PAV Pan Warpage and Film Thickness Effects on Properties of Residue

ETG Task Force Status Report

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Introduction

- Reports of warped PAV pans have surfaced once again
  - ✓ Long-standing issue
    - One of reasons steel pans were specified (SHRP)
    - Issue is recognized in ASTM but ASHTO quiet on this issue
  - ✓ Pan dimensions are a left-over from TFO method
- Conclusion
  - ✓ Means for specifying and measuring allowable warping in PAV pans is needed
  - ✓ Pan dimensions need to be revisited
  - ✓ Levelness of PAV rack also warrants attention

Statement of Problem

- Are potential variations in PAV film thickness sufficient to affect the physical properties of PAV residue?
- What are likely reasons for variations in film thickness?
  1. Pan warpage – are pans warped?
  2. Dimensions of rack – supports equi-distant from bottom of vessel?
  3. Levelness of supporting rack – is PAV vessel bottom level?
  4. Re-entrant radius at pan circumference – increase thickness?
  5. Pan diameter – will either increase or decrease film thickness
- Four items need to be addressed:
  1. How important are the variations? Is this mountain or mole hill?
  2. How can effect of varying film thickness be measured?
  3. What are the appropriate limits for warpage?
  4. Estimated effects should be verified with limited testing program

Existing methods for measuring pan warpage

- Spinning method
  - ✓ Place pan on flat surface and manually spin pan
  - ✓ If pan spins it is not level
  - ✓ Qualitative therefore not definitive and hard to enforce
  - ✓ Observe that pans do have preferred orientation - important
- Method recommended in Asphalt Institute MS-25
  - ✓ Simple and non-qualitative
  - ✓ No limits given
  - ✓ Good starting point for development
  - ✓ Refine measurement technique and provide limits
    - Use existing data to establish limits

Flatness - Check for Downward Bow

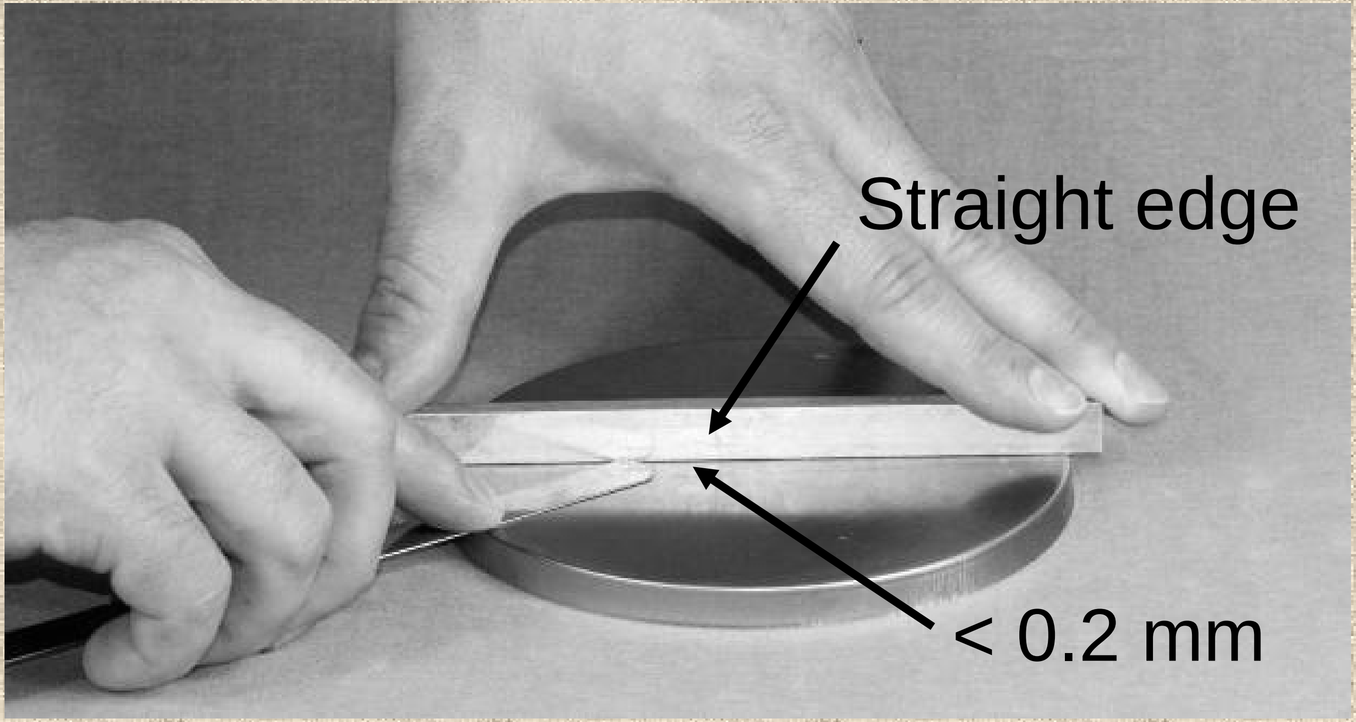
- Press on one side of the pan
  - ✓ Opposite side should not raise by more than 0.2 mm
  - ✓ Rotate pan 90° and repeat

< 0.2 mm →

Note: The test method does not require this procedure and its tolerances.

Flatness - Check for Upward Bow

- Invert and check for gap at center of pan



- Neither of these procedures account for non-coplanar warpage at circumference

Why Is Profiling Needed?

- Three possible warping modes:
  1. Pan bottom may be concave
  2. Pan bottom may be convex
  3. Circumference may not be co-planar
- None of the previous methods address warpage
- Support method may also affect film thickness
  - ✓ With edge support angular location of pan will affect thickness if circumference is not coplanar
  - ✓ With shelf support pan assumes repeatable position as affected by gravity and possible warpage in shelf
- Profiling should be done with support consistent with equipment in laboratory where pans are used

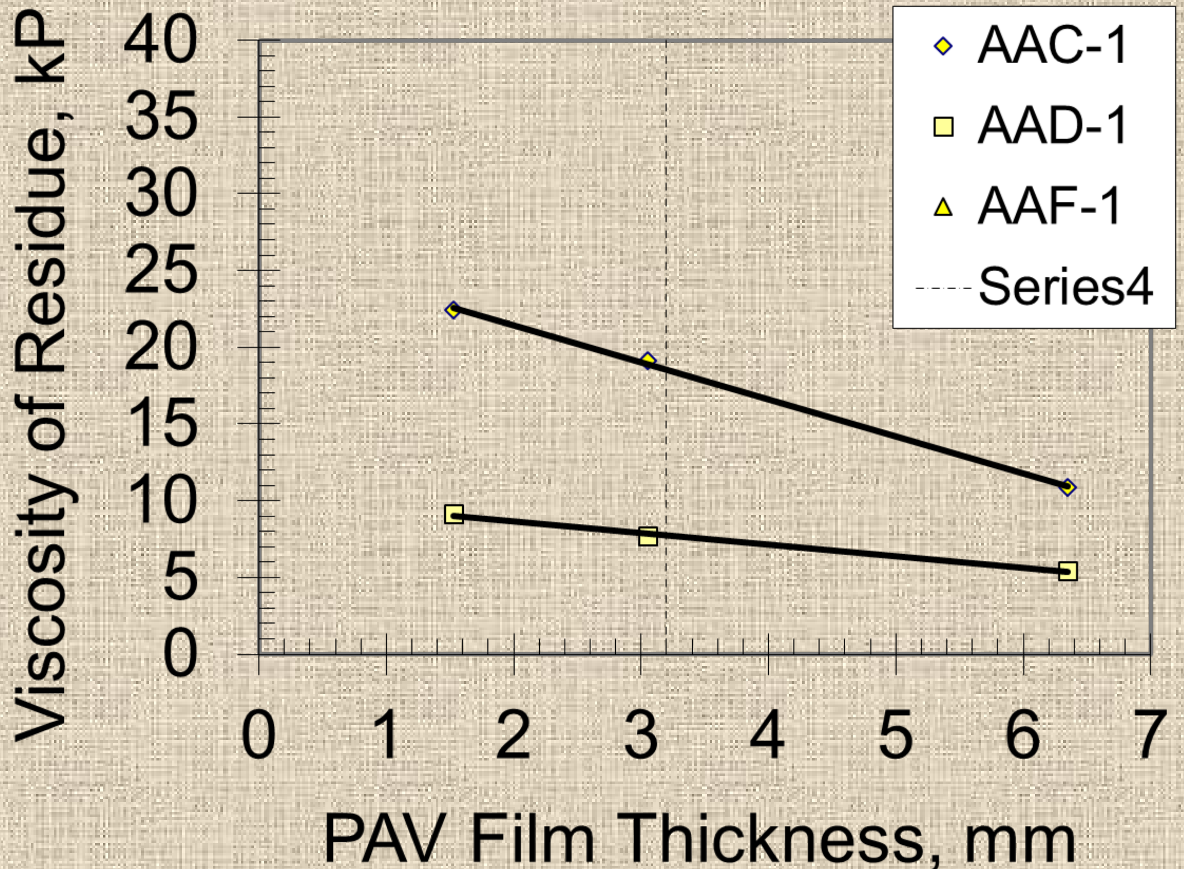
How Do We Measure Profile?

- Profile gage!
  - Commercial profiling gages are expensive and may be overkill
  - Need special purpose gage
- Re-entrant corner with a go-no go radius gage
  - May be overkill!
- Pan dimensions – thickness should also be specified uniformly

Pan Supported on Rotating Glass Plate

Dial Gage Rides on Linear Track

SHRP Viscosity Results



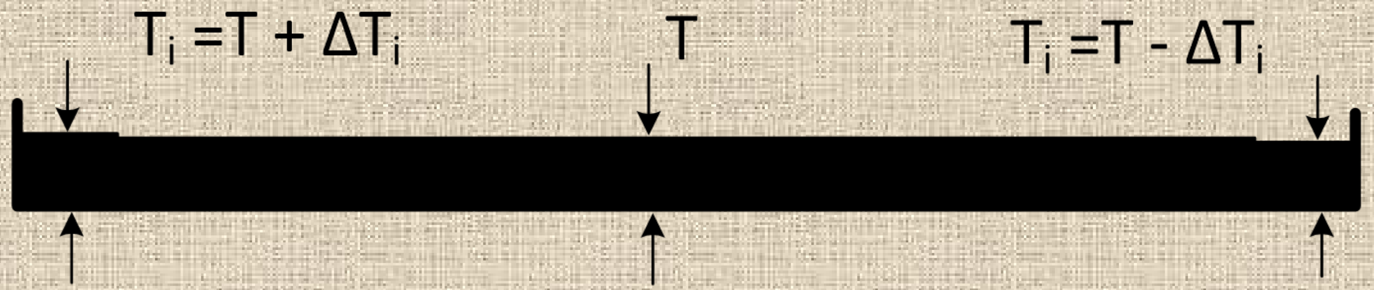
How Can We Estimate Effect of Variations in Film Thickness?

- Effect is function of thickness squared
- $AI = A + t^2$
  - Coefficient A is binder dependent
- Except for warpage above are easily estimated from geometry
  - Warpage needs to be measured from actual warped pans
  - Could also make cast of pan and profile cast
  - Orientation needs to account for support system
- Approach to measurements with inventory of warped pans
  - Simulate both edge and shelf support and determine profile
    - Shelf support – Epoxy drop under pan as pan is lowered onto glass
    - 3-Point support on glass
    - Limited use of casting technique

Weighted Effect of Different Thicknesses

- Divide area of pan into of six concentric circles
- Subdivide each circular area into 20 segments of approximately equal area
- Determine profile at the center of each of these areas
- Determine weighted aging as sum of areas multiplied by thickness ratio squared

$$Aged\ Property = \sum_{i=1}^{n} A \left\{\frac{Ti - Tavg}{Tavg}\right\}^2$$



Available Data for Determination of A

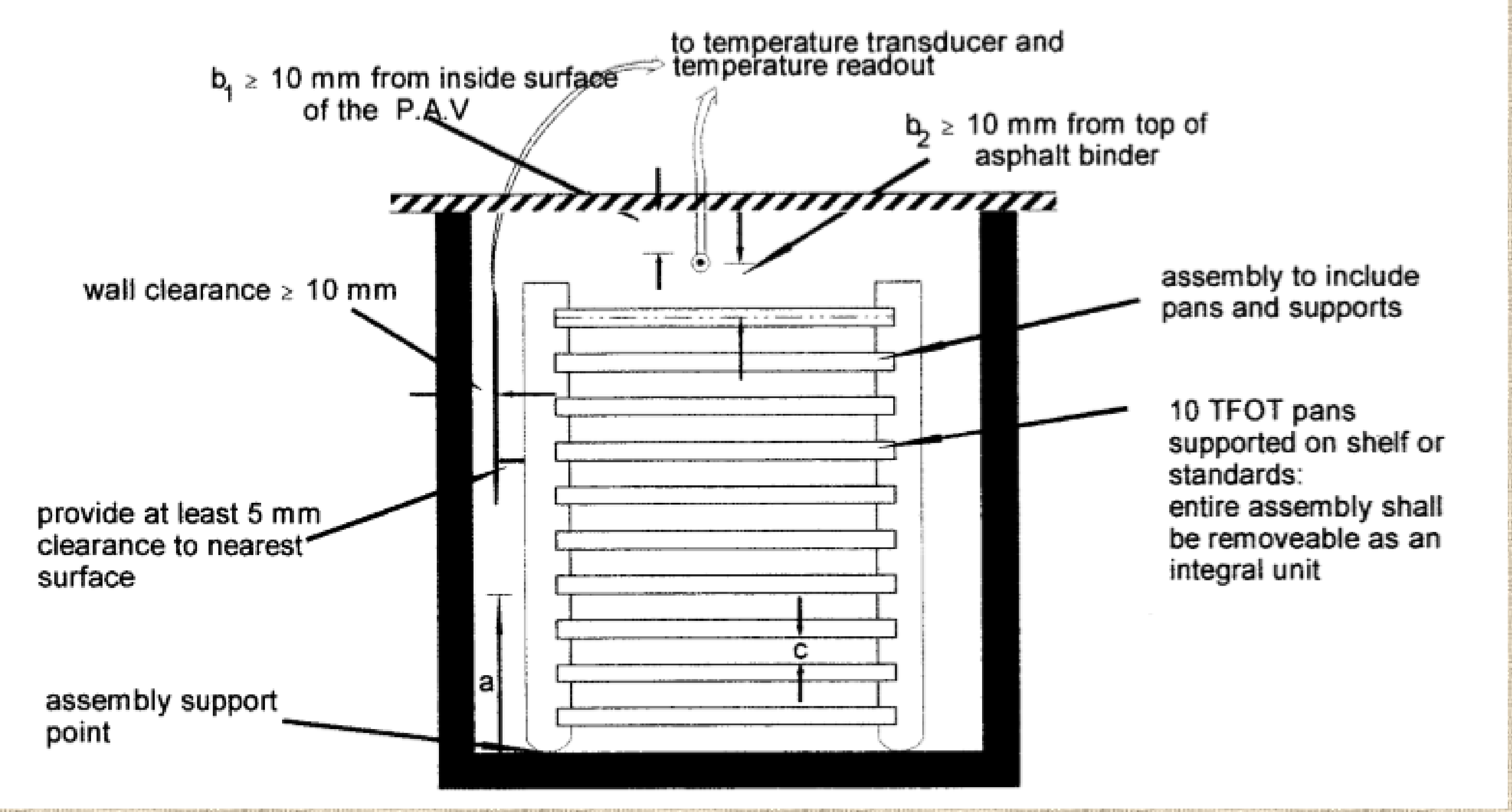
- ✓ SHRP data on core asphalt binders (140 hr – 60 C)
- ✓ FHWA data on four binders
- ✓ Gerry Reinke data

Binder	Mass	aging	4 mm S	4 mm m-value	**ΔTc**
Citgo 58-28	50 g	20 hr. PAV	-30.5	-32.2	1.7
Citgo 58-28	10 g	20 hr	-29.8	-30.5	0.8
Citgo 58-28	20 g	20 hr			
Marathon 58-28	50 g	20 hr.	-32.1	+31.5	-0.5
Marathon 58-28	10 g	20 hr.	-30.3	-27.9	-2.4
Marathon 58-28	50 g	40 hr.	-31.0	-26.3	-4.7
Valero 58-28	50 g	20 hr	-35.5	-30.7	-4.8
Valero 58-28	50 g	40 hr.	-35.2	-27.6	-7.6
Valero 58-28	10 g	20 hr	-36.0	-29.2	-6.8
Valero 58-28	20 g	20 hr	-36.4	-29.8	-6.5

What about PAV rack levelness?

- Obscure requirements given in initial version of test method
  - ✓ Measured dimensions of rack
  - ✓ Unrealistic and never enforced
- AASHTO and ASTM quiet on this issue
- Issue has been discussed periodically
  - ✓ Varying rack design complicates measurement
  - ✓ Levelness of oven not reliable
    - Warping of vessel can affect rack levelness
  - ✓ Probably less critical than pan levelness
- Should measure pans as they sit on their support
  - ✓ Easily done with edge support – small electronic level
    - How level?
  - ✓ Impossible with shelf support

Schematic From Test Method



What Remains?

- Update pan dimensions
- Develop method for profiling pans – prototype available
- Compare profile measurements with other recommended methods
- Assortment of warped pans has been collected
- Evaluate effectiveness of profile gage compared to other methods
- Estimate tolerances based on assumed binder aging ratios
- Verify estimated aging with measurements of binders aged with the measured /profiled pans
- Expect to be able to make recommendations at next ETG