

Is your asphalt only living half as long as it could?

Writing and enforcing specifications for asphalt compaction

May 2017

Problem and Solution

The cracking life of an asphalt overlay can be shortened by as much as half or increased by as much as double depending on the compaction that occurs between the paver laying down the material while it's still hot and when it becomes too cold to further densify under the rollers.

Most local agencies have asphalt compaction specifications in their contracts as well as inspectors who check the contractors' operations. But following specifications that tell a contractor how to do the compaction, called *method specifications*, typically leads to very poor results because even the most experienced inspector or contractor cannot tell how well or poorly compacted the asphalt is by just watching the compacting operation or looking at the completed surface. In these situations the possible life can be cut in half. On the other hand, a city or county can use quantitative *quality control/quality assurance (QC/QA)* specifications that call for measurement of compaction to determine the extent to which the contractor has met the compaction requirements. The data collected can also

be used to apply a payment reduction if the compaction specification has not been met sufficiently or to give a bonus for exceptional compaction. In addition, it is important that quantitative specifications that rely on nuclear gauges to measure density include requirements to calibrate the nuclear gauge results with cores on each project. Nuclear gauge results that are not calibrated with cores can be highly variable and difficult to defend when used on the thin overlays that make up the majority of city and county work. Results from calibrated nuclear gauges can quickly provide compaction information to the contractor and the owner during paving.



To really determine whether you are getting good compaction on your asphalt,

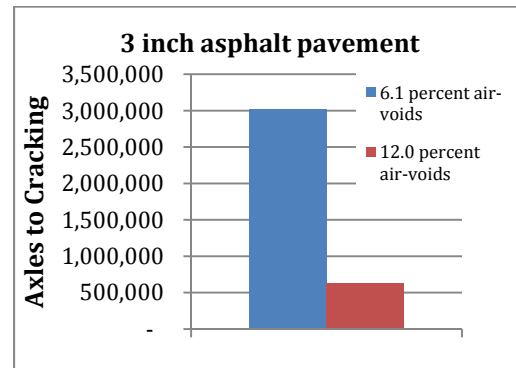
The City and County Pavement Improvement Center, hosted by the University of California Pavement Research Center, is dedicated to increasing pavement knowledge and technical capability among local government staff, planners, and managers by providing timely, relevant, and practical technical support, training, research, publications, and outreach.

and really getting the maximum benefit from each dollar you spend, we recommend that local government agencies implement specifications that require measurement of compaction, review the results on an ongoing basis during construction, and include and enforce application of payment reductions for poor compaction. We also recommend using cores from each mix on each project to calibrate nuclear gauges, and taking cores from each lot for potential dispute resolution.

Cost and Sustainability Benefits

Research has shown that use of *method specifications* (which tell contractors how to do the work instead of allowing them to figure that out and then have the agency measure the results) or lack of enforcement of other types of asphalt compaction specifications often results in air-void contents in the range of 10 to 14 percent. Research has also shown that enforcing compaction specifications based on measured results can easily bring those values down to 8 percent—and even down into the 4 to 6 percent range, particularly if there are incentives (extra pay) as well as payment reductions, and the owner manages the contract (details later) to help the contractor achieve good compaction. A general estimate is that each 1 percent increase in air voids decreases the life of the overlay by about 10 percent, so 14 percent air-voids means that an overlay intended to last 10 years will last about 5 years if it's poorly compacted but can last up to 20 years if it's well compacted. Data from some studies indicate that the sensitivity of cracking performance is even more

sensitive than this example indicates.^{1,2} This can be seen in the plot below of truck axle loadings to cracking based on laboratory testing results and simulation from the FHWA WesTrack project.



Higher air-void content due to poor compaction causes not only poor cracking performance, but it also leaves the asphalt surface more permeable to water and therefore much more likely to fail due to moisture damage, and more permeable to air which increases oxidation and aging, resulting in early raveling and block cracking.

The life cycle cost implications of poor compaction are obvious: poor compaction approximately doubles the cost of your maintenance and rehabilitation for that overlay, while really good compaction can as much as halve it. Reduced payments and bonuses should be tied to these life cycle effects. The environmental impacts of asphalt overlays mostly come from the

¹ Harvey, J., and B. W. Tsai. *Effects of Asphalt Content and Air Void Content on Mix Fatigue and Stiffness*. Transportation Research Record 1543, , 1996, pp 38-45.

² Monismith, C., J. Deacon, J. Harvey. 2000. *WesTrack: Performance Models for Permanent Deformation and Fatigue*. University of California, Berkeley. Summarized in Epps, J., et al. 2002. *Recommended Performance-Related Specification for Hot-Mix Asphalt Construction: Results of the WesTrack Project*. NCHRP Report 455.

material production. So, as with cost, poor compaction can as much as double the environmental impacts, including greenhouse gas emissions, because the overlays have to be replaced twice as often, while good compaction can double the time between replacements.

Other benefits of well-compacted asphalt overlays are that you have to deal with construction traffic delay less often because of the longer lives, and there is a lot less bad publicity from your overlays looking like they need to be redone after 5 years.

What You Need to Do

These specification elements will get you on the road to good asphalt compaction:

- Use a quantitative (QC/QA) specification where you measure compaction, and do not mix method requirements (how to do the compaction) in the specification.
- Reference the required compaction in terms of *in-place bulk density* and *theoretical maximum density* (TMD)³ and not to *laboratory theoretical maximum density* (LTMD).
- Use nuclear gauges calibrated for the specific mix and project to measure in-place density (about 10 measurements per 500 tons is reasonable) to provide daily feedback to both contractor and agency.

³ TMD can be measured using AASHTO T 209, ASTM D 2014 or Caltrans Test 309. Compaction is measured in terms of the in-place density from the calibrated nuclear gauge or core divided by the TMD. 95% compaction (also called relative density) means that the density of the core is 95% of the TMD. No air-voids equals 100% compaction, so 95% compaction relative to TMD means that there are 5% air-voids.

- Collect and keep cores (about 3 cores per 500 tons) for in-place density measurement in case of a dispute.
- Use average compaction per measurement unit based on gauge results (or cores in case of a dispute) from the project to determine how well the contractor is meeting your specification.
- Make sure that your staff and/or consultant have experience putting the specification together.⁴ Apply payment reductions if they don't meet your specification, and look at the data and enforce those payment reductions. Consider incentives for exceptionally good compaction.
- Have experienced staff—yours or a subcontractor—use the nuclear gauge in the field and take the cores.
- Apply the specification to hot mix asphalt (HMA) and rubberized HMA.
- Pay attention to segregation and longitudinal joint compaction.⁵

But What About...?

Won't this increase the bid cost for my asphalt? *Experience has shown that initial costs may go up slightly (at most 10%, but remember those life cycle cost savings!), but once the bar is set contractors can meet it with no added cost. Good compaction is mostly about good construction management, and doesn't require special equipment or materials.*

⁴ CCPIC will post a model specification later in 2017.

⁵ CCPIC will have another Best Practices for Pavement on these subjects.

Isn't the cost of managing this specification high? *It is pennies on the dollar compared to life cycle cost savings. You don't need to use the full Caltrans HMA specification, and the actual specification language can be very simple and straightforward. The coring and lab testing costs are a small percentage of the cost of the construction contract.*

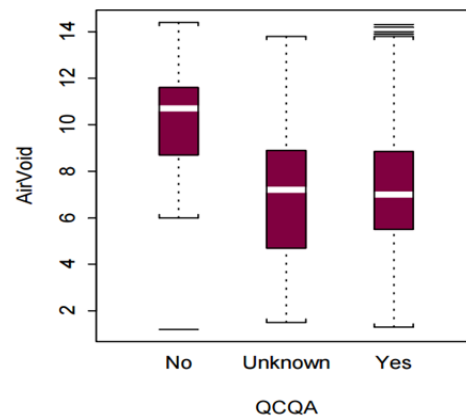
Won't coring damage my new pavement? *Good core patching practice is simple and well-patched core holes will not fail early. There's a choice: have a longer-lasting pavement that has a few patched holes, or have a pavement that ages, gets water-damaged and cracks up early—but without patched holes.*

What can I do to help my contractors meet and exceed the specification and further increase the life of my overlays? *Do not apply the specification to parts of the project where the contractor may find it very difficult or impossible to meet it, particularly where any hand placement or compaction is required. Organize your project bidding and contracting schedule and your construction windows to maximize the time that the contractor has to pave when it is HOT (particularly important for rubberized mixes), and don't pressure the contractor to pave when it is COLD. Allow the contractor to use warm mix additives to extend the time they have to compact. You can have the contractor demonstrate on a trial section that they can meet your specification before proceeding with the job.*

How Others Have Done This

Research has shown that Caltrans reduced its typical air-void content from the 10 to 14

percent range to an average of about 7 percent within a few years of implementing this type of specification in the 1990s, and they continue to get good compaction even on thin overlays. The figure below⁶ shows the results of coring on the state network and the distributions of air-voids from cores for projects built under the Caltrans QC/QA specification with disincentives for measured compaction (shown as Yes), and those built under the previous method specification (shown as No).



Cities and counties in California that use and enforce this type of specification can expect to get similar results, while cities and counties that don't will typically get air-voids in the range Caltrans had before implementing the specification.

Where to Get More Information

Sample specifications prepared specifically for local governments will soon be available on the CCPIC website.

⁶ Figure 3.7 from Lu, Q. and J. Harvey. 2005. *Investigation of Conditions for Moisture Damage in Asphalt Concrete and Appropriate Laboratory Test Methods*. UPCRRC Report UPCRRC-RR-2005-15.