Forensics

- A Perspective on Certain Types of Pavement Defects Observed -

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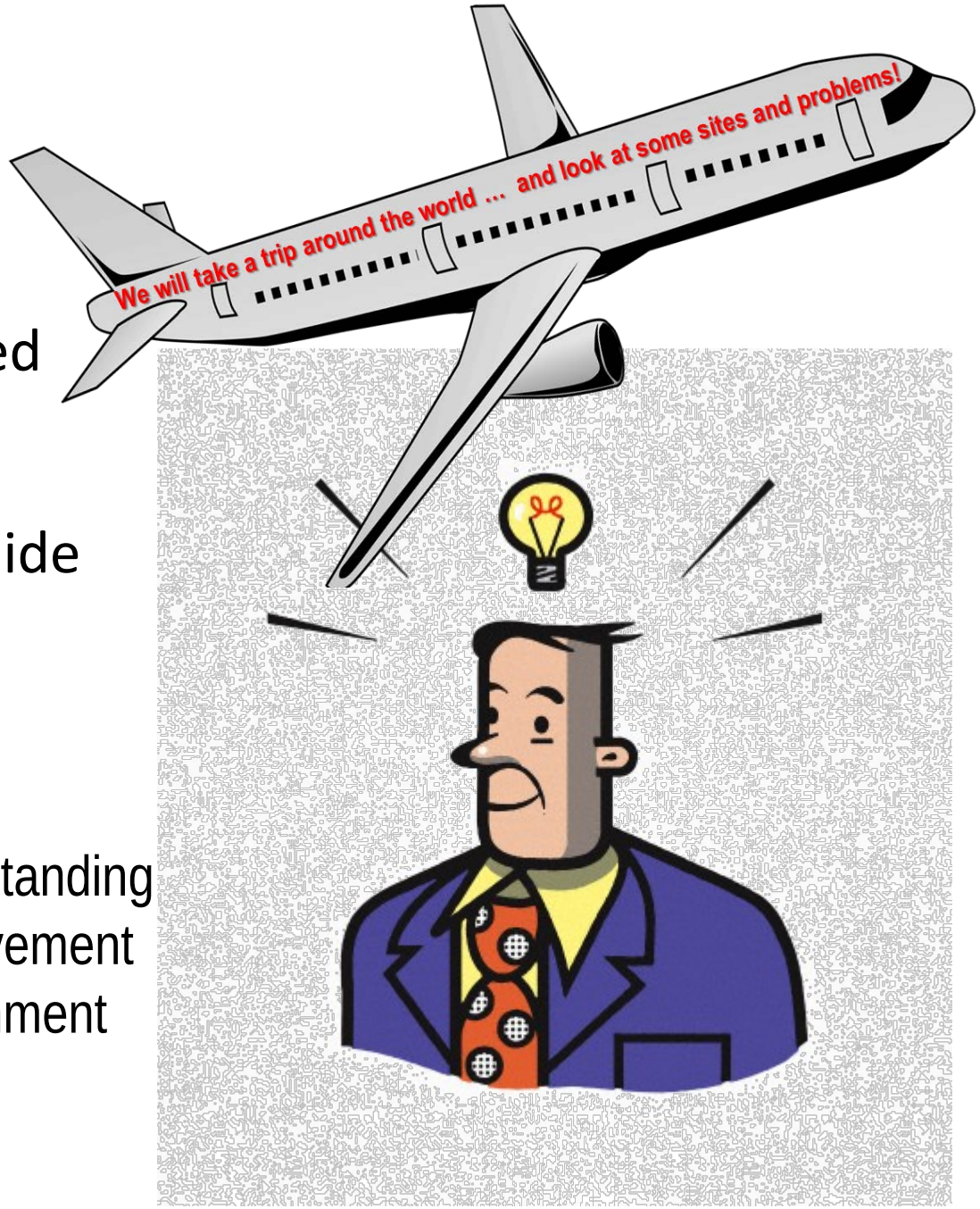
Abatech Inc.

Pavement Forensics



- My personal view of some aspects – based on approximately 40-years of experience
- May things can go wrong – by understanding what can go wrong can guide us with the development of quality programs to build successful pavements!
- Consider many aspects
  - Materials
  - Construction
  - Environment
  - Loading
  - Etc.

} Understanding the pavement environment

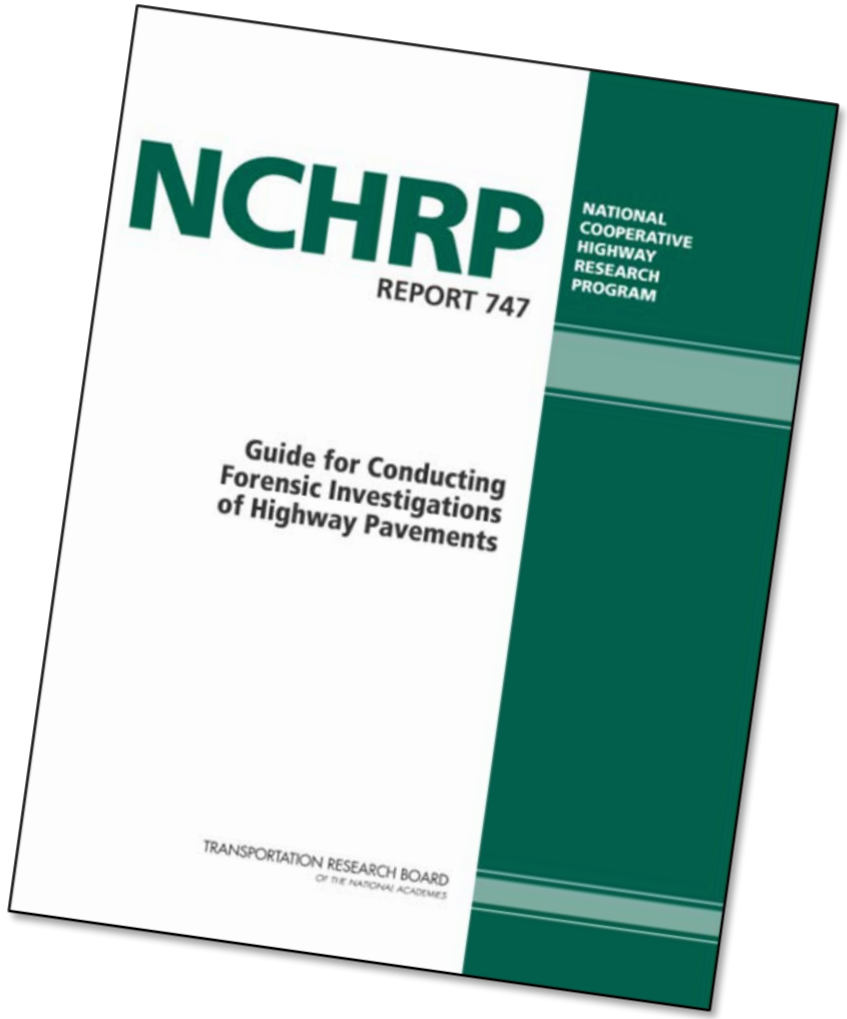

China
Philippines
USA
Ecuador
Chili
England
Turkey
Kyrgyzstan
Afghanistan
Sri Lanka
Tanzania

Steps in process

1. Understand existing conditions/ desk top review/ photographs/ old reports/ etc. etc.
   a) Is testing needed?
   b) Develop detailed plans for NDT and destructive sampling testing, visual survey, other surveys
   c) Literature survey …. many ideas can be developed from review of information
2. Obtain project information
   a) Contract documents
   b) Specifications
   c) Correspondence
   d) Site records/ note books, etc.
   e) Materials, geology, site conditions, rock sources, binders
   f) Test data, analysis results, spreadsheets, etc.
3. Conduct detailed plan developed from consideration of all information
   1. Visual survey
   2. Destructive cores and test pits
   3. NDT – FWD, LWD, DCP, GPR, etc.

NCHRP Published Guide

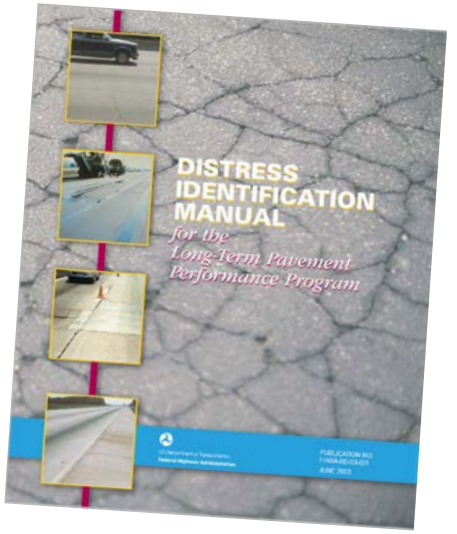
- Published in 2013 and provides a useful check list for those conducting forensic investigations
- For those new to pavement forensics – this is a very useful document to review



Other resources

- MS-22 – Construction of Hot-Mix Asphalt Pavements
- Hot Mix Asphalt Paving Handbook

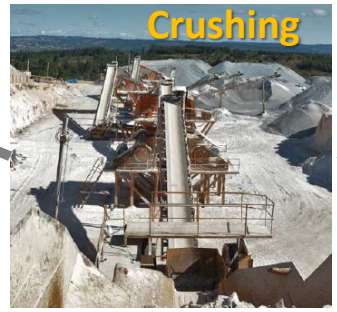
- Many other resources in published literature
  - … remember .. we should always be comparing our assumptions and finding to published work!
  - … *must be sufficiently established to have gained general acceptance* …



https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1025447

Understand the whole process …..

Stockpiles



Asphalt/ bitumen supply

Additives (if used)

Binder Storage

Bag house/ filler/ returned fines

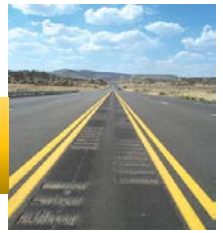
Feed systems

HMA Plant

Trucking

Soils, Foundation, Climate, Water

Performance



Test data

- What does this tell us?
  - How sampled?
  - Is it representative?
  - Is it a true representation!

- A look at this aspect with data later!

Asphalt Man Tool Box …. my three favorite!

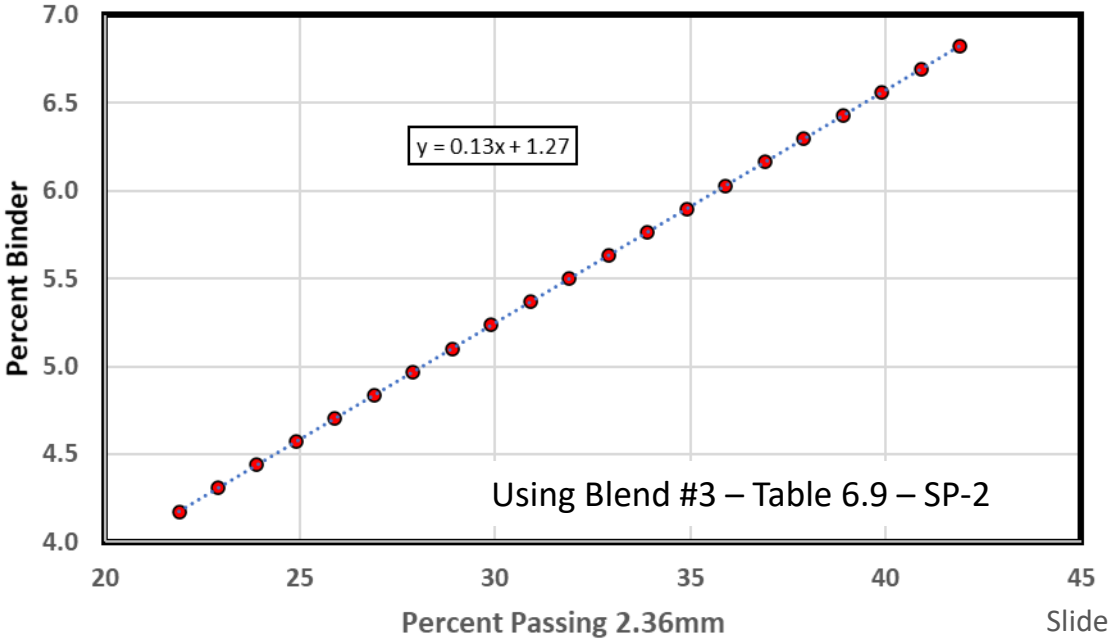
1. Is material segregated?
    - Plots of binder versus fines content – we need to consider this!
2. Volumetric charts
    - Build on concepts developed by McLeod, Edwards and others
    - As an industry we are “hung up” on the reliance of induvial charts for each volumetric parameter when these can be combined into a single chart!
3. Use of calculations of G_{se} from G_{mm} and P_b - or – a P_b estimation from G_{mm} and G_{se}
    - Why do this?
        - In production we would like G_{se} to remain constant!

1. Binder is mainly associated with fines

- Variability and bias in test data can be associated with segregation
- How do we check ….
  - Plot the binder content against % fine aggregate
    - 2.36mm/#8 sieve is what I generally use for this, sometimes other sieves depending on mix type
    - Slope is about 0.1 to 0.15 depending on gradation and aggregate properties
  - Adjustment of test was a feature of some specifications recognizing that segregation could exist in the sample process
  - If scatter is about the line shown (or similar – the assess segregation versus poor plant control!!

Surface area factors in MS-2 (2014

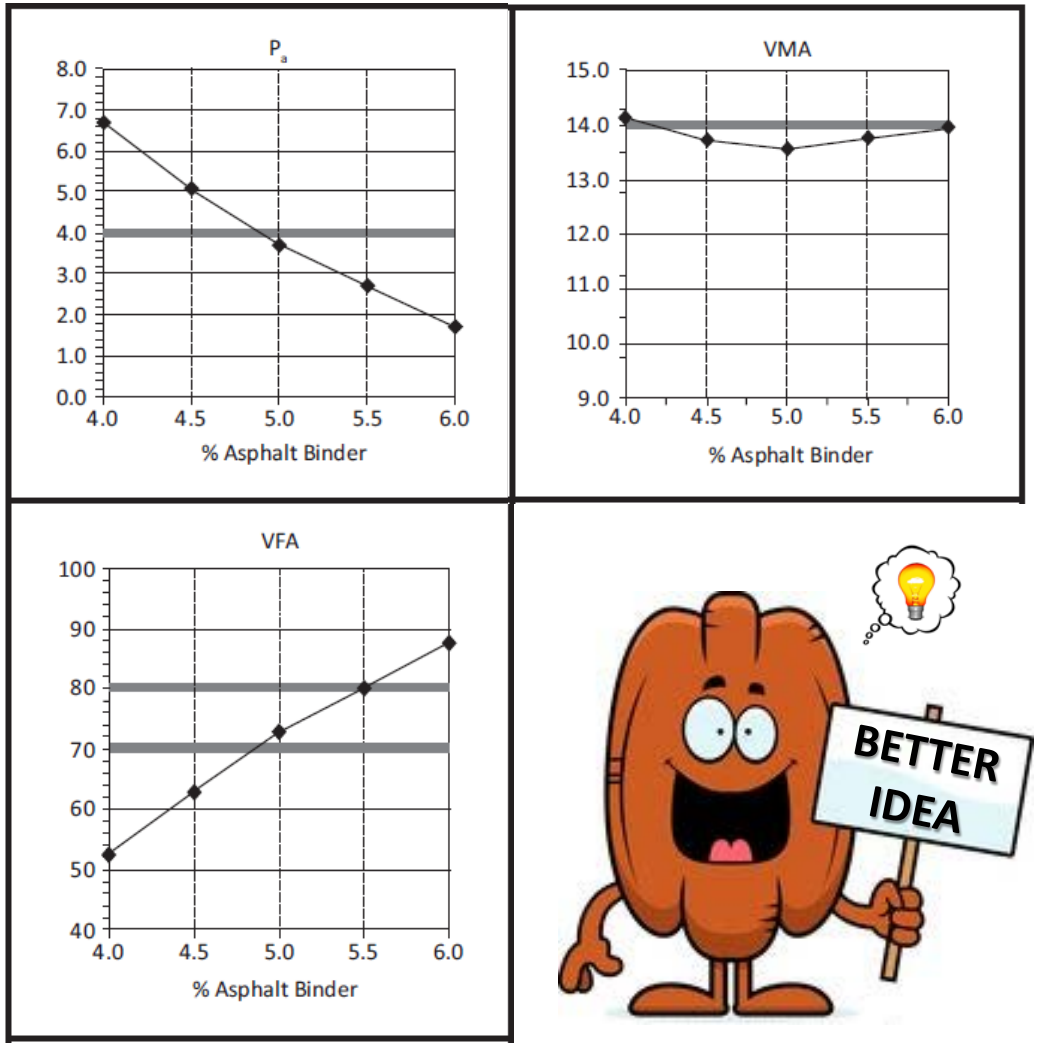
Sieve Size (mm)	Surface Area Factor, m^2/kg (ft^2/lb)
Maximum aggregate size	0.41 (2)
4.75	0.41 (2)
2.36	0.82 (4)
1.18	1.64 (8)
0.60	2.87 (14)
0.30	6.14 (30)
0.15	12.29 (60)
0.075	32.77 (160)



2. Volumetric charts … or chart

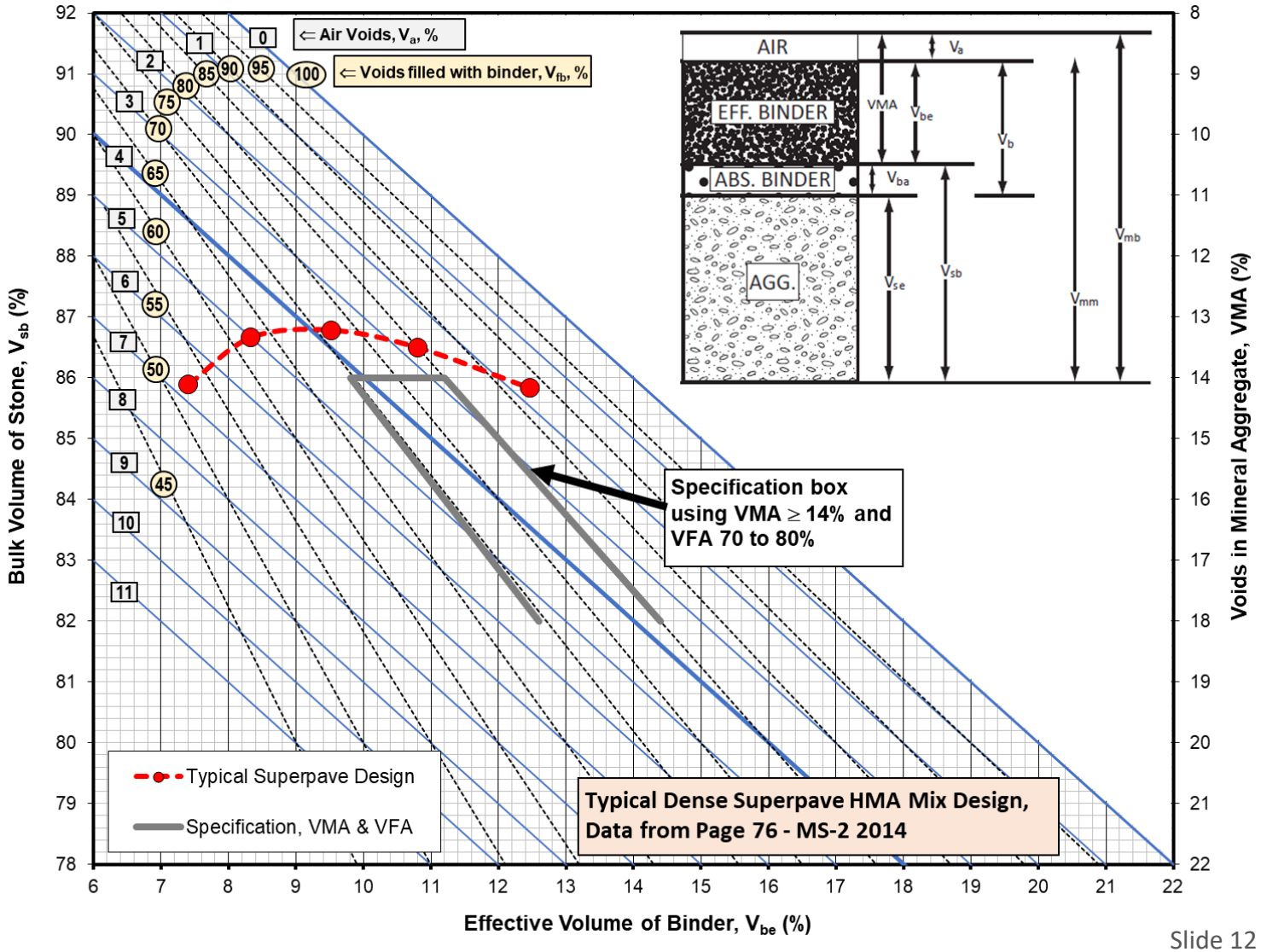
Typical Dense Superpave HMA Mix Design, Data from Page 76 - MS-2 2014

- Since the mid 1940s mix designs with HMA have traditionally made use of plots of Air Voids, VMA and VFB (and/or compacted aggregate density, mix density, etc.) on separate plots against binder content
- More recently, McLeod (some 60-years ago!) advocated the use of singular volumetric charts
  - ….
- However, current practice is to use individual graphs … as shown



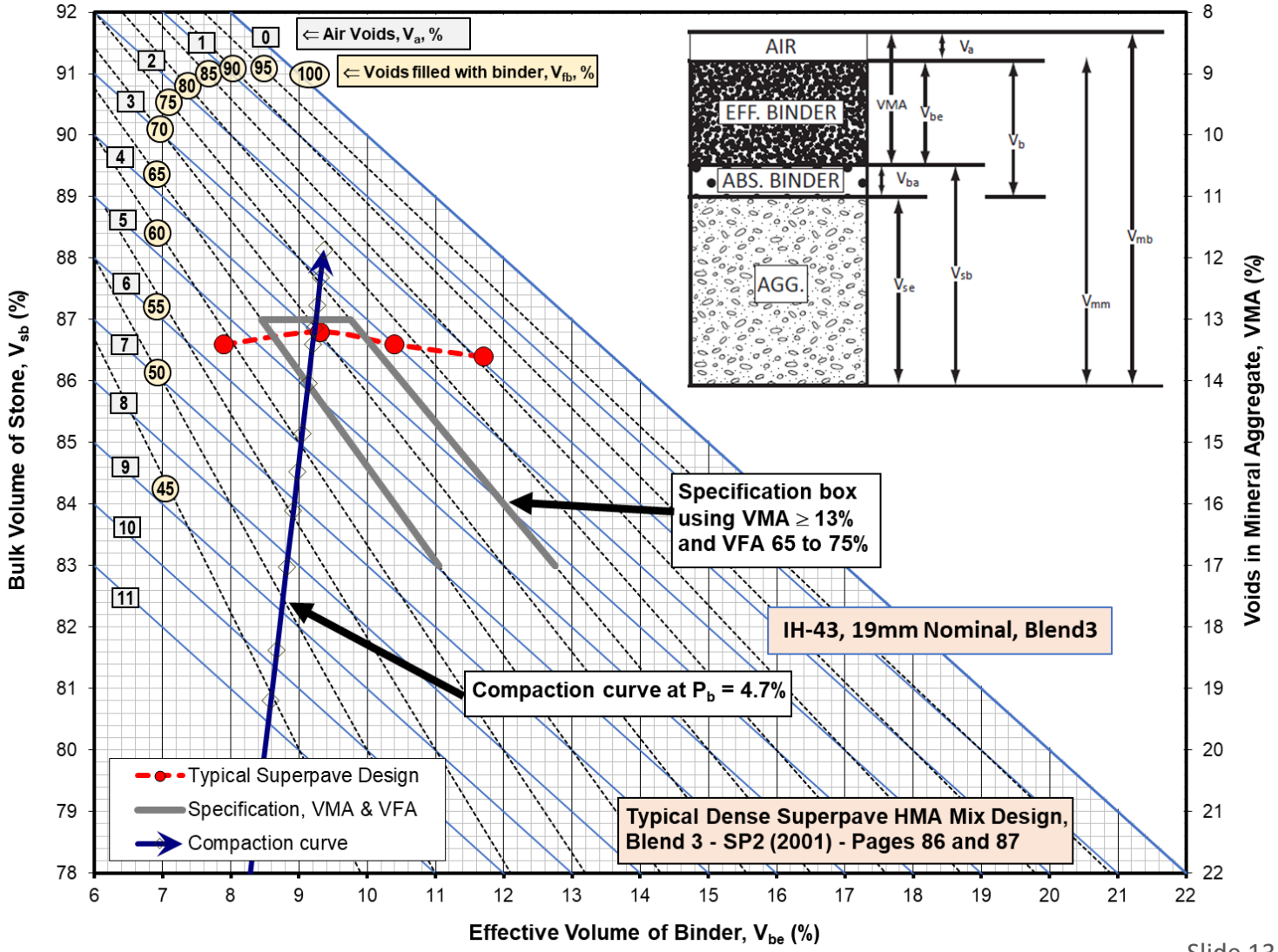
2. Combined Volumetric Chart

- Chart shows the same information in a single plot – but is more informative of direction needed with this design
  - Need to increase VMA by change to aggregate structure
  - Binder volume is insufficient at 4% with gradation – P_b with a passing design will be higher
  - For adequate durability we are generally looking for minimum 10% binder volume



2. Combined Volumetric Chart

- Example from SP-2 (2001 printing)
- Note angle of compaction curve
- This design has a tight tolerance for VMA



3. G_{se}, G_{mm} and P_b

- In the lab – we measure G_{mm} and P_b
  - But normally consider these completely independent of each other
  - However, they can be combined in analysis
  - Why?
- From G_{mm} and P_b we can compute G_{se}
- For a mix design G_{se} should remain consistent – that is the rock in the ground should be a constant during production
  - If NOT – problems with VMA, density control, site voids, etc.
  - A variation in G_{se} may also alert the reviewer to problems in lab testing with either G_{mm} or P_b

Tolerance on G_{se} variation … +/- 1.0% …
…. or I prefer +/- 0.020 (warning limit)

$$G_{mm} = \frac{100}{\frac{P_s}{G_{se}} + \frac{P_b}{G_b}}$$

Simple rearrangement – gives for G_{se}:

$$G_{se} = \frac{P_s}{\left(\frac{100}{G_{mm}} - \frac{P_b}{G_b}\right)} = \frac{(100 - P_b)}{\left(\frac{100}{G_{mm}} - \frac{P_b}{G_b}\right)}$$

… or for P_b– gives:

$$P_b = \frac{100\left(\frac{G_{se}}{G_{mm}} - 1\right)}{\left(\frac{G_{se}}{G_b} - 1\right)}$$

Note – we measure G_{mm} and P_b
G_{se} – is given in the design


… and now we go on to look
at some data/photos …

1. Ravelling during construction

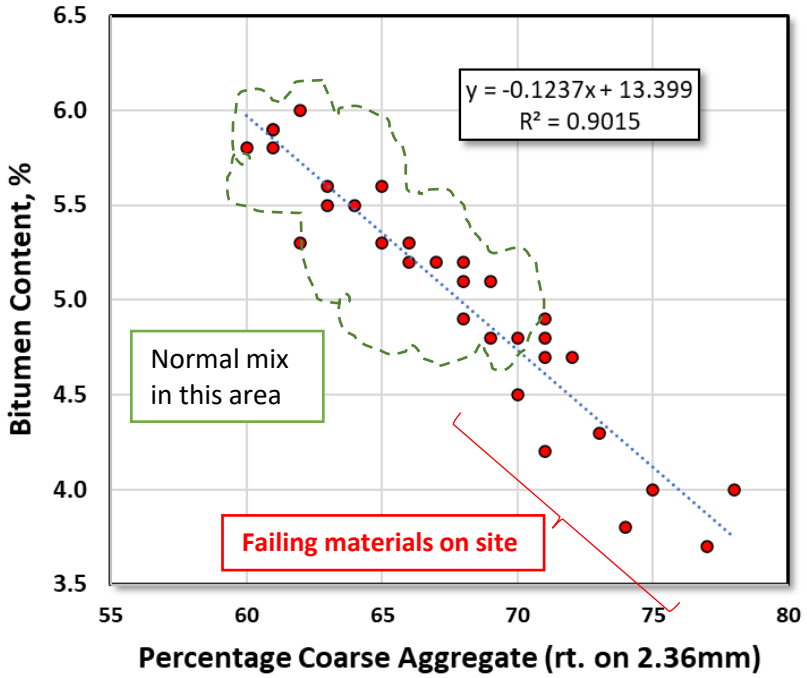
- Bad ravelling at joints and patches of ravelling occurred during construction … late 1982 .. with a 65% 37.5mm HRA base material

Why?

1982

What we saw ….

- Mix samples represented segregated materials as laid
  - Those performing poorly had very high coarse aggregate contents
  - The next question was to determine the cause of segregation …..
- Some possible reasons
  - Mixing plant ..
  - Trucking …
  - Paving operations and/or equipment

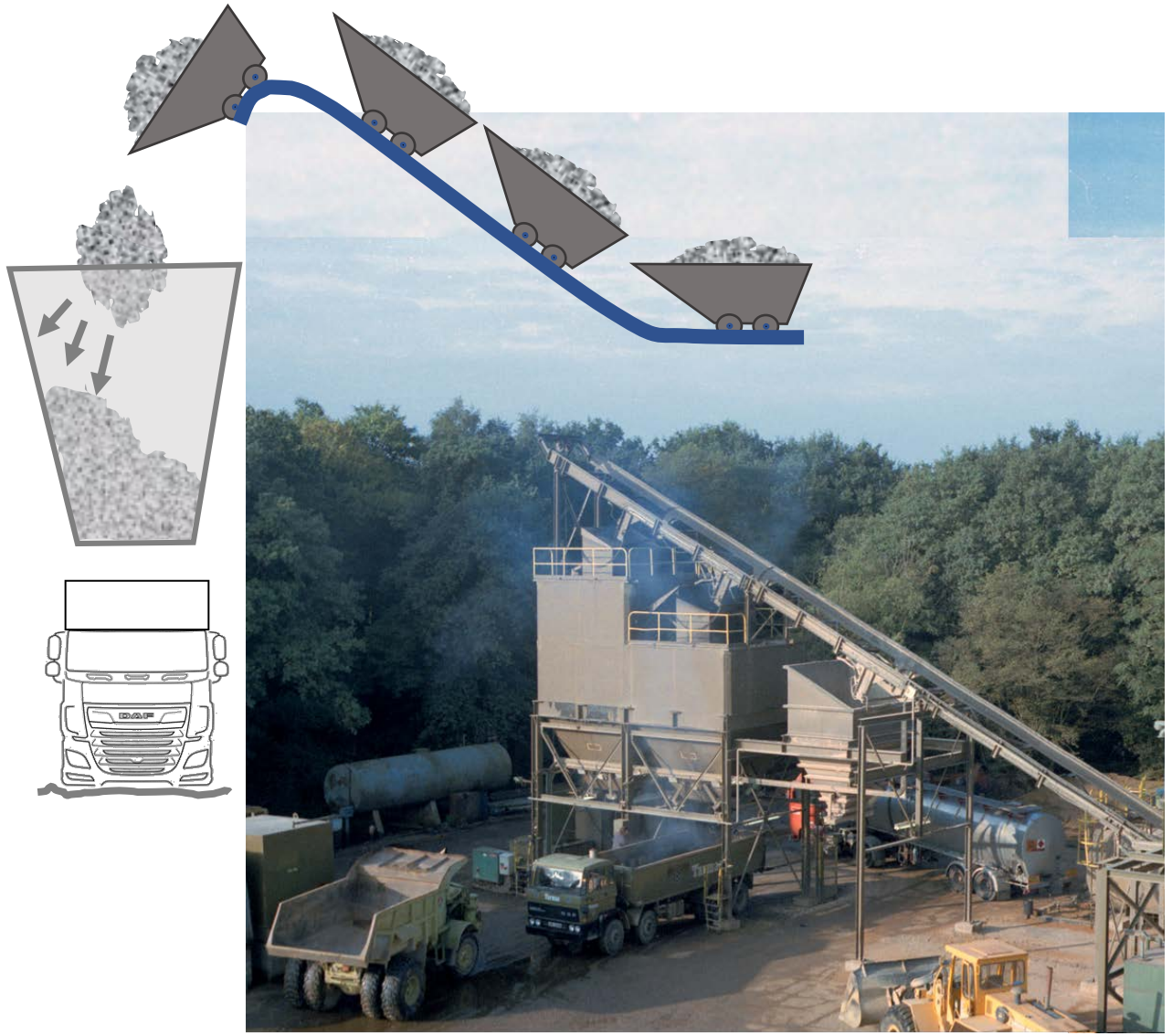


65% 37.5mm Hot Rolled Asphalt RB – has a gap gradation and is sensitive to segregation – in this case the coarse aggregate was a gavel with some rounded particles!

1982

Bad skip design!

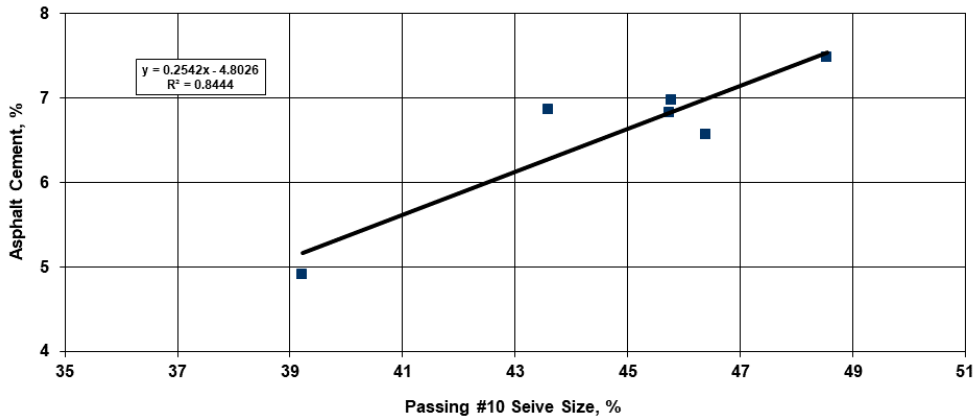
- Various design aspects of an asphalt plant can result segregation occurring
- This basic design existed in the early 1980s – a “tipping” skip to take material from a batch plant pugmill to hot storage capacity of about 120 tons
- Result – large stones ran to one side of hopper – segregation on truck



1982

2. Florida – car park

- A two year old pavement in Florida
  - Same material laid either side of joint!
  - Clearly issues with laydown, compaction and joint construction
    - Voids – 4.8% to 14.7%
  - Segregation
  - Roller marks!



Segregation is apparent – most likely associated with laydown on this site!

2002

3. Importance of planning the production operation – photograph taken May 16th, 2016

End of truck defects obvious

End of truck load segregation

Why is this occurring in this region – what is underlying reason!

2016/18

3. Two years of performance!

- Bad cracking after just two years

2016/18

3. Importance of planning the production operation

- Plant production is significantly slower than laydown capability
  - Must match the speed of the paving to the speed of the production

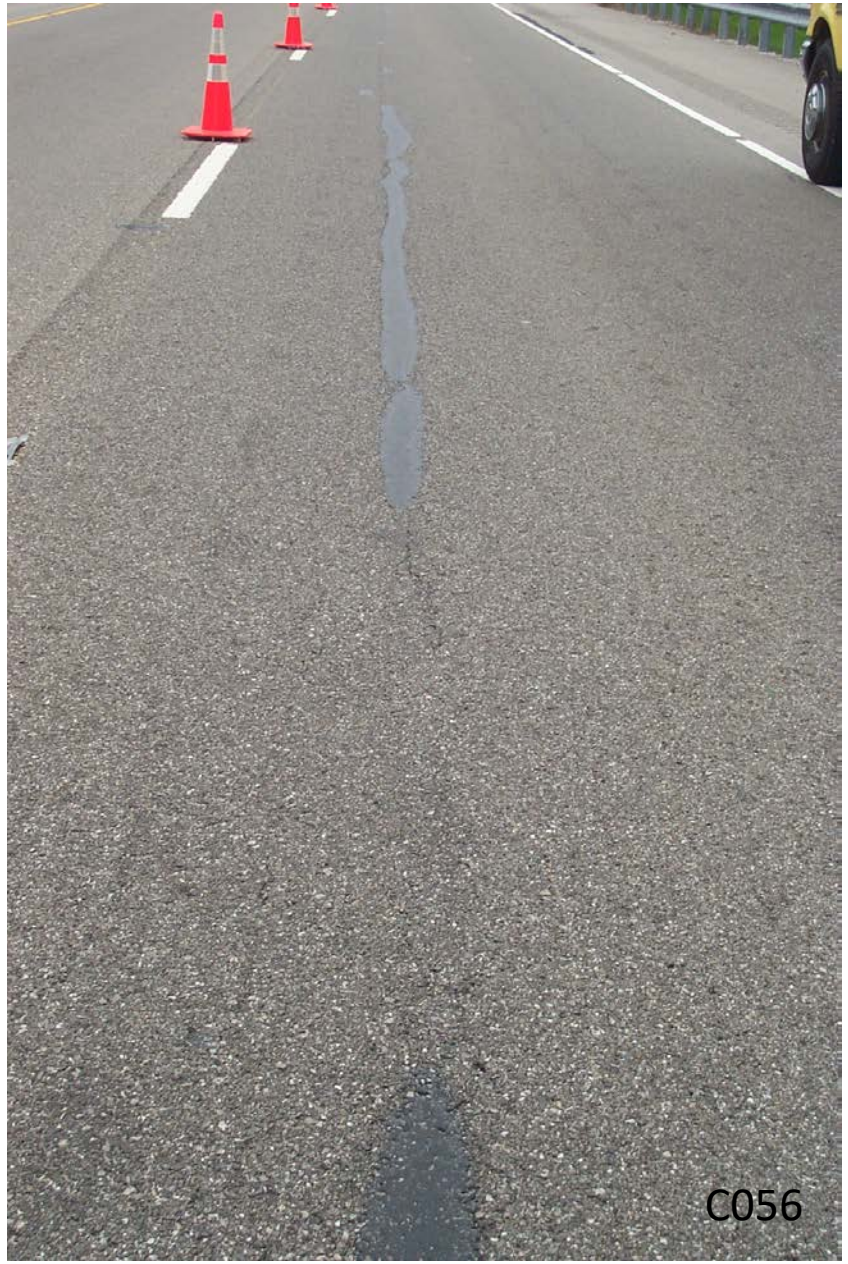
2016/18

3. Paving practices review

- Review paving plans on site frequently to ensure
  - Product rate matches paving rate
  - Good handling of trucks, paving procedures and rolling
    - Guides
      - Hot Mix Asphalt Paving Handbook - https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1025447
      - MS-22 Construction of Quality Asphalt Pavements - https://bookstore.asphaltinstitute.org/catalog/book/ms-22-construction-quality-asphalt-pavements
  - Site training review/tail gate meetings/and follow-up with implementation on site

4. Cracking and pavers

- Screed extensions
- Auger gear box
  - Incorrectly configured paving machines can result in surface cracking
  - Cracking not associated with wheel paths and longitudinal in nature
  - Look at paving process very carefully

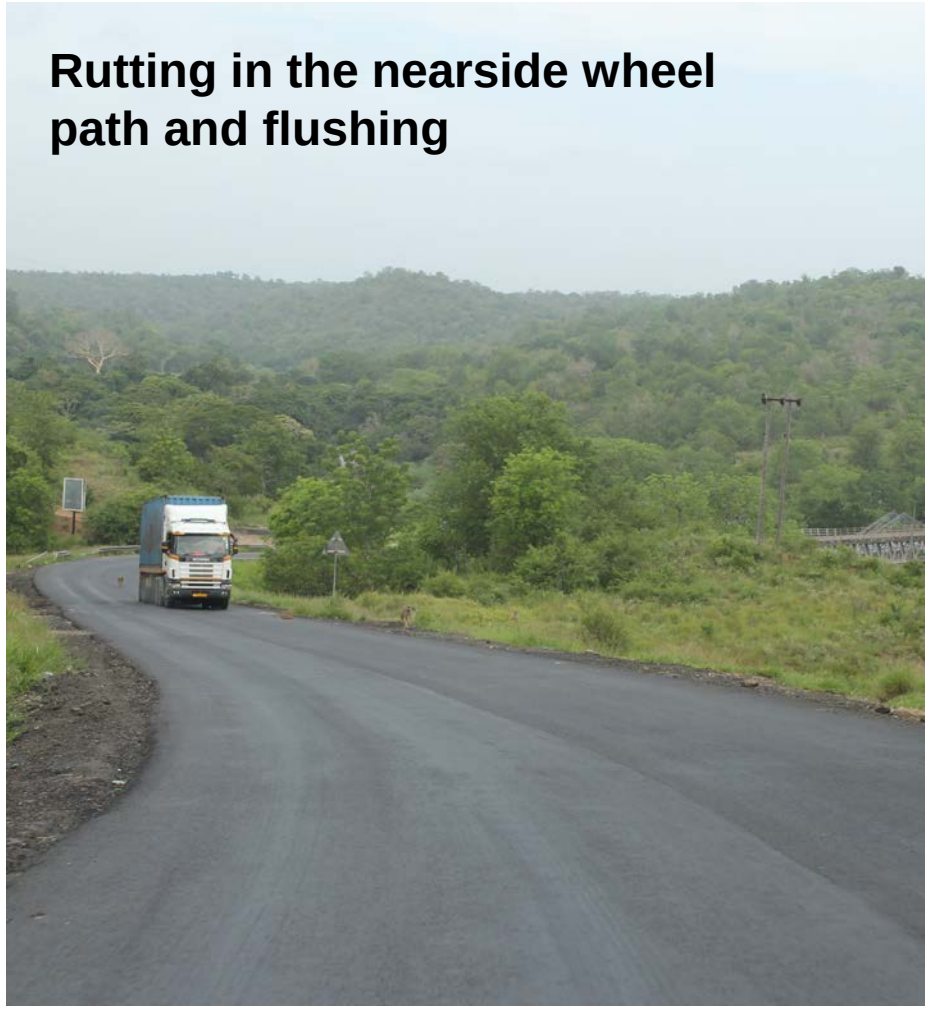


5. Problem with Superpave 19mm mix

Rutting in the nearside wheel path and flushing

2011

5. Problem with Superpave 19mm mix



2011

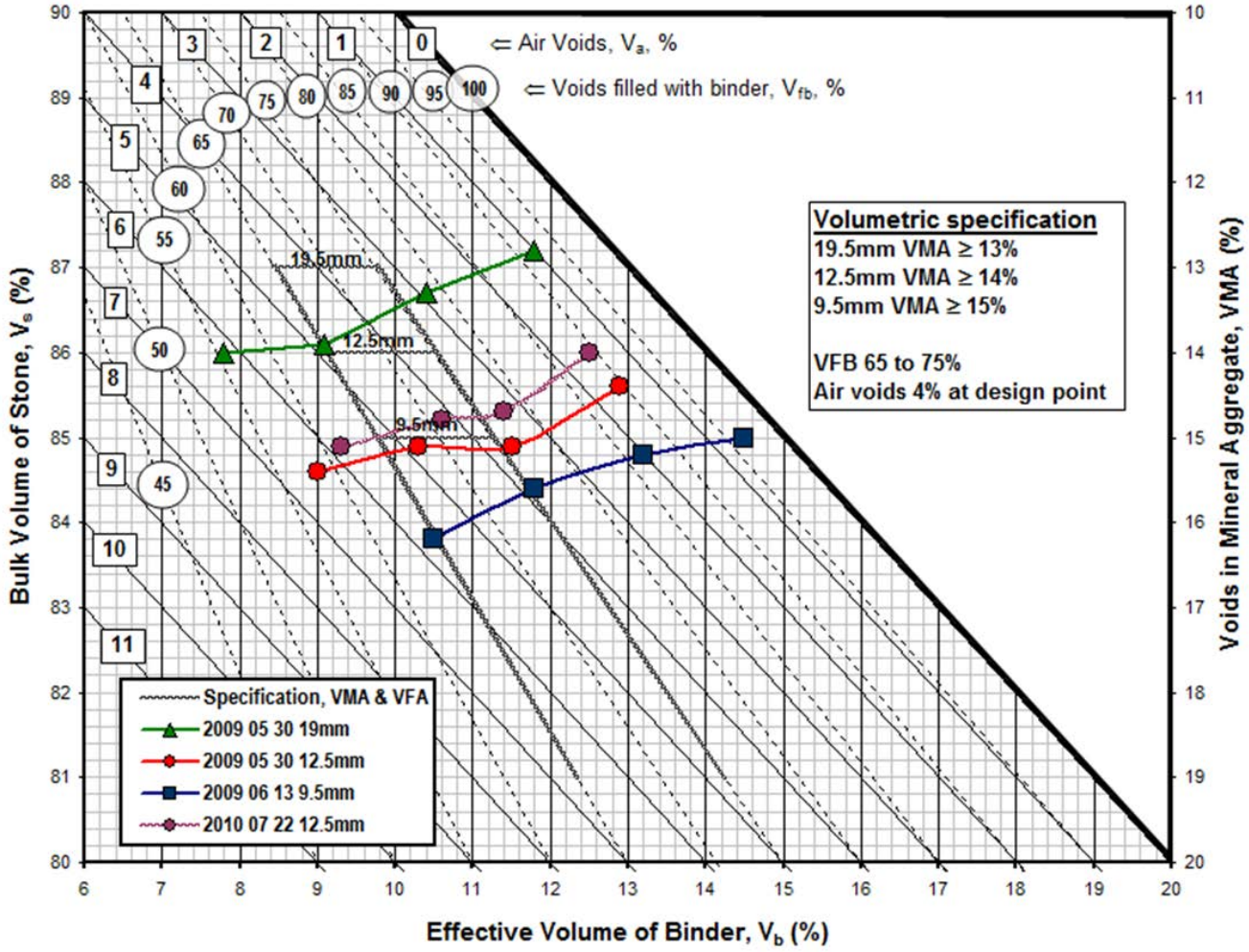
5. Problem with Superpave 19mm mix

Cracking,
slippage,
patching, etc.

2011

5. Problem with Superpave 19mm mix

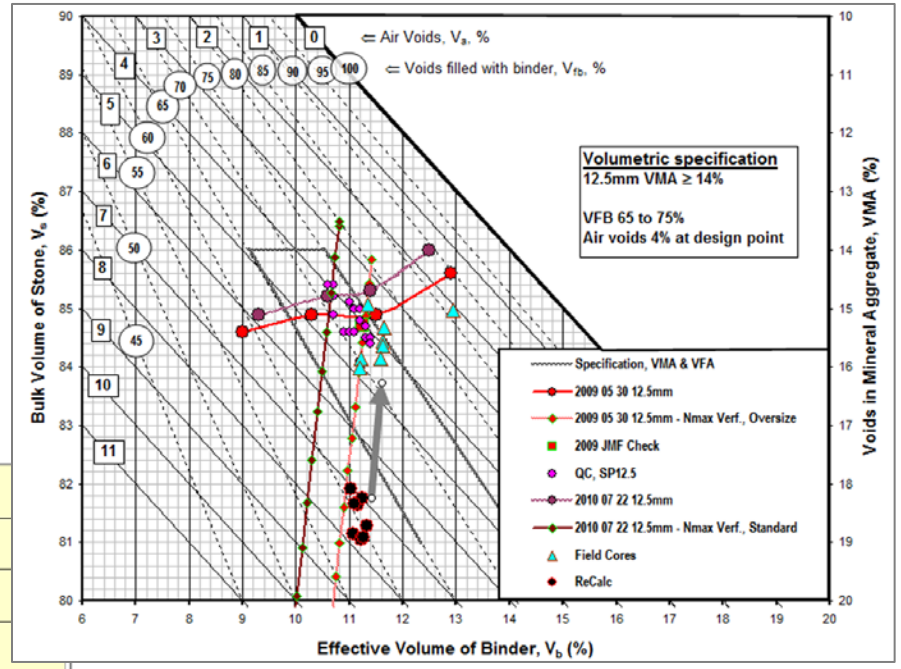
- All mix designs problematic

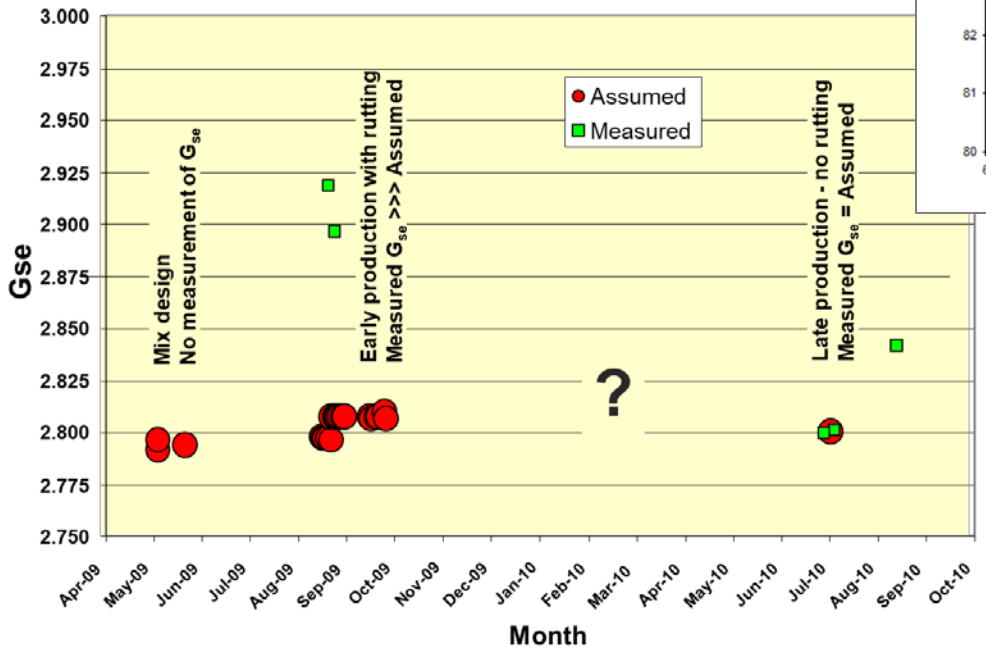


2011

5. Problem with Superpave 19mm mix

- G_{se} varying very significantly
- Volumetrics – all over the place!
- So why …???

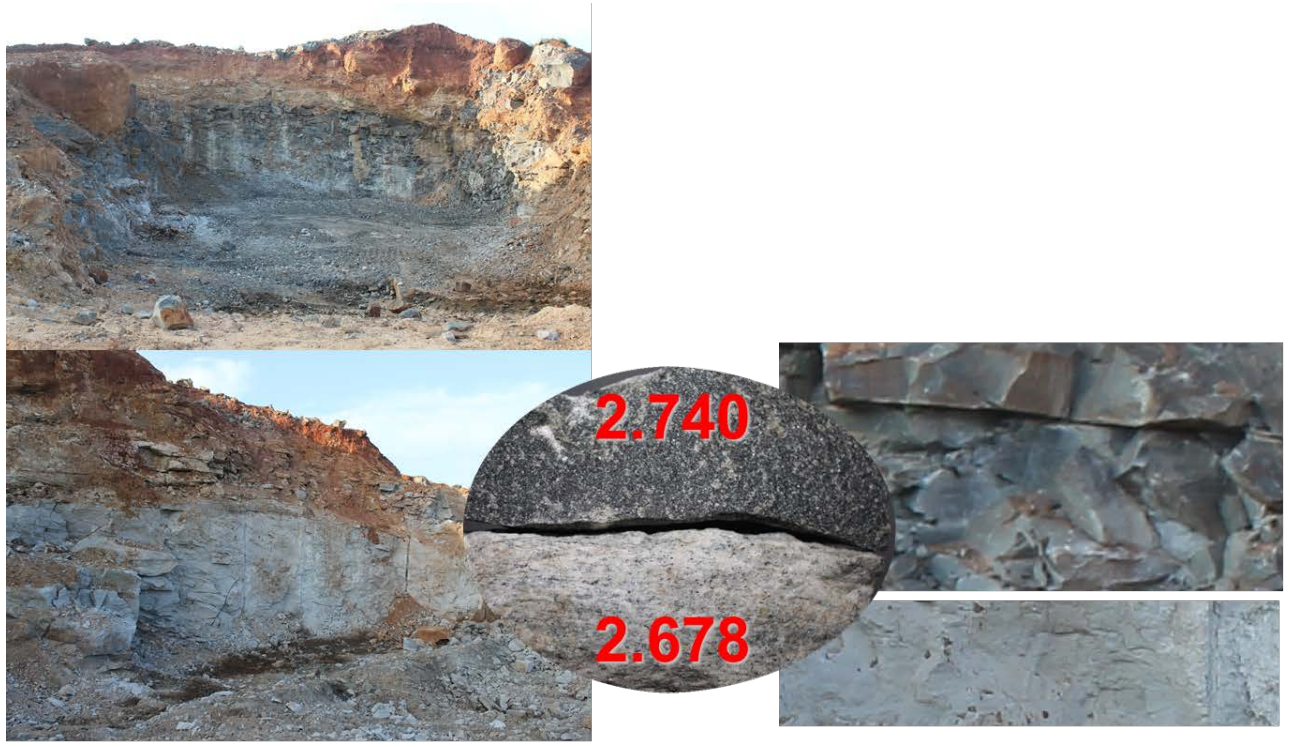




2011

5. Problem with Superpave 19mm mix

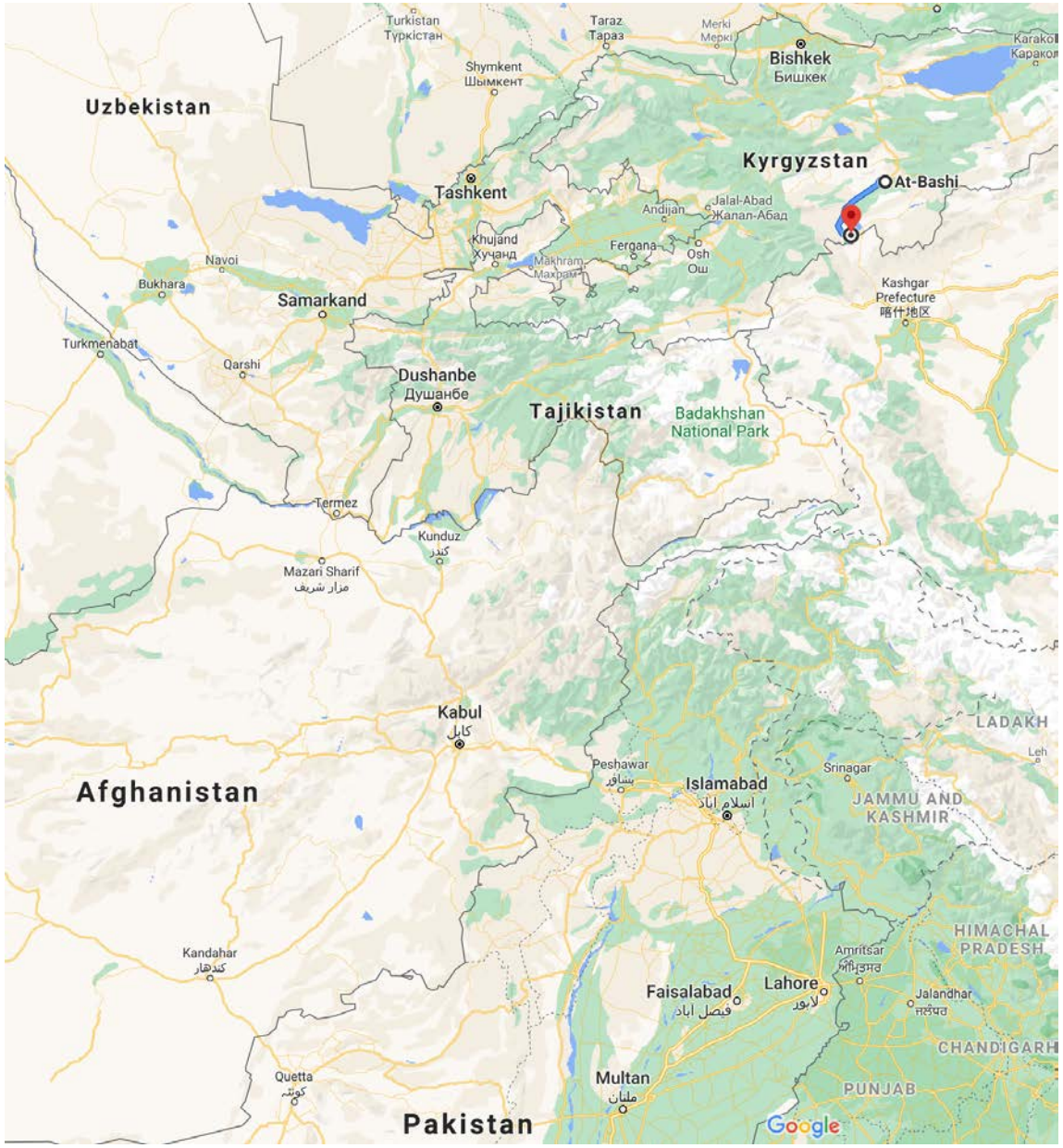
- Start at the beginning!
  - Rock a big problem on this project!
    - Very variable density!
  - Suggested action limits on G_{se} of +/- 0.015
  - QC charts for control, etc.



Some tests as high as 3.0!

6. Control of water!

- This next problems deals with the control of water in cold climate location!
- Cracks observed – mainly longitudinal a few months after construction of a new alignment.
- Location – At Bashi, Kyrgyzstan – road to border with China



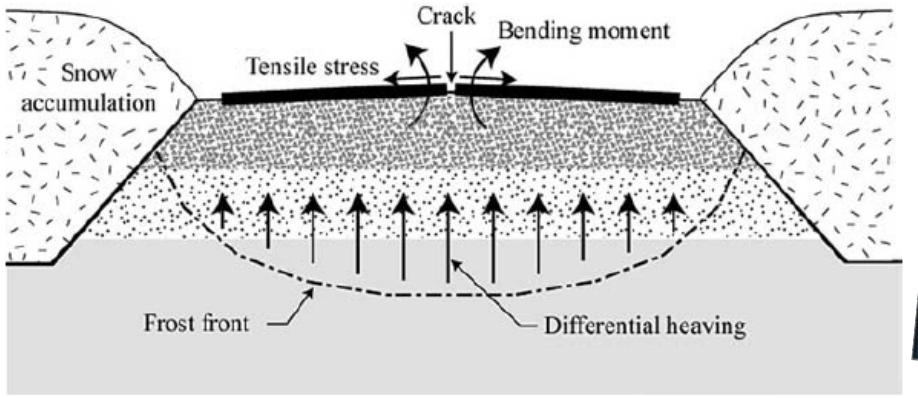
2013

6. Cracks can be deep!!!

2013

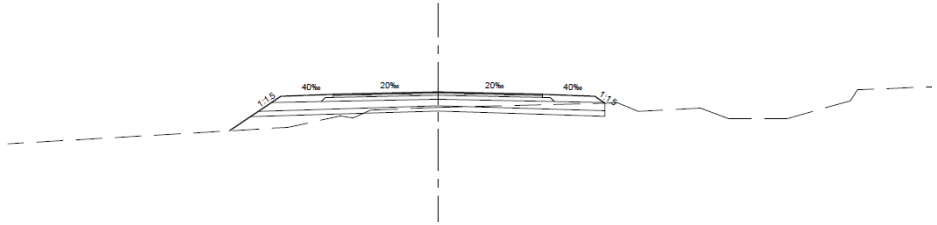
6. The cause!

- Differential heaving
- Inputs
  - Water in foundation that will freeze
  - Differential surface temperature to result in different depths of frost penetration
- Prevention
  - Detailed drainage design
  - Frost “blankets” – soils that do not hold water – laid a depth equivalent to frost penetration!



2013

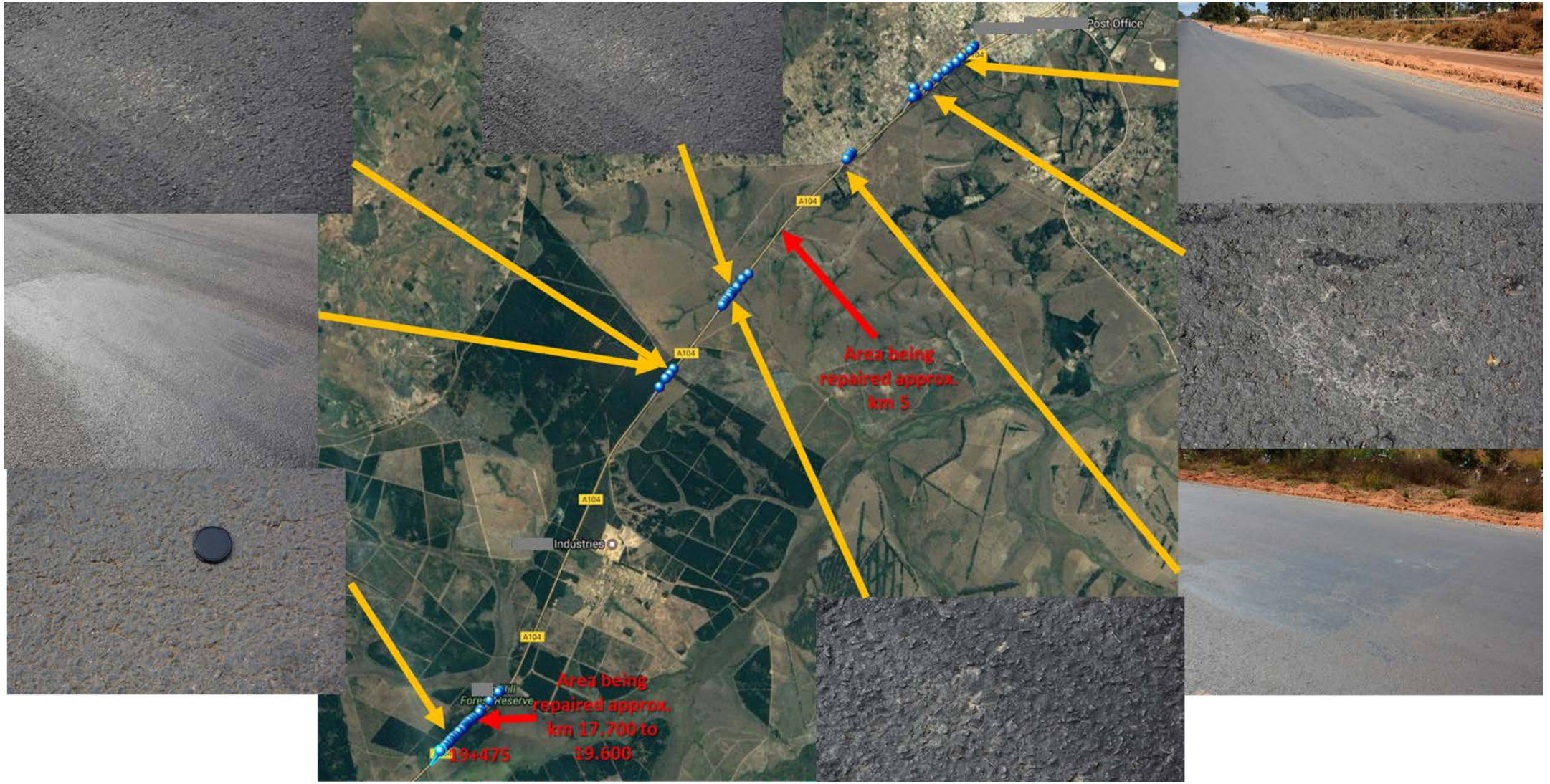
6. Water control is difficult



- Control of water critical – need to carefully consider location of phreatic surface and movement of groundwater
- Freezing water flowing out of a layer can “dam” water unfrozen moving through the layer

2013

7. SP19 – poor performance after paving

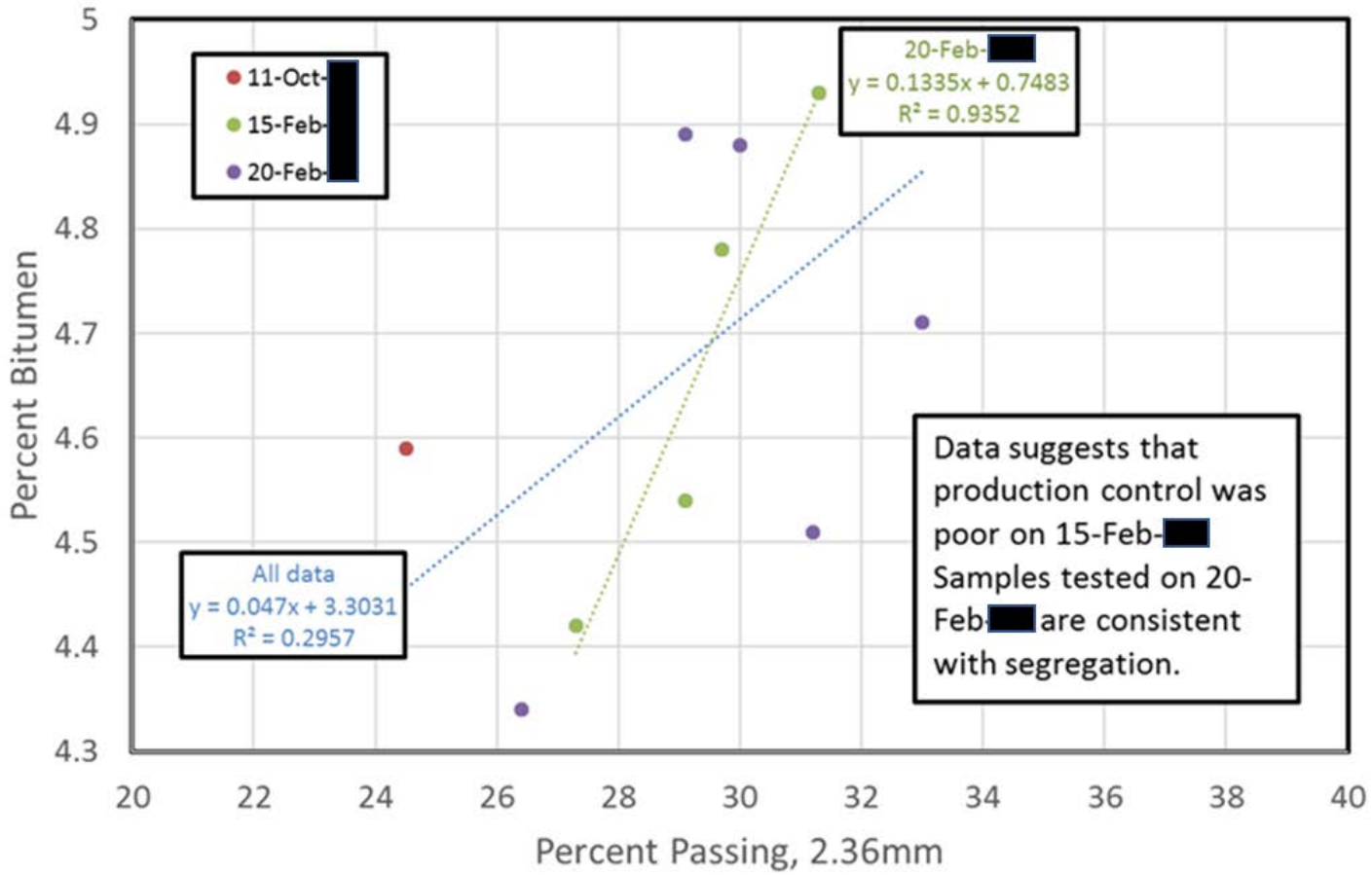


7. Paving practice resulting in coarse/stony areas

- Emptying wings on paver results in segregated/coarse area/stony areas – practice in general area
- Most likely - also on other areas

7. A look at data in problem areas/days laid

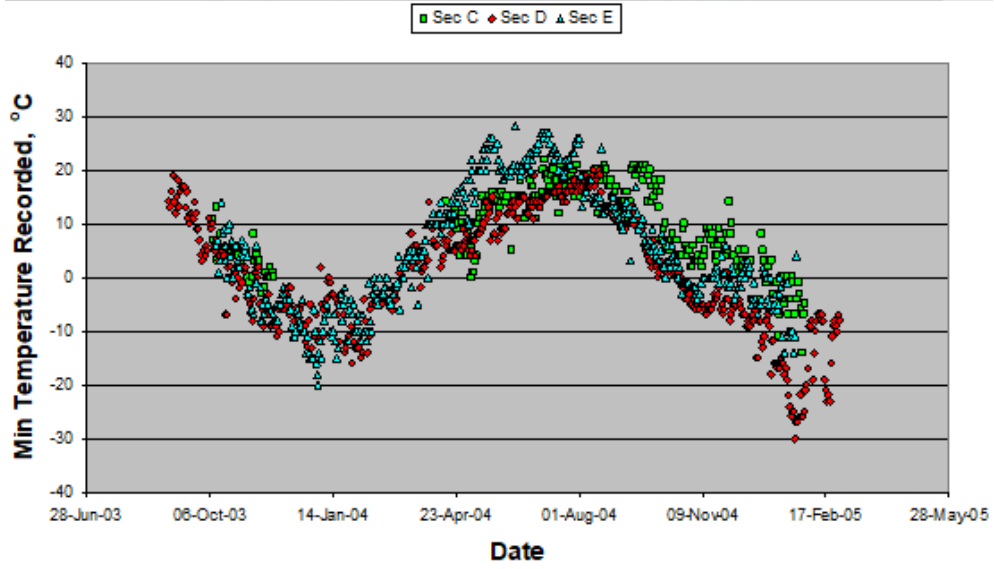
- Areas throughout site identified as cracking
- Damage is not confined to these areas
- Problems
  - Some segregation issues
  - Possible plant control
  - Paving practices



8. Selection of modifiers

- Important to understand what modification do …
- Always consider
  - Thermal cracking
  - Fatigue cracking
  - Durability
  - Permanent deformation/deformation
  - Water damage
- Site conditions
  - Climate
  - Soil conditions
  - Pavement design

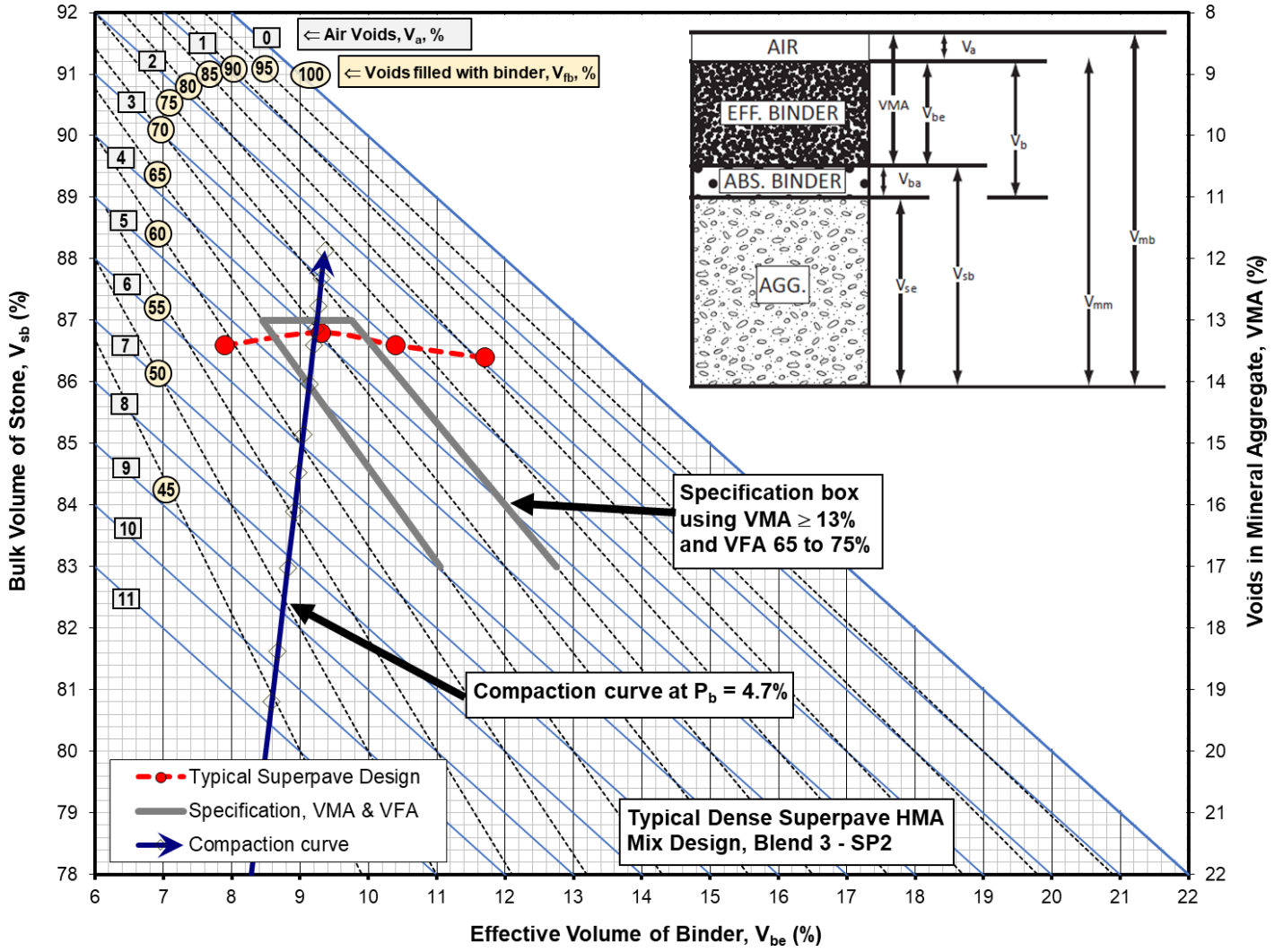
Incorrect application of asphalt modification resulted in stiff mix prone to thermal cracking



2005

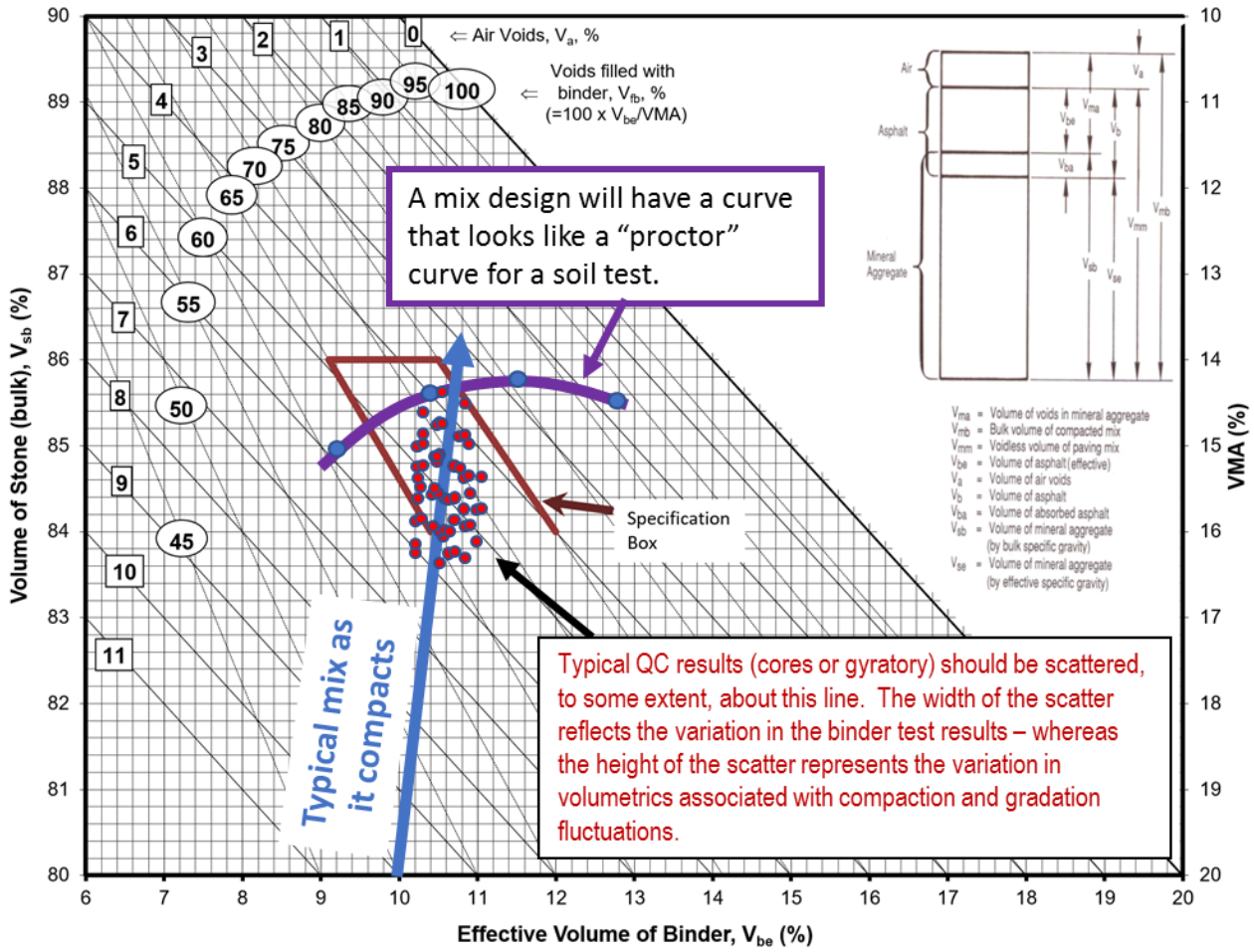
9. Volumetrics

- Understanding volumetrics is of key importance to the behavior of asphalt materials
- This single chart combines all the volumetric parameters into a single curve and is much more efficient than using a single curve for each parameter
- Uses
  - Design
    - Understanding the effects of Gsb – how this effects VMA
    - Specification boxes – are they compliant
  - Quality control
    - How designs compare to QC results to trends expected



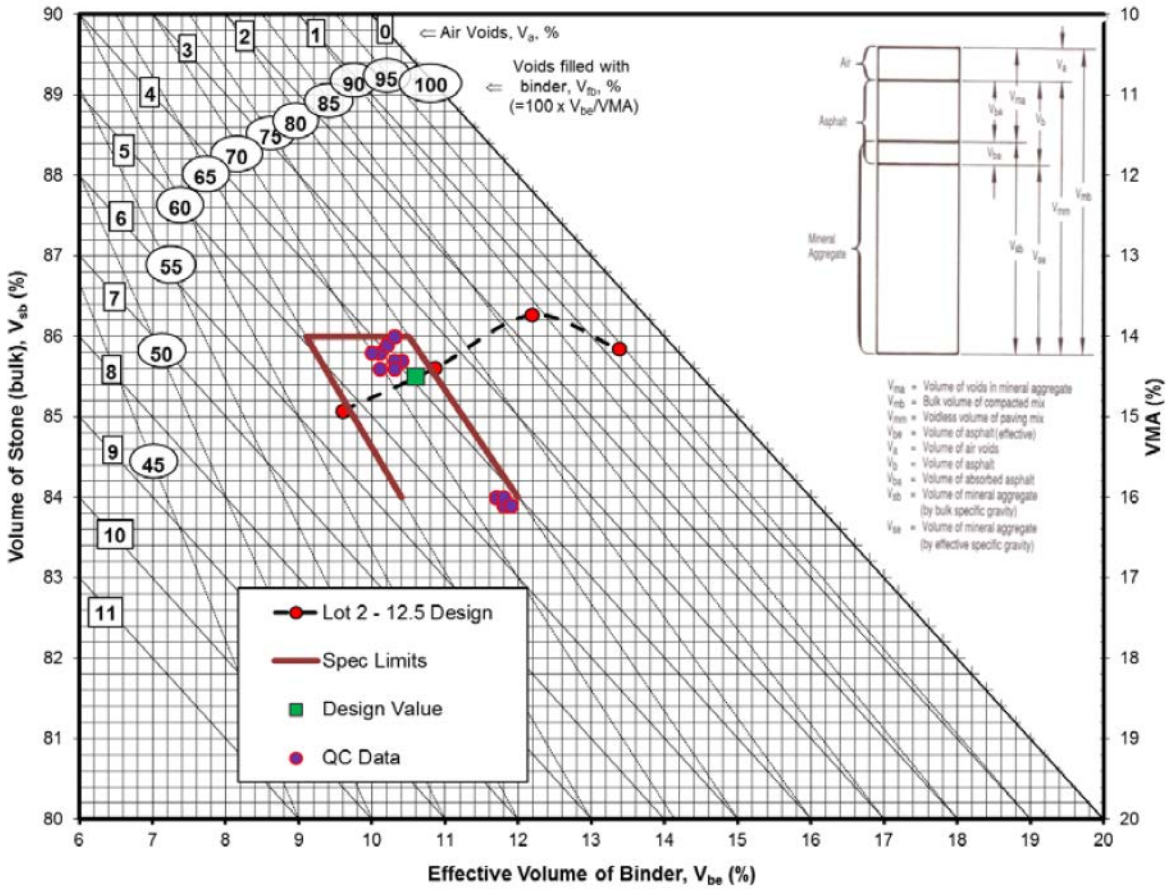
9. What we expect to see in data

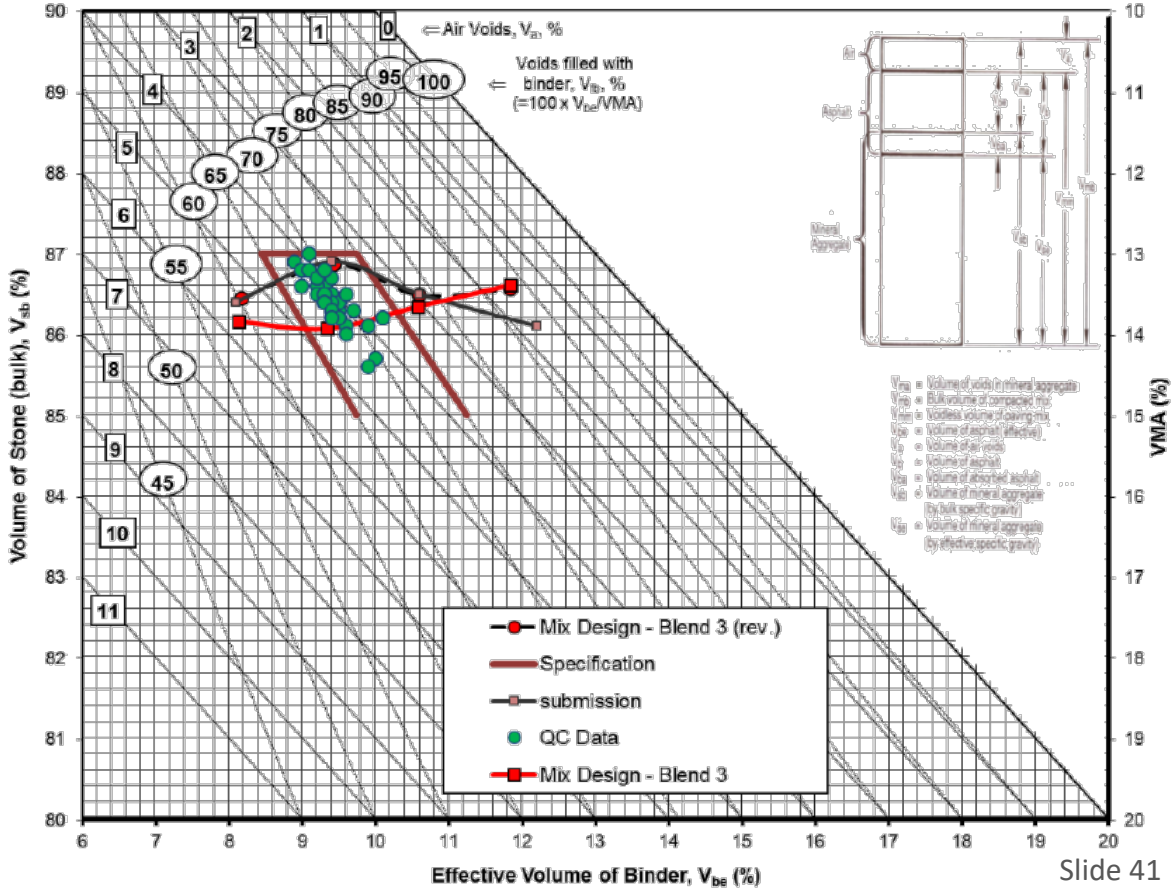
- Data should be scattered about a line that represents a compaction curve
- Scatter is associated with test variability, variations induced by sampling, etc.



9. Examples of result fabrication

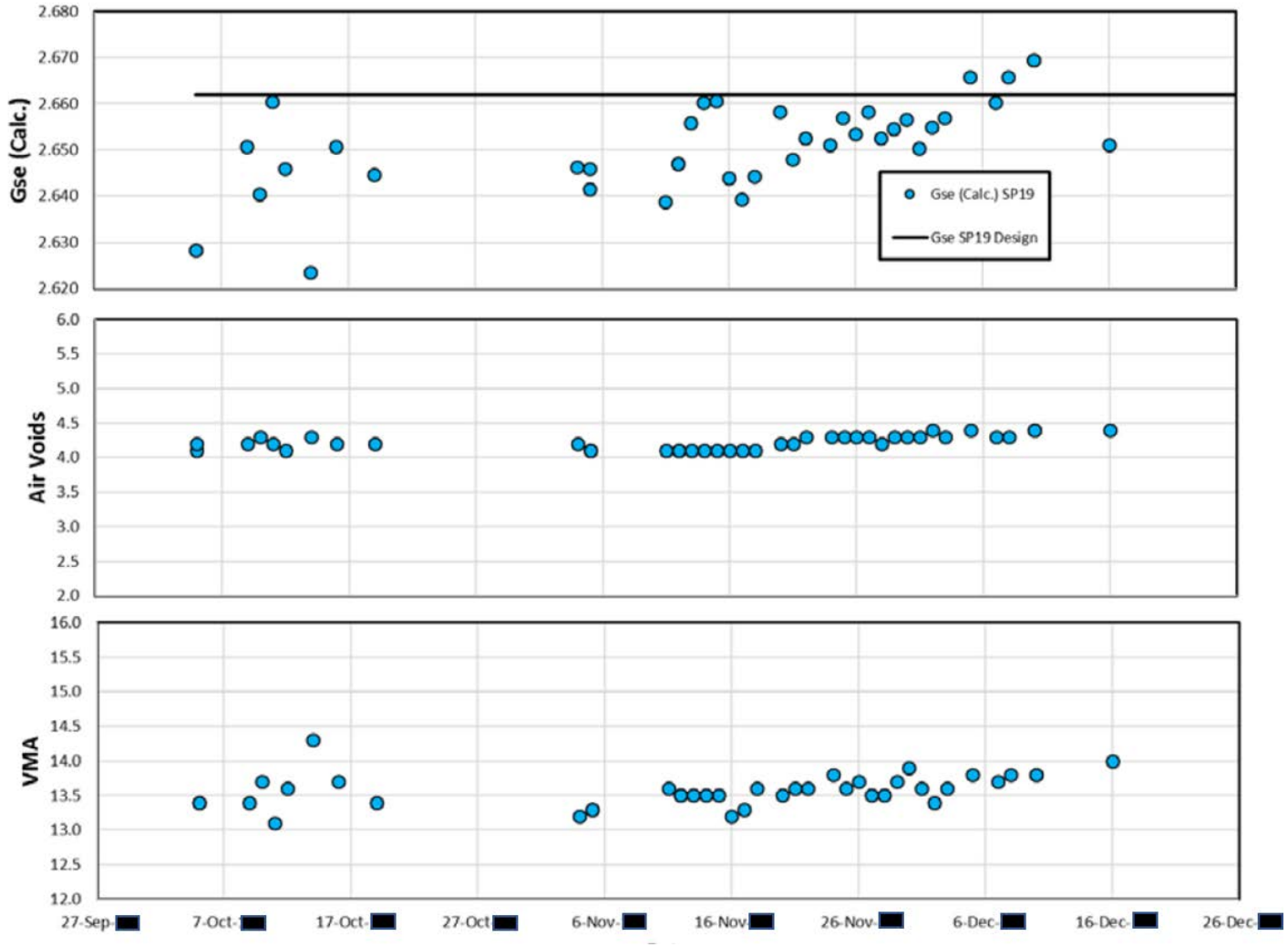
- Two examples of data manipulation – obvious due to slope effects by G_{mm} adjustment





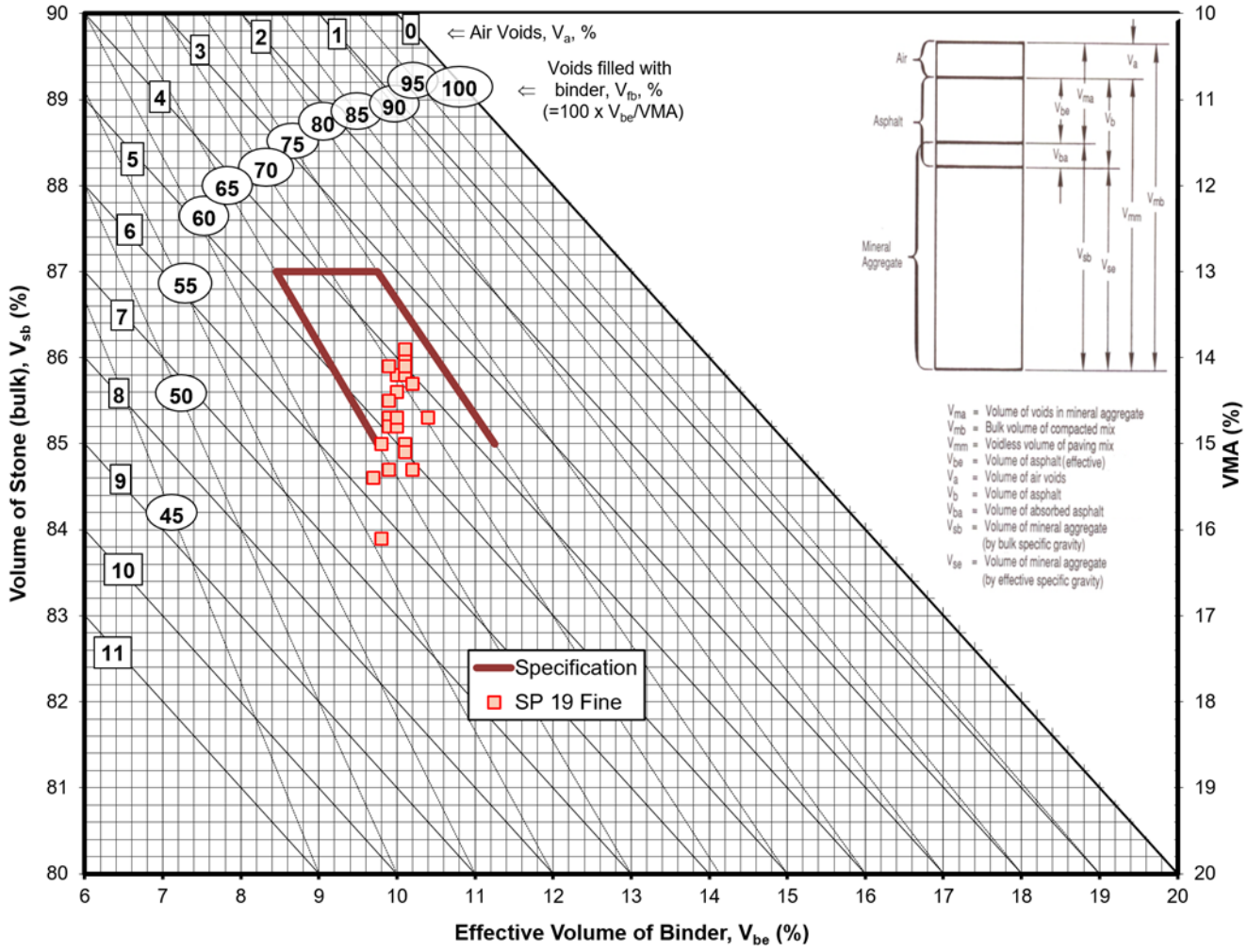
9. Example of result fabrication

- G_{mm} chosen as a value to produce a void content in specification for gyratory specimens
- Need to make trend charts
- Repeating “constant” values is a “red flag” in this result as is the variation in G_{se}



9. Example of result fabrication

- Restarted production shows data in correct format
  - Improvements to G_{mm} procedure
  - Correct understanding of variation associated with sampling, segregation, compaction temperature, etc.



10. Avoid roller cracking

- Roller cracks / checks marks – must not be produced during laydown and compaction
- Use PTRs and/or adjust rollers (speeds and weights) to avoid creation!

Summary thoughts

- Some tools and examples of issues that I have seen
- Please keep a open mind … and do not jump to early conclusions … but don’t forget the basics!

  - Not all issues covered …. would take a long time to cover

Summary thoughts Address the issues ….

- Training on site for the full crew …
  - Explain the operation
    - Likely risks
    - Importance of the team
- Engineers/technicians
  - Read the guides and be aware of issues that will effect quality
  - Understand the full process

Thank you / Questions / Comments