# Flexible Base Selection and Information Guide

Materials & Tests Division

Soils & Aggregates Section

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# INTRODUCTION

This document provides a basic overview of Item 247, "Flexible Base," from the Texas Department of Transportation (TxDOT) 2014 Standard Specifications for Construction and Maintenance of Highways, Streets and Bridges. The information in this document will provide personnel of all experience levels with enough information to designate and associate the appropriate type and grade of flexible base required for any project. The information in this document is relevant to both construction and maintenance. Additional specific and detailed information can be found in other references and resources, which include, but are not limited to, the following:

- TxDOT Materials & Tests Division's website,
- TxDOT 2014 Standard Specification for Construction and Maintenance of Highways, Streets and Bridges (Specification Book) Item 247, "Flexible Base,"
- TxDOT test methods, Series 100-E and 400-A,
- TxDOT Guide Schedule of Sampling and Testing,
- TxDOT training class CON411, "Inspection of Flexible Base & Embankment," and
- the Soils & Aggregates Section of the Materials & Tests Division.

For questions or comments, please call 512-506-5907.

# FLEXIBLE BASE

Flexible base is a granular, unbound material placed as a base course in the pavement structure. The base course serves multiple functions, including:

- supplying foundational support and structural capacity to the pavement,
- providing a stable course to minimize cracking of the surface layers, and
- dissipating stresses induced by traffic loading to subbases and underlying subgrades to minimize the potential for rutting.

The selection of an appropriate base material for any pavement is dependent on the anticipated traffic levels and the overall interaction of the base course with the entire pavement structure.

A good quality base material has the following characteristics:

- Resistant to load.
    - Withstands compaction without particle breakdown.
    - Withstands construction traffic without raveling.
    - Withstands traffic loads without shearing.
- Resistant to environmental factors.
    - Moisture resistant.
    - Freeze thaw resistant.

- Available at a reasonable cost to the department in a time frame appropriate for the item of work.
- A smooth surface for final pavement surface (as required when the final surface will be a 1 or 2 course surface treatment).

## MATERIAL REQUIREMENTS AND SELECTION

Item 247 requires a type and grade of flexible base be designated. The different types of base materials are described below, followed by the criteria used to define the material grades.

### MATERIAL TYPE

The material types—A, B, C, D, or E—are a general description of the material make-up. Item 247 defines each type as shown in Table 1.

*Table 1: Flexible Base Material Types*

| Type | Description |
|---|---|
| A | Crushed stone produced and graded from oversize quarried aggregate that originates from a single, naturally occurring source. This does not include gravel or multiple sources. |
| B | Crushed or uncrushed gravel. Blending of two or more sources is allowed. |
| C | Crushed gravel with a minimum of 60% of the particles retained on a No. 4 sieve with two or more crushed faces as determined by Tex-460-A, Part I. Blending of two or more sources is allowed. |
| D | Type A material or crushed concrete. Crushed concrete containing gravel will be considered Type D material. Crushed concrete must meet requirements for recycled materials and be managed in a way to provide for uniform quality. The engineer may require separate dedicated stockpiles to verify compliance. |
| E | Caliche, iron ore, or as otherwise shown on the plans. |

Since the type is a description of the material make-up allowed, it is important to understand the following factors that influence the selection of certain materials.

#### Crushed or Uncrushed

Crushed material is preferred. The shape of the particles is very important to the strength and stability of the base. Aggregate interlocking is aided by having angular particles that have a rough surface texture since these characteristics help prevent movement of one particle upon another. When the material is not crushed, particles tend to be rounded with a smoother texture. Rounded particles do not interlock each other as well as crushed particles since the particles tend to roll over one another. Smoother textured particles may allow slippage when they are in contact with one another.

**Stone or Gravel, or Other**

Crushed stone, such as limestone, is the most common rock available in Texas. From source to source, crushed stone can have variable hardness and quality. Gravels often have high clay content and are rarely used without some form of stabilization. Other materials such as crushed concrete, caliche, and iron ore may be suitable as flex base in specific circumstances and offer flexibility when more traditional sources may not be available.

## MATERIAL TYPE SELECTION

Table 2 presents basic recommendations for selecting the type of flexible base.

*Table 2: Basic Recommendations for Type Selection*

| Type | Description |
|---|---|
| A or D* | Strongest, most durable base |
| B or C | Marginal base |
| E | Non-standard requirements |

* When crushed concrete is allowed.

Type A and D materials are generally considered high-quality base since crushed materials have, in general, higher stability than rounded materials. Type A and D are often used in combination with Grade 1–2, which has the most stringent material requirements. Type D allows the use of Type A or crushed concrete. This option provides an alternative where crushed concrete may be used if economically feasible.

Types B and C are generally used for areas that have gravel as a local material.

Type E may be used for new or unspecified materials.

## MATERIAL GRADE

Item 247 designates flexible base grades as 1–2, 3, 4, or 5. The grades are defined by the physical material requirements presented in Table 3. The numbering sequence of the grade is not intended to be an order of quality or level of expected performance. A Grade 1–2 will not necessarily provide a higher quality performing base than a Grade 5. Generally, the application of the base for the typical section of the pavement structure dictates the grade selection.

*Table 3: Flexible Base Material Requirements from Item 247*

| Property | Test Method | Grade 1–2 | Grade 3 | Grade 4 | Grade 5 |
|---|---|---|---|---|---|
| Master gradation sieve size (cumulative % retained) | Tex-110-E | | | As shown on the plans | |
| 2½" | | 0 | 0 | | 0 |
| 1¾" | | 0–10 | 0–10 | | 0–5 |
| ⅞" | | 10–35 | – | | 10–35 |
| ⅜" | | 30–65 | – | | 35–65 |
| #4 | | 45–75 | 45–75 | | 45–75 |
| #40 | | 65–90 | 50–85 | | 70–90 |
| Liquid limit, % max[1] | Tex-104-E | 40 | 40 | As shown on the plans | 35 |
| Plasticity index, max[1] | Tex-106-E | 10 | 12 | As shown on the plans | 10 |
| Plasticity index, min[1] | Tex-106-E | As shown on the plans | | | |
| Wet ball mill, % max[2] | Tex-116-E | 40 | – | As shown on the plans | 40 |
| Wet ball mill, % max increase passing the #40 sieve | Tex-116-E | 20 | – | As shown on the plans | 20 |
| Compressive strength, psi, min | Tex-117-E | | | As shown on the plans | |
| Lateral pressure, 0 psi | | 35 | – | | – |
| Lateral pressure, 3 psi | | – | – | | 90 |
| Lateral pressure, 15 psi | | 175 | – | | 175 |

[1] Determine plastic index in accordance with Tex-107-E (linear shrinkage) when liquid limit is unattainable, as defined in Tex-104-E.

[2] Grade 4 may be further designated as Grade 4A, Grade 4B, etc.

## MATERIAL GRADE SELECTION

The selection of *grade* for flexible base may be dependent on any of the following:

- Material type specified. For example, Type B or C aggregates may not meet requirements for Grades 1–2 or 5.
- Magnitude and amount of traffic loading:
  - traffic volume,
  - percentage of trucks in the average daily traffic,
  - equivalent single axle loads (ESALs), and
  - load (average 10 heaviest wheel loads daily).

- Overall interaction of the base course with the entire pavement structure:
  - lateral confinement within the structure (width of shoulder), and
  - thickness and type of surfacing.
- Availability and quality of local aggregate sources.
- Highway type (FM, SH, US, IH, etc.).

Availability and cost may dictate the selection of grade in areas with limited sources. Local sources may be the least expensive material due to transportation costs; however, they may not be as high in quality as sources that are not local. It is essential when performing the pavement design and cost analysis to model the base layer based on the grade of base that will be selected.

### Grade 1–2

Grade 1–2 base is intended for use with pavements providing low confinement or low lateral support, and for pavements experiencing moderate to high traffic. Low confinement typically exists in the following situations:

- Pavements with thin surfacing. Seal coat or thin hot-mix asphalt (HMA) placed directly on the base may be too thin and not provide adequate confinement to the base.
- Pavements with little or no shoulders. In this situation, the lack of shoulder provides no lateral support and the base may become unstable as vertical loads are applied. The base must rely on its own cohesion and stability.

Grade 1–2 is the only grade of base to include a requirement for an unconfined compressive strength from laboratory testing, unless it is specified on the plans or general notes for a Grade 4. The unconfined compressive strength provides an indication of how well the base material will perform when placed within a pavement structure with minimal or no confinement.

### Grade 3

Grade 3 base material is generally not recommended for base courses in pavement structures. This grade of material is primarily used for subbase courses or maintenance uses, such as backfilling pavement edges, rehabilitation, or shoulder work.

### Grade 4

Grade 4 (properties shown on the plans) presents the flexibility to customize a base specification to address unique pavement and material design situations, such as but not limited to the following:

- a designated special grade to be used by other items of work,
- local materials,
- experimental sections, and
- recycled materials.

**Grade 5**

Grade 5 base is a modification of a Grade 1–2 base and has most of its characteristics, except for the unconfined compressive strength requirement. Grade 5 base material allows the use of a harder aggregate with a lower fines content. Fines may be less cohesive than those found in Grade 1–2. Since the Grade 5 base has the potential to have non-cohesive fines but has strengths equivalent to a Grade 1–2 base when confined, a 3 psi lateral confinement is used for Grade 5 base requirements. The material that meets this specification may have difficulty providing its own stability; therefore, Grade 5 is recommended for situations where stability is provided by the pavement structure and roadway features, such as shoulders, thick surface course, or other material placed over the base. Unless Grade 5 base is used as a subbase under an appropriate base and with appropriate thickness, it is not recommended for high-traffic roadways with thin surfaces or for roadways with no shoulders.

Table 4 contains the basic criteria for grade selection.

*Table 4: Basic Recommendations for Grade Selection*

| Shoulder Width | HMA Surface Thickness | Traffic (Design ESALs)* | Base Grade** |
|---|---|---|---|
| < 3 ft | Surface Treatment | < 500,000 | 1–2 or 4 |
| | | ≥ 500,000 | 1–2 |
| | HMA < 3 inches | All Traffic Levels | 1–2 |
| | HMA ≥ 3 inches | < 500,000 | 1–2 or 4 |
| | | > 500,000 | 1–2 or 5 |
| > 3 ft | Surface Treatment | < 500,000 | 1–2 or 4 |
| | | > 500,000 and ≤ 3,000,000 | 1–2 or 5 |
| | | ≥ 3,000,000 | 1–2 |
| | HMA < 3 inches | < 500,000 | 1–2 or 4 |
| | | > 500,000 | 1–2 |
| | HMA ≥ 3 inches | < 500,000 | 1–2 or 4 |
| | | > 500,000 | 1–2 or 5 |

* Percentage of heavy vehicles or trucks in addition to design ESALs should be taken into consideration.

**Use Grade 4 when experience with local sources has demonstrated adequate performance.

# APPENDIX: MATERIAL PHYSICAL PROPERTIES

Testing is performed in the laboratory to determine the material physical properties. Tests include the following:

- Tex-104-E, *Determining Liquid Limit of Soils.*
- Tex-105-E, *Determining Plastic Limit of Soils.*
- Tex-106-E, *Calculating the Plasticity Index of Soils.*
- Tex-110-E, *Particle Size Analysis of Soils.*
- Tex-113-E, *Laboratory Compaction Characteristics and Moisture-Density Relationship of Base Materials.*
- Tex-116-E, *Ball Mill Method for Determining the Disintegration of Flexible Base Material.*
- Tex-117-E, *Triaxial Compression for Disturbed Soils and Base Materials.*

**Test methods Tex-104, 105, and 106-E** are used to measure the plasticity index (PI) of the fine material (materials passing No. 40 sieve), known as the Atterberg limits. The PI provides an indication of cohesion that is needed to bond the base together to produce a stable foundation for the pavement structure. However, fines with a high PI number may lead to an unstable base and deform under traffic loads because a high PI number may be indicative of high clay content. Bases with high PI may also tend to be more susceptible to moisture capillary action and loss of strength.

The PI is determined from measuring the liquid and plastic limits. The liquid limit is the moisture content at which a soil changes from a plastic to liquid state of consistency. The plastic limit is the lowest moisture content at which the soil can be rolled into a thread of 1/8-in. diameter without breaking into pieces. The PI is calculated by subtracting the plastic limit from the liquid limit. Figure A1 illustrates the testing equipment used to measure the liquid and plastic limits.


**Figure A1: Tex-104, 105, and 106-E, Liquid and Plastic Limit Testing Equipment**

**Tex-110-E** measures the gradation of the base material using a mechanical shaker and wire sieves, as shown in Figure A2. Sieving consists of passing a known quantity of dry aggregate through a set of sieves. The sieves have rectangular openings and are shaken either in a vertical or vertical and horizontal motion that causes the aggregate to move over the surface of the sieve.

**Figure A2: Tex-110-E, Mechanical Sieve Shaker and Wire Mesh Sieves**

The structural capacity, drainage, and frost susceptibility of the base can be affected by the gradation. In general, there are three basic gradation ranges: aggregate with very low fines, aggregate with fines just filling the voids, and aggregate with fines overfilling the voids.

A low-fines (less than 10% passing the No. 200 sieve) base derives strength from particle-to-particle contact. In this case, the material would be unstable unless it was confined. However, the base would provide excellent drainage characteristics and would not be susceptible to frost.

A base with fines just filling the voids (typically 10% to 20% passing the No. 200 sieve) also derives strength from particle-to-particle contact. In this situation, the base would be very stable even when unconfined because the fines would provide cohesive properties when filling the voids between the larger aggregate particles. Drainage characteristics would be adequate, and in some cases the base would not be susceptible to frost.

A base with high fines (greater than 20% passing the No. 200 sieve) derives strength from particle-to-particle contact as well; however, the particles in this case are the fines and not the larger aggregate. This results in a lower-strength base with poor drainage characteristics and potentially frost susceptibility.

For base courses in a pavement structure, bases with fines just filling the voids or low fines are preferred since these gradation ranges provide both strength and stability. Materials with low fines (coarse aggregate gradations) tend to resist repetitive load better than finer-graded materials but often require more confinement to remain stable.

**Tex-113-E** produces a moisture-density curve to determine the maximum dry density and optimum moisture content. Figure A3 is a graph with a moisture-density curve illustrating the maximum dry density and optimum moisture content. This information is used by the contractor to construct the flexible base and by TxDOT to measure density for acceptance.

Item 247 requires that bases be compacted to 100% of the maximum dry density and at a moisture content of ±2 percentage points of the optimum moisture content. Furthermore, the base should not be sealed until it has cured to a moisture content of 2 percentage points below optimum. With the example shown in Figure A3, this would be:

- Target field density: greater or equal to 142.1 lb/ft$^3$.
- Target compaction moisture content: 4.5% to 8.5% field moisture.
- Moisture content before sealing: less than 4.5%.

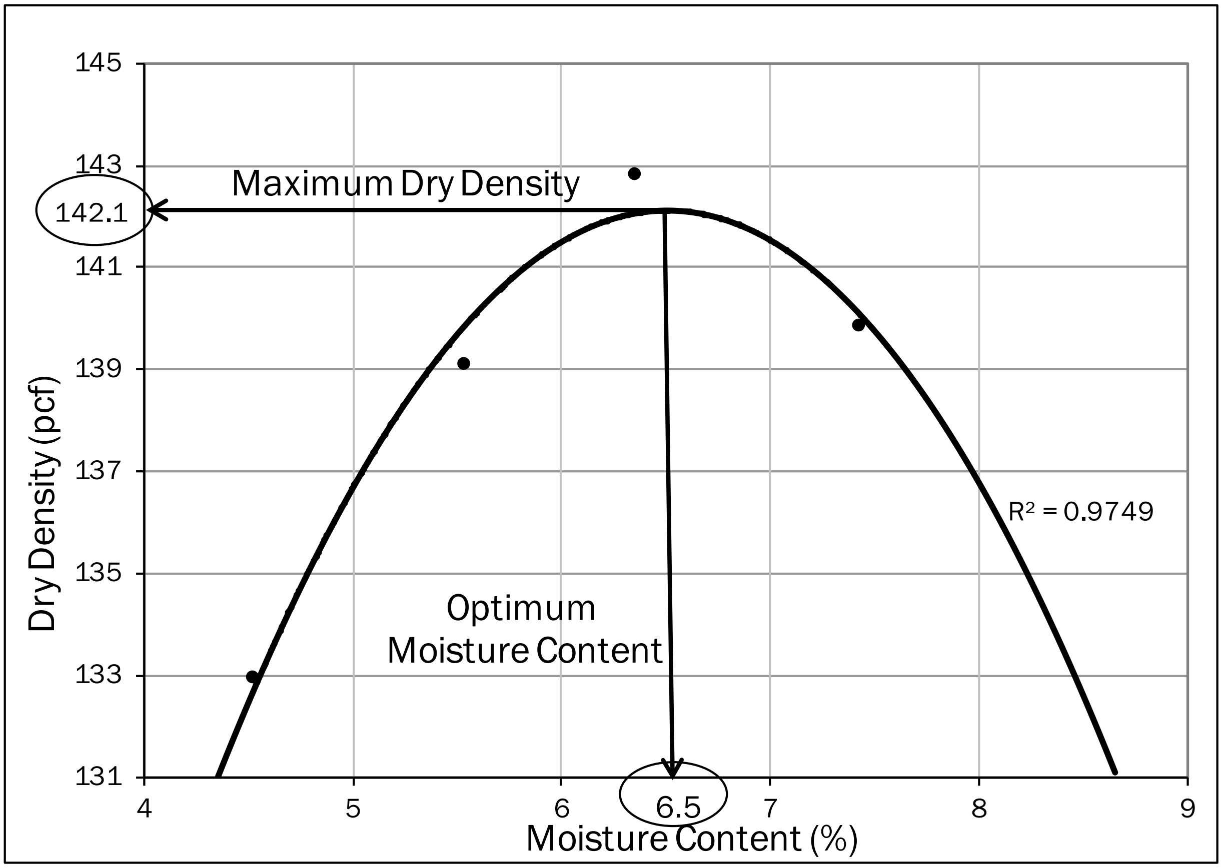


**Figure A3: Tex-113-E, Moisture-Density Curve**

**Tex-116-E** is used to measure the ability of the base to withstand degradation. To withstand the stress from repetitive loading, a durable base is needed. A durable base will not degrade excessively over time and will have strength and toughness. These physical durability property requirements are reflected by the wet ball mill testing in Tex-116-E. The intent of the test is to ensure base materials contain hard aggregates with the ability to bear loading and not break down during hauling, spreading, and construction. Testing is performed with water and metal spheres and detects soft aggregates that may be subject to weathering. Figure A4 is a picture of the testing equipment. An example of base materials after the wet ball mill test is shown in Figure A5.

Figure A4: Tex-116-E, Wet Ball Mill Testing Equipment

**Granite**

WBM & % Increase are well below specification maximums

**Caliche**

WBM & % Increase exceed specification maximums

Figure A5: Base Material after Tested with Wet Ball Mill

**Tex-117-E** is a compression test used to measure the confined and unconfined compressive strength. Bases are designed to provide structural capacity in the pavement structure. The compressive strength test is to determine a shearing strength test that measures the resistance to sliding between particles thus the capacity of a base material to withstand traffic loads in the pavement structure. This test may also provide an indication of the internal friction and cohesion. The test provides stability and strength information at different lateral (confining) pressures. Under Item 247, compressive strengths when required are measured using confining pressures of 0, 3, and 15 psi.

Higher-strength properties and internal stability of the flexible base will be needed when the pavement structure consists of thin surface courses, such as seal coats or less than 3 in. of HMA. The amount of stress in the base generally decreases as lateral support (confining pressure) increases. For instance, when the thickness of the HMA increases, the stresses in the base decreases. Lower-strength property requirements may be specified when the confining pressure increases. The width of the shoulder in the pavement structure also contributes to the amount of confinement in the base under traffic loads.

To measure compressive strength, test specimens are loaded under an increasing axial stress until failure. The compressive strength indicates the amount of load that a base with a given gradation, plasticity, aggregate hardness, and texture will contribute to the pavement structure. Figure A6 shows an example of a test specimen with a triaxle cell and a compression loading frame.


Figure A6: Tex-117-E, Compressive Strength Testing Equipment