GUIDELINES FOR DESIGN OF FLEXIBLE PAVEMENT WIDENING

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PREFACE

This design guide is designed to guide Texas Department of Transportation (TxDOT) engineers through the process of pavement widening and to enable TxDOT designers to make more informed and better decisions regarding pavement design and construction. These guidelines should result in better utilization of resources, reduced maintenance costs, and improved public safety. This design guide was compiled based upon the responses of a multi-district survey within TxDOT, interviews with district personnel, observations of field performance of various widening methods, and reviews of existing published guidelines and manuals relevant to flexible pavement widening.

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HOW TO USE THIS DESIGN GUIDE

This design guide is designed to assist in the decision-making process concerning the widening of flexible pavements. It offers some recommended investigative and construction alternatives for widening given different case scenarios and should serve as a general guideline in that regard. The ultimate design and construction techniques are left to the discretion of the pavement engineer, design director, and/or area engineer.

The first step in selecting a widening strategy is to evaluate the existing pavement condition, which can be obtained through the Pavement Management Information System (PMIS). The different sections of this design guide are organized according to recommended investigative methods, stabilization, pavement drainage, equipment options, longitudinal joint construction, and some construction alternatives, which offer a quick reference for widening alternatives. For example, if the widening candidate is a flexible pavement in good condition that will not be in need of rehabilitation, reference the section entitled “Some Construction Alternatives” for a typical construction drawing. Each section provides suggestions regarding investigation and construction techniques as well as ideal pavement sections. Also included with the recommended construction methods are some precautions that should be taken based on the experience of the districts surveyed and forensic investigations conducted by the Texas Transportation Institute (TTI).

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RECOMMENDED INVESTIGATION PROCEDURES

Discussion

Although all of the investigative methods listed in Table 1 are methods followed by some districts, the most common and most recommended methods are marked with an **X.** These include: a review of the construction records, soil borings, pavement cores, engineering properties of the base and subgrades, stabilization design (if any) of the base and subgrades, and testing the subgrades for sulfates and organics. If no stabilization will occur, then testing the subgrades for sulfates and organics will not be necessary. In many instances where the existing pavement is in good condition and will not be rehabilitated, the most critical of these methods are the preliminary and field investigations as most of the necessary information can be gleaned from reviewing the construction records and by taking pavement cores and soil borings.

Field Investigation

It is very important to match the existing pavement structure to prevent trapping moisture in the existing base materials. (See Figures 1a and 1b.) Problems were reported in many Districts when pavements with flexible bases were widened with different base material especially cement treated base. Cracks form at the longitudinal joint and moisture ingress often leads to rapid deterioration of the existing section. A thorough review of the construction records as well as taking pavement cores is extremely important and should provide adequate information regarding the existing material properties, mix designs, and material thicknesses.

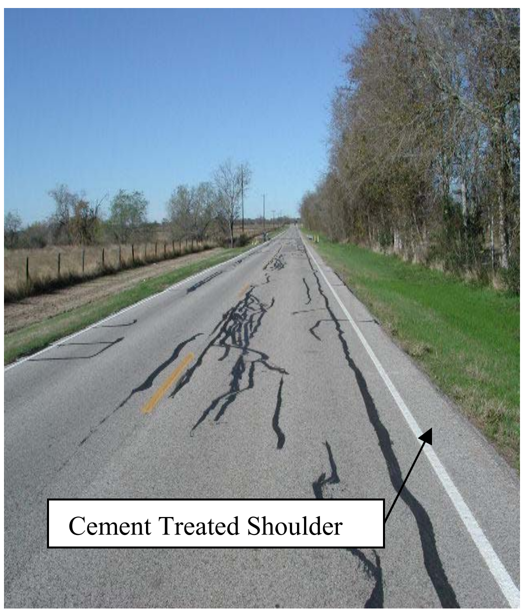


Figure 1a. Cement Treated Shoulder

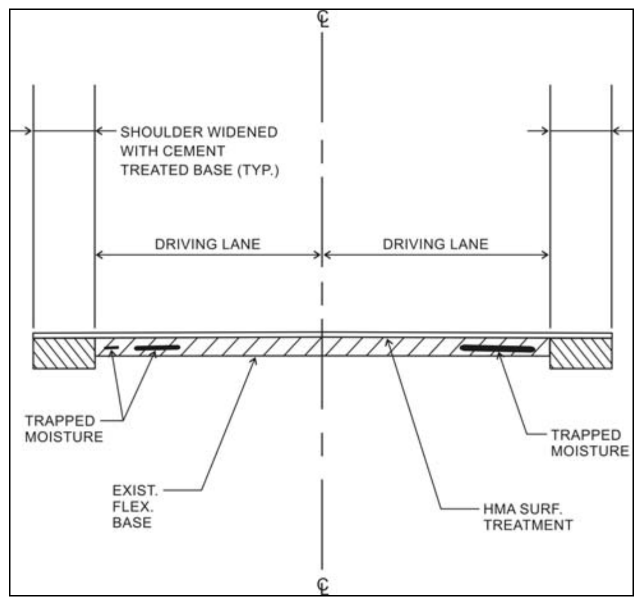


Figure 1b. Moisture Trapped in Existing Flex Base

Table 1. Minimum Testing Recommendations for Various Pavement Conditions

Investigation	Information Sought	Minimum Testing Recommendations		
		Flexible Pavement in Good Condition	**Flexible Pavement in Poor Condition**	**Jointed Concrete Pavement**
Preliminary				
Review of Construction Records	• Existing material properties, mix designs, and layer thicknesses	**X**	**X**	**X**
Field				
• Soil Borings	• Soil properties and subgrade moduli. Also, provides samples for laboratory investigation	**X**	**X**	**X**
• Pavement Cores	• To verify existing material properties and thicknesses	**X**	**X**	
• Falling Weight Deflectometer (FWD) Survey	• Layer moduli (for use in Flexible Pavement Design System 19 [FPS19])	**X**	**X**	**X**
• Ground Penetrating Radar (GPR) Survey	• Detection of moisture in the existing base and determination of layer thicknesses		**X**	
• Dynamic Cone Penetrometer (DCP)	• Determination of subgrade strength	**X**	**X**	**X**
Laboratory				
• Base Materials	• Base materials			
1. Engineering Properties	1. Optimum moisture and density	**X**	**X**	**X**
2. Sieve Analysis	2. Gradation		**X**	**X**
3. Modified Triaxial	3. Triaxial classification		**X**	
4. Capillary Rise/Tube Suction	4. Indication of moisture susceptibility		**X**	
5. Stabilization Design (If Any)	5. Optimum stabilizer content		**X**	**X**
• Subgrade Materials	• Subgrade materials			
1. Engineering Properties	1. Optimum moisture and density and Atterberg limits	**X**	**X**	**X**
2. Sulfate Testing	2. Sulfate content	**X**	**X**	**X**
3. Organics Testing	3. Organic content	**X**	**X**	**X**
4. Stabilization Design (If Any)	4. Optimum stabilizer content	**X**	**X**	**X**

SUBGRADE AND BASE STABILIZATION

Suitability for Stabilization

During the field investigation, the condition of the subgrade should be noted. If the subgrade is highly plastic or weak, then stabilization may be required. The most commonly used stabilizers are cement and lime. A soil must have a plasticity index of at least 10 in order to be stabilized with lime (Little 1995). If no laboratory investigation is to be conducted, then a field test to check the suitability of lime treatment can be performed. This test is performed by taking a wet soil and squeezing it into a ribbon between the thumb and pointer finger as shown in Figure 2. If the wet soil will not form any ribbon, the soil is likely not suitable for treatment with lime (Sebesta et al. 2004).

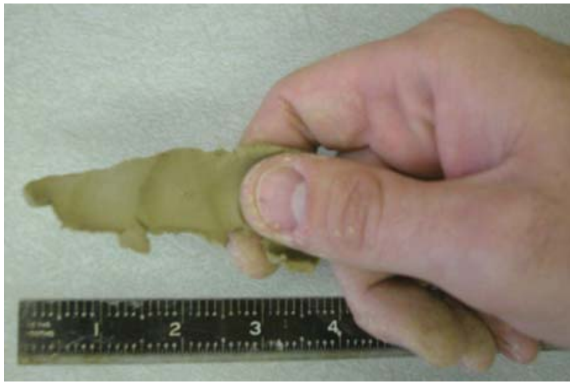


Figure 2. Soil Ribbon to Check for Plasticity (Sebesta et al. 2004)

Presence of Soluble Sulfates

Also to be noted is whether or not soluble sulfates are present in the soil. A stabilizer other than lime should be considered if the soluble sulfate content is greater than 8000 ppm because soils treated with calcium based stabilizers will often experience heaving as a result of the chemical reactions with the sulfate and/or sulfide minerals (Harris et al). If values higher than 3000 ppm are detected, the District pavement Engineer should perform a risk analysis of the projects and modifications to the construction process may be required. Figure 3 shows the most recent map indicating the counties in Texas that are known to have sulfates present in the soil. The district pavement engineer should be able to provide further information regarding sulfate testing and concentrations, as each District laboratory has been supplied with the test equipment to run the rapid sulfate determination either in the lab (Tex Method 145E) or in the field (Tex Method 146E).

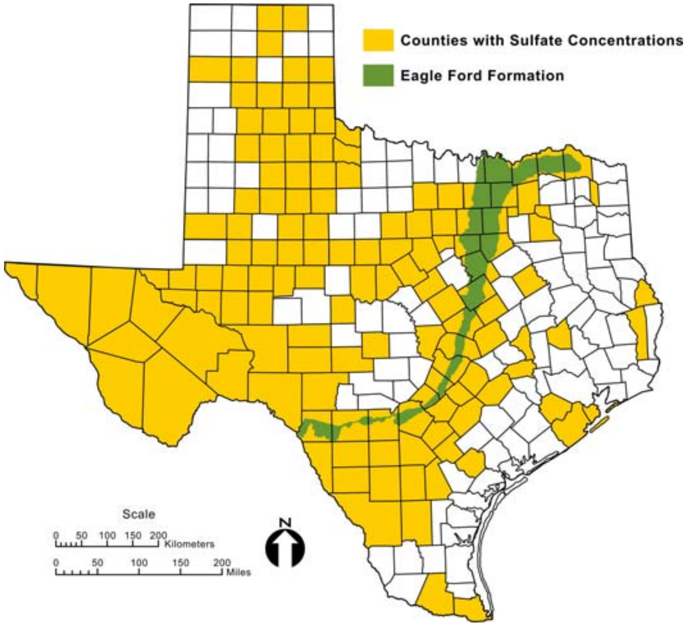
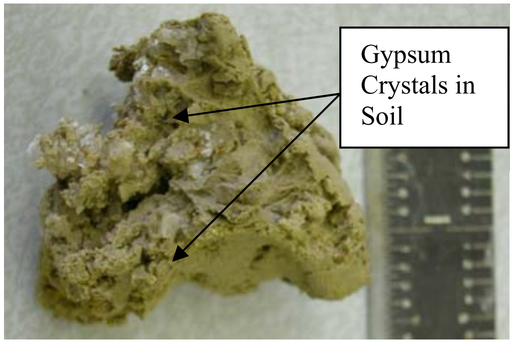


Figure 3. Texas Counties Known to Have Sulfates (Harris et al. 2004)

The presence of sulfates can at times be visually identified in the field by the presence of gypsum crystals in the soil. These crystals look like small specs of glass in the soil and can most readily be seen in direct sunlight. However, in many cases the particles are too small to be seen by the naked eye. The pictures in Figures 4a and 4b show how these glass-like crystals can vary greatly in size.



a.

b.

Figure 4. Gypsum Crystals, Scale in Inches (Sebesta et al. 2004)

Presence of Organics

Whether or not organics are present in a soil should also be determined. A stabilizer other than lime should be considered if the organic content is greater than 1 percent because the organic material can inhibit the reaction between the lime and the clay minerals (Little 1995). Organic soils can easily be identified in the field as they will be dark in color and often have a strong odor. Figure 5 shows two examples of organic soils. The district pavement engineer should be consulted for further information regarding organic testing.

Figure 5. Example of Organic Soils

Stabilizer Selection

According to TxDOT's *Guidelines for Modification and Stabilization of Soils and Bases for Use in Pavement Structures*, the selection of the appropriate stabilizer for subgrades, bases, and salvaged existing materials is dependent upon factors such as: soil mineralogy, soil classification, goals of treatment, mechanisms of additives, desired engineering and material properties, design life, environmental conditions, and engineering economics. The decision tree shown in Figure 6 offers assistance in selecting a stabilizer for subgrades, and Figure 7 offers assistance in selecting a stabilizer type for base and salvaged existing materials.

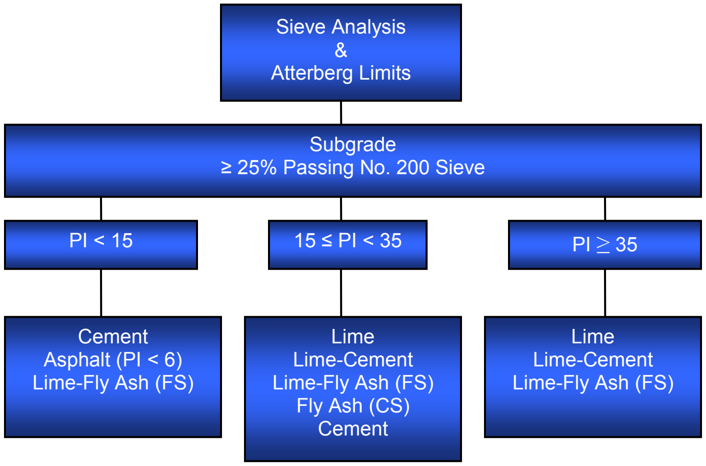


Figure 6. Additive Selection for Subgrade Soils (TxDOT 2005b)

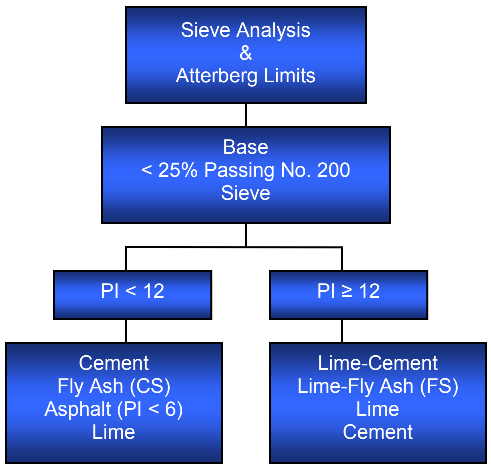


Figure 7. Additive Selection for Base and Salvaged Existing Material (TxDOT 2005b)

Stabilization Mix Design for Subgrades and Bases

After selecting the stabilizer to be used from the decision trees shown in Figures 6 and 7, a laboratory mix design should be conducted in accordance with the appropriate TxDOT procedure. In Table 2 suggested laboratory mix design criteria are listed for cement, lime, fly ash, and emulsified asphalt stabilized materials. These suggested values are based on the 7-day unconfined compressive strength, results of the tube suction test (TST), which is test method Tex 144E, and the retained strength upon completion of the TST. The dielectric values obtained in the TST are an indicator of the amount of free water in the sample and of the moisture susceptibility of the material. If no TST will be conducted, it is recommended that the samples be subjected to moisture conditioning in order to determine the retained strength values. Mix designs meeting the design criterion in Table 2 should provide adequate strength and resistance to moisture susceptibility. The lower initial strength requirements for lime and fly ash materials are due to the long-term pozzolanic strength gain of these materials, which will not be accounted for in the preliminary short term mix design tests.

Table 2. Recommended Design Criterion for Stabilization

Stabilizer Type	Material Being Stabilized	Unconfined Compresive Strength UCS (psi)	Suggested Final Surface Dielectric (ε) in TST	Retained Strength (TST/Dry Strength Ratio)
Cement	Base	≥ 300	≤ 10	≥ 100
	Subgrade[1]	≥ 50	N/A	N/A
Lime	Base	≥ 100	≤ 16	≥ 80
	Subgrade[2]	≥ 50	N/A	N/A
Fly Ash	Base	≥ 100	≤ 16	≥ 80
	Subgrade[2]	≥ 50	N/A	N/A
Emulsified Asphalt	Base	≥ 150	≤ 10	≥ 80
	Subgrade	N/A	N/A	N/A

1. This recommendation is based on Tex-120-E and is the strength required after 7 days of moist curing.
2. This recommendation is based on Tex-121-E and is the strength required after 10 days of capillary rise.

Alternative Stabilization Selection Considerations for Subgrades and Bases

Since it is a fairly common practice to select stabilizer type and amount based on district experience, particularly in a situation where shoulders will be added to a pavement in good condition and not in need of repair, the following recommendations should help aid in the selection process.

For lime stabilization of subgrades, 6 percent hydrated lime by dry weight is a typical treatment. It would be good to know the plasticity index of the soil being stabilized because it is a proven practice in the Fort Worth District to lime-treat 8 inches of subgrade with 6 percent lime for PI < 30 and to lime-treat 16 inches of subgrade with 6 percent lime for PI > 30 (Wimsatt 2006). For subgrades, especially low PI (less than 15), a cement treatment of 3 to 6 percent by dry weight is typical.

For lime stabilization of base material, a PI ≥ 12 is highly recommended for successful stabilization. A treatment of 6 percent hydrated lime by dry weight is typical. Also, a treatment of between 2 to 4 percent by dry weight of type I cement is typical. For cement contents greater than 4 percent, shrinkage cracking is often an issue.

The use of stabilized bases for widening projects is not recommended if:

a. the existing structure has a flexible, untreated base
b. the subgrade soils have a PI > 35 (This has lead to extensive longitudinal cracking as will be discussed later.)

PAVEMENT DRAINAGE

Although not widely used in Texas, the literature search indicated that the use of edge drains, in some circumstances, may prolong pavement life. Comparisons between pavements with and without edge drains have shown that the subgrade moisture at the shoulder could be considerably lower for sites with edge drains than without (Fleckenstein and Allen 1996). Also, an increase in the average subgrade moduli could be expected after the installation. Also, it has been shown that the ride index for pavements with edge drains should be improved, which is an indicator of improved long-term pavement performance (Fleckenstein and Allen 1996). Results from several studies have shown that the earlier edge drains were installed, the better the pavement performance would be.

A study by Birgisson and Roberson (2000) found that retrofitting existing pavements with edge drains requires careful evaluation and may be used to their full advantage in drainable materials. It was also suggested that flow through pavement layers must be unimpeded for the drainage system to be effective. Typical edge drain configurations for installation at the joint and at the shoulder's edge are shown in Figures 8 and 9.

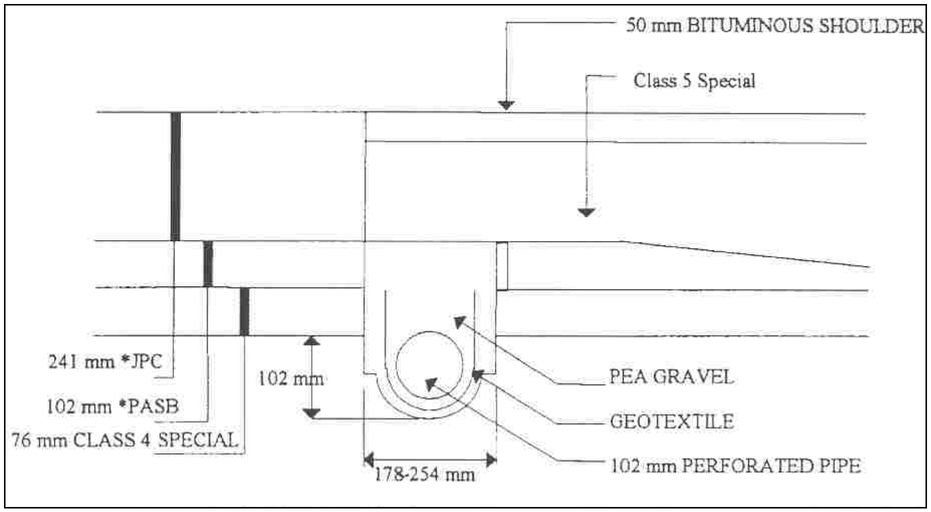


Figure 8. Typical Edge Drain Configuration at the Joint (Birgisson and Roberson 2000)

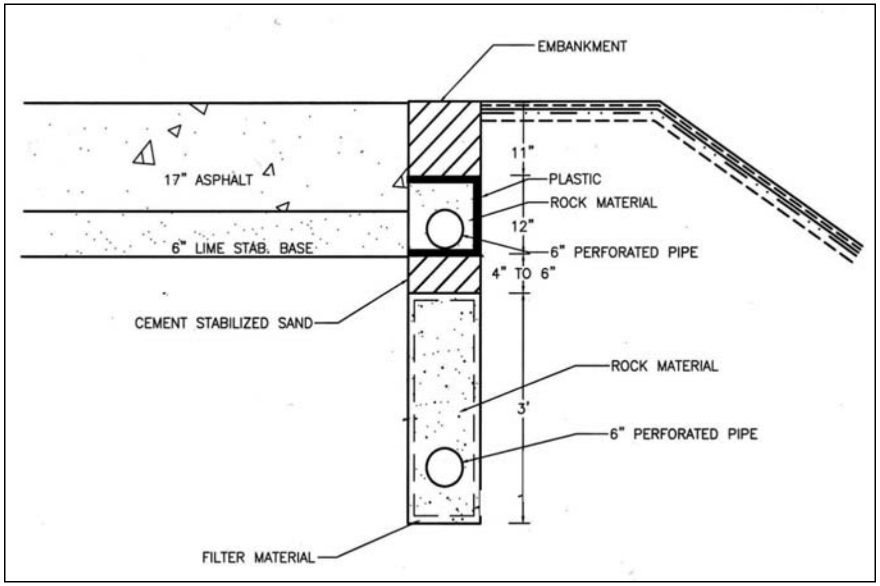


Figure 9. Typical Edge Drain Configuration at the Shoulder's Edge (Scullion, 1998)

The cost to state highway agencies in terms of poor pavement performance is significant for those who do not properly maintain edge drains. There is indication that plugged subsurface drainage may be worse than no drainage system because the pavement system becomes permanently saturated (Baumgardner 2002). Technology is available to evaluate the efficiency of edge drain systems. The tipping buckets, as shown in Figure 10, has been used in Texas to simultaneously log both rainfall and the outflow from edge drains systems.

Figure 10. Tipping Bucket (Scullion, 1998)

It is suggested that the edge drains and the outlet pipe be inspected after installation using a borescope or miniature pipeline camera and that if problems like sagging or coupling occur, then consideration should be given to the use of a more rigid pipe, like 40 PVC (Fleckenstein and Allen 1996). This recommendation is validated by a 1996 video inspection of a retrofitted transverse and longitudinal drainage system that was installed by lateral drilling and tied into the existing storm drainage system on I-45 in Houston. It showed that many of the pipes were sagging and holding water or sludge (Servos and Scullion 1996). Some of the findings of this investigation are shown in Figure 11.

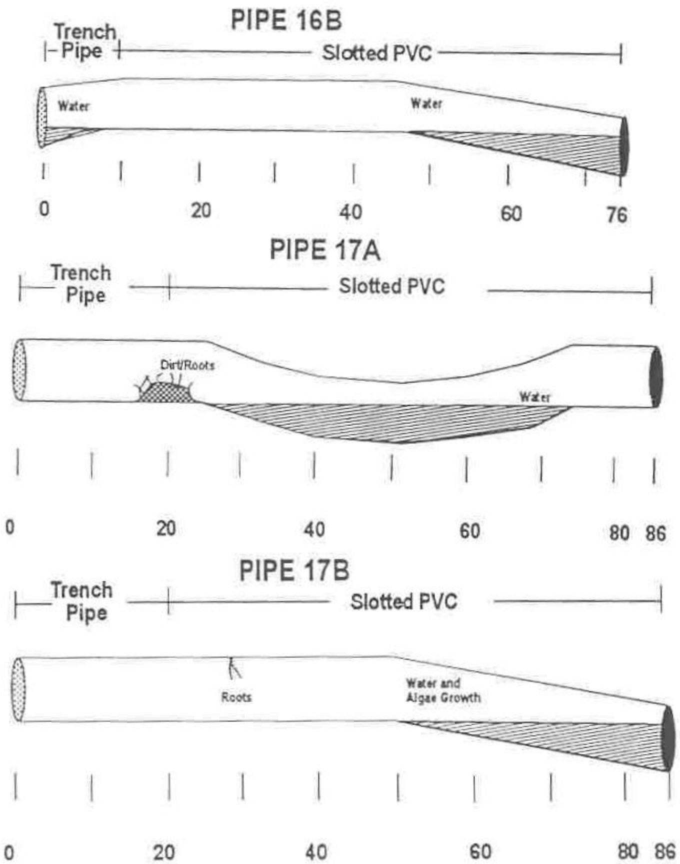


Figure 11. Findings from Video Inspection of Pipes (Servos and Scullion 1996)

Edge drains should be considered essential if the existing pavement is trapping moisture or if the widening operation could cause water to get trapped.

Also, 8 to 10 inches of dense-graded aggregate should be placed under the outlet headwalls to increase foundation strength (Fleckenstein and Allen 1996). It is suggested that these drains be inspected at least once a year, and the use of video equipment is recommended to better determine the condition of the drain. Also, vegetation should be mowed from around outlet pipes at least twice a year, and all ditches should be mowed and kept clean of debris. Painted arrows on the shoulders, such as the one shown in Figure 12, offer an easier means of locating edge drain outlets that may be overgrown with vegetation (Baumgardner 2002).

Figure 12. Painted Arrow Reference Marker (Baumgardner 2002)

The advantages of having larger headwalls for outlet pipes, such as the one shown in Figure 13, include (Baumgardner 2002):

- outlet pipes are easier for maintenance personnel to locate,
- vegetation is located farther away from the outlet pipe,
- erosion is reduced, and
- larger headwalls prevent cutting/crushing of the outlet pipe.

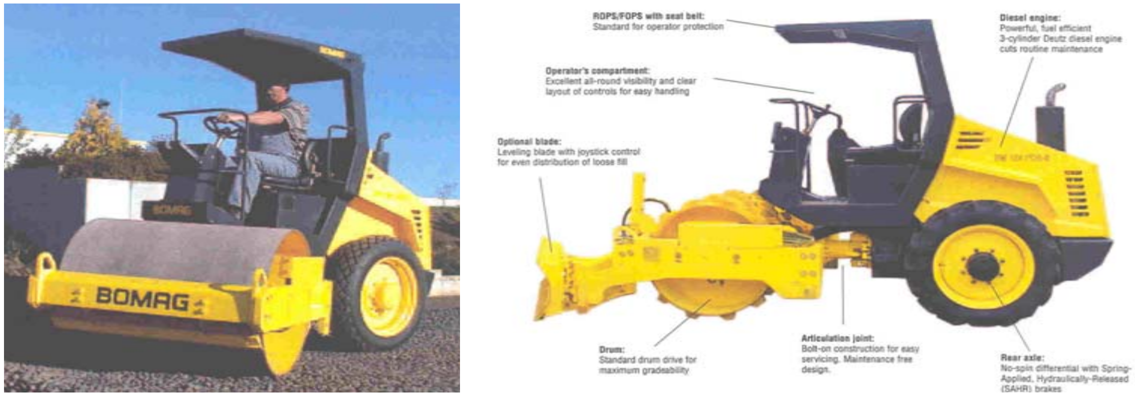
Figure 13. Outlet Pipe Headwall (Baumgardner 2002)

EQUIPMENT OPTIONS

There was a common complaint among the districts surveyed in regard to obtaining the required density when a narrow shoulder is being added to an existing pavement. Most often the inability to meet density requirements is attributed to a lack of the right equipment. Another issue is that when a narrow roller is used, density requirements are still difficult to meet because of the lighter weight of the equipment. Based on discussions with maintenance supervisors and pavement contractors, this can easily be overcome by decreasing lift thicknesses to 4 inches. This section provides information on some rollers that are readily available in Texas that could be used in compacting these narrow shoulders. Some of these rollers are shown in Figure 14 with the corresponding equipment specifications shown in Table 3. This information is provided only to show that narrow equipment is available and is not meant as an endorsement of these manufacturers.

a. Hamm® Model 2220 D **b. Hamm® Model 2222 DS** **c. Dynapac CC-122 Tandem Roller**

(http://www.hammcompactors.com) **(http://www.constructioncomplete.com)**



d. Caterpillar CP-323C **e. BOMAG BW124 Series (http://www.bomag.com)**

(http://www.cat.com/cda)

Figure 14. Rollers Readily Available in Texas

Table 3. Equipment Specifications

Equipment Manufacturer	Equipment Model	Working Width (Inches)	Operating Weight (Pounds)
Hamm	2220 D	54	10,700
Hamm	2222 D	54	11,250
Dynapac	CC-122	47	5,730
Caterpillar	CP-323C	54	10,190
BOMAG	124 Series	51.6	7055-7165

Also, in speaking with maintenance supervisors from several districts, it was found that in some cases when the widening addition is around 2 feet, the rear tandem of a fully loaded 6-ton dump truck will be used to achieve required densities and will follow behind the motor grader (Stewart 2006).

EMBANKMENT WIDENING

The districts surveyed commonly stated that when widening a pavement with steep side slopes, such as the one shown in Figure 15, there is often enough room to construct the widening without affecting the existing side slopes. If the existing foreslopes fall within the design recommendations for a recoverable foreslope as defined in the American Association of State Highway and Transportation Officials (AASHTO) *Roadside Design Guide*, then every effort should be made to maintain the existing foreslopes. (A recoverable foreslope is defined as 1V:4H or flatter.) A common practice is to borrow from the backslopes, if necessary, to maintain the foreslopes. If the foreslopes are steeper than 1V:3H, then a guardrail may be required. See Figure 16 for a guide for the use of guardrails. Table 4 also provides some recommendations for fill height and suggested side slopes for various soil types.

Figure 15. Flexible Pavement with Steep Side Slopes

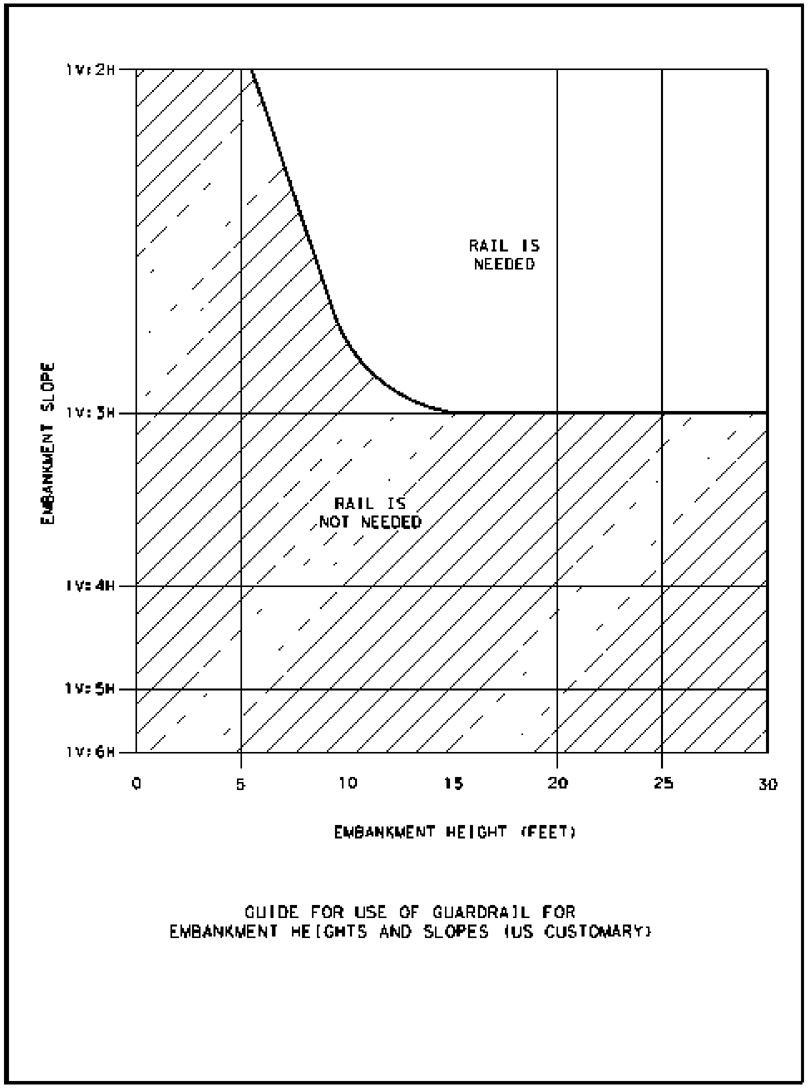


Figure 16. Guide for Use of Guardrail (TxDOT 2005a)

Table 4. Suggested Embankment Slopes for Different Types of Soil (Hopkins et al. 1988)

AASHTO SOIL CLASSIFICATION	UNIFIED SOIL CLASSIFICATION	FILL HEIGHT (FT)	SIDE SLOPE	DESIRED COMPACTION (% OF MAX DRY DENSITY)
A-1	GW, GP, SW (Some GM or SM)	NC*	2 to 1	95 – 100
A-3	SP	NC*	2 to 1	95 - 100
A-2-4 A-2-5	Most GM and SM	< 50	3 to 1	95 – 100
A-2-6 A-2-7	GC or SC	< 50	3 to 1	95 – 100
A-4 A-5	ML, MH	< 50	3 to 1	95 – 100
A-6 A-7	CL, MH	< 50	3 to 1 or 4 to 1	95 – 100

NC* - Not Critical

Deschamps et al. (1999) made several recommendations for the successful construction of embankment widening. These included:

- Remove existing vegetation and organic top soil in order to obtain an adequate construction joint between the old and new fill and to eliminate the potential for weak seams to develop because of decomposition.
- Construct benches in existing slopes to provide a good construction joint between old and new fill and to provide a horizontal surface upon which adequate compaction of the lifts can be achieved. One recommendation is that a 10 foot bench be proved on all slopes steeper than 4V:1H.
- Compact fills to a minimum dry density equal to or greater than 95 percent of the maximum dry density achieved in the standard Proctor tests with the water content of the fill being -2 percent to +1 percent of the optimum moisture obtained in the Proctor test.
- When the width of the embankment widening is less than the width of conventional compaction equipment, it may be necessary to compact lifts wide enough to accommodate the equipment.
- Consideration needs to be given to the permeability of the existing embankment material and the material to be used in the widening. If the permeability of the new material is greater than the existing, then water can infiltrate, which could lead to a reduction in shear strength of the material. Also, if the permeability is less than that of the existing material, then water may become trapped within the embankment

It is equally important when constructing this type of widening project that the required clear zones are maintained for the particular type of construction project, whether 2R or 3R as per the *TxDOT Roadway Design Manual*. At times, widening of a 2R project with steep side slopes may be problematic because of obstruction location. In that event, it was suggested that the road be built up and then widened. Another goal in maintaining the existing side slope is to avoid drainage realignment. Obviously, it will be quite costly if it becomes necessary to realign ditch lines, culverts, etc. If there is concern about a widening project with steep side slopes, contact the Geotechnical and Bridge Division for further recommendations.

NARROW BRIDGE WIDENING

The districts surveyed commonly stated that unless there was funding available to widen a narrow bridge and the bridge did not present a specific safety concern, such as the one shown in Figure 17, then the bridge would remain as is. The determining factors for widening a narrow bridge most often were the category under which the widening fell, whether 2R or 3R, and whether or not construction was funded by a safety bond. For instance, a culvert that extends 24 feet headwall to headwall may not be extended for a 2R project being funded with maintenance funds, even if the pavement is to be widened to 24 feet as well. If, however, the widening is being funded by safety bond funds, then the structure would be extended. However, all widening projects should seek to maintain or improve safety. Therefore, it is important to ensure that all bridge rails and approach rails comply with current TxDOT standards. Rails should be retrofitted or replaced in order to comply. If there is concern about a widening project with a narrow bridge, contact the Geotechnical and Bridge Division for further recommendations.

Figure 17. Flexible Pavement Widening at Narrow Bridge Approach

LONGITUDINAL JOINT CONSTRUCTION

Constructing a waterproof longitudinal joint is critical in widening construction. It is even more so when the longitudinal joint will be close to the outside wheel path of the completed sections. General guidelines for construction good joints are described in this section. There are four tasks that must be accomplished in order to properly construct a longitudinal joint. These are: compacting the unsupported edge of the first paved lane, overlapping the mix of the second lane over the top of the first, raking the mix off of the first lane, and compacting the joint between the two lanes (Scherocman 2004).

1. For successful compaction of the unsupported edge of the first paved lane, the type and position of the roller is critical. Scherocman (2004) states that a pneumatic tire roller normally cannot be used within about 6 inches of the unsupported edge of the lane without pushing the material sideways. He suggests that a steel wheel roller, either in vibratory or static mode, is more effective at achieving proper compaction for the required density, and the proper location for the edge of the steel drum is extended over the edge of the first lane by about 6 inches as shown in Figure 18. By placing the roller at this location, there will be no transverse movement of the mix.

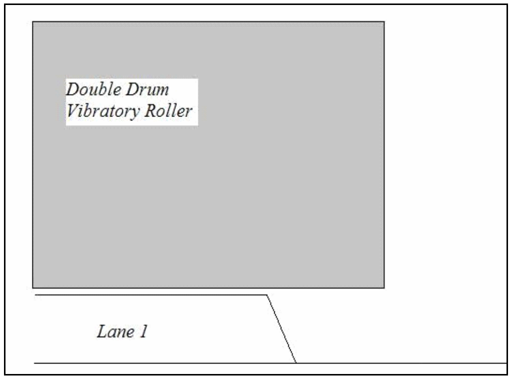


Figure 18. Proper Location of the Steel Wheel Roller over the Unsupported Edge of the First Paved Lane (Scherocman 2004)

Also, placing the roller either inside of or directly over the edge of the unsupported edge will result in transverse movement of the mix, and a crack typically forms at the edge of the drum as is shown in Figure 19. The amount of movement will depend on the properties of the asphalt. Also, the transverse movement of the mix creates a dip, which makes matching the joint with the second lane difficult.

Figure 19. Crack Development in the Mix at the Unsupported Edge of Pavement (Scherocman 2004)

2. The second critical factor in successfully constructing a longitudinal joint, according to Scherocman (2004), is overlapping the mix of the second lane over the top of the first. If an excessive amount of mix is placed over the edge of the first lane, it will have to be removed by raking the joint. If too little mix is placed over the edge of the first lane, then a depression will occur on the lane 2 side of the joint. Lane 1 refers to the existing side of the joint, and Lane 2 refers to the newly placed material. The amount of overlap needed is about 1 to 1.5 inches for proper joint construction. Also, since a dense graded asphalt concrete mix compacts at a rate of 0.25 inches per foot, to achieve a compacted thickness of 1 inch the mix must be placed from the back of the paver screed at an uncompacted thickness of about 1.25 inches. An example of the proper amount of lane overlap is shown in Figure 20, for which no mix will have to be raked off of lane 1.

Figure 20. Proper Amount of Overlap from Lane 2 to Lane 1 (Scherocman 2004)

3. Consequently, the third key to proper joint construction is not to have to rake the joint during construction. When raking the joint, the amount of mix that is needed at the joint is usually pushed into the hot mix on lane 2 by setting the rake down on the compacted mix of lane 1 and shoving the mix on top of the hot mix on lane 2. This will result in a low density on the lane 2 side of the joint. Improper raking of the longitudinal joint is shown in Figure 21.

Figure 21. Improper Raking of the Longitudinal Joint (Scherocman 2004)

4. The final key to successful longitudinal joint construction is compaction of the joint, which is dependent upon the location of the rollers. In the past, it was often common practice to compact the longitudinal joint from the cold side of the joint, which proved to be very inefficient. Since most of the drum was located on lane 1 with only 6 to 13 inches of the width of the drum extending over the joint onto lane 2, most of the weight of the roller was on the previously compacted section. While the roller is moving over the cold mix, the temperature of the new hot mix is decreasing, which reduces the opportunity to obtain the desired density. A better location for a pneumatic tire or steel wheel roller would be on the hot side with the roller extended over the top of the joint a short distance. For a pneumatic tire roller, the center of the outside tire should be placed directly over the top of the joint as shown in Figure 22. Figure 23 shows the proper placement for a steel wheel roller. The majority of the weight of the drum should be placed on the lane 2 side with only about 6 inches extended over the first lane.

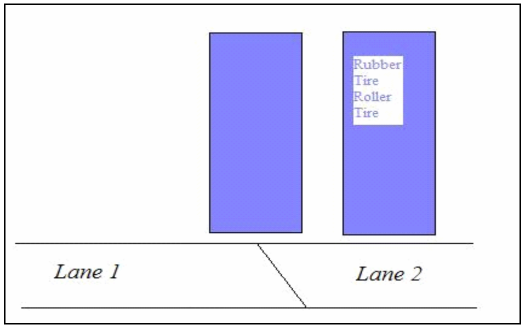


Figure 22. Proper Placement of Pneumatic Tire Roller on the Hot Side (Scherocman 2004)

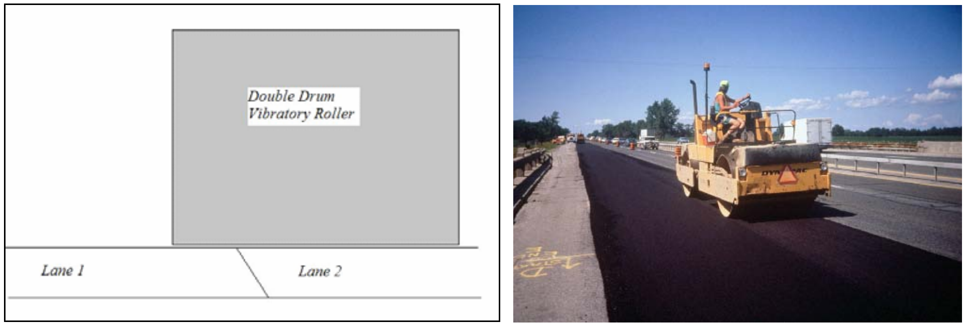


Figure 23. Proper Placement of Steel Wheel Roller on the Hot Side (Scherocman 2004)

A study on longitudinal joints conducted by the National Center for Asphalt Technology (NCAT) in the early 1990s found that there was an area of low density and high air voids from the center of the joint over 6 to 8 inches. This allowed water to enter the areas of low density, and freezing would break out the asphalt and lead to premature failure. As a result the tapered joint technique shown in Figure 24 was developed.

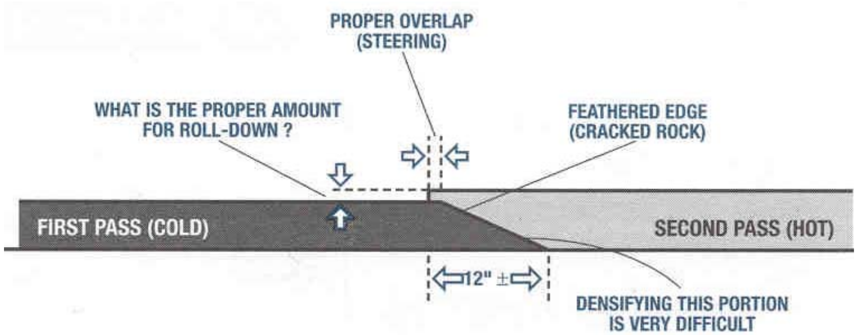


Figure 24. Tapered Joint Technique (National Asphalt Pavement Association 2002)

Another alternative for avoiding construction joints in the wheel path is to consider offsetting the construction joints as shown in Figure 25.

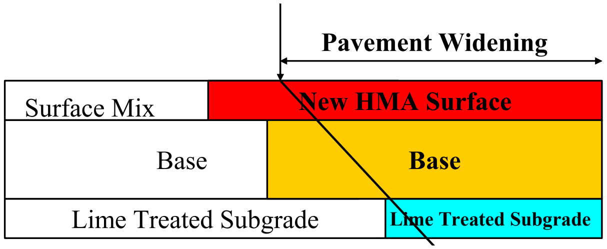


Figure 25. Offset Construction Joint (Mikhail 2005)

The following is the special provision to Special Specification Item 3146, Quality Control/Quality Assurance of Hot Mix Asphalt, and it concerns longitudinal joint density (Estakhri 2001).

Article 3146.7 Construction Methods is supplemented by the following:

(9) Longitudinal Joint Density: The Contractor shall perform a joint density evaluation for each sublot at the random sample locations selected for in place air void testing. At each location, the Contractor shall perform a nuclear density gauge reading with the center of the gauge placed at eight (8) inches from a mat edge that will become a longitudinal joint. This reading will be compared to a nuclear density gauge reading taken on the interior of the mat more than 2 feet from the mat edge. When the density at the eight (8) inch offset from the mat edge is more than three (3) pounds per cubic foot below the interior mat density, the evaluation fails. The Contractor shall investigate the cause of failure and take corrective actions during production to improve the joint density.

Production of the hot mix asphalt shall cease when two (2) consecutive evaluations fail unless otherwise approved by the Engineer. The Contractor shall make changes to the hot mix or the placement process before production is resumed. The Contractor may produce enough mixture to place approximately 2,000 linear feet of pavement one (1) paver width wide. Two (2) joint density evaluations shall be performed within these 2,000 linear feet of production and if both evaluations are acceptable, the Contractor may resume normal operations. However, if one (1) or both of the joint density evaluations fail, the Contractor shall make additional changes as approved by the Engineer and an additional 2,000 linear feet of pavement shall be laid and evaluated as before. This procedure of placing and evaluating 2,000 linear feet sections will be continued until both joint density evaluations pass. The Engineer may require the Contractor to implement different joint construction methods or provide special joint making equipment to improve joint density. Normal production and joint density verification will resume when both joint density evaluations pass. Although it is the Contractor’s responsibility to perform joint density evaluations, the Engineer may make as many independent joint density verifications as deemed necessary at the random sample locations. The Engineer’s results will be used to determine joint density when available.

SOME CONSTRUCTION ALTERNATIVES

Flexible Pavement in Good Condition

The method described in Table 5 and shown in Figure 26 was found to be a common practice among the various districts surveyed. As noted in the "Additional Information" column in Table 5, there are some necessary precautions that should be taken during the construction process when building in this manner. Among these are several very important factors, including: the placement and sealing of the joint, ensuring that the construction equipment can compact these narrow sections, and matching sections to avoid trapping moisture in the existing base as was previously discussed in the "Recommended Investigation Procedures" section.

As was previously mentioned, this particular widening method was common among the districts surveyed when the existing pavement was in good condition, and in this case there is little laboratory investigation or pavement design involved. In such a case, it was stated repeatedly that matching sections is crucial to prevent trapping moisture, which can lead to deterioration of the existing lanes. Also, it was commonly noted that it is extremely important to get a good density in the subgrade widening since not doing so will adversely affect the densities in the subsequent layers. Once again, it is critical to confirm with the contractor prior to construction that there is equipment available that can adequately compact these narrow sections. This construction detail is only to serve as a reference and to show a common practice. Consult with the district pavement engineer, design director, and/or area engineer for the final design of the pavement widening.

Table 5. Recommended Design Approaches for Flexible Pavements in Good Condition

Construction Procedures	TxDOT Spec. Item	Additional Information
• Notch down and remove existing pavement	• 105	• If possible, avoid placing the joint in the wheel path (see section on longitudinal joint construction).
• Widen subgrade using ordinary compaction or density control	• 112 and 132.3	• Check that the contractor has the appropriate equipment to construct these narrow sections (see section on equipment options). It is suggested that subgrade material be compacted in lifts of no more than 4 inches.
• Proof roll the subgrades	• 216	• This is highly recommended to ensure the subgrade will provide uniform pavement support. See Table 6 for recommendations on proof rolling stress levels.
• Place base material	• 247, 260, 265, 275, or 292	• Again, equipment is an issue in placing narrow sections. It is suggested that base material be placed in lifts of no more than 4 inches. ***Also, efforts should be made to match the existing material. By placing a stabilized base next to a flexible base, the risk of deteriorating the existing pavement due to trapping moisture is high. (See Figure 1a and 1b and section on recommendations for subgrade and base stabilization.)***
• Place the hot mix asphalt surface	• 340 and 341	• It is recommended that air void requirements for the main lanes also apply to the shoulders.
• Seal the pavement	• 316	• Sealing the entire pavement width is ideal. At a minimum, seal over the joint at least 1 foot to prevent moisture intrusion.

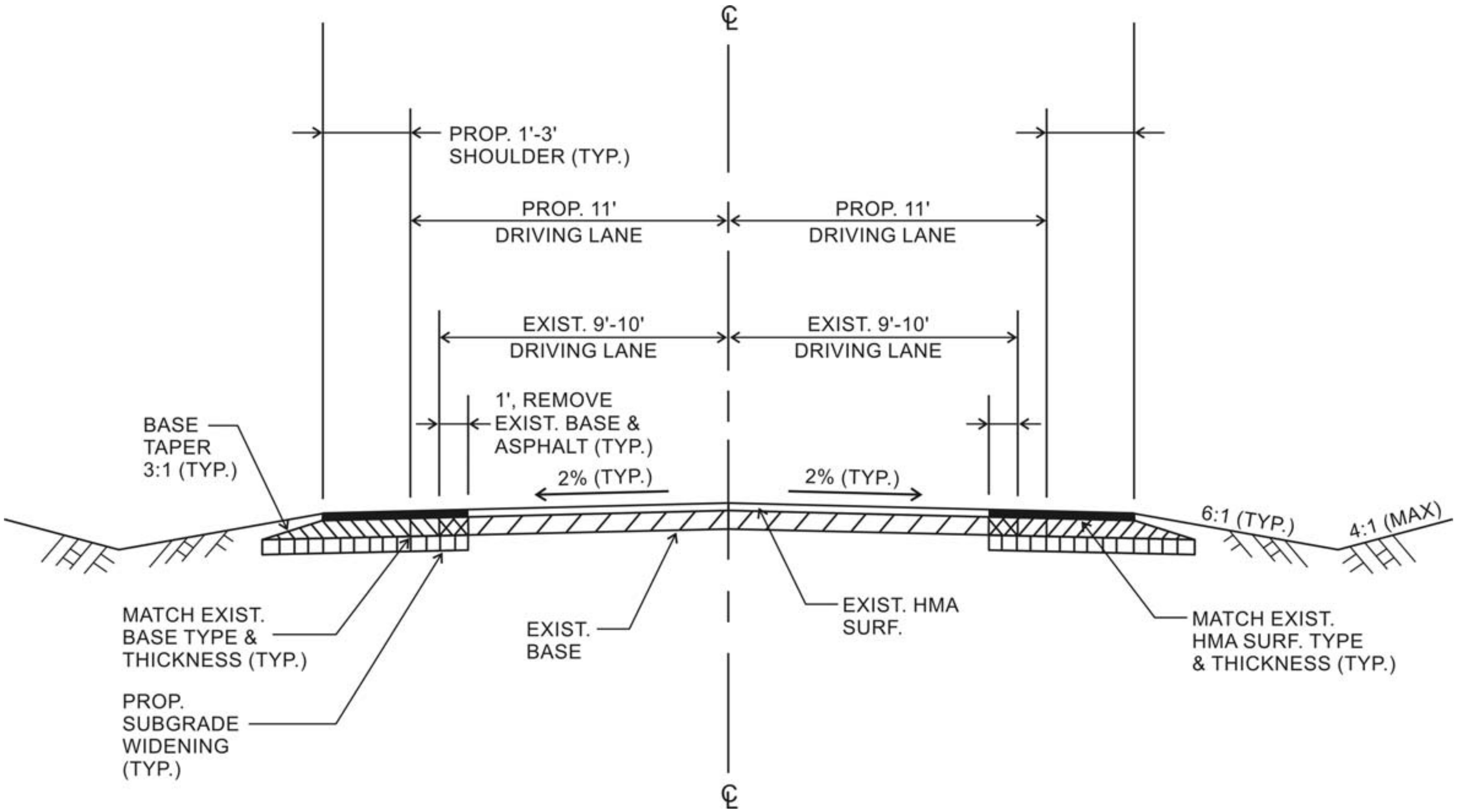


Figure 26. Typical Section for Widening Flexible Pavements in Good Condition

Note: In this detail there is a note to remove 1 foot of existing base and asphalt. Avoid doing this if the result will be having the joint in the wheel path. In that case, simply notch down at the existing edge of the pavement.

Table 6. Guide for Selecting Initial Proof Rolling Levels (TxDOT 2001)

Well Graded Soils

- (GW) Gravel-sand mixtures little or no fines
- (GW-GM, GW-GC, GC) Gravel-sand-silt-clay mixtures
- (SW) Sand or gravelly sands, little or no fines
- (SW-SC) Sand-silt-clay mixtures, slightly plasticity
- (SW-SM, SM) Silty sands or sand-silt mixtures

Poorly Graded Soils

- (SP) Sands or gravelly sands, little or no fines
- (SP-SC, SP-SM) Sand-silt-clay mixtures, plastic
- (GM, GP-GM, GP-GC) Silty gravels or gravel-sand-silt mixtures
- (SC) Sand-silt-clay mixtures or clayey sands, plastic to high PL
- (ML) Silts and very fine sands, slight or no plasticity
- (GP) Gravels and gravel-sand Mixtures, little or no fines
- (CL, CL-ML, OL) Lean clays, silty clays, slightly plastic to plastic
- (MH) Elastic silts, micaceous or diatomaceous silts
- (CH, OH) Fat clays, silty clays, highly plastic

Relative Subgrade Support	Poor	Fair		Good			Excellent
Stress Level	Minimum	1	2	3	4	5	Maximum
Load (tons)	30	34	38	42	46	50	50
Tire Inflation pressure (psi)	40	50	60	70	80	90	130

In Magdy Mikhail's presentation on asphalt pavement widening given to the Texas Pavement Asphalt Alliance in 2005, he offered several recommendations for consideration in pavement widening. Firstly, he stated that widening projects should be given enough time and consideration during design because if you trap moisture, you will affect the long-term performance of the pavement. (See Figure 27 for an alternative that will allow the water to drain.) Mikhail gave several examples of Farm to Market roads that performed well for long periods of time that suddenly deteriorate rapidly after widening. Also, subgrade stabilization can be difficult because there may not be enough time for curing. In such cases, consider adding some reclaimed asphalt pavement (RAP), or placing a flex base instead of subgrade stabilization or using geotextiles. To expedite construction of flexible bases the Bryan District recommends the use of a geotextile and 4 inches of Grade 2 granular base in lieu of traditional stabilization.

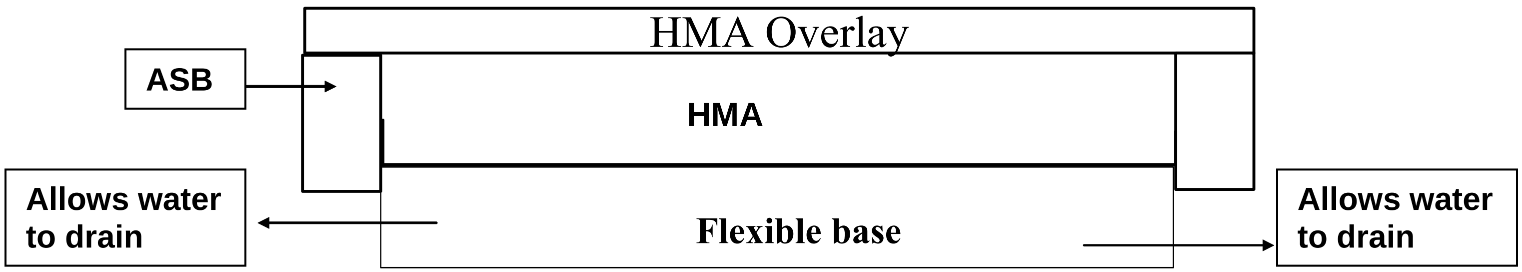


Figure 27. Alternative Section for Widening Flexible Pavements in Good Condition (Mikhail 2005)

According to Mikhail, edge drop-offs may be a major issue on widening projects, which is most likely the reason cement treated bases and asphalt stabilized bases are used in the widening rather than matching the existing section. According to Lawson and Hossain's 2004 report, a simple and cost-effective approach to dealing with edge drop-offs during construction is to install a 45-degree asphalt fillet along the edge of the pavement, which would tie the existing shoulder into the resurfaced roadway. This also allows a vehicle to reenter the roadway safely without over-steering (Lawson and Hossain 2004). Table 7 offers some traffic control recommendations for dealing with edge drop-offs in construction zones. Refer to the *2006 Texas Manual on Uniform Traffic Control Devices (TMUTCD)* for further recommendations on traffic control.

Table 7. Traffic Control Needs in Construction Zones for Edge Drop-Off Conditions (Lawson and Hossain 2004)

Edge Drop Height (inch)	Lateral Position of Edge Drop					
	In Wheel Track	In Lane	On Lane Line	At Edge of Pavement	At Edge of Shoulder	Outside of Shoulder up to 30 ft.
1 to 1-1/4	Uneven Pavement Sign	Uneven Pavement Sign	Uneven Pavement Sign	Low Shoulder Signs	Do Nothing	Do Nothing
1-3/8 to 2	Disallowed	Disallowed	Channelizing Devices with Steady-Burn Lights	Channelizing Devices with Steady-Burn Lights	Channelizing Devices with Steady-Burn Lights	Do Nothing
2-1/8 to 5-7/8	Disallowed	Disallowed	Channelizing Devices with Steady-Burn Lights	Channelizing Devices with Steady-Burn Lights	Channelizing Devices with Steady-Burn Lights	Channelizing Devices
5 or more	Disallowed	Disallowed	Disallowed	Positive Barrier	Positive Barrier	Channelizing Devices with Steady-Burn Lights

Figure 28 provides a design alternative for matching the existing pavement structure, and Figure 29 provides another alternative for the placement of edge drains.

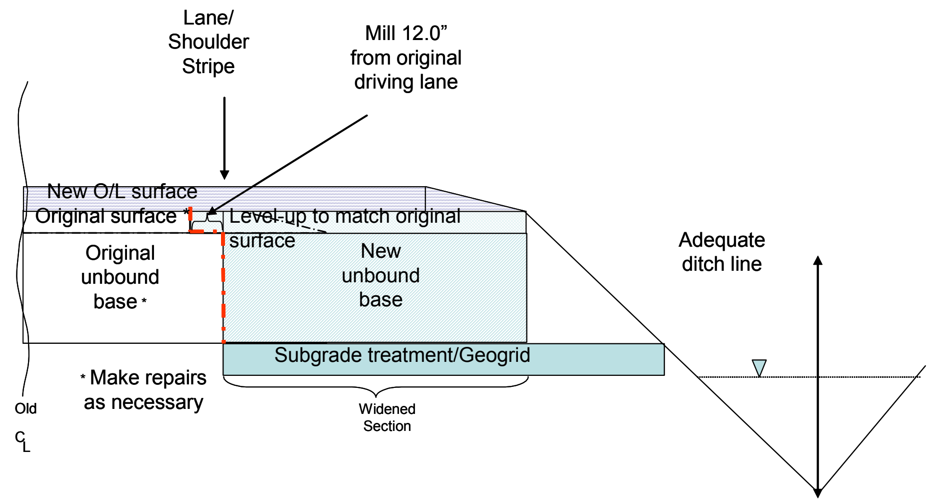


Figure 28. Alternative for Matching Sections for Widening Flexible Pavements in Good Condition (Mikhail 2005)

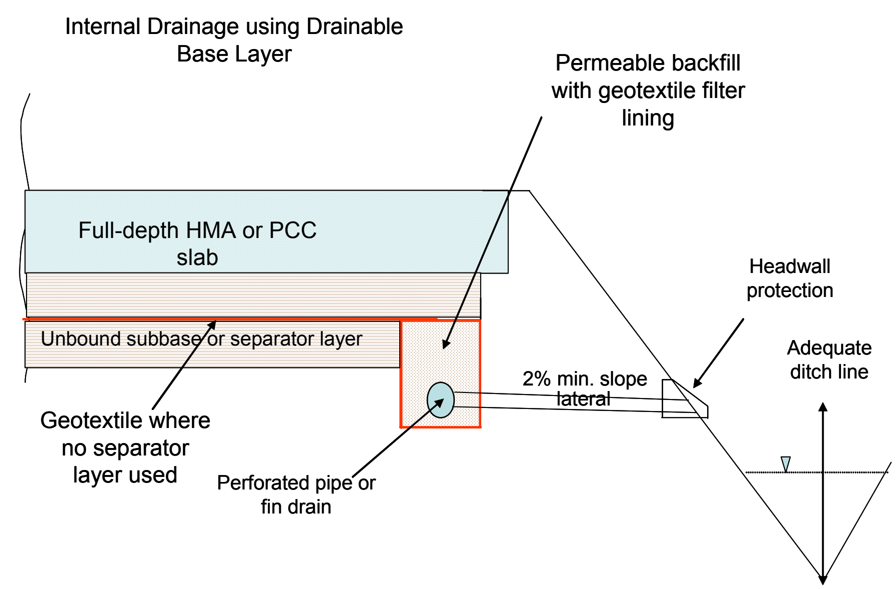


Figure 29. Alternative for Installing Edge Drains for Widening Flexible Pavements in Good Condition (Mikhail 2004)

Flexible Pavement in Poor Condition

Full depth recycling was found to be a first choice alternative when the existing pavement was in poor condition. As is indicated in the "Additional Information" column in Table 8, the amount of existing HMA surface to be reworked into the existing base should be kept below 50 percent, and care must be taken to avoid contamination of the reworked base with the subgrade soil. Since the existing material thicknesses can vary, it is highly recommended that a GPR survey or coring of the pavement to be recycled be conducted to verify layer thicknesses.

In the event that full depth recycling will be the method used for the pavement widening, it is highly recommended that a complete laboratory investigation be conducted in order to develop the pavement design. Again, this construction detail shown in Figure 30 is only to serve as a reference and to show a common practice. The district pavement engineer, design director, and/or area engineer should be consulted for the final design of the pavement widening.

Table 8. Recommended Design Approaches for Flexible Pavements in Poor Condition Using Full Depth Recycling

Construction Procedures	TxDOT Spec. Item	Additional Information
• Widen subgrade using ordinary compaction or density control	• 112 and 132.3	• Equipment is an issue in placing narrow sections.
• Rework existing HMA surface and base into stabilized subbase	• 251	• ***The amount of existing HMA surface to be reworked into the existing base should be kept below 50%. Also, care must be taken to avoid contaminating the reworked base with the subgrade soil.***
• Place base material	• 247	• It is suggested that base material be placed in lifts of no more than 6 inches.
• Seal the pavement	• 316	• Sealing the entire pavement width is ideal.
• Place the HMA surface	• 340 and 341	• It is recommended that air void requirements for the main lanes also apply to the shoulders.

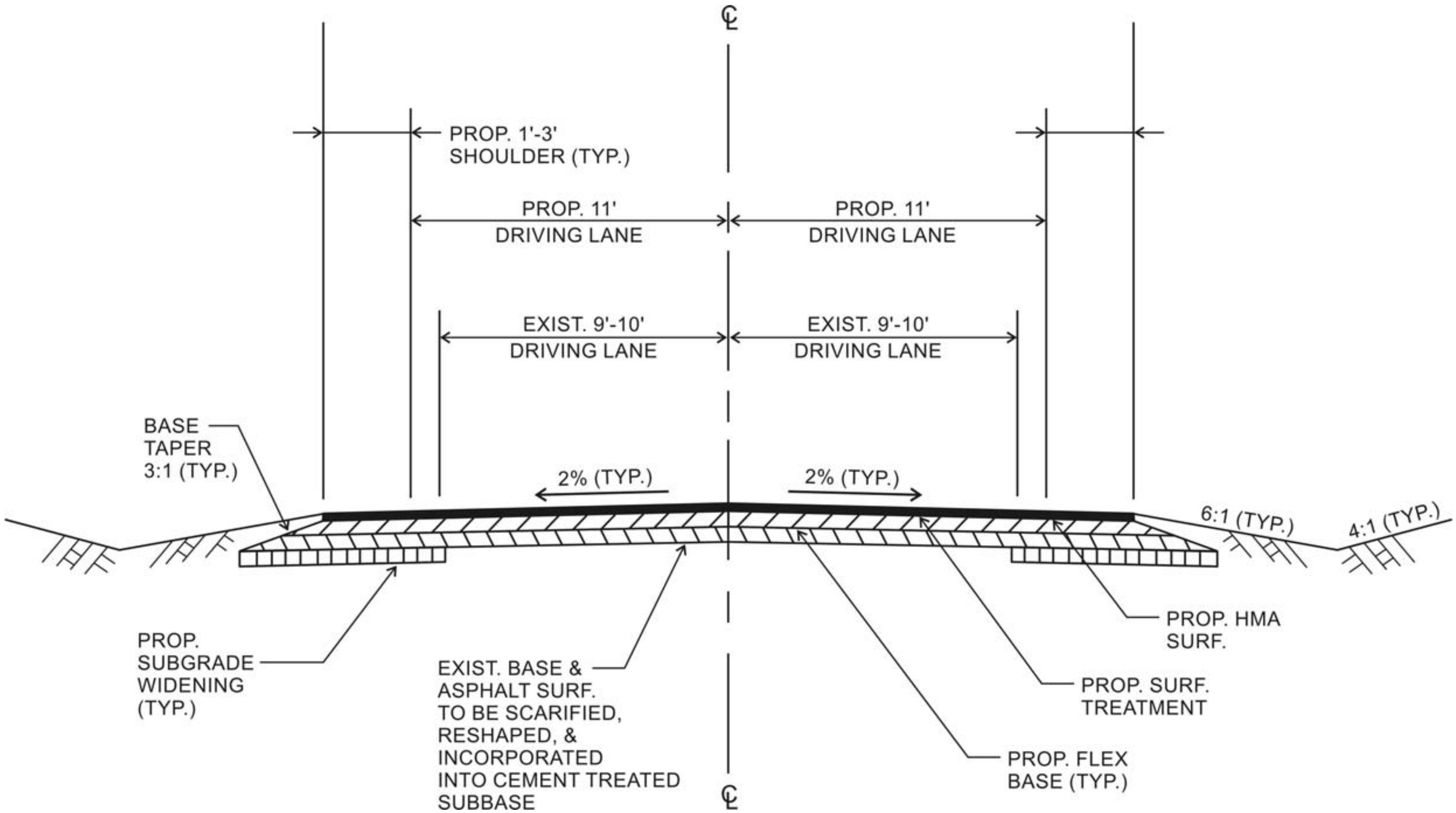


Figure 30. Typical Section for Widening Flexible Pavements in Poor Condition Using Full Depth Recycling

One critical aspect of any full depth reclamation job is to select the appropriate type and level of stabilization. Guidelines for doing this are shown in Table 9. These were developed under TxDOT study 4182 (Scullion, 2003). If the existing subgrade and base are reasonable then it may not be necessary to use any stabilization, this is referred to as the Base Thickening option. This table also provides FPS 19 design moduli values if a full structural design is required for the project.

Table 9. Design Criteria and Recommended Moduli Values for Bases in Full Depth Recycling Projects

District Objective	Base Thickening	Upgrade base to Class 1	Create a Super Flexible Base	Create a Stabilized Base (Class L)	Create a Stabilized Base (Class M)
Used When	• Existing base is uniform • No widespread structural damage • Existing subgrade is good(>15ksi) • Low traffic	• Low – moderate traffic • Good Subgrade • Moisture not a concern	• High Volume Roadways • Moisture a concern • Reasonable Subgrade > 10ksi • Early opening to traffic	• Bridging over poor subgrade • Strengthening required • Low quality variable base/stripped HMA • Higher Rainfall • Early opening to traffic	• Bridging over poor subgrade • Strengthening required • Low quality variable base • Higher rainfall • Early opening to traffic
Selection of Stabilizer[1]	No Stabilizer added to the existing material. (This is a base thickening project, where new untreated granular material is placed on top of existing.)	Full Texas Triaxial Test Method 117-E 10 day capillary rise, then • 45 psi at 0 psi confining • 175 psi at 15 psi confining (add low levels of stabilizer)	Full Texas Triaxial Test Method 117-E • 60 psi at 0 psi confining, • 225 psi at 15 psi confining, • < 0.5 % gain in moisture over molding moisture after 10 days capillary	Test Method 121-E 7 day moist cure, then • Unconfined strength > 300 psi, • 100% retained unconfined strength after 10 days capillary rise (To reduce time consider 85% retained strength after 4 hour submersion)	Test Method 121-E 7 day moist cure, then For cement • Unconfined strength > 175 psi, • 100% retained unconfined strength after 10 days capillary rise For lime or fly ash • 100 psi after capillary rise (To reduce time consider 85% retained strength after 4 hour submersion)
FPS 19 Moduli	70 ksi	100 ksi	125 ksi	200 ksi	150 ksi
Comments	• New base should be of higher or equal quality than existing, and • Blending of existing and new base strongly recommended to avoid trapping moisture in upper layer			• Avoid cutting into high PI subgrade, if existing structure is thin then add new base before milling where needed • To avoid longitudinal cracking consider grids and flex base overlay where the PI subgrade soils > 35 • Max RAP 50% • If lab strength > 350 psi then consider precracking • Max Cement 4%	• Avoid cutting into high PI subgrade, if existing structure is thin then add new base before milling where needed • To avoid longitudinal cracking consider grids and flex base overlay where the PI subgrade soils > 35 • Max RAP 50% • Blend of stabilizers often useful

1. Obtained samples of the existing materials by field auger. In the lab if the flexible material is susceptible to breakdown then use only the -1/2 inch fraction in laboratory test program. This is an attempt to partially account for aggregate breakdown during the recycling process.

Alternatives for High PI Locations

Although the application shown in Figures 31 and 32 is not widely used around the state, it has been included in these guidelines as a viable alternative when the flexible pavement to be widened is on top of a highly expansive subgrade, PI > 35. Based on the experience of the Bryan District, use of the Tensar Grid is very effective at intercepting reflection cracks from the lower layers and, thus, minimizing the longitudinal cracks that are often a result of edge drying. The Bryan District now routinely uses this procedure on its widening projects. Figures 31a and 31b show geogrid being placed on Old Spanish Road (OSR)in the Bryan District and the same section two years after the geogrid was placed. According to Darlene Goehl, the district laboratory engineer, the district now has in place over 100 miles of pavement where geogrids were used to minimize edge drying problems.

a. Geogrid Being Placed on OSR **b. OSR after 2 Years of Geogrid Placement**

Figure 31. Geogrid in the Bryan District

Again, a complete laboratory investigation with the existing and proposed material is highly recommended in this case, especially to determine the appropriate type and optimum amount of stabilizer. The construction detail in Figure 32 is only to serve as a reference and to show a common and successful practice in the Bryan District when dealing with highly expansive subgrades. Consult the district pavement engineer, design director, and/or area engineer for the final design of the pavement widening.

Table 10. Recommended Design Approaches for Flexible Pavements in Poor Condition on Highly Plastic Subgrades

Construction Procedures	TxDOT Spec. Item	Additional Information
• Widen subgrade using ordinary compaction or density control	• 112 and 132.3	
• Rework existing base into stabilized subbase	• 251	• It is suggested that base material be placed in lifts of no more than 6 inches.
• Place geogrid	• SS 5100	
• Place base material	• 247	
• Seal the pavement	• 316	• Sealing the pavement is recommended to prevent moisture intrusion.
• Place the HMA surface	• 340 and 341	• It is recommended that air void requirements for the main lanes also apply to the shoulders.

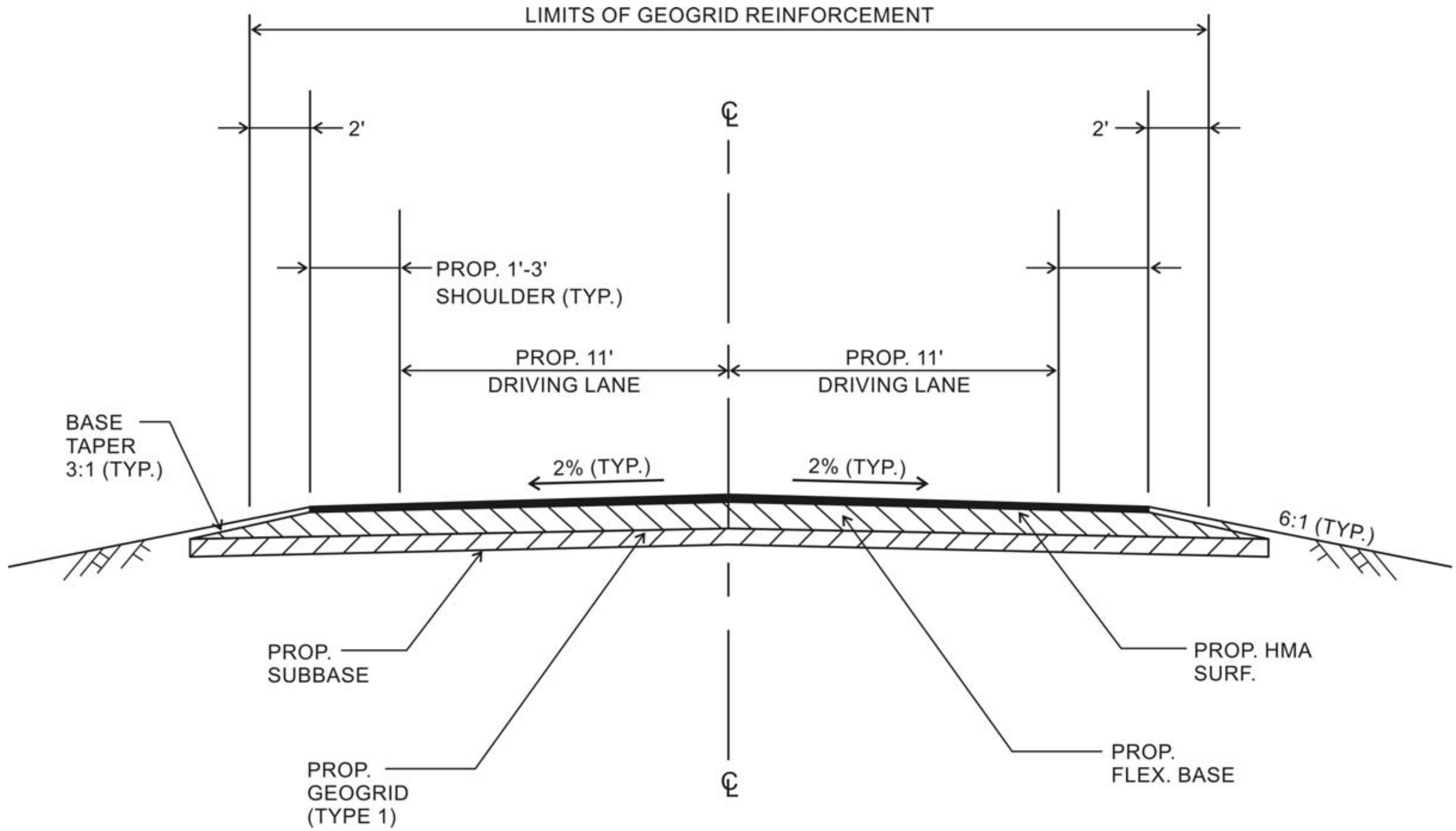


Figure 32. Typical Section for Widening Flexible Pavements in Poor Condition on Highly Plastic Subgrades

Options for Low Volume Roads

Another cost-effective alternative for widening low volume roads when there are less than 1000 vehicles per day (vpd) and the existing pavement is in poor condition is to rework and treat the existing base before widening to the desired width. A two-course surface treatment would then be applied. As is indicated in the “Additional Information” column in Table 10, care must be taken to avoid contamination of the reworked base with the subgrade soil. Since the existing material thicknesses can vary, it is highly recommended that a GPR survey or coring of the pavement to be reworked be conducted to verify layer thicknesses. Also, this testing will verify whether there is sufficient existing base thickness to construct with this method.

In the event that reworking the existing base will be the method used for the pavement widening, it is highly recommended that a complete laboratory investigation be conducted in order to develop the pavement design. Again, the construction detail shown in Figure 33 is only to serve as a reference and to show a common practice. The district pavement engineer, design director, and/or area engineer should be consulted for the final design of the pavement widening.

Table 11. Recommended Design Approaches for Flexible Pavements in Poor Condition by Reworking the Existing Base

Construction Procedures	TxDOT Spec. Item	Additional Information
• Widen subgrade using ordinary compaction or density control	• 112 and 132.3	• Equipment is an issue in placing narrow sections.
• Rework existing HMA surface and base into stabilized base and widen	• 251	• It is suggested that base material be placed in lifts of no more than 6 inches. Care must be taken to avoid contaminating the reworked base with the subgrade soil.
• Seal the pavement	• 316	• Sealing the entire pavement width is ideal.

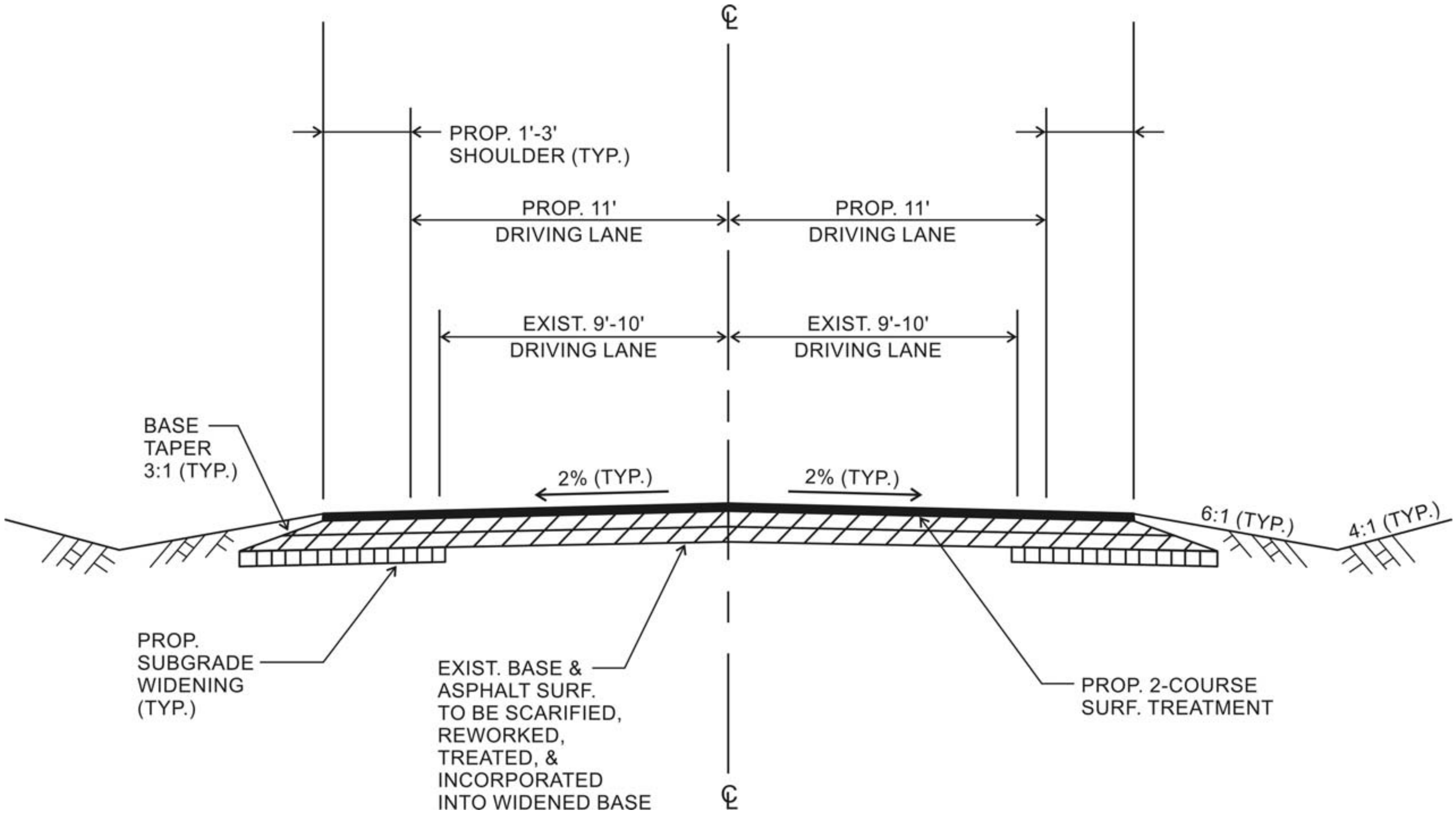


Figure 33. Typical Section for Widening Flexible Pavements in Poor Condition by Reworking the Existing Base

JOINTED CONCRETE PAVEMENT

The method described in Table 12 and shown in Figure 34 was found to be a common practice among the various districts surveyed. As noted in the "Additional Information" column in Table 12, there are some necessary precautions that should be taken during the construction process when building in this manner. Among these are several very important factors, including: the placement and sealing of the joint and ensuring that the construction equipment can compact these narrow sections.

This particular widening method was common among the districts surveyed when the existing pavement was a jointed concrete pavement (JCP). When widening JCP, it is not critical to match sections. Matching sections is critical when the existing base material is moisture susceptible, such as flexible base. Widening JCP's is often performed with full depth hot mix or cement treated base. However widening with flexible base material is not recommended. As was previously mentioned under "Flexible Pavement in Good Condition," there is usually little laboratory investigation or pavement design involved. As is the case with a flexible pavement in good condition, it is extremely important to get a good density in the subgrade widening, as not doing so will adversely affect the densities in the subsequent layers. Once again, it is critical to confirm with the contractor prior to construction that there is equipment available that can adequately compact these narrow sections. This construction detail is only to serve as a reference and to show a common practice. Consult with the district pavement engineer, design director, and/or area engineer for the final design of the pavement widening.

Table 12. Recommended Design Approaches for Jointed Concrete Pavements

Construction Procedures	TxDOT Spec. Item	Additional Information
• Widen subgrade using ordinary compaction or density control	• 112 and 132.3	• Check that the contractor has the appropriate equipment to construct these narrow sections (see section on equipment options). It is suggested that subgrade material be compacted in lifts of no more than 4 inches.
• Proof roll the subgrades	• 216	• This is highly recommended to assure the subgrade will provide uniform pavement support. See Table 6 for recommendations on proof rolling stress levels.
• Place base material	• 247, 260, 265, 275, or 292	• Equipment is an issue in placing narrow sections. It is suggested that base material be placed in lifts of no more than 4 inches.
• Seal the pavement	• 316	• Sealing the entire pavement width is ideal. At a minimum, seal over the joint at least 1 foot to prevent moisture intrusion.
• Place the HMA surface	• 340 and 341	• It is recommended that air void requirements for the main lanes also apply to the shoulders.

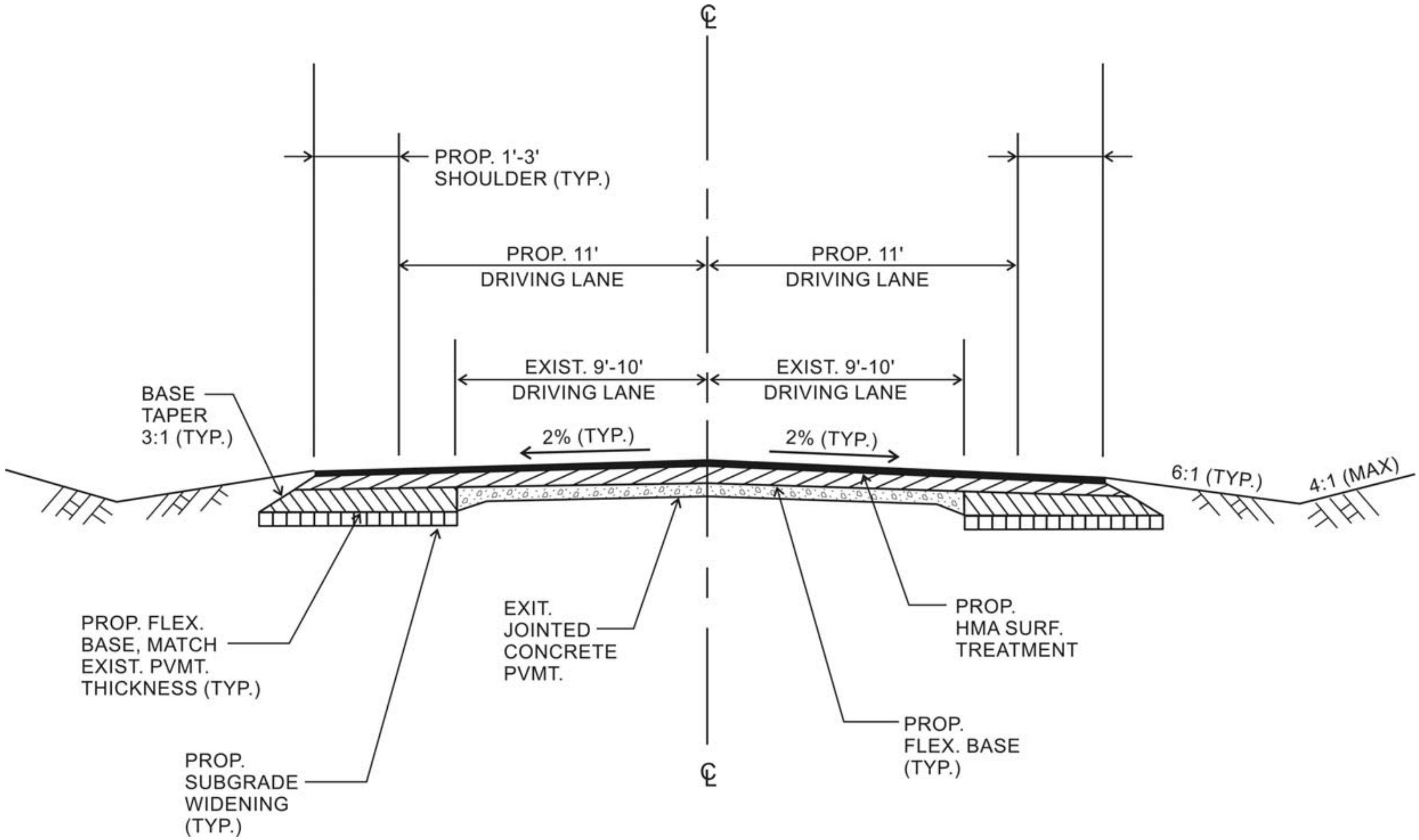


Figure 34. Typical Section for Widening Jointed Concrete Pavements

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