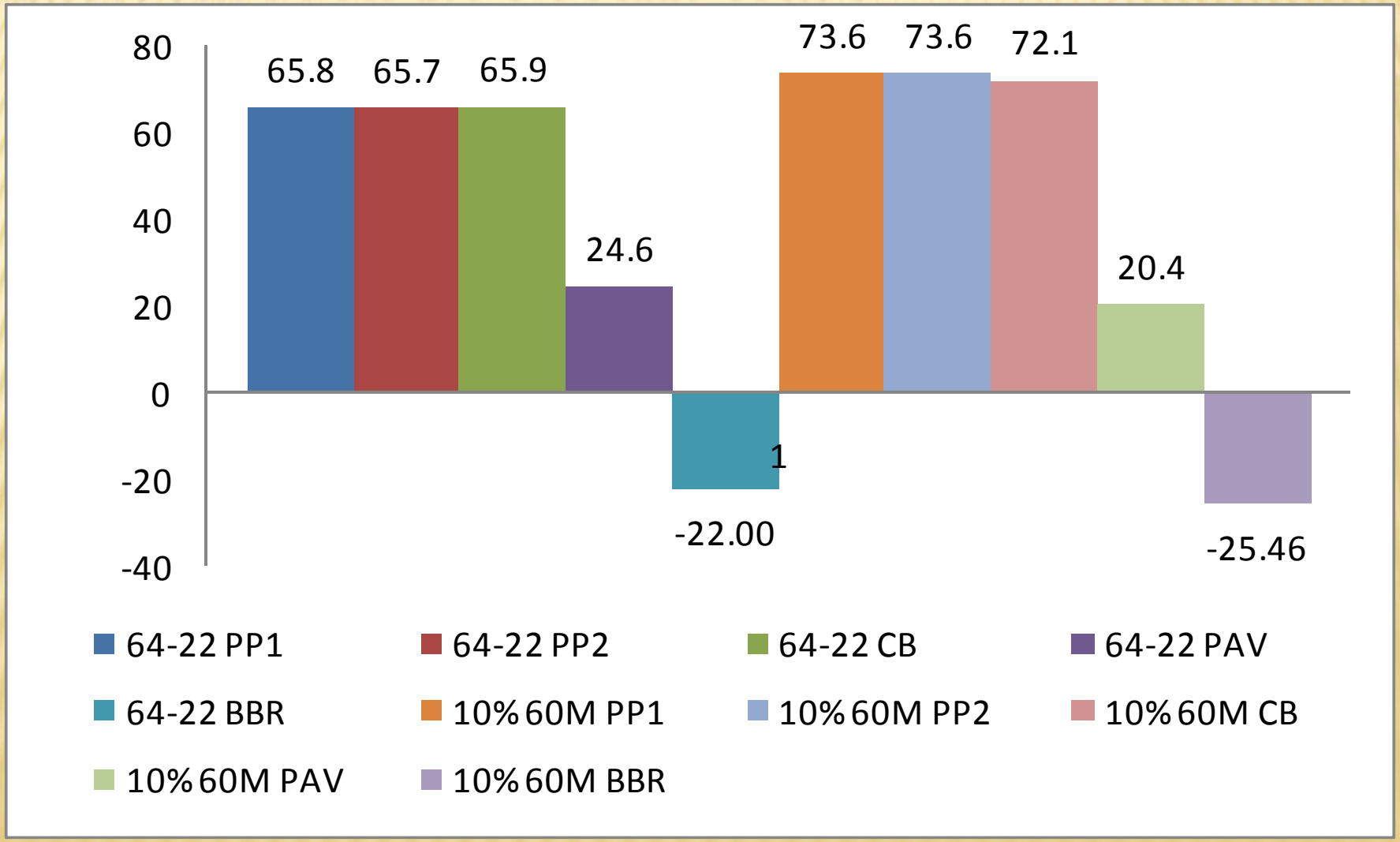
COMPARISON OF GEOMETRIES DSR 64-22 NEAT 70-22 (64-22+PPA)



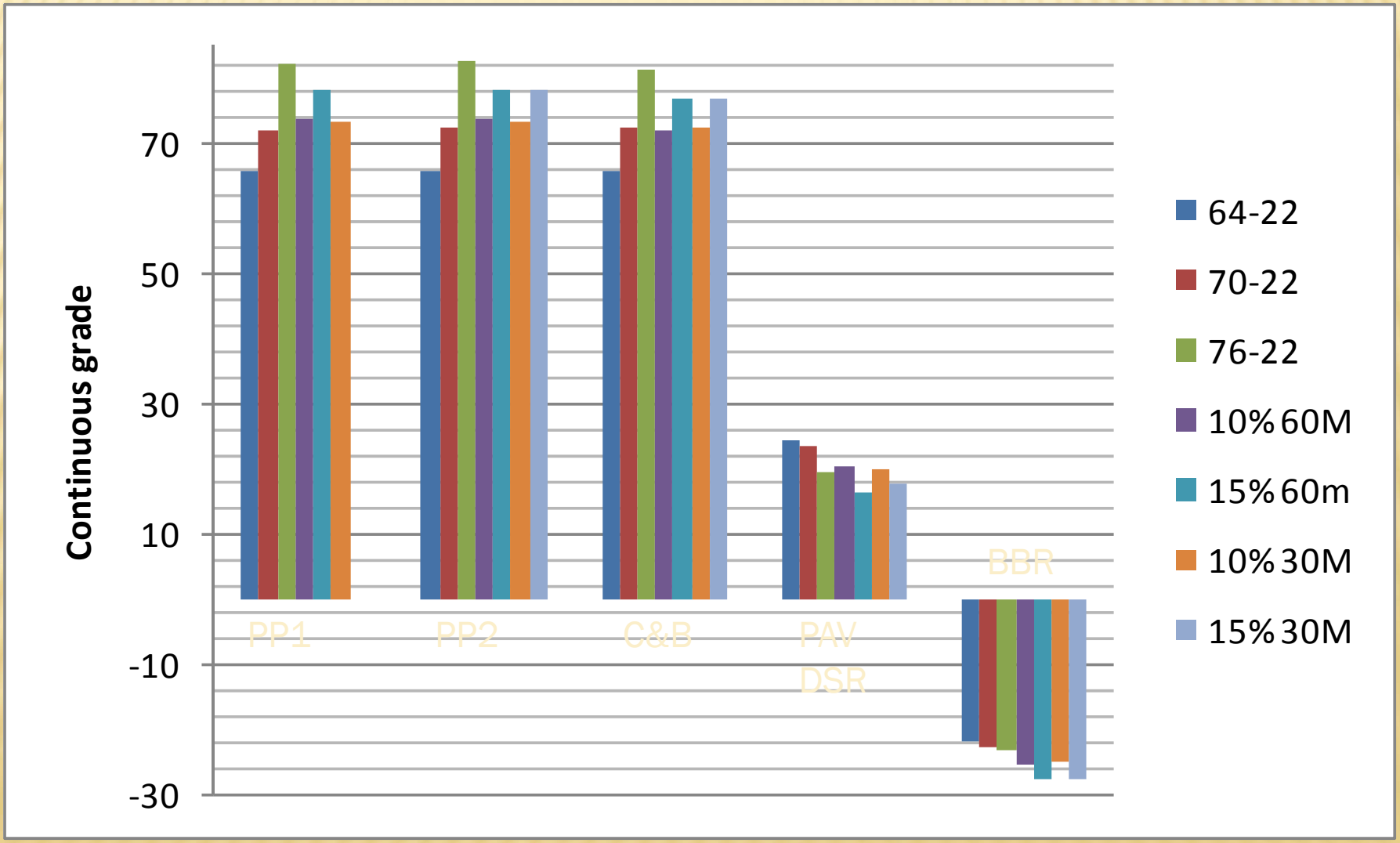
COMPARISON OF GEOMETRIES DSR 64-22 NEAT 70-22 (64-22+PPA)

- For Neat binder and or non particulate modifier the three geometries provide equivalent results using current G*/sin δ criteria.

CONTINUOUS GRADE FOR SPECIFIC BINDERS WITH DIFFERENT GEOMETRIES

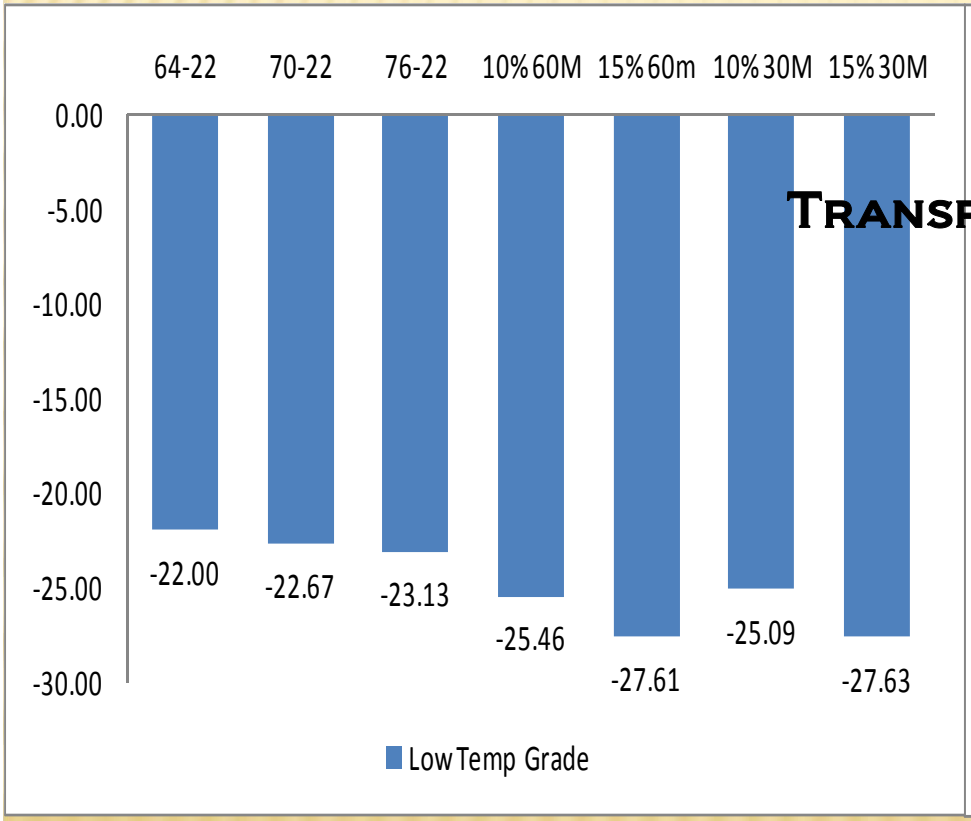


PG CONTINUOUS GRADING FOR BLENDS USING DIFFERENT GEOMETRIES

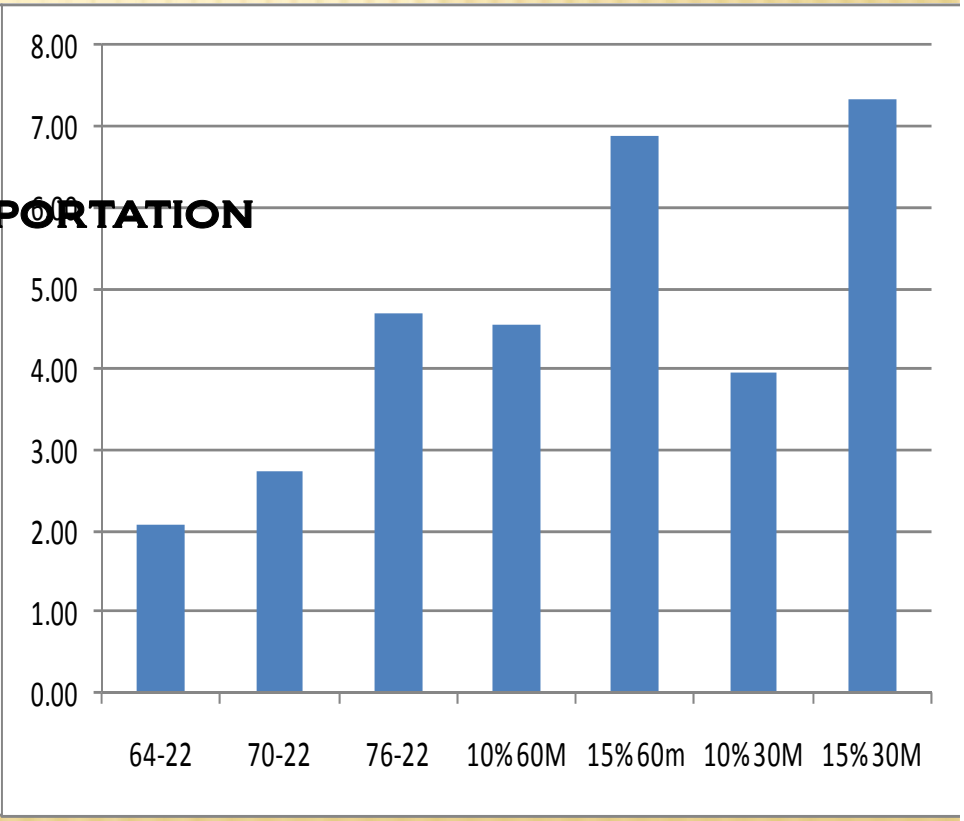


EFFECT OF CRM ON LOW TEMPERATURE GRADE

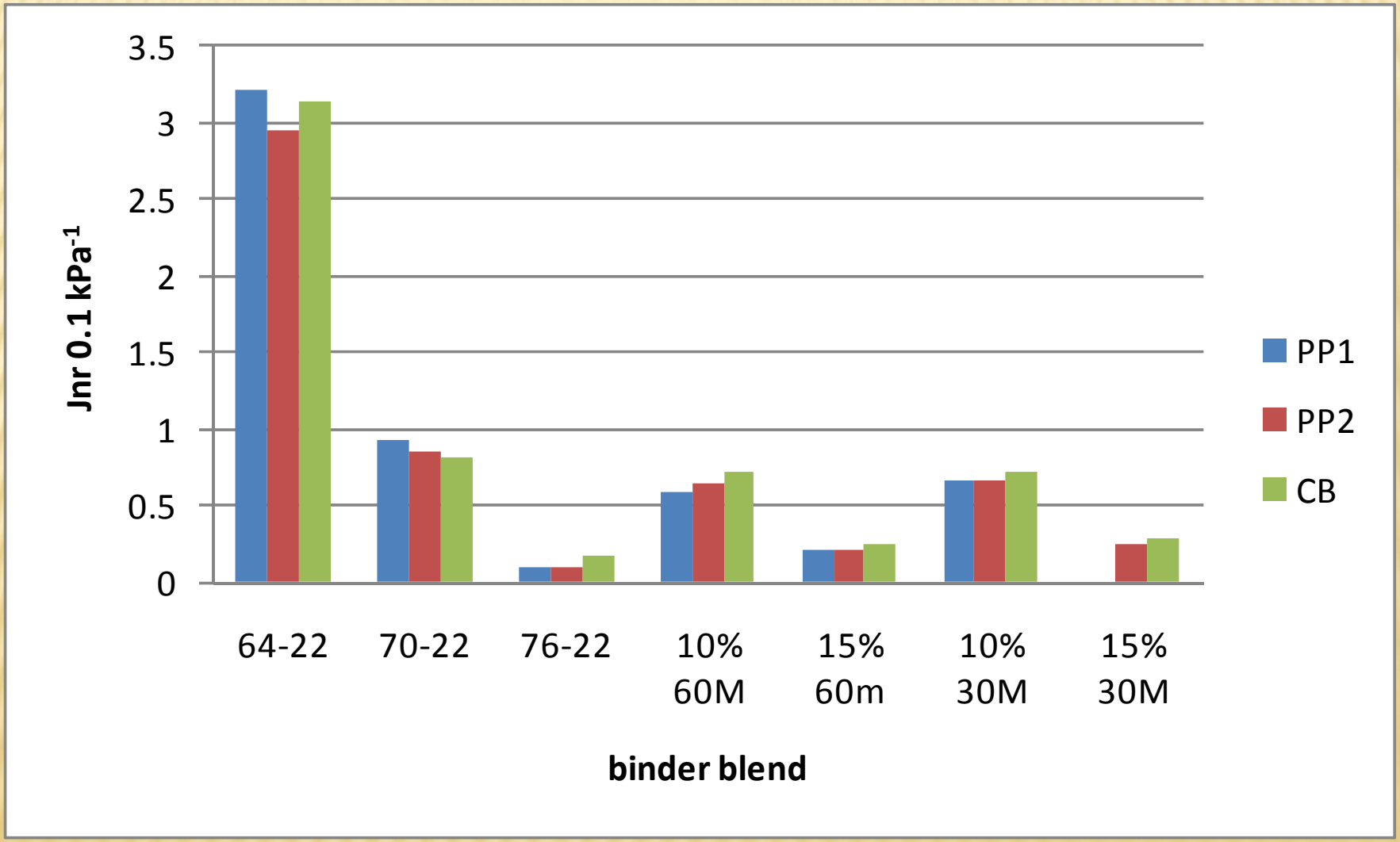
Low Temp Continuous Grade
All m controlled



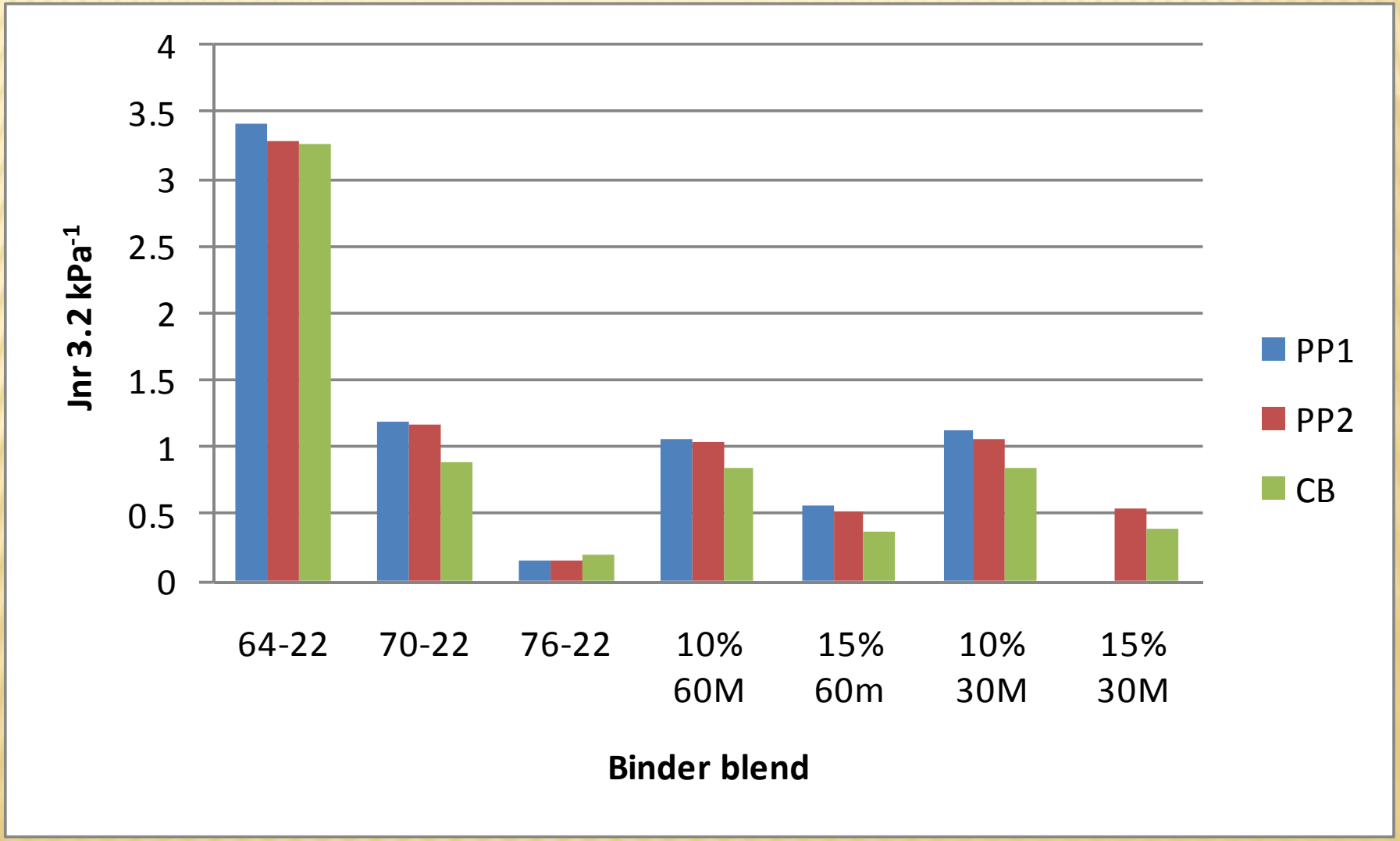
Difference between S and M grade temp
All m controlled



MSCR JNR 0.1KPA DATA FOR VARIOUS BLENDS



MSCR JNR 3.2KPA DATA FOR VARIOUS BLENDS



OTHER ISSUES

- Solubility – What values should be considered?
  - 99%
  - 93%
  - No solubility
- MSCR % Recovery – Rubber and polymers are not the same. Do we have a separate spec?

NEW CRM SPEC TO MATCH MSCR BINDER SPEC

Original					
DSR G*/sinδ Min 1.0	64				
RTFOT					
64 Standard MSCR3.2 <4.0	[(MSCR3.2 – MSCR 0.1)/ MSCR 0.1] < .75	64			
64 Heavy MSCR 3.2<2.0		64			
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PAV					
S grade DSR G*sinδ Max 5000	28	25	22	19	16
H & V grade DSR G*sinδ Max 6000	28	25	22	19	16

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SUMMARY

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- CRM binder is sensitive to crude source.
- Rubber size will effect test results. Particles should be ¼ gap size or less.
- Careful formulation is needed to meet all Jnr specs, but it can be done successfully.
- CRM Binders can be produced to meet PMA specs.
- Large CRM particle sizes can be tested in DSR

SUMMARY

- There may be some differences for CRM binder spec and PMA Spec
  - Solubility for CRM binder may be different.
  - Stress sensitivity may be different.
  - Most other properties will be the same.
- Addition of ground tire rubber (GTR) to asphalt is an accepted practice in HMA production
- Modification of liquid asphalt binders with GTR is well established and can provide high performance pavements which aid in reduction of the number of waste tires deposed of in landfills and elsewhere

THANK YOU