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# Milled pavement texturing to optimize skid improvements

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## HIGHLIGHTS

- Pavement texturing can improve flexible pavement's skid resistance.
- A forward speed of 70–80 feet per minute is recommended.
- A cutting depth between 0.25 and 0.5 inches are recommended.

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## ABSTRACT

This research evaluated the use of a milling machine to texture pavement surfaces and its effect on skid improvement. Texturing tests with different milling drums, forward speeds and cutting depths were conducted on 31 asphalt pavement sections across Texas. Macrotexture and friction were measured before the milling and 3, 6, 12, and 18 months after the milling. The results show that sections milled with fine drums exhibited a higher skid resistance and macrotexture after milling. The test results also indicate that the forward milling speed is positively associated with both skid resistance and macrotexture. In other words, higher milling speeds tend to produce surfaces with higher skid resistance and macrotexture. The data suggests that milling operations on average provide a service life of about 12 months on seal coats, whereas milling on HMA sections extends the service life beyond 18 months.



## 1. Introduction

A common method to rehabilitate aging asphalt pavements is to remove the upper portion of the existing surface and place a new layer (mill and overlay). This method helps smooth the pavement surface and improve ride. This is usually done with a milling machine, which uses a cutting drum with teeth to remove the asphalt. Pavement texturing is performed by the same milling machines but only removes as little as 3/8 inch off the surface. Different from a typical mill-and-fill operation, no new wearing course is placed after the milling. Instead, the milled surface will already have the desired texture and skid resistance, and can be opened to traffic directly. This procedure is used in Texas as a stop gap measure due to funding or weather constraints before an overlay can be placed on the surface.

### 1.1. Influence of pavement texturing

It has been reported that pavement texturing by milling can improve skid resistance. For example, Yaran and Nesichi [1] showed that the skid resistance of a road section in Israel remained high for more than a year and a half after milling. An Iowa texturing research project [2] showed that the friction number of unmilled sections with AC surfacing averaged 38 while the average friction number of the adjacent milled section of the asphalt surface was up to 44. An Oregon DOT conducted a mill-abrading (combination of mill and shotblast) research project [3], indicating that milling increased the skid number of a PCC pavement from 34 to 39. Another study from Virginia [4] also concluded that pavement skid resistance can be effectively increased by texturing the surface.

Studies also showed that pavement texturing can reduce rutting. For example, Marks [2] found that almost all of the rutting was removed by milling with a cutting depth of 0.5 inch. In another research in Wisconsin [5], average road rut values were reduced for 6 years after milling. Rutting was not significant in the first two

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years but became significant at the third year and gradually diminished over the remaining time of the investigation. After 6 years, the surface exhibited rut values almost the same as before the milling.

Texturing by milling also affects the distress and ride quality of pavement. Okpala [5] reported that distress decreased after the pavement was milled. However, this improvement only lasted for less than one year after milling. Their roughness (IRI) results did not indicate any significant difference before and after the milling. It was concluded that the texturing did not improve the ride quality of smoother pavements, even though it was effective in eliminating the rutting.

Researchers have shown that pavement texturing has a short-term effect on road noise levels. Yaran and Nesichi [1] concluded that traveling at high speeds (more than 50 mph) on milled pavements is noisier than unmilled sections. Okpala [5] also found that there was a significant difference in the sound pitch between pre-milled and post-milled sections for a period up to about two weeks after milling, but that the difference became indiscernible after three months. Moreover, there was no significance difference in exterior noise assessment between milled and unmilled sections.

### 1.2. Factors affecting pavement texturing performance

The patterns of a textured surface relies heavily on factors such as milling machine speed, how the drum bits or teeth are located on the cutting drum, and the speed of the cutting drum. Milling operations can be categorized into standard milling, fine milling and micro milling by the number of teeth on the cutting drum [6]:

- Standard milling – Teeth are spaced 5/8 inch apart, 150 bits per drum.
- Fine milling – Teeth are spaced 5/16 inch apart, 300 bits per drum.
- Micro milling – Teeth are spaced 0.2 inch apart, 450–500 bits per drum.

Table 1 provides a summary of existing applications of pavement texturing. In most cases, the micro milling (or fine milling) drum was used. Marks [2] found that texturing using standard milling practices yielded a relatively coarse textured surface that can be detrimental to the safety of motorists.

Studies showed that drum speed and machine forward speed need to be coordinated to produce desired patterns. For example, a report from the Wirtgen Group [7] states that the forward speed should be increased together with the drum speed in order to obtain the same particle size. According to a report from the Asphalt Recycling and Reclaiming Association [8], a reasonable ratio of forward speed to drum speed should be maintained to achieve an acceptable level of quality. The report states that if the forward speed is greater than the drum rotation speed in revolutions per minute (rpm), the machine will produce a very rough textured milled surface. The same research report suggests that the forward speed in feet per minute should not exceed 2/3 of the cutter rpm. Similar findings are also mentioned in an article published by Asphalt Pro Magazine [9], indicating that for 5/8 inch standard mill drum spacing, the best drum speed is around 100 rpm. With a drum speed of approximately 100 rpm, a forward speed of 60 feet per minute (fpm) will provide the optimum pattern. But if the forward speed exceeds 100 feet per minute, the pattern begins to outrun the cut.

Several studies reported on the limit of milling machine forward speeds. For example, an ARRA report [8] states that to achieve a desired texture, the forward speed of the milling machine must be limited. With a standard milling drum, 30 fpm per 100 rpm cutter head speed gives the desired result. For micro milling (or fine milling) drum, a lower value of milling speeds should be used [6]. Marks [2] tested a milling operation with a 411 tooth drum. The forward speed varied from 17 to 28 fpm while the drum speed was a constant 100 rpm. It was found out that the slower the speed the smoother and finer the texture. Another research study in Georgia [10] showed that with a 20 fpm forward speed and 1/16 inch cutting depth, Mean Profile Depth (MPD) values around 0.6 mm can be obtained.

According to ARRA, the milling depth of pavement texturing is usually limited to around 0.4 inch [8]. A TxDOT research project [11] recommended that typical milling cuts to texture flushed pavements range from 0.5 to 0.75 inch maximum. An NCHRP report on pavement friction [12] states that texturing operations typically removes 0.75 to 1.25 inch from the asphalt surface. As shown in Table 1, most of the existing texturing applications use cutting depth from 0.3 to 0.5 inches.

### 1.3. Motivation of this research

Despite the research efforts discussed above, the effects of these milling operation factors (e.g., cutting depth, milling speed, etc.) on the duration of skid improvements have not previously been addressed. It is not clear how different configurations of the machine settings will improve skid and how long that skid improvement lasts. Therefore, in this research study, we conducted pavement texturing tests on various sections across Texas. The skid resistance and macrotexture were measured at each test section for different configurations of milling depths and machine forward speeds. Data were collected during an 18 months investigation period and statistical analysis was conducted to optimize the milling operation.

## 2. Field testing

A number of factors were considered in selecting test sections for evaluation. The most important factors were (1) the availability of the milling machines and pavement sections with the desired skid resistance; (2) the interest and willingness of Texas Districts to assist in evaluating the test sections; (3) the geographical locations and site conditions. The last factor was used to select sections representative of different climatic and surface conditions. At last, 31 test sections (having lengths of 500 feet) were identified in 4 different climatic zones in Texas. While 15 sections have HMA surfaces, the other 16 sections have seal coat surfaces. These sections represent an array of asphalt pavement surface textures with different milling characteristics. The sections are mostly located on 4-lane divided highway facilities.

The literature review indicates that depths of cut up to 0.5 inches are typically used for texturing purposes. Increasing the depth of cut will extend the friction longevity. However, given the surface height variations typically found on both HMA and in particular seal coat surfaces, this parameter cannot be controlled very accurately. Therefore, in this research study, we evaluated two depths of cut (i.e., 0.25 and 0.5 inches).

Two types of milling drums (standard milling drum and fine milling drum) were used in this project. The standard milling drum has in the order of 150 teeth and results in cuts or grooves spaced 5/8 of an inch apart. The fine milling drum with about 300 teeth cuts grooves about 5/16 of an inch apart.

Computer simulations were run to aid the selection of drum rotational speed. Fig. 1 shows the resulting milling patterns for drum speeds of 60, 80 and 100 rpm for a standard milling drum