



Watershed Protection Development Review

An Estimate of Sealant Wear Rates in Austin, TX

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Abstract

Parking lot sealant has been shown to be a major source of PAHs to the environment, yet yields predicted by a recent USGS/City of Austin study (0.2% per year), do not match wear rates as observed by looking at parking lots around Austin, Texas, nor with the industry recommended re-application rate of every 3-5 years. A photographic study was conducted using 12 parking lots in Austin with age ranges from 0-5 years old to estimate amount of sealant on lots of different ages. Amount worn off over time was then calculated using average sealant wear and the ages of all lots. Although this approach is very conservative and likely underestimates total loads of sealant leaving parking lots, the results suggest that at least 4% of sealant wears off of parking lots annually. This value provides a starting place for estimating best-case loading scenarios for PAHs from sealed parking lots.

Introduction

Collaborative studies by the City of Austin and the U. S. Geological Survey (USGS) have identified parking lot sealant, and particularly coal tar-based sealant, as a major and previously unrecognized source of polycyclic aromatic hydrocarbon (PAH) contamination. Biological studies, conducted by the City of Austin in the field and in the laboratory, indicated that PAH levels in sediment contaminated with abraded coal tar sealant were toxic to aquatic life and were degrading aquatic communities.

Field observations reveal that coal tar sealant applied to parking lots abrades and leaves the lot over a period of years. The sealant wears unevenly with higher rates of loss in high traffic areas. This is easily observed in aerial photographs (Figure 1). Parking areas with little wear appear darker, and in worn drive areas the aggregate and aged asphalt binder underneath the sealant appears lighter. This is due to the black color of coal tar sealant, and its ability to remain black over long periods of time (Schoenberger 2001).



Figure 1. Worn Parking Lot in Austin, Texas.

When applied, the sealant (and its constituent PAHs) forms an inert coating on the parking lot surface where it may remain for many years (Fig. 2). However, once the sealant wears and abrades, PAH's are introduced into the environment in stormwater runoff. These particles wash into the drainage system and eventually into stream and river sediments. Understanding the rate at which sealant derived PAHs enter the environment will improve strategies for controlling PAHs accumulation in urban watersheds. Mahler et al (2005) performed an artificial wash-off study that estimated the yield of PAH's entering the environment based on measured concentrations from known areas on different parking lot surfaces. This value can be extrapolated to an annual wear rate using various assumptions (44 rain events per year, 0.17 gallons of sealant per square yard applied per ASTM standard D3320), resulting in approximately 0.2% of PAHs in sealant applied leaving the lot per year. The Mahler et al. study was not designed for estimating annual loads from parking lot surfaces. It used a gentle spray of distilled water (approx. 1/10 of an inch, low rainfall energy) to attempt to wash abraded sealant off of parking lot surfaces, which may have been inadequate to represent natural rain events (high rainfall energy). Additionally, the study units were relatively small (50m²) and didn't account for wind, tires or other modes of moving sealant around or off the lot.

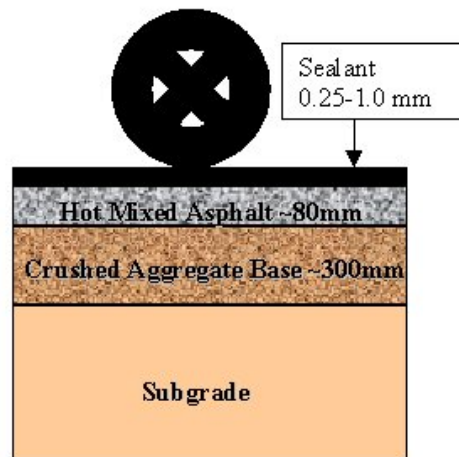


Figure 2. Generalized cross section of parking lot with sealant on asphalt.

Our study was designed to provide a more realistic estimate of sealant wear rates using visually apparent amounts of sealant on parking lots across a range of ages (0-5 years). To do this we sub-sampled parking lots by taking randomized, carefully standardized, digital pictures and using them to calculate the area of the picture covered by sealant. We assumed all parking lots start out completely (100%) covered by sealant and calculated the percent sealant lost. Our hypothesis was that sealant wears off lots on the scale of the industry recommended re-application rates of every 3-5 years (>10% per year), much faster than the 0.2% per year estimated yields from the Mahler et al. (2005) study. In addition to time, we hypothesized that traffic volume would also play an important part in abrading sealant off of parking lots.

Methods

Site selection

Twelve parking lots in the Austin area were selected based on knowledge of the date they were sealed with coal tar sealant and their age distribution over a five-year study period (the industry recommended maximum re-application period). The lots had been sealed by various contractors with various coal-tar based sealant preparations. All of the lots selected were commercial in nature, serving strip malls, high-turnover restaurants or large churches.

Sampling plan

Each lot was divided into two areas, a parking space area and a drive isle area. We used an *a priori* 200-photo sample limit, based on time and staff constraints. Using an area-weighted calculation, the 200 data points were distributed among the 12 parking lots, using a minimum of 3 and a maximum of 20 per area type (park and drive). Maps were generated with an excess (50) of randomly placed points that staff used to locate the correct location of each photo site. Beginning with lowest point number on the map, staff would take the requisite number of photos per lot. If a location was unavailable because of a parked car or other obstruction or unsuitable due to obvious repair, paint or oil spots, another random photo location was used. Once the stipulated number of photos was taken in both drive and park areas, the data collection was complete for that parking lot.

Table 1. Parking lot reference numbers, age of sealant application, parking lot areas by use and number of photos taken per lot by area type. Age of sealant, park area and drive areas are averaged at the bottom and number of photos for park and drive areas are totaled.

<u>Parking lot Number</u>	<u>Age of sealant (years)</u>	<u>Park Area (sq. ft.)</u>	<u>Drive area (sq. ft.)</u>	<u># Park photos</u>	<u># Drive photos</u>
1	0.16	10441	21337	3	3
2	0.33	30379	38463	4	5
3	0.52	7015	9214	3	3
4	0.91	38599	32045	5	4
5	1.01	56975	83915	8	11
6	2.00	13224	31346	2	4
7	2.01	167504	174021	20	20
8	2.16	62688	94110	8	13
9	3.67	43731	61445	6	8
10	4.08	107717	141242	15	19
11	4.12	42319	44320	6	6
12	5.39	84452	105377	11	14
Average/Totals	2.20	55420	69736	91	110

Photography

A Nikon D50 digital SLR camera was mounted on a Bogen tripod positioned with the back of the camera 46 cm from the ground with the focal length of the lens set at 32 mm, giving a sampling frame of 1.05 by 0.69 meters (0.725 sq meters). For a consistent exposure, a 13.8 by 10 cm (4X5 inch) piece of 18% grey card (Kodak) was placed in the center of the frame and the camera was set to “Program” mode with the on board light meter set to “spot” mode so that the grey card would have the same density in all images regardless of the ambient light level. All photos were 3008 x 2000 pixels, or 1.5 megabytes. For even, flat lighting the camera and subject were shaded by a large piece of non-reflective black mat board. All photos were taken from August 22 to September 21, 2006 and between 9:00 am and 2:00pm.

Image analysis

Images were cropped and converted to grayscale tiff format using Adobe Photoshop and then analyzed with Scion Image (a repackaged version of NIH Image available at www.scioncorp.com) using the “density slicing” function. Density slicing was used to identify the coal tar sealant in photographs of parking lot surfaces (Figure 3). Scion Image was configured to select all pixels darker than the grey card (lower left hand corner in each photo). Results (% sealant) were exported to spreadsheet and statistical software for further analysis.

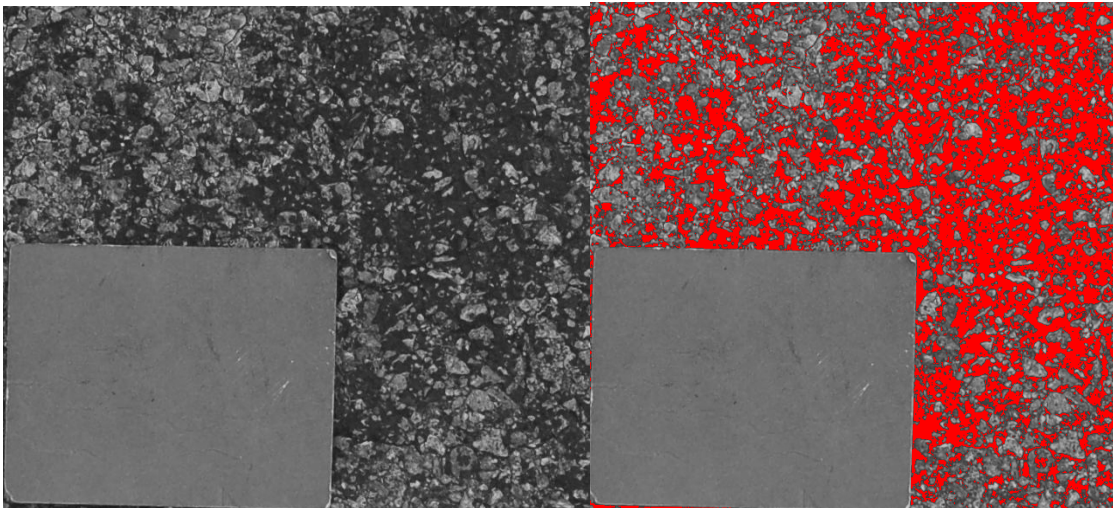


Figure 3. Example of density slicing technique of separating sealant from unsealed asphalt. The photo on the left shows a black and white image where black=sealant, while the photo on the right shows the separation of sealant from background, using false red color.

A standard curve was generated using reference photographs from unsealed parking lots (0% coverage of sealant), newly sealed parking lots (100% coverage) and a series of quartiles at approximately 25, 50 and 75% covered by sealant. These intermediate quartiles were selected in the field by three observers, verified by a third party graphics expert, and placed along a linear interpolation of the unsealed and sealed values. The curve was used to standardize all test lots to the same relative distribution of percent cover and to normalize variation in aggregate color.

Estimation of traffic volume on parking lots

Traffic volume was hypothesized to be an important variable in sealant wear. The amount of times a parking lot was driven across was estimated according to the Institute of Transportation Engineers Trip Generation Report Handbook which gives mathematical formulas for determining the number of trips a business will generate based on size and type. We chose the broadest categories, describing shopping centers as one unit rather than by summing the individual businesses. This was the most practical way to

approach this because the older lots have undergone tenant turnover during the study period. To calculate the unit exposure to traffic, the total number of vehicle trips since the parking lot was sealed (daily estimate of trips x number of days since sealed) was divided by the area of the parking lot. This normalized traffic volume per unit area so that all lots were directly comparable.

Results and Discussion

We analyzed 191 data points to calculate the amount of sealant coverage on the 12 study parking lots. We performed the analysis separately for parking and drive areas as well as combined for each lot. When all of these data (both drive and park areas) are plotted against age of parking lot sealant it demonstrates that there is a wide range of sealant coverage on lots of all ages (Figure 4). However, the younger sealant data points (< 1 year) ranged from 100% to 65% covered by sealant, while the older lot data (> 1 year) ranged from 100% to 45% covered by sealant. We looked at this variability more closely by plotting the maximum and minimum % coverage of sealant on study lots remaining as a function of age (Figure 5). This results in a wedge shaped distribution where minimum sealant wear on lots does not change over time (no slope) but maximum sealant coverage changes over time significantly ($r=0.65$) with a slope of approximately 6.6% sealant wear per year.

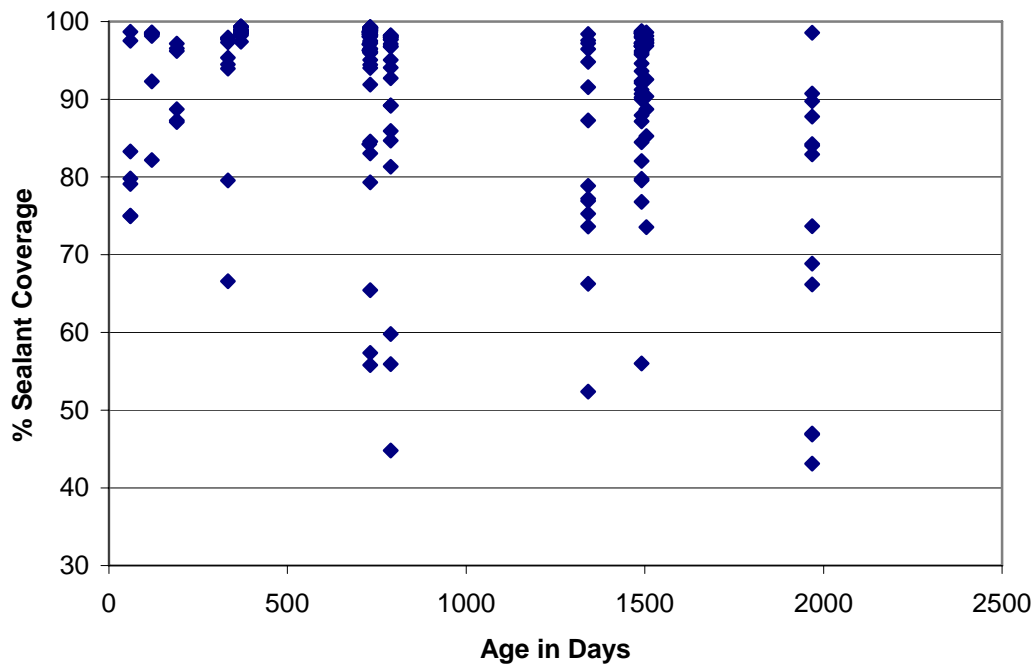


Figure 4. Percent sealant remaining on 12 parking lots as a function of age in days. The vertical lines of data points represent all data from each of the 12 parking lots.

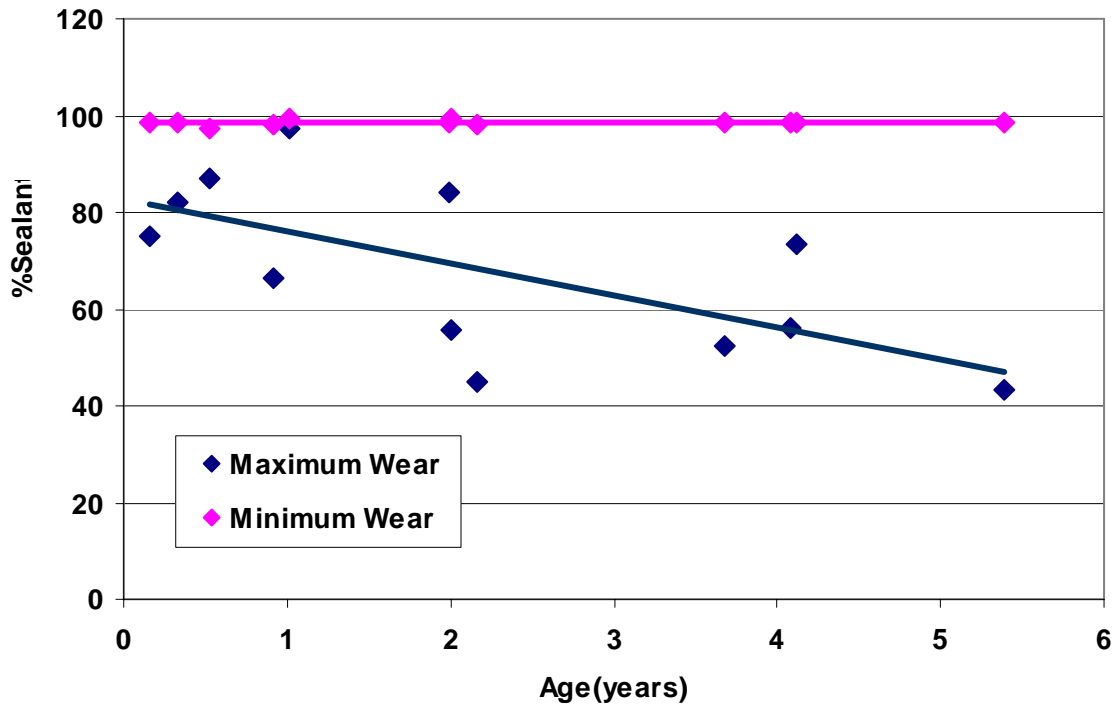


Figure 5. The observed minimal (blue) and maximal (pink) sealant wear as a function of age in years.

Study lots were grouped into age bins to look at wear patterns more generally (Table 2). The age of each lot was averaged to the closest whole year except for the three lots in the 6-month group, which were evaluated individually. Coincidentally, no lot fell into the three-year-old category. Average wear losses were from 4-32% and generally increased in each age group except for the 6 month group, which was higher than the 1 and 2 year group losses, due to one lot (number 1) that had a particularly high amount of initial sealant loss. The high initial loss should be considered a substandard application, but is representative of poor sealant performance that periodically occurs. Maximum wear rates ranged from 25 to 57% with an overall average of 32%. Minimum wear rates, as discussed above, did not vary at all and essentially represent no sealant loss. Standard deviation generally increased in these groups the older a lot was, with a low of about 7% in the one year group and a high of about 28% in the one five year lot.

Table 2. Wear patterns by nominal age groups in study parking lots. All values are percent of sealant worn off of lot except standard deviation, which is a straight percent.

Age	Max. Wear	Avg. Wear	Min. Wear	Number of lots in group	Std Dev
6 month	25	9	1	3	8.6
1 year	34	4	1	2	6.9
2 year	55	8	1	3	12.3
4 year	48	10	1	3	10.6
5 year	57	32	1	1	27.7
Total/Average	32	10	2	12	12

Drive areas of parking lots had more wear than parking areas, as would be expected (t-test, $p < 0.05$). The average coverage of sealant on drive areas for all 12 lots was 86% while parking areas averaged 95%. Wear as a function of vehicle trips on a parking lot was explored using estimated daily trips on each lot multiplied times the number of days since the lot was sealed and divided by lot area. This value did not contribute significantly to wear patterns documented and although drive areas were more closely related to traffic volume than park areas or combined totals (Figure 6), our hypothesis that traffic volume would be a primary predictor of wear rates must be rejected at this time. Intuitively, it is clear that traffic volume on parking lots should help explain wear rates. However, due to high variability in wear patterns or in our method of estimating traffic volume, we did not document this relationship.

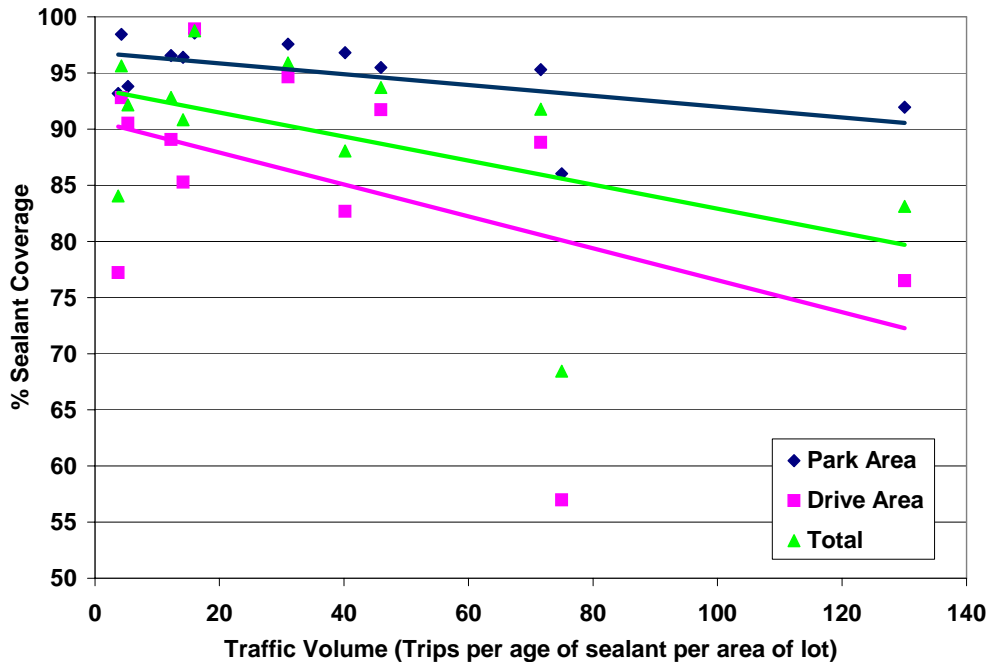


Figure 6. Sealant remaining in drive areas, park areas and all areas as a function of traffic volume.

The overall average sealant loss on all lots (both drive and park areas) in all age groups was 10.4%, which if divided by the mean of the ages of all lots (2.2 years) results in an average annual loss of 4.7%. However, the relationship between average annual loss and time was not linear so taking the geometric mean of average annual losses results in a more accurate prediction of 4.3% loss per year. This means

that on a three-year-old lot, one might expect to see 12.9% loss of sealant and on a five-year-old lot, 21.5% loss, etc.

In parking areas and other areas with little to no driving traffic on them, we saw very low amounts of sealant wear, ranging from 0-5% over a five year period. In the most worn areas of our 12 study lots we saw a significant annual average of 6.6% of sealant applied leaving the lots per year. In one study lot, we saw an average of 16% sealant loss (both drive and park areas) on a lot that was less than two months old. On our oldest lot (5.3 years old), we saw 32% loss over the life of the sealant, or an average of over 6 percent per year. We also had one lot that was over 4 years old, but had only lost 7% of it's sealant in that time (<2% per year). This wide range of sealant losses made it difficult to develop a significant overall wear model that could be applied to all sealant jobs in the Austin area. However, average annual wear rate of 4.3% per year is a fairly robust and conservative number and should be useful in discussing load estimates of PAHs from coal tar sealed parking lots.

Conclusions

Perhaps the most important constraint on this study was the fact that our methods only detected sealant loss when underlying aggregate in asphalt parking lots was exposed, thereby providing visual evidence that no sealant was present. In reality, a relatively large percentage of the sealant applied to the asphalt must be worn off the parking lot before aggregate begins being exposed. If the average newly sealed parking lot has two coats in park areas and three coats in drive areas (industry standard, <http://mspave.com/index-3.html>), resulting in over a millimeter of sealant, most of that would need to be gone before aggregate broke through. Exactly how much is worn before aggregate shows, or how to correct for this error, has not been explored at this time and will require further study. Regardless, our sealant loss estimates can be assumed to represent the absolute minimum losses that are occurring on sealed parking lots in the Austin area.

Our overall annual wear rate of 4.3% can be used to calculate some useful load estimates, such as 2.3 grams of PAHs worn off every square meter of coal tar sealed parking lots per year (1.47 kg sealant applied per square meter times a concentration of 36,000 ppm PAH times 4.3% per year times 1000, to get grams). If quantitative estimates of sealed parking areas in a drainage can made, this may be the most appropriate method for calculating watershed annual loads from sealant. For example, in Mahler et al., all sealed parking lots in the suburban Williamson Creek watershed in Austin were identified, resulting in about 2% of total area, or 1.5 square kilometers. This would result in 3450 kg of PAHs per year leaving parking lots in the Williamson Creek watershed. Since watershed delivery isn't perfectly efficient, much of this load is probably waylaid before it gets to the receiving water. However, these quantities of PAHs are probably contributing significantly to long term PAH increases in Austin's receiving waters (Van Meter and Mahler 2005).

Our results suggest that the amount of sealant leaving parking lots is much higher than the extrapolated annual yields from Mahler et al. (2005). This value for the Austin area (using 44 rain events per year) would be less than 0.2% per year, where our conservative estimates would be over 4% per year, or over 20 times higher. As previously stated, even this estimate is probably far below total actual loads, but is much closer to the scale of the industry recommended reapplication rate of every 3-5 years and closer to what is intuitively observed in older parking lots around Austin.

In our study lots, parking areas represented 44% of total area and drive areas 56%. One aspect of the sealant process that was clearly documented was that almost all apparent wear occurs in drive areas, and that in those areas, the wear rate is closer to 7% per year. These areas are what drive the re-application of sealant every 3-5 years, since they look so visibly worn. A parking lot doesn't have to have a majority of

it's sealant worn off before it will appear very worn, due to the striking contrast between the totally black park areas and the worn drive areas. We found that drive areas appeared very worn, and contrasted with the park areas after as little as 10% of the aggregate was showing through the sealant. Obviously this is a subjective and aesthetic variable, but does indicate that sealant is probably re-applied based on very little drive area wear, in locations that don't necessarily need it, and that comprehensive overall wear rates should include contributions from various coatings of sealant. Our minimal estimates of wear in the parking area do not take into account multiple layers. Nor do they take into account northern sealant stressors like snowplows and salt. In order to address these variables, a perimeter-controlled study of pollutant load from stormwater run-off of parking lots should be performed capturing all materials leaving the surfaces. This study should include sufficient replicates and control of age and traffic variables as well as representative coating methods, materials, and layering.

References:

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